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# MATERIALS HANDBOOK

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# MATERIALS HANDBOOK

An Encyclopedia for Purchasing Agents Engineers, Executives, and Foremen

*by* GEORGE S. BRADY

SIXTH EDITION

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MATERIALS HANDBOOK

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# PREFACE TO THE SIXTH EDITION

The First Edition of "Materials Handbook" was published in 1929. It grew out of the author's need for a quick reference to basic data on all kinds of industrial materials when he was an American Trade Commissioner. It began with an intensive study of the materials of each industry and a card index of comparative data.

Accumulated data were based on the ready-reference information needed in preliminary discussions of purchasing requirements. Later, when the author was managing editor of two industrial trade papers, and then a consulting engineer, the collection and classification of data were extended to cover the primary requirements of industrial executives, designers, architects, and builders of mechanical equipment and plant. Still later, when he was chief materials consultant to the Office of Civilian Supply and to the Board of Economic Warfare, the scope was extended to include in the book the chief materials entering into international trade because of the widened interest in all world materials throughout American industry brought about by the war.

It is not the author's intention to provide an exhaustive treatise on any material, as it is assumed that purchasers and designers will consult producers of the materials for detailed specifications. General information, with the most commonly used comparative figures, is given on materials in their group classifications in order to give a general picture; patented and trade-named materials are then described to give a more specific understanding of commercial applications. The relative position and the length of description of proprietary materials are for purposes of illustration and bear no relation to the relative merits of the products of any one producer. Some processed industrial materials have been included for more intelligent judgment of the basic raw materials and because these materials are the raw materials in some industries.

Statements regarding characteristics of the materials and nomenclature are not the personal opinions of the author, but are backed

by the most competent authorities in each case or are the most common usage of successful manufacturers. Names are selected by the greatest and most reasonable use. Local, slang, and colloquial names are omitted unless they represent particular grades or uses.

Part II also represents a development from a need. It began as an Appendix containing such tables as are frequently required for reference. In this edition, it developed into an arrangement of basic economic data because the experience of the author in dealing with procurement officials in Federal and military service has paralleled that of the National Association of Purchasing Agents, namely, that the materials' procurement function is a profession drawing on all the technical sciences, and that the procurement official no longer is content merely with the administrative "how" of buying, but wants basic technical facts on the "why" in simple usable terms.

Because of the numerous sources of information, it is impossible to give credit in the published volume to the producers and experts who have furnished data, but acknowledgment is here made to the ready and willing cooperation that has been received from producers, technical authorities, industrial-paper editors, and government bureaus in this country and in England. Encouragement and advice given to the work by members of the National Association of Purchasing Agents have also been of real help to the author. Credit is given to James F. Moulton, Jr., for much work in checking statements on physical and chemical properties.

GEORGE S. BRADY

WASHINGTON, D. C.,
*February,* 1947.

# A FOREWORD FOR THE USER

For the purchasing executive or the product engineer who must think in terms of a wide variety of materials, nothing is more useful than to fix in the mind a few figures that will serve as milestones to give a quick comparative judgment of material characteristics. A new figure is of little value unless it brings to the mind a comparison with a known value.

Only a few such values need be remembered. For purposes of comparison it is well to keep in mind such data as these: The average tensile strength of common low-carbon soft steel is 40,000 lb. per sq. in.; the average point of hardness at which metals are no longer machinable with ordinary tools is 300 Brinell; the average weight of ordinary steel is 7.8 times that of water, and aluminum is about one-third the weight of steel. With only a little effort the non-chemist can familiarize himself with the chemical groupings and characteristics of important basic chemical radicals, such as the benzene ring, ethyl, methyl, amine, for better judgment of chemical materials.

A relatively short amount of reading with a perceptive mind will soon fix in the consciousness important points of relativity on strengths, hardness, weights, degrees of screen fineness, of organic compositions, and other matters that will make the path easier for a ready judgment of any new material that may come to the attention.

# PART I

## *Materials, Their Properties and Uses*

**Abrasives.** Substances used for surfacing and finishing metals, stone, wood, glass, and other materials by abrasive action. The natural abrasives include the diamond, emery, corundum, sand, crushed garnet and quartz, tripoli, and pumice. The artificial abrasives are marketed under many trade names, but are in general either silicon carbide or aluminum oxide. The massive natural abrasives, such as sandstone, are cut into grinding wheels from the natural block, but most abrasive material is used in the grain or built into artificial shapes.

For industrial grinding, artificial abrasives are preferred to natural abrasives because of their greater uniformity. Grading is important because uniform grinding requires grains of the same size. The abrasive grains are used as a grinding powder, are made into wheels, blocks, or stones, or are bonded to paper or cloth. Abrasive cloth is made of cotton jeans or drills to close tolerances of yarns and weaves, and the abrasive grains are stuck on with strong hide glue. The crushed material is graded in sizes from 8 to 240 mesh and marketed in kegs or cans. Coarse grain is 12 to 24 grit; very fine is 150 to 240. Floated flours consist of grains of extreme fineness and uniformity marketed as Grinding flour for grinding optical glass and fine cutlery, usually in grain sizes from 280 to 600 mesh. Levigated abrasive powders used for final burnishing of metals or for metallographic polishing are abrasives reduced to an extremely fine, smooth powder. The so-called Green rouge is levigated chromic oxide, and Mild polish is levigated tin oxide; both are used for burnishing soft metals. Ultrafine Polishing powder is made by pressure grinding and washing to make it chemically neutral. Gainal, of the Fisher Scientific Co., is a fine aluminum oxide powder with the particles so small that they are visible only with the electron microscope, the smaller cubes

being 1.5 microns (0.0015 mm.), with tinier particles 0.0005 mm., or 0.0000197 in.

The hardest abrasive is the diamond, which has a hardness of 10 on the Moh scale. The artificial abrasives silicon carbide and boron carbide have a hardness between 9 and 10. Garnet is one of the softest of the so-called hard abrasives, with a hardness of 6 to 7.5. Rouge is one of the hardest of the soft abrasives, with a hardness of 5.5 to 6.5. The Mild abrasives, used in silver polishes and window-cleaning compounds, such as chalk and talc, have a hardness of 1 to 2 Moh. Abrasives for metal polishes may also be pumice, diatomite, silica flour, tripoli, whiting, kaolin, tin oxide, or fuller's earth. This type of fine abrasive must be of very uniform grain in order to prevent scratching. Ground glass is regularly marketed as an abrasive for use in scouring compounds and in match-head compositions. Lapping abrasives, for finish grinding of hard materials, are diamond dust or boron carbide powder.

In the metalworking industry, aluminum oxide wheels are used for grinding materials of high tensile strength. Silicon carbide is harder but is not as strong as aluminum oxide. It is used for grinding metals that have dense grain structure and for stone. The first artificial Grinding wheels were introduced in 1825 from India where they had been made for centuries by binding natural corundum grains with gum resin or shellac. There are five processes for making Abrasive wheels, each giving different characteristics: Vitrified wheels are made by running the mixture into molds and, when dry, subjecting to intense heat. They are used for heavy work up to 6,500 surface ft. per min. The silicate process consists in tamping the material into molds with a silicate binder, and then baking in an oven. The silicate bond releases the grains more easily than the vitrified. Synthetic resins, such as the phenol resins, are used for bonding where greater strength is required than is obtained with the silicate, but less openness than with the vitrified. Resinoid bonds are used up to 9,500 surface ft. per min., but cut-off wheels are operated far beyond this point. Shellac binder is used on wheels for light work and for finishing. Rubber is used for high speed or fine finish. Butadiene synthetic rubber bonds give longer life than those of natural rubber.

The choice of a binder for grinding wheels is important, as it must be strong enough to hold the grains together to accomplish the desired results, and then to release them before they become too dull. Coarse-grained wheels are used for fast removal of stock or for ductile materials, and fine-grained wheels for hard and brittle material or for fine finish. With any given bond the amount of bond determines a hard or soft wheel as distinct from hard or soft grains. The structure, or spacing of the grains in the bond, must be uniform to obtain uniform grinding. Some wheels are made with a porous honeycombed structure to give free cutting and cooler operation on some types of metal grinding. The Open-structure wheel of the Norton Co., and the Por-Os-Way of A. P. De Sanno & Co., Inc., are wheels of this type.

**Abrasive garnet.** Garnet is a general name for a group of minerals varying in color, hardness, toughness, and method of fracture, used for coating abrasive paper and cloth and for cutting glass and stone. Almandite is the type most used for abrasive purposes, although andradite and rhodolite are also employed. The best garnet abrasives come from red almandite, obtained in large crystals in New York state. The garnet of North Carolina is a by-product of kyanite mining, the ore containing 10% of garnet, 15 kyanite, and 30 mica. Garnet is crushed, ground, and separated, and graded in settling tanks and sieves. Hornblende is a common impurity and is difficult to separate, but good quality abrasive garnet should be free of this mineral. Garnet-coated paper and cloth are preferred to quartz for the woodworking industries, because garnet is harder and gives sharper cutting edges, but aluminum oxide is often substituted for garnet. The less expensive quartz is sometimes colored to imitate garnet. The grades of garnet grains used on Garnet paper and cloth range from No. 5, the coarsest, which is about 15 mesh, to 7/0, the finest, which is about 220 mesh. The paper used as a backing is a good quality kraft of 50 to 70 lb. weight, or a rope manila stock. The usual size is 9 by 11 in. The cloth is usually in two weights, the lightweight being used as a flexible rubbing-down material. Some garnet is made into wheels by the silicate process, but vitrified wheels are not made because of the low melting point of garnet.

**Abrasive sand.** Any natural sand used for abrasive and grinding purposes, but the term does not include the sharp grains obtained by crushing quartz and used for sandpaper. The chief types of abrasive sand include sandblast sand, glass-grinding sand, and stone-cutting sand. Sand for stone sawing and for marble and glass grinding is usually ungraded, with no preparation other than screening, but it must have tough, uniform grains. Chats is a name for sand tailings from the Missouri lead ores, used for sawing stone. Banding sand is used for the band grinding of tool handles, and for the grinding of plate glass, but is often replaced by artificial abrasives. Banding-sand grains are fine, 95% being retained on a 150-mesh screen. Burnishing sand, used for metal polishing or grinding valve seats, is a fine-grained silica sand with rounded grains. It should pass a 65-mesh screen, and be retained on a 100-mesh screen.

**Acaroid resin.** A gum resin obtained from the base of the tufted trunk leaves of various species of *Xanthorrhoea* trees of Australia and Tasmania. It is also called Gum accroides and Yacca gum. The Yellow acaroid from the *X. tateana* is relatively scarce. Another gum of the yellow class comes from the tree *X. preissii* of Western Australia, and is in small hollow pieces of yellow to reddish color. It is known as Black boy resin, the name coming from the appearance of the tree. Red acaroid, known also as Red gum and Grass tree gum, comes in small dusty pieces of reddish-brown color. This variety is from the *X. australis* and about 15 other species of the tree of southeastern Australia. The resins contain 80 to 85% of resinotannol and considerable coumaric acid with cinnamic acid. They are thus closely related chemically to the balsams. Acaroid resin has the property unique among natural resins of capacity for thermosetting to a hard, insoluble, chemical-resistant film. By treatment with nitric acid it yields picric acid; by treatment with sulphuric acid the resin yields fast brown to black dyes. The resins are soluble in alcohols and in aniline, only slightly soluble in chlorinated compounds, and insoluble in coal-tar hydrocarbons. Acaroid has some of the physical characteristics of shellac, but is difficult to bleach. It is used for spirit varnishes and metal lacquers, coatings,

paper sizing, in inks and sealing waxes, binders, for blending with shellac, production of picric acid, and in catarrhal medicine.

**Acetaldehyde.** A water-white inflammable liquid with an aromatic penetrating odor, used as a reducing agent, in the manufacture of synthetic resins, in making pentaerythritol, in rubber antioxidants, as a preservative, for making dyestuffs, for the explosive pentolite, and for silvering mirrors. It is also called Ethanal. It is made by the oxidation of ethyl alcohol and has the composition $CH_3 \cdot CHO$. The specific gravity is 0.801 and boiling point 20.8°C. It is soluble in water, alcohol, and in naphtha. Paraldehyde, $(CH_3 \cdot CHO)_3$, may be used instead of acetaldehyde in resin manufacture, has a higher boiling point, 124°C., is less flammable with higher flash point, but is not as reactive and will not reduce silver solutions to form a mirror. Paraldehyde is used in the tanning industry for fulling leather.

**Acetamide.** Also called Acetic acid amine and Ethanamide. A grayish-white crystalline solid with a melting point of 77 to 81°C., specific gravity 1.139, composition $CH_3 \cdot CO \cdot NH_2$, and slight mousy odor. It is soluble in water and in alcohol. It is used as a liquid flux for soldering on painted or oily surfaces, as an antacid in lacquers and explosives, as a softening agent in glues and leather coatings, and as a nonhazing plasticizer in cellulose nitrate and acetate films. Its ability to dissolve starch and dextrine makes it useful in adhesives for waxy papers. With added corrosion inhibitors it is used as an antifreeze, a 50% solution in water having a freezing point of −27.5°C. Acetaldehyde ammonia, $CH_3 \cdot CHOH \cdot NH_3$, is a white crystalline solid with a melting point of 80°C. Aldamine of the Niacet Chemicals Corp. is this product. It is used as a rubber vulcanization accelerator, pickling inhibitor for steel, and in the manufacture of plastics.

**Acetic acid.** Also known as Ethanoic acid. A colorless, corrosive liquid of pungent odor and composition $CH_3 \cdot COOH$, having a wide variety of industrial uses as a reagent, solvent, and esterifier. It is employed as a weak acid for etching and for soldering, in stain removers and bleaches, as a preservative, in photographic chemicals, for the manufacture of cellulose acetate, as a solvent for essential

oils, resins, and gums, as a precipitant for latex, in tanning leather, and in beverages. Acetic acid is found in the juices of many fruits, and in combination in the stems or woody parts of plants. It is the active principle in Vinegar, giving it the characteristic sour taste, acid flavor, and pungent odor. It is made commercially by the oxidation of ethyl alcohol, and also produced in the destructive distillation of wood. The specific gravity is 1.049, boiling point 118°C., and it becomes a colorless solid below 16.6°C. The pure 99.9% solid is known as Glacial acetic acid. Standard and Laundry special contain 99.5% of acid, with water the chief impurity. Various standard strengths of water solution are 28, 56, 70, 80, 85, 90%.

Acetic anhydride, $CH_3COOCOCH_3$, a colorless liquid with boiling point 139.5°C., is a more powerful acetylating agent, and is used in making cellulose acetate. It forms acetic acid when water is added. Hydroxyacetic acid, $HOCH_2COOH$, or Glycolic acid, is produced synthetically and is intermediate in strength between acetic and formic acids. It is soluble in water, is nontoxic, and is used in foodstuffs, dyeing, tanning, and in resins. Its esters are solvents for resins. Acetin is an ester of acetic acid made from glycerin and acetic acid, used as a solvent for basic dyes and tannins. It is a neutral straw-colored liquid of specific gravity 1.20 and boiling point 133 to 153°C. It is also used in low-freezing dynamites and smokeless powder. The triacetic ester, Triacetin, is a water-white liquid of specific gravity 1.16 and flash point 271°F., partly soluble in water and soluble in aromatic hydrocarbons. It is used as a plasticizer.

**Acetone.** An important industrial solvent, used in the manufacture of lacquers, plastics, smokeless powder, for dewaxing lubricating oils, for dissolving acetylene for storage, for dyeing cotton with aniline black, and as a raw material in the manufacture of other chemicals. It is a colorless, inflammable liquid with a mint-like odor and is soluble in water and in ether. The composition is $CH_3 \cdot CO \cdot CH_3$, specific gravity 0.790, boiling point 56°C., and solidification point −94°C. Acetone is prepared by a special fermentation of grain, forming butyl alcohol and acetone. The oily residue from the distillation is called Acetone oil and is used as a denaturant of alcohol. Diacetone, or Diacetone alcohol, is a color-

less liquid of the composition $CH_3 \cdot CO \cdot CH_2 \cdot COH(CH_3)_2$ with a faint odor. It is used as a high boiling solvent for nitrocellulose and cellulose acetate, for gums and resins, in lacquers and thinners, and in ink removers. Because of its low freezing point and its miscibility with castor oil it is used in hydraulic brake fluids. The specific gravity is 0.938, boiling point 166°C., and freezing point −44°C. Synthetic Methyl acetone is a mixture of about 50% of acetone, 30 methyl acetate, and 20 methanol, used in lacquers, cellulose plastics, paint removers, and for coagulating latex.

**Acetylene.** A colorless gas of the composition CH:CH, used for welding torches, for lighting, and for producing other chemicals. Because of the shortage of short-chain hydrocarbons from petroleum during the war the Germans used acetylene as a raw material for the production of butadiene, ethyl alcohol, ethylene, glycerin, adipic acid, and other chemicals. It contains 92.3% of carbon, and is therefore nearly gaseous carbon. When pure, it has a sweet odor, but has a disagreeable odor when it contains hydrogen sulphide as an impurity. Acetylene burns brightly in the air, and was widely used for theater stage lighting before the advent of the electric light. When mixed with oxygen as Oxyacetylene for welding, it gives a temperature of 3500°C. In a mixture of about 3% of acetylene to 97 of air, it is used as an explosive gas. The maximum explosive effect is with a mixture of 7.7% of the gas with 92.3 of air. The gas has a specific gravity of 0.92. It is nontoxic, and is soluble in water, alcohol, or acetone. It liquefies under a pressure of 700 lb. per sq. in. at 70°F. Acetylene is easily generated by the action of water on calcium carbide, but is also produced from petroleum. It is marketed compressed in cylinders, dissolved in acetone to make it nonexplosive. One volume of acetone will dissolve 25 volumes of acetylene at atmospheric pressure, or 250 volumes at 10 atm. Prestolite is a trade name of the Prestolite Co., Inc., for acetylene dissolved in acetone.

**Acrylic resins.** Colorless, highly transparent, thermoplastic synthetic resins made by the polymerization of acrylic derivatives, chiefly from the esters of Acrylic acid, $CH_2:CH \cdot COOH$, and Methacrylic acid, $CH_2:C(CH_3) \cdot COOH$. Chemically, acrylic acid, which is the starting point in the production of these resins,

is ethylene with one hydrogen atom replaced by the fatty acid group COOH. It is a liquid boiling at 141°C. They vary from soft, sticky semisolids to hard, tough solids, depending upon the constitution of the monomers and upon the polymerization. They are used for adhesives, protective coatings, finishes, laminated glass, transparent structural sheet, and molded products. Acrylic resins are stable and resistant to chemicals. They do not cloud or fade in light when used as a laminating material in glass. For molding they may be compounded with fillers, plasticizers, and pigments. Methyl methacrylate is a hard rigid resin of the acrylic series. In sheet form the density is 1.185, tensile strength 5,800 to 8,800 lb. per sq. in., compressive strength 13,500 lb. per sq. in., flexual strength 14,000 lb. per sq. in., refractive index 1.49, Brinell hardness 18 to 20, softening point 203°F., and dielectric strength 480 volts per mil. It is superior to ordinary glass in the transmission of ultraviolet light, transmitting the rays down to 250 millimicrons wave length. The direct transmission of white light is 93%, and the flat sheet has optical homogeneity. The material is resistant to acids and to petroleum solvents. Sheet can be molded and bent by heating to 220 to 300°F., and is easily sawed, drilled, or machined. The powder can be injection- or compression-molded. Because of its transparency, it is especially adapted for molded products such as costume jewelry, handbag frames, and novelties.

Lucite is methyl methacrylate of E. I. duPont de Nemours & Co., Inc., marketed as molding powder and in rods, tubes, and cast and molded sheets. Lucitone is this material molded in dentures in pink and translucent. Crystalite, of Rohm & Haas Co., is an acrylic molding powder. Plexiglas, of this company, is transparent methyl methacrylate in sheets and rods. Acryloid and Acrysol are acrylic resins of this company, the Acryloids being copolymer solid resins, and the Acrysols being solutions for coatings and finishes for leather, textiles, and paper. Plexene M, of this company, is a styrene-acrylic copolymer thermoplastic resin for injection molding. The specific gravity of the molded material is 1.08, dielectric strength 350 volts per mil, and tensile strength 15,000 lb. per sq. in. Acryloid A-10 resin of the Resinous Products & Chemical Co., used for coatings and finishes, is a solution of the resin in cellosolve acetate, and Acryloid B-7 is a solution in ethylene dichloride. Un-

colored coatings made with these resins will transmit 92% of the light rays. They are resistant to oils and many chemicals, are waterproof, and have good dielectric strength. Vernonite, of Rohm & Haas Co., is an acrylic denture resin. Lucite, Plexiglas, and the English Perspex are used for transparent aircraft windows and nosing.

**Activated charcoal.** A nearly chemically pure amorphous carbon made by carbonizing and treating dense material such as coconut shells, peach pits, or hardwood. When made from coal, or in the chemical industry, it is more usually called Activated carbon. It may be made by dry distillation, or by leaching the charcoal with steam or chemicals. It is used as an absorbent material for gas masks, and for purifying acids, recovering solvents, and decolorizing liquids. Coconut charcoal, valued for gas masks, is an activated charcoal usually made by heating coconut shells in a closed retort, crushing, and steam treating. Activated charcoal made in Germany for gas masks was produced from ground peat by mixing with zinc chloride and heating to 700°C. to drive off moisture, $ZnCl_2$, and HCl, and then leached. A requirement of activated charcoals, besides high absorbing power, is that they possess strength to retain a porous structure to pass the air or liquid. Powdered activated charcoal is ground so that 95% will pass through a 300-mesh screen. For water purification it should be fine enough to wet easily, but not so light that it will float on the top. For decolorizing or deodorizing oils and chemicals it is mixed in the liquid and settles out in a few hours. A single drop of water will hold 10,000 particles of powdered charcoal. In sugar and oil refining it removes color but does not bleach like chemicals. Hydrodarco, of the Darco Corp., is a powdered activated carbon. Norit, of the American Norit Co., Inc., is a group of highly adsorptive activated carbons. Other trade names for activated charcoals are Dorsite, Bachite, and Kelpchar, the latter being made from seaweed. Tec-Char, of the Tennessee Eastman Corp., is by-product charcoal obtained in wood distillation, and in graded grains for various uses. Nuchar is an activated carbon of the West Virginia Pulp & Paper Co. The activated carbon of the Masonite Corp. is made by subjecting wood

chips to high steam pressure and disintegrating them by sudden release of the pressure. The doughy mass is then briquetted and carbonized.

**Adhesives.** Materials, usually liquid solutions, employed for sticking, or adhering, one surface to another. The commercial adhesives include pastes, glues, pyroxylin cements, rubber cements, latex cement, and special cements of chlorinated rubber, synthetic rubbers, or synthetic resins. Adhesives are characterized by the degree of tack, or stickiness, by their strength of bond after setting or drying, by the rapidity of bonding, and by their durability. Adhesives for rapid machine application must have good initial tack. Tack is often increased by adding rosin or ester gum, while the speed of drying may be altered by changing the solvent. The strength of bond is inherent in the character of the adhesive itself, particularly in its ability to adhere intimately to the surface to be bonded. Adhesives prepared from organic products are in general subject to disintegration on exposure. The life of an adhesive depends usually upon the stability of the ingredient that gives the holding power, although otherwise good cements of synthetic materials may disintegrate by the oxidation of fillers or materials used to increase tack.

Pastes are usually water solutions of starches or dextrines, sometimes mixed with gums, resins, or glue, and containing antioxidants. They are the cheapest of the adhesives, but deteriorate on exposure. They are widely employed for the adhesion of paper and paperboard. Much of the so-called Vegetable glue is Tapioca paste. It is used for the cheaper plywoods, for postage stamp adhesives, envelopes, and for labeling. Latex pastes of the rub-off type are used for such purposes as photographic mounting as they do not shrink the paper as do the starch pastes. Glues are usually water solutions of animal gelatin, and are stronger and more durable than pastes. The only difference between animal glues and edible gelatin is in the degree of purity. Hide and bone glues are marketed as dry flake, but fish glue is liquid. Mucilages are light vegetable glues, generally from water-soluble gums. Pyroxylin cements may be merely solutions of nitrocellulose in chemical solvents, or they may be compounded with resins, or plasticized with

gums or synthetics. They dry by the evaporation of the solvent, and have little initial tack, but because of their ability to adhere to almost any type of surface they are called Household cements. Cellulose acetate may also be used. These cements are used in the shoe industry for bonding the soles of women's shoes. The bonding strength is about 20 lb. per sq. in., or equivalent to the adhesive strength of the outer fibers of the leather to be bonded. Some of the commercial pyroxylin and acetate cements are simply solvent solutions of recovered motion-picture film and retain the original plasticizers. Cold solder is pyroxylin cement mixed with aluminum powder to give a metallic appearance. Other plastics are also used in adhesives. For hot-press lamination of wood the plastic cement is sometimes marketed in the form of thin sheet. Tego resin film, of the Resinous Products & Chemical Co., Inc., is a phenol resin sheet of this class. Urac 110 resin, of the American Cyanamid Co., is a urea-formaldehyde resin in powder form for adding to starch adhesives to make them waterproof for use in laminating.

Rubber cements for paper bonding are simple solutions of rubber in a chemical solvent. Like the latex pastes, the excess can be rubbed off the paper. Stronger rubber cements are usually compounded with resins, gums, or synthetics. An infinite variety of these cements is possible, and they are all waterproof with good initial bond, but they are subject to deterioration on exposure as the rubber is uncured. This type of cement is also made from synthetic rubbers which are self-curing. Ubapol, of the Union Bay State Chemical Co., is a synthetic rubber solvent cement. Curing cements are rubber compounds to be cured by heat and pressure or by chemical curing agents. When cured, they are stronger, give better adhesion to metal surfaces, and have longer life. Latex cements are solvent solutions of rubber latex. They provide excellent tack and give strong bonds to paper, leather, and fabric, but they are subject to rapid disintegration unless cured.

Cements compounded from synthetics are less subject to deterioration than the vegetable and animal products, and may have high bonding strength. They are the only adhesives that give reliable cold bonds to metals, especially after curing or chemical setting. Cold bonds as high as 300 lb. per sq. in. can be obtained with compounded synthetic cements, while heat-cured bonds as

high as 1,000 lb. per sq. in. can be obtained. Neoprene cements may be simple solutions in a solvent with strengthening fillers and a curing agent, or they may be compounded with resins. Like the rubber cements they may be marketed in two parts to be mixed just before use. The Fairprene cement of E. I. duPont de Nemours & Co., Inc., is a Neoprene cement in which an activator is mixed before use. It then cures at room temperature. The synthetic rubber cements are also marketed as Sealing tapes with the cement coated on both sides of a thin fabric for application as gaskets, and for sealing seams at riveted metal joints or bulkheads.

**Adipic acid.** Also called Butane dicarboxylic acid. A white crystalline solid of the composition $COOH(CH_2)_4COOH$, used as a plasticizer in synthetic resins and coatings, and in the production of nylon. It is made by the treatment of fatty acids with nitric acid, or can be made synthetically. The molecular weight is 146.11, melting point 152°C., and it is soluble in alcohol and slightly soluble in water.

**Admiralty metal.** An alloy containing about 70% of copper, 1 tin, and the remainder zinc, sometimes termed Admiralty bronze. The usual alloy is a 70-30 cartridge brass with 1% of the zinc replaced with an equal amount of tin. This composition is listed by the American Brass Co. as Admiralty alloy. The tin increases the hardness and strength but decreases the ductility. Admiralty metal of the Revere Copper & Brass, Inc., has 71% of copper, 28 zinc, and 1 tin. The hard-drawn tube has a tensile strength of 100,000 lb. per sq. in. and elongation of 3%. Federal specifications permit up to 0.06% of iron and 0.075 lead as impurities. The weight is 0.305 lb. per cu. in. It machines readily, especially when it contains lead. The alloy has been standard for condenser tubes, and in sheet form where corrosion resistance is required.

**Agar-agar.** The dried bleached gelatinous extract from various species of Seaweed, *Algae,* mostly from the Pacific and Indian Oceans. The double Malay word means seaweed. When dissolved in hot water, agar forms a transparent jelly, and is used for fixing bacteria for counts, as a stabilizer in toilet lotions and medicines, and in foods. Kantan is a variety of agar from the Tengusa sea-

weed, *Gelidium corneum,* of Japan. Commercial agar is colorless, yellowish, or pink to black. It is marketed in strips, blocks, or shredded, and is obtained by boiling the dry seaweed and straining out the insoluble matter.

Algin, or Alginic acid, is a protein gelatin obtained from seaweed as a by-product in the manufacture of iodine and potash, or directly from the weed. The American production of the agar type of algin, as distinct from the Irish moss of the Atlantic, is from the giant Kelp, *Macrocystia pyrifera* and *Gelidium cartilagineum* of the coast of California and Mexico, but it is not valued as highly for bacteriologic use as the Asiatic. The kelp grows straight up in water 60 to 100 ft. deep and then spreads out on the water another 60 to 80 ft. It is cut about 3 ft. below the surface, and three crops are harvested annually. The plant is 90% water. The dried kelp is washed with boiling water, cooked with soda ash, filtered, sterilized, and treated with muriatic acid to extract the algin in fiber form. In the form of Sodium alginate it is used as a stabilizer in ice cream and other foods, in textile printing, as an emulsifier and stabilizer in medicines to replace gum arabic and as a laxative, and in water paints, boiler compounds, polishes, and in meat packing. Algin is a colorless mass resembling gelatin, and has the empirical formula $C_{21}H_{27}O_{20}$. When dry, it becomes hard and horny, insoluble in alcohol, and only slightly soluble in cold water. Dry seaweed contain 20 to 30% of algin.

Sodium alginate, made by dissolving algin in a sodium carbonate solution and neutralizing with hydrochloric acid, forms tough, flexible, colorless sheets, soluble in water. When applied as a coating for fabrics, it is again treated with acids to make it insoluble and waterproof. Kelgin is the trade name of the Kelco Co. for sodium alginate used as a stabilizer in the food industry, and Keltex is the material in granular powder for use in the textile industry. Dariloid, of this company, is sodium alginate used to replace gelatin in ice cream. Alginic fibers are silklike threads made by forcing a sodium alginate solution through spinnerets into a calcium chloride bath and then making insoluble by treatment with a beryllium acetate solution. They are used for dress fabrics. A soluble Alginate fiber is used for making fancy striped fabrics where uneven spacing of threads is desired without change in the loom.

The aliginate yarn is washed out of the fabric after weaving, leaving the desired spacing. At least 25 mineral salts are known to be present in seaweed as well as several vitamins. In the utilization of the seaweed as gelatin or alginate these are left in the Kelp meal which is marketed as poultry and stock feed. In Asia the whole plant is cooked and eaten.

**Agate.** A natural mixture of crystalline and colloidal silica, but consisting mainly of the mineral chalcedony. It usually occurs in irregular banded layers of various colors derived from mineral salts, and when polished has a waxy luster. The specific gravity is about 2.6, and the mineral is sometimes harder than quartz. It consists of about 98% of silica. Agate is used for knife-edges and bearings of instruments, for pestles and mortars, for textile rollers, ornamental articles, and the finer specimens are employed as gem stones. The finest of the massive agates come from Uruguay and Brazil. Moss agate encloses filaments, mostly green, suggestive of moss. The moss agates of Montana, and the yellow-green moss agate of California known as Amberine, are used as gem stones. Agate was probably deposited from a silica gel solution, and also occurs in the form of stalactites and in petrified wood. The Agatized wood of Wyoming and Arizona has a green fluorescence. It is cut into ornaments. Clear, translucent, yellow agates are called Sard, while the clear reddish ones are Carnelian. Both are used as gem stones. Sardoine is a brownish carnelian found in Western United States. The Iris agate, with rainbow colors, from Montana and Oregon, is highly prized. Moss opal of Nevada and California is moss agate intergrown with opal. Commercial agates may be artificially stained with mineral salts, dyed, or treated with acids to bring out color differences.

**Ajowan oil.** Also called Ptychotis oil. A yellow essential oil distilled from Ajwan seed of the herbaceous plant *Carum copticum*, or *Ptychotis ajowan*, of India. The seed yields 3 to 4% of oil containing up to 50% Thymol and some Cymene, most of the thymol separating out on distillation. Thymol is known as Ajwan ka phul, meaning Flowers of ajwan, and the latter part of the name is Anglicized to thymol. Ajowan oil has a specific gravity of 0.900 to 0.930. It is used in pharmaceuticals. The cymene is used as a

scent in soaps, and has high solvent properties. It is also obtained from spruce turpentine. It is a liquid of specific gravity 0.861 and boiling point 177°C. Thymol, $(CH_3)_2CHC_6H_3(CH_3)OH$, is a white crystalline solid with a strong thyme odor, soluble in alcohol, and melting at 50°C. It is used in antiseptics, and as a deodorant for leather. Thymol is also obtained from horsemint oil and from eucalyptus oil, or can be made synthetically from meta cresol. It was originally distilled from the Thyme plant, *Thymus vulgaris*, of the Mediterranean countries, the dried leaves of which are used as a condiment.

**Albumin.** The water-soluble and alcohol-soluble protein obtained from blood, eggs, or milk, and used in adhesives, textile and paper finishes, leather coatings, varnishes, as a clarifying agent for tannins, and in oil emulsions. Crude Blood albumin is a brown amorphous lumpy material obtained by clotting slaughterhouse blood and dissolving out the albumin. The remaining dark red material is made into Ground blood and marketed as a fertilizer. Blood albumin is sold as clear, pale, amber, and colored powders. Blood albumin from human blood is a stable, dry white powder. It is used as a 25% water solution for treatment of shock. The white of egg is known as Albumen. Egg albumin is prepared from the dried egg white, and is marketed in yellowish amorphous lumps or powdered. Milk albumin is made by coagulating casein.

**Alcohol.** The common name for ethyl alcohol, but the term properly applies to a large group of organic compounds that have important uses in industry, especially as solvents and in the preparation of other materials. A characteristic of all alcohols is the monovalent —OH group. In the primary alcohols there is always a $\cdot CH_2OH$ group in the molecule. The secondary alcohols have a :CHOH group, and the tertiary alcohols have a distinctive ⋮COH group. Alcohols with one OH group are called Monohydroxy alcohols; those with more than one OH group are known as Polyhydroxy alcohols or Polyhydric alcohols. Another method of classification is by the terms saturated and unsaturated. The common alcohols used in industry are ethyl, methyl, amyl, butyl, isopropyl, and octyl. The alcohols vary in consistency. Methyl alcohol is like water, amyl alcohol is oily, and melissyl alcohol is a solid. Many of

the alcohols are easiest made by fermentation; others are produced as Synthetic alcohol from natural gas or from petroleum hydrocarbons. Much of the American production of ethyl alcohol is from blackstrap molasses. Solidified alcohol, used as a fuel in small stoves, is a jellylike solution of nitrocellulose in ethyl alcohol marketed in tins. It burns with a hot flame.

**Aldehyde.** A group name for substances made by the dehydrogenation or oxidation of alcohols, such as formaldehyde from methyl alcohol. By further oxidation the aldehydes form corresponding acids, as formic acid. The aldehydes have the radical group —CHO in the molecule, and because of their ease of oxidation are important reducing agents. They are also used in the manufacture of synthetic resins and many other chemicals. Aldehydes occur in animal tissues and in the odorous parts of plants, giving odor and flavor to many of these.

**Alder.** The wood of several species of tree of the genus *Alnus* of the same family as the birch and beech. The Red alder is from the *A. rubra,* or *A. oregona,* growing in the Northwestern United States. The wood has a reddish-brown color, a fine even grain, is tough and resilient, can be worked easily, and takes a good polish. It is much used for furniture, cabinetwork, and interior finish as it rivals mahogany and walnut in appearance. Black alder is from the tree *A. glutinosa,* widely distributed in the Northern Hemisphere. It is of a reddish-white color, and has a smooth, fine grain, with a weight of about 35 lb. per cu. ft. It is used for plywood, cabinetwork, and toys. Formosan alder is from the *A. maritima* of Asia. The wood is light yellow streaked with reddish lines and has a fine texture.

**Aldol.** A viscous, pale-yellow liquid of the composition $CH_3 \cdot CHOH \cdot CH_2 \cdot CHO$, also called Acetaldol, made by condensation of acetaldehyde with an alkali. It is used to replace formaldehyde in the manufacture of synthetic resins, in cadmium plating baths, in dye baths, in refining ores, in the manufacture of butadiene rubber, and in engraving. It has a specific gravity of 1.090 to 1.105, and is soluble in hot water and in alcohol. Paraldol, which is a

double molecule of aldol, is a white crystalline product with a melting point of 82°C.

**Alkali.** A caustic hydroxide characterized by its ability to neutralize acids and form soluble soaps with fatty acids. Fundamentally, they are inorganic alcohols, with the monovalent hydroxyl group —OH in the molecule, but in the alkalies this group is in combination with a metal or an ammonia group and they have none of the characteristics of alcohols. All alkalies are basic, and have a pH value from 7 to 14, and the alkalies are those bases which are freely soluble in water. The common alkalies are sodium hydroxide and potassium hydroxide, which are the ones used in soluble oils and cutting compounds, in soaps and cleaning solutions, and for etching aluminum alloys. All the alkalies have a brackish taste and a soapy feel; most of them corrode animal and vegetable tissues, from which they derive the names caustic soda and potash. The alkalies have a wide range of usage in the manufacture of chemicals.

**Alkali metals.** A name given to lithium, sodium, potassium, rubidium, strontium, caesium, calcium, and barium because of the basic reaction of their oxides, hydroxides, and carbonates. Carbonates of these metals are called Fixed alkalies. The metals show a gradation in properties and increase in chemical activity with increase in atomic weights. All are silvery white and are soft enough to be cut with a knife. They tarnish rapidly in the air and decompose water at ordinary temperatures. All have remarkable affinity for oxygen. Rubidium and caesium ignite spontaneously in dry oxygen. Calcium, strontium, and barium are also called Earth metals. Thin films of the alkali metals are transparent to ultraviolet light but opaque to visible light.

**Alkanet.** Also called Orcanette and Anchusa, and in medicine Alkanna. The root of the plant *Alkanna tinctoria,* related to the heliotrope, growing in the Mediterranean countries, Hungary, and western Asia. The coloring principle, Alkannin, is soluble in alcohol, benzene, ether, and in oils, and is produced in dry extract as a dark-red, amorphous, slightly acid powder. It is used for coloring fats and oils in pharmacy and in cosmetics, for giving an even-red

color to wines, for coloring wax, and as a chemical indicator. Alkannin paper, also called Boettger's paper, is a white paper impregnated with an alcohol solution of alkanet. The paper is red, but it is turned to shades from green to blue by alkalies.

**Alkyd resins.** A group of thermoplastic synthetic resins known chemically as hydroxycarboxylic resins, of which the one produced from phthalic anhydride and glycerol is representative. They are made by the esterification of a polybasic acid with a polyhydric alcohol, and have the characteristics of homogeneity and solubility that make them especially suitable for varnishes and enamels, resistant coatings, calking compounds, adhesives, and plasticizers for other resins. They are modified with drying oils or fatty acids, and find wide use as finishes for automobiles, marine finishes, and baking enamels for refrigerators and household equipment. They bake to a high gloss, and are resistant to oils, light, and weathering. The oil-modified resins are used as waterproof coatings for textiles. The alkyd resins vary greatly with the raw materials used and with varying percentage compositions, from soft rubbery gums to hard brittle solids. Phthalic anhydride imparts hardness and stability. Maleic acid makes a higher melting-point resin. Azelaic acid gives a softer and less brittle resin. The long-chain dibasic acids, such as adipic acid, give resins of great toughness and flexibility. In place of glycerol the glycols yield soft resins, and sometimes the glycerol is modified with a proportion of glycol.

When mixed with urea-formaldehyde or melamine resin the alkyd resins give harder and more resistant baked coatings. Blended with ethyl cellulose they are used as tough flexible coatings for electrical cable. Emulsions of the alkyd resins are used in some resistant water paints. The resins have high adhesion to metals, are transparent, easily colored, tough, flexible, heat- and chemical-resistant, have good dielectric strength, and are the most readily blended of the synthetic resins. Amberlac and Duraplex are alkyd resins of the Resinous Products & Chemical Co., Inc., in a wide range of formulations. The Paraplex resins are oil-modified soft resins used for coatings for textiles and paper, and for blending with cellulose plastics to give better adhesion in lacquers. Aquaplex, of this company, is a group of oil-modified resins for use in water

paints. Teglac resins, of the American Cyanamid & Chemical Corp., used for indoor finishes and clear-coat varnishes, are hard alkyd resins made with natural resin acids as blending agents. Petrex resin, of the Hercules Powder Co., is a series of alkyd resins used in lacquers, varnishes, adhesives, and inks. Glyptal, of the General Electric Co., is a phthalic anhydride glycerol resin for lacquers and insulation. Dulax, of E. I. duPont de Nemours & Co., Inc., Beckol, of Beck, Koller & Co., Esterol, of the Paramet Chemical Corp., are alkyd resins. Neolyn resins, of the Hercules Powder Co., are alkyd resins produced from rosin. They are used as modifiers for nitrocellulose and for vinyl resins in lacquers and adhesives to add toughness to the film.

**Alligator leather.** A light, tough leather with platelike scales on the surface. It is made from the skins of large saurians, or lizards, of the order *Crocodilia,* abounding in muddy tropical streams. The species *Alligator mississippiensis* inhabits the swamps of Southeastern United States. The mature animal is usually about 7 ft. long, and reaches this length in little over 5 years. Alligator leather is especially valued for luggage, pocketbook, and shoe leathers. It is much imitated with embossed split sheepskins, but sheepskin is soft and easily scuffed. Lizard leather, from the Java ring lizard, is another reptile leather valued for women's shoes.

**Alloy.** A solid solution of two or more metals. Chemically, an alloy is a solution that is entirely homogeneous, but the commercial use of the term also includes mixtures of metals that do not dissolve in each other. Lead, for example, does not dissolve in copper but forms separate particles in the metal matrix; in steel it does not dissolve but forms strings in the metal. Both are useful combinations and are called alloys. The commercial utility of an alloy arises from the fact that the pure metals are often too soft, weak, or rare to be used alone. Thus, copper, a soft metal, when alloyed with the brittle metal zinc, forms a strong, hard alloy, brass, that has wide usage. Alloys show definite relations that one metal bears to another, and definite characteristics can be obtained from the combinations, although these may be changed by the interaction of one alloying element on another. Thus, silicon and nickel give definite added properties to copper when added separately, but give

an additional separate property when used together because of the formation of a nickel-silicide compound. Some alloys contain chemical crystals of the metals. Thus, bronze contains a percentage of copper-tin crystals, while in brass the copper and zinc may be only mechanically dissolved. The melting point is always lowered by the addition of one metal to another.

The number of possible alloys is infinite. They are made by the fusion of the metals, as distinct from products made by the diffusion of particles in close contact under high pressure, which process is called powder metallurgy. The most common general groups of alloys are brass, bronze, babbitt, alloy steels, nickel silver, aluminum alloy. A Technic alloy is a low-cost alloy used in laboratories or dental schools to avoid the use of expensive alloys of gold or platinum in practice working. They may be copper or aluminum with tin, nickel, silver, and iron, to give the approximate working characteristics of the expensive metal. A Master alloy, or Foundry alloy, is an alloy used for adding elements to metals in the foundry. Some of these may not be metallic alloys in the true sense. Carburite, for example, is a high-graphitic iron master alloy containing 55% of carbon and only 26 iron, bonded with fluxing material into blocks for adding to steel to increase the carbon content.

**Alloy steel.** A general name for steels that owe their distinctive properties to elements other than carbon. Alloy steels usually take the name of the element or elements having the greatest influence on the characteristics of the alloy, regardless of the percentage of the element contained in the steel. These alloy steels include vanadium steel, nickel steel, nickel-chromium steel, manganese steel, and silicon steel. The American Iron & Steel Institute defines alloy steel as a steel in which a minimum limit is specified or guaranteed for alloying elements. These minimum percentages are chromium, 0.25%; copper, 0.60; manganese, 1.65; nickel, 0.25; silicon, 0.60; or any amounts of titanium, tungsten, or molybdenum. Steels having casual amounts of these elements less than those specified are not rated as alloy steels, although vanadium steel may be any carbon steel that has been cleansed with vanadium. Alloy steels are also marketed under a great variety of trade names, covering a particular steel made into rough castings, such as Tufaloy, a high-

strength cast steel of the Fort Pitt Steel Casting Div., H. K. Porter Co., Inc., or covering a group of steels marketed in rods and sheets such as Agathon steel of the Central Alloy Steel Corp., and Carilloy of the Carnegie-Illinois Steel Corp. The alloy steels are used for automotive and machinery parts where high strength or special characteristics are required. Most tool steels and structural steels with special properties are now alloy steels. High-speed steels are alloy steels, but are usually classed as a separate group.

At the beginning of the century the proportion of alloy steels produced was small; at the end of the First World War it was 1 out of every 25 tons; and at the end of the Second World War alloy steel constituted 1 out of every 7 tons of steel produced. Universal steel is a name applied to alloy steels containing a low percentage of carbon to give them a wide range of utility. They are usually nickel-chromium steels, as these steels can be used with carbon as low as 0.15% without losing their heat-treating properties. High-alloy steels are steels containing very large percentages of elements, usually to obtain some special property such as corrosion resistance. They are often not steel in the true sense, but are iron alloys.

**Allyl plastics.** A group of water-white casting plastics produced by the polymerization of the ester of allyl alcohol. Allyl alcohol, $CH_2{:}CH{\cdot}CH_2OH$, is a colorless liquid also known as Propenol. The specific gravity is 0.849, boiling point 96°C., and freezing point −129°C. The allyl radical, $CH_2{:}CH{\cdot}CH_2$—, combines readily with chlorine and the other halogens, and it is also easily oxidized to acrylic acid, the starting point for the acrylic plastics. Allyl ester is a clear sirupy liquid of specific gravity 1.26 which polymerizes with a peroxide catalyst to form allyl plastics. The liquid monomer can be poured into molds and hardened by polymerization. The polymerized castings are hard and crystal clear. Allyl plastics have a specific gravity of 1.34 to 1.40, dielectric strength of 1,275 volts per mil, refractive index 1.57, Rockwell M hardness 116, and compressive strength 19,600 lb. per sq. in. As the plastic has high clarity and less light dispersion than most optical glass it is used for lenses, prisms, and reflectors. It can be colored easily with dyes, and is also used for mechanical and elec-

trical parts. Kriston, of the B. F. Goodrich Chemical Co., is an allyl ester plastic. Allite was an allyl plastic of the Columbia Chemical Div. Vibron 103 is another allyl plastic of the Naugatuck Chemical Div. Methallyl alcohol, $CH_2:C\cdot CH_3\cdot CH_2OH$, also forms esters which can be used for the production of plastics. It is a liquid boiling at 114.5°C.

**Almond oil.** An essential oil distilled from the ground macerated kernels of the bitter almond, *Prunus amygdalus,* of the Mediterranean countries, and from the kernels of the Apricot, *P. armeniaca,* both oils being identical and containing the glucoside Amygdalin. The American production is mostly from the by-product pits of the apricot-canning industry of California. The almond is a small tree closely resembling the peach. The fruit is inedible, but the seed inside the pit is marketed as roasted and salted nuts and is made into a paste for confections. Oil of bitter almonds is used in perfumery and as a flavor. For flavoring use, the poisonous hydrocyanic acid is extracted. Synthetic almond oil is Benzaldehyde, $C_6H_5CHO$, a colorless volatile oil with an almond flavor, produced from benzol or from toluol.

**Alpaca.** An English nickel silver used as a base metal for tableware. It contains about 65% of copper, 20 zinc, 13 nickel, and 2 silver, and has a white color similar to silver. It is usually plated with silver, takes a fine polish, and is resistant to corrosion. Alpaca is widely imitated, often without the silver. Alpaca is also the name of a fabric made from Alpaca fiber, the fine woollike hair of animals of the llama family of Bolivia, Peru, Chile, and Argentina. Alpaca fiber is long and fine, with a downy feel, but it does not have the strength or elasticity of fine wool. Llama hair (pronounced lyah-ma) from the llama of Bolivia, is marketed as Coarse alpaca. The Vicuña, another animal of the llama family, is almost extinct, and the commercial vicuña cloth is made of alpaca or fine wool, or mixtures. There is a limited production of true vicuña from domestic herds in Bolivia. It is the softest of all animal weaving fibers. Alpaca and vicuña cloths are used for shawls, jackets, and fine goods. Imitation alpaca fabric for clothing linings is a lustrous, smooth, and wiry fabric plain-woven with a cotton warp

and a worsted mohair filling. When made with a rayon filling, it is called Rayon alpaca.

Alum. A colorless to white crystalline substance of the composition $KAl(SO_4)_2 \cdot 12H_2O$, or $K_2Al_2(SO_4)_4 \cdot 24H_2O$, occurring naturally as the mineral Kalunite, and also in combination as the mineral Alunite. It is also called Potash alum to distinguish it from other forms. It has a sweetish taste and is very astringent. It is used as an astringent in the leather and textile industries, in sizing paper, as a mordant in dyeing, in medicines as an astringent and styptic, and in baking powder. It is an important water-purifying agent. From a water solution it crystallizes out forming positively charged particles which attract the negatively charged organic impurities, thus purifying the water as they settle out. Alum has a specific gravity of 1.757, melts in its water of crystallization at 92°C., and when heated to redness is converted to Burnt alum, a porous, friable material which dissolves slowly in water. Alum is marketed as U.S.P., lump, pea, nut, ground, and powdered. The rice crystal alum of the General Chemical Co. is from 10 to 30 mesh, and the granular is from 30 to 60 mesh. Alumstone is a gray or pinkish massive form of alunite found in volcanic rocks. A pure variety from Italy is called Roman alum, or Roche alum. Soda alum, in which the potassium is replaced by sodium, occurs naturally in the South American Andes as the mineral Mendozite. It is more soluble than alum, but is more difficult to purify. Filter alum, also called Patent alum and Aluminous cake, used for waterworks filtration, is Aluminum sulphate, $Al_2(SO_4)_3$, plus a varying amount of water of crystallization. In the anhydrous form it is used as a dehydrating agent for gases. It is a white crystalline solid readily soluble in water. When filter alum contains a slight excess of alumina it is called basic.

Commercial aluminum sulphate is also called Concentrated alum, and replaces potash alum for many uses because of its cheapness. It comes in colorless crystals having a strong astringent taste, and is used as a mordant in dyeing, in water purification, sizing papers, tanning, in printing inks, and in dry colors. For use in pickling and tanning leathers, it contains not more than 0.01% of iron oxide. Ammonia alum, used in tanning sheepskins and fur skins,

and in fireproofing and dyeing textiles, is Ammonium-aluminum sulphate, $Al(NH_4)_2(SO_4)_2 \cdot 12H_2O$, a colorless or white crystalline powder soluble in water and, like other alums, insoluble in alcohol. It is valued for water purification because it forms chloramine, and is also used in vegetable glues and porcelain cements.

**Alumina.** The oxide of aluminum, $Al_2O_3$. In natural or artificial crystalline form it is used as an abrasive under the name of aluminum oxide. It is widely distributed in nature in combination with silica and other minerals, and is an important constituent of the clays for making porcelain, bricks, pottery, and refractories. The Alumina clay from the large deposits in western Idaho contain an average of 20% $Al_2O_3$, 5.6% iron oxide, and a high percentage of titanium oxide. Pure alumina is a white, amorphous powder when prepared by calcining and precipitation. The melting point is 3670°F. It is also used as a mordant in dyeing. Activated alumina is a partly dehydrated aluminum trihydrate in the form of hard porous masses. It has a strong affinity for moisture or gases and will remove them from the air. Heating will then reactivate the alumina by driving out the gases or moisture. It is used for dehydrating organic solvents. Hydrated alumina C-730, of the Aluminum Co. of America, is a trihydrate of aluminum, $Al_2O_3 \cdot 3H_2O$, used as a catalyst carrier. The particles are 0.1 to 0.6 micron. At elevated temperatures the material becomes active and the fine powder is an auxiliary catalyst. It is also used as a filler in plastics and in cosmetics.

Calcined alumina is alumina that has been calcined to a degree that prevents adsorption of more than 0.5 to 2% of water. It comes in fine powder and is used for electrical insulators, abrasives, and in procelain and ceramic mixes. Aluminum hydroxide is a white bulky water-insoluble powder of the composition $Al(OH)_3$ produced by the reaction of a soluble aluminum salt and an alkali and precipitated from solution. The specific gravity is 2.42 and refractive index 1.535. It is used as a base for lake pigments, for making gloss white, and as a water-repellent agent in fabric and paper coatings. Hydrated alumina C-741 is this material with the particles coated with stearic acid for use as a reinforcing pigment for rubber.

**Aluminum.** Called Aluminium in England. A white metal with a bluish tinge, symbol Al, atomic weight 26.97, obtained chiefly from bauxite, but also from alunite and kalunite, and in Sweden from andalusite. It is the most widely distributed of the elements next to oxygen and silicon, occurring in all common rocks, but it is difficult to extract. The metal was discovered in 1727, but was obtained only in small amounts until it was reduced electrolytically in 1885. Aluminum has a specific gravity of 2.70, melting point of 658.7°C., is resistant to corrosion, but is dissolved by alkalies and hydrochloric acid. It is nonmagnetic, even when highly alloyed with iron. Its physical properties are greatly affected even by slight additions of other elements. So great is the effect of alloying elements that a commercial aluminum 99.2% pure will have a strength 25% greater than 99.9% pure aluminum but will be harder. Pure aluminum is next to gold in order of malleability. The tensile strength of cast aluminum is 12,000 lb. per sq. in., with elongation of 30% and a Brinell hardness of 30. Annealed wrought aluminum, 99.9% pure, has a tensile strength of 9,000 lb. per sq. in., and elongation of 60%. The electrical conductivity is 59% that of copper, and the coefficient of expansion is 0.0000137. The chief impurities in commercial aluminum are copper, iron, and silicon, but sheet aluminum averages 99.3% pure. Alcoa 2S is commercially pure aluminum, 99+% pure, of the Aluminum Co. of America. It has a specific gravity of 2.72, tensile strength, annealed, of 13,000 lb. per sq. in., elongation 35%, and Brinell hardness 23. When cold-rolled, the tensile strength is 24,000 lb. per sq. in., elongation 5%, and Brinell hardness 44.

Commercial aluminum comes in three grades: above 99% aluminum, 98 to 99%, and 94 to 98%. Special grades can be obtained 99.8% pure. The 1-lb. notched ingot is the usual form of the metal marketed for die casting. The metal is also marketed in bars, rod, tubing, sheet, plate, wire, and shapes. Aluminum sheet is finished by cold-rolling in gray plate and bright finish, the former being produced by allowing the rolls to take on a coating of fine particles and oxide. Very thin sheets are rolled in packs. Foil as thin as 0.00025 in. can be rolled. Because of its high strength-weight factor a large part of the production of aluminum goes into transportation equipment and the moving parts of machinery. It

is also used for ornamental architectural work, containers, cooking utensils, chemical equipment, and for making parts where the light weight and easy working properties are valued. The metal is transparent to X rays, and is used in thin sheets as ray filters. It extrudes easily, and is used to replace tin alloys for collapsible tubes. In powder and flake form it is used in paints and fireworks.

Aluminum can be surface-colored in many shades by immersion in solutions of ammonium hydroxide containing salts of metals, or can be dyed chemically. Dyed aluminum is more corrosion resistant than the painted metal and retains the metallic appearance. Alumilite, of Aluminum Colors, Inc., is sheet aluminum with colored chemical coatings applied electrolytically. Anodized aluminum, originally called Eloxal in Germany, is aluminum, or low-copper aluminum alloys, treated by electrolytic oxidation in solutions of sulphuric, oxalic, or chromic acid to give a coating of aluminum oxide 0.1 to 0.6 mil in thickness to protect the metal from further oxidation. Aluminum is a powerful deoxidizer for steel, and for this purpose is added to molten steel in the form of Ferroaluminum. This master alloy is marketed in 20 and 50% grades, the former melting at 1900°F., and the latter at 2100°F. With 50% aluminum the alloy is very brittle and breaks into lumps. Ferroaluminum is also used for adding aluminum to steel, or for adding iron to aluminum alloys.

**Aluminum alloy.** A term which, when not further qualified, refers to Aluminum-copper alloys with or without other alloying elements. Copper hardens and strengthens aluminum, and also gives age-hardening properties, especially when a small amount of magnesium is present. The wrought alloy normally does not contain more than 4% of copper, as the alloys with more than this amount do not roll easily. Aluminum alloy casts well. In casting alloys, 8% copper is considered the economic point to obtain a balance of strength and low specific gravity. An aluminum-copper 92-8 alloy when cast has a tensile strength of 18,000 lb. per sq. in., Brinell hardness of 70, and specific gravity of 2.85.

Originally, the trade name Duralumin, of the Durener Metallwerke, was given to wrought aluminum-copper alloys containing sufficient magnesium to give heat-treating characteristics, and

hardened with a slight amount of manganese. The original duralumin contained 4% of copper, 0.5% magnesium, and 0.5% manganese. For hardening, duralumin is quenched from a temperature of about 950°C., and allowed to age-harden for 4 days through chemical combination of the magnesium with the aluminum. Annealed duralumin has a tensile strength of 28,000 lb. per sq. in., elongation 22%, and Brinell hardness 50. After heat-treating and ageing the strength is 59,000 lb. per. sq. in., elongation 18%, and hardness 95. The metal can be again annealed by raising to a temperature of 650°C. and cooling. The alloy is more ductile than brass, can be cold-worked, drawn, and forged, and welds easily. But it corrodes easily and is hot-short. The alloy with up to 1.25% silicon was called Superduralumin. Other early duralumin-type alloys were Aldrey, Aludur, Pantal, Alferium, Almag, Simalec, Sigmalium, Partinium, Arional, and Almelec, the latter containing both silicon and iron, and the Simalec having high silicon and magnesium. Aerolite had only 1.15% of copper, with small amounts of magnesium, zinc, iron, and silicon. Anticorodal, a German corrosion-resistant aircraft alloy, had 1% of silicon, 0.5 manganese, and 0.5 magnesium. The tensile strength is 45,000 lb. per sq. in., and elongation 14%. The Hiduminium alloys, developed by the Rolls-Royce laboratories and produced by High Duty Alloys, Ltd., were improvements on the German duralumin and contained titanium, nickel, and other elements. The German alloy Constructal also contained titanium, and Lautal contained 2% silicon. The French alloy Almasilium had 2% of silicon and 1 magnesium. In the United States the term duralumin has come to mean any wrought aluminum alloy containing 3 to 4.5% of copper, 0.4 to 1.0 magnesium, and 0 to 0.7 manganese, with or without small amounts of iron and silicon.

Zinc and tin in aluminum alloy cause hot-shortness, but zinc increases the strength. Magnesium forms a silicide with the silicon present, and also gives age-hardening with the copper. Small amounts of manganese inhibit grain growth. Titanium in small amounts gives greater corrosion resistance, but causes brittleness in large amounts. Iron in small amounts increases strength, but causes hot-shortness and sets up intercrystalline corrosion. Aluminum-

copper alloy itself is subject to intercrystalline corrosion unless anodized or clad with pure aluminum.

The most commonly used casting alloys contain 7 to 8.5% of copper, 1 to 2 zinc, and a maximum of 1.7 of other elements, mostly iron. Alcoa No. 112, and S.A.E. No. 33 fall within this range, but British alloy 3-L-11 has less iron and zinc. Alcoa No. 122 has 10% of copper, 0.2 magnesium, and 1.2 iron. When sand-cast, it has a tensile strength of 22,000 lb. per sq. in., elongation of 2%, and Brinell hardness of 70. Alcoa 195, with 4% copper as the only alloying element, has a tensile strength, sand-cast and heat-treated, of 32,000 lb. per sq. in., elongation 3%, and Brinell hardness 80. Aluminum-copper casting alloys are made by adding a Hardener alloy to the aluminum. This hardener alloy contains 50% of aluminum and 50 copper, with a tolerance of plus or minus 2% of either, the impurities being a maximum of 1% of iron, 1 zinc, and 0.50 silicon.

For die castings and permanent mold castings, and for special uses such as automotive pistons, a wide range of aluminum-copper alloys is employed. The English alloys B.E.S. No. 362 and B.E.S. No. L8 contain 11 to 13% copper and are close-grained. B.E.S. No. L11 has 6 to 8% copper, and is classed as a medium-hard, ductile alloy. Bohnalite J, of the Bohn Aluminum & Brass Co., with 10% of copper, and Bohnalite B, with 4.5% of copper and 0.3 magnesium, are casting alloys, the former, when permanent molded, having a tensile strength of 35,000 to 50,000 lb. per sq. in., and Brinell hardness of 125 to 160.

Rolled aluminum alloy comes in tempers of soft, ¼ hard, ½ hard, ¾ hard, and hard. Federal specifications for aluminum alloy in wrought form call for 3.5 to 4.5% of copper, 0.2 to 0.75 magnesium, 0.4 to 1.0 manganese. Heat-treated bars of this material must have a minimum tensile strength of 50,000 lb. per sq. in., with elongation of 16%. Alcoa 17S, of the Aluminum Co. of America, contains 3.5 to 4% of copper, 0.2 to 0.5 magnesium, 0.4 to 0.5 manganese, and has a tensile strength of 60,000 lb. per sq. in, with elongation of 20% and Brinell hardness of 95. Bohnalite S'17, of the Bohn Aluminum & Brass Corp., has about the same composition and characteristics. Aluminum alloy R-317, of the Reynolds Metals Co., Inc., is the same type of alloy with small additions of

other elements giving added strength and free machining. The tensile strength is 62,000 lb. per sq. in., yield point 40,000 lb. per sq. in., elongation 22%, and specific gravity 2.80. Reynolds alloy R-301 contains 4.5% of copper, 1 silicon, 0.8 manganese, 0.4 magnesium, and may have up to 1% of iron and 0.1 chromium. It has a minimum tensile strength of 65,000 lb. per sq. in., yield strength 57,000 lb. per sq. in. It is marketed as a clad metal with a coating containing 1% of magnesium and 0.5 manganese giving corrosion resistance equal to 99.5% aluminum. Alcoa 24S is essentially the same alloy, but with more manganese. Both are used for aircraft construction.

Cerium-aluminum alloys are standard aluminum-copper or aluminum-silicon alloys containing an addition of 0.30 to 0.35% of cerium. They have a fine grain structure, and the strength and hardness are increased. The cerium is added in the form of a master alloy containing about 9% cerium made by dissolving misch metal in molten aluminum. Various patents have been obtained on alloys containing beryllium. Aluminum-beryllium alloys contain less than 1% of beryllium which is supplementary to other elements. Beryllium hardens, adds strength, and in castings increases the tendency to age-harden. Very small amounts in aluminum alloys make them tarnish resistant.

Aluminum alloys are marketed under a wide variety of trade names, with characteristics varied by slight additions of alloying elements. The French Benit metal contains 2% of copper, 0.45 magnesium, and 0.27 tungsten, the latter adding strength and ductility. Fairey metal, of the British Aluminum Co., for airplane propellers, is a duralumin-type forging alloy. Ultralumin was a German casting and forging alloy. Permite is aluminum alloy of varying compositions produced by Aluminum Industries, Inc. Londal is a name for wrought alloys of the London Aluminum Co., Ltd. Tennal, of the National Bronze & Aluminum Foundry Co., is a name for casting alloys. Weisalloy is sheet aluminum alloy used for partitions and cabinets by the Henry Weis Mfg. Co. A ductile wrought alloy, Hyblum, of the Sheet Aluminum Corp., contains about 2% of alloying elements, copper, nickel, silicon, and magnesium.

**Aluminum brass.** There are two distinct types of aluminum brass. The first is a casting brass in which a small amount of aluminum acts as a flux to eliminate impurities and give the brass greater fluidity for intricate castings. The excess of aluminum remaining in the alloy is usually not more than 0.50%. The addition of aluminum also permits the use of higher percentages of lead up to about 5%, making the castings easy to machine. The second type is wrought brass modified with aluminum, producing alloys with properties between the brasses and the aluminum bronzes. Even slight additions of aluminum, dispersed as metal in the alloy and not as oxide, improve the oxidation resistance of brasses, and brass with as little as 0.10% of aluminum will have a bright color when extruded or forged. Larger amounts increase the strength and hardness, but decrease the ductility.

A 60-40 brass containing 1% of aluminum has its strength increased about 30% and its hardness about 25%. Revalon, of Revere Copper & Brass, Inc., contains 76% of copper, 22 zinc, and 2 aluminum, and is used for condenser tubes. The soft alloy has a tensile strength of 62,000 lb. per sq. in., elongation of 50%, Rockwell B hardness 33, while the hard-drawn material has a tensile strength of 83,000 lb. per sq. in., elongation 15%, and hardness of 86. It has 22.5% of the electrical conductivity of copper, and is very corrosion-resistant. Ambraloy 927, of the American Brass Co., has the same composition and properties. This alloy is known in England as High-tensile brass. Ad-aluminum, of the Chase Brass & Copper Co., has 82% of copper, 15 zinc, 2 aluminum, and 1 tin. Alcunic, of the Scovill Mfg. Co., is a 70-30 brass modified by replacing some of the zinc with 2% of aluminum and 1 nickel.

**Aluminum bronze.** A copper-aluminum alloy with aluminum as the chief alloying element, with or without other alloying materials. Plain additions of aluminum to copper increase the strength up to three times that of the original copper, and change the color from red to pale gold. The commercial alloys usually contain from 5 to 10% of aluminum. Single-phase alpha alloys up to 7% aluminum have the structure of pure copper with the aluminum in solid solution, and the alloy is tough and ductile. At about 7.5%

aluminum the structure changes from homogeneous to duplex, and the alloy becomes increasingly hard and difficult to cold-work. Chemical control of the alloy is important, as free aluminum oxide may make hard spots. Deoxidizers refine the grain size. Iron is the most common metal used for refining the grain, but nickel, manganese, and zinc affect it in varying degrees.

All of the alloys are resistant to corrosion. They can be cast or forged, but the high-aluminum alloys are difficult to machine because of free aluminum oxide present. The duplex alloys can be hardened by quenching from a high temperature, and drawn. Aluminum bronze is used for high-strength and nonmagnetic parts, condenser tubes, and corrosion-resistant chemical equipment. The hard crystals in a soft matrix make it useful for bearings. The alloys high in aluminum are used for architectural castings to contrast in color with aluminum-silicon alloys.

Standard aluminum bronze for castings contains 8% of aluminum. It has a tensile strength, annealed, of 76,000 lb. per sq. in., elongation 55%, and Brinell hardness 125. When hardened, the tensile strength is 134,000 lb. per sq. in., elongation 13%, and hardness 240. The weight is 0.293 lb. per cu. in., and the melting point 1940°F. Ambraloy 928, of the American Brass Co., and Revere alloy 430, of the Revere Copper & Brass, Inc., have this composition but are wrought alloys. The hard-drawn rod has a tensile strength of 125,000 lb. per sq. in., with elongation of 5%. Revere alloy 429 has 95% of copper and 5 aluminum. In hard-drawn condenser tube it has a tensile strength of 70,000 lb. per sq. in., and elongation of 25%. Atlas 90, of Ampco Metals, Inc., contains 10% aluminum, and has a minimum tensile strength of 90,000 lb. per sq. in.

Additions of iron to aluminum bronze increase the strength, refine the grain and reduce the tendency to self-anneal, and improve forging qualities. The copper-aluminum-iron alloys are used for cast dies, gears, and strong wear-resistant parts. They have a hardness up to 325 Brinell. McGill metal, of the McGill Metal Co., is the name of a group of these alloys. A typical analysis is 89% of copper, 9 aluminum, and 2 iron. This alloy has a tensile strength up to 90,000 lb. per sq. in., elongation 10 to 20%, and Brinell hardness 160. It is a casting metal, but can be forged, and it machines

about the same as medium carbon steel. A casting alloy used for aircraft engine parts, with 10% of aluminum and 1 iron, has a tensile strength of 75,000 lb. per sq. in., and Brinell hardness of 100. This is Lumen alloy 11-C of the Lumen Bearing Co., and Grade B in Federal specifications, Grade A having more iron and less aluminum. U.S. Navy aluminum bronze 46B-186 has 7 to 9% of aluminum and 2.5 to 4.5% iron. This is S.A.E. alloy 68, and has a tensile strength of 80,000 lb. per sq. in. Daraloy 437, of the Darling Valve & Mfg. Co., is a standard Grade A aluminum bronze used for valve stems, facings, and pressure castings. The tensile strength is 80,000 lb. per sq. in., elongation 18%, and Brinell hardness 90. Resistac, of the American Manganese Bronze Co., has 9% of aluminum and 1 iron. When heat-treated, the tensile strength is 90,000 lb. per sq. in., and Brinell hardness 90. Avialite, a similar composition of the American Brass Co., is used for die-pressed parts and for heat-resistant parts for aircraft engines. Atlas 89, of Ampco Metals, Inc., is also this alloy. These alloys are also valued for heavy-duty gears. Ambraloy 930, of the American Brass Co., is a wrought metal with 8% of aluminum and 2.5 iron. The tensile strength is up to 125,000 lb. per sq. in. Amcoloy 4640, of Ampco Metals, Inc., is an extruded aluminum-iron bronze, with tensile strength up to 105,000 lb. per sq. in., elongation 8 to 12%, and Brinell hardness 207 to 229.

Nickel is also used in aluminum bronzes, especially in those containing iron. It increases the corrosion resistance and produces dense castings suitable as hydraulic castings, but the alloys require more care in casting. Aurornet 55, of the Aurora Metal Co., contains 76 to 80% of copper, 10 to 12 aluminum, 4 to 6 iron, and 4 to 6 nickel. The wrought metal has a tensile strength of 110,000 lb. per sq. in., elongation 2%, and Brinell hardness 250. Small additions of titanium give strength to the aluminum bronzes and act as a deoxidizer. The bronzes containing manganese are classed with the superbronzes. Lead is sometimes added for bearing bronzes, or for free-cutting casting alloys. It reduces the strength rapidly, and only 1.5% is needed for free cutting, though larger additions may be made to increase frictional qualities. Atlas 10 bronze, of Ampco Metals, Inc., has 9% of aluminum and 9 lead. The tensile strength is 50,000 lb. per sq. in., and Brinell hardness

50 to 60. Calsun bronze, of the American Brass Co., has 2.5% of aluminum and 2 tin. When soft, the tensile strength is 50,000 lb. per sq. in. and elongation 30%; when hard-drawn into wire, the tensile strength is 135,000 lb. per sq. in. and elongation 4%.

Aluminum-chromium alloy. Aluminum alloys containing chromium as an important alloying element, although high-strength, aluminum-copper, aircraft alloys may also contain chromium. A high-strength alloy originally developed by the Stockholm Metallographic Institute under the name of Cromal contained 2 to 4% chromium with small amounts of nickel and manganese. The tensile strength is up to 60,000 lb. per sq. in. The alloy designated as aluminum-chromium alloy in Federal specifications is an aluminum-magnesium heat-treatable alloy with little or no copper, 1.10 to 1.40% magnesium, and 0.30 chromium. The heat-treated wrought metal has a tensile strength of 32,000 lb. per sq. in., and elongation of 15%. Alcoa 53S, of the Aluminum Co. of America, has 0.25% of chromium, with 1.25 magnesium and 0.7 silicon. The heat-treated and aged alloy has a tensile strength of 39,000 lb. per sq. in., elongation 14%, and Brinell hardness 80. Alcoa 51S, and also Bohnalite S51 of the Bohn Aluminum & Brass Corp., for drawn tubing, has 1% silicon, 0.6 magnesium, and 0.25 chromium. Alcoa 52S has 2.5% magnesium and 0.25 chromium. When cold-rolled to half-hard temper the tensile strength is 37,000 lb. per. sq. in., elongation 10%, and Brinell hardness 67.

Aluminum-magnesium alloy. A group of alloys which have been used more in Europe than in the United States. They contain up to 10% of magnesium, and are distinct from the magnesium alloys which have high magnesium and low aluminum, and from the aluminum-copper alloys containing small amounts of magnesium. Magnesium in small amounts in aluminum alloys gives heat-treating properties, increasing the strength and hardness by the formation of chemical compounds. With more than 4% magnesium they are difficult to cold-work and are normally used only for castings. The castings tend to be hard and brittle unless modified with other elements. All of the high-magnesium aluminum alloys form an anodic film on the outside which retards further corrosion, and they are thus suitable for architectural or marine

castings. The early German alloy known as K. S. Seewasser alloy had 2.25% magnesium and 0.2 antimony. It forms a protective coating of antimony oxychloride on the surface. The original German aluminum-magnesium alloy invented by Dr. Ludwig Mach, and called Mach's metal, contained 5% magnesium, and his Magnalium contained 10% magnesium. It had a tensile strength of 22,000 lb. per sq. in., elongation 4%, and specific gravity 2.63. Ulmal was a German alloy with 10% of magnesium, 1 silicon, and 0.50 manganese.

For heat-treated sand castings, the alloy giving the highest combination of strength, toughness, and resistance to impact is the one containing 10% magnesium with the balance aluminum. Alcoa 220 and S.A.E. alloy 324 have this composition and have a tensile strength of 42,000 lb. per sq. in., elongation 12%, and Brinell hardness 75. The specific gravity is 2.55. A casting alloy containing 3.8% magnesium is Alcoa 214. It is readily machinable and is corrosion-resistant. The tensile strength is 22,000 lb. per sq. in., elongation 6%, and Brinell hardness 50. Aluminum alloy MG-7, of High Duty Alloys, Ltd., is a corrosion-resistant metal containing 6.5 to 7.25% magnesium, 0.60 manganese, and 0.75 iron. The tensile strength of the fully aged metal is 26 tons per sq. in. Birmabright, of the Birmingham Aluminum Casting Co., Ltd., is a similar salt-water resistant alloy in cast and wrought forms. Lead up to 1.25% gives free-cutting properties to the 7% magnesium alloy but lowers the strength and ductility.

**Aluminum-manganese alloy.** Any aluminum alloy containing manganese as the important alloying element, although many other aluminum alloys contain some manganese which strengthens the alloy and reduces the tendency to electrolytic corrosion. The amount of manganese is usually very small, the rich alloys, with up to 10% of manganese, being employed only for adding manganese to aluminum. A.S.T.M. and Federal specifications call for 1 to 1.5% of manganese and 97 aluminum, with small allowable percentages of copper, iron, silicon, and zinc. The minimum tensile strength, soft, is 19,000 lb. per sq. in. and elongation 23%. The hard-drawn metal has a tensile strength of 27,000 lb. per sq. in. and elongation of 4%. Alcoa 3S, which in sheet form is used for

making cans, has 1.2% of manganese, and for this purpose is used ¾ hard. The full-hard cold-rolled metal has a tensile strength of 29,000 lb. per sq. in., elongation 4%, and Brinell hardness 55. Bohnalite 53, of the Bohn Aluminum & Brass Corp., is this alloy. Acieral is a European alloy with 1% of manganese and some magnesium and iron. Navalium is a name proposed by the British Institute of Naval Architects for light alloys of the Al-Mn-Mg and Al-Mn-Mg-Si types used for shipbuilding. The addition of 1 to 2% of copper to aluminum-manganese alloys increases the strength and makes forging easier. A U.S. Navy forging alloy has 2% of copper and 1.5 manganese. Aeron, a German alloy, contains 1% of manganese, 4 copper, and some silicon. Titanite, of the Aluminum Smelting & Refining Co., is an aluminum-manganese casting alloy containing titanium. The sand castings have a tensile strength of 29,000 lb. per sq. in. and elongation of 6%.

**Aluminum-nickel alloy.** Nickel, employed for special purposes to replace copper in aluminum alloys, makes the alloys stronger, more corrosion-resistant, and improves the luster. Usually, not more than 6% of nickel is used, with some magnesium to make them responsive to age-hardening. An early lightweight bearing metal under the name of Bersch metal contained 7% of nickel. Batterium metal was an aluminum-copper-nickel alloy developed by the British National Physical Laboratory for corrosion-resistant parts. The Y-alloy developed by this laboratory for automotive pistons, and marketed under the name of Birmidium by the Birmingham Aluminum Co., Ltd., contains 4% of copper, 2 nickel, 1.5 magnesium. The heat-treated rolled bar has a tensile strength up to 54,000 lb. per sq. in. with elongation of 3%. The cast alloy is resistant to alternating stresses at elevated temperatures, is wear-resistant, and is resistant to the action of sea water, but is difficult to cast. The specific gravity is 2.73, and the Brinell hardness 135. Alcoa 142, a casting alloy of the Aluminum Co. of America, contains 4% of copper, 2 nickel, and 1.5 magnesium. It has a tensile strength up to 42,000 lb. per sq. in. and Brinell hardness 90 to 120.

Hiduminium is the name of modified Y-alloys developed by the Rolls-Royce laboratories and produced by High Duty Alloys, Ltd. R.R. 50 alloy contains 1.2% of copper, 1.3 nickel, 0.1 magnesium,

0.18 titanium, 1.1 iron, and 2.2 silicon. Heat-treated castings have a tensile strength of 13.6 tons per sq. in., elongation 4.5%, and Brinell hardness 80. R.R. 53 alloy has 2.2% of copper, 1.3 nickel, 1.6 magnesium, 0.08 titanium, 1.4 iron, and 1.2 silicon. This alloy is used for fine die castings. Magnalite, of the Walker M. Levett Co., contains 2.5% of copper, 1.5 nickel, 0.5 zinc, and 1.3 magnesium. B.E.S. L24 alloy, used for airplane engine pistons, contains 3.5 to 4.75% of copper, 1.75 to 2.25 nickel, 1.25 to 1.75 magnesium, 0.75 max. iron, and 0.50 max. silicon. When quenched and aged, the castings have a tensile strength of 30,000 lb. per sq. in., and Brinell hardness of 95. Bohnalite Y, of the Bohn Aluminum & Brass Corp., has 5% of copper, 2 nickel, and 1.5 magnesium. Nickeloy, of the Western Electric Co., has about 4% of copper, 1.5 nickel, with small amounts of other elements. Neonalium was a German alloy containing 6 to 14% of copper, 1 nickel, and small amounts of other elements. The Swiss alloy, Meral, contains 3% of copper, 1 nickel, 0.8 magnesium, and 0.30 manganese.

**Aluminum oxide.** An artificial corundum, $Al_2O_3$, made by fusing bauxite in an electric-arc furnace at a temperature above 4000°F., and then cooling slowly for about 10 days. The mass is then broken and crushed to grain sizes. When pure, it forms in colorless crystals, and this crystalline material is employed as an abrasive. It is preferred to corundum for most purposes because of its uniformity. The white aluminum oxide amorphous powder used largely in the chemical industries is a precipitated material. The white aluminum oxide abrasive used for light-colored wheels for toolroom grinding is 99.5% pure crystalline aluminum oxide calcined. Aluminum oxide crystals are hexagonal in shape, and are minute in size. The larger grain sizes are made up of many crystals, which is a distinctive point from silicon carbide. The specific gravity is about 3.75, and the hardness is about 9 moh. The chief impurity is titanium oxide, which is extremely hard. When hard, sharp crystals are required, the highest grades of purity are employed; for average use, the material is generally preferred with some impurities. Alundum 32, of the Norton Co., is an aluminum oxide with each abrasive grain as a single crystal of pure alumina. In the manufacture the crystals grow in a matrix of chemically

unstable glass. When the lumps are wet with water this calcium sulphite glass dissolves and leaves the crystals free. The cutting edges are thus the natural edges of the crystal, while in the ordinary crushed material some of the edges may be slag.

Aluminum oxide abrasive is used for grinding wheels for the finishing of high-tensile metals such as hard steels and the hard bronzes. On abrasive paper and cloth it is used for finishing and sanding in the woodworking industries and for finishing hard and tough metals. For abrasive paper the grains are glued to one side of 40- to 130-lb. kraft paper. The cloth is marketed in sheets or in belts, plain-glued or waterproof. The usual grain sizes for paper and cloth are No. 16 to No. 500. Grinding compounds for valve grinding are often aluminum oxide grains in oil. The grains are also marketed in kegs and cans in screened grain sizes to No. 240 and in fine flour to No. 600 for use as a metal-polishing abrasive to be glued to the periphery of polishing wheels. For abrasive wheels, there are 20 standard grain sizes from No. 8, the coarsest, which will pass through a screen having 8 openings per linear inch, or 64 per sq. in., to No. 240, which will pass through a screen having 240 openings per linear inch. The grade of the wheel, or strength of the bond, is by letter designation, increasing in hardness from E to Z. The aluminum oxide abrasives in all forms are sold under trade names. Alundum, of the Norton Co., Aloxite, of the Carborundum Co., and Lionite, of the General Abrasives Co., Inc., are abrasives of aluminum oxide. Other trade names are Aluminoid, Aluminox, Alulion, Alobrant, Alowalt, Borolon, Borite, Idilite, Clevite, Natalite, Natumite, Bathite, Hytens, Adamite, Adalox, Metalite, Durundum, Sterlith, Staralox, Excelite, and Orelite.

Aluminum oxide has a high melting point, 2050°C., and is employed in making refractory linings and crucibles, usually with refractory clay as a binder. The aluminum oxide refractories have high strength at elevated temperatures and high resistance to spalling. Aluminum oxide grains are also made up into pellets with a ceramic bond to be used as Catalyst carriers in the chemical industry. The pellets are 40% porous and are acidproof. Alfrax is the trade name of the Carborundum Co. for aluminum oxide as a catalyst carrier and as a refractory. Tabular alumina is aluminum oxide converted to the corundum form by heating to a temperature

below the fusing point. It is used for making high-grade electrical insulators, refractory bricks, and as catalyst supports. It comes in a dense variety with less than 0.25% soda and less than 10% water absorption, and also in porous form with 16 to 22% water absorption.

**Aluminum palmitate.** One of the important metallic soaps. A yellow, massive salt, or a fine white powder of the composition $Al(C_{16}H_{31}O_2)_3 \cdot H_2O$, made by heating a solution of aluminum hydroxide and palmitic acid. It is soluble in oils, alkalies, and benzol, but insoluble in water, and is used in waterproofing fabrics, paper, and leather, and in paints as a drier. In finishing leather and paper it adds to the gloss. It is also used to increase viscosity in lubricating oils. Another material of the same class is Aluminum resinate, $Al(C_{14}H_{63}O_5)_3$, a brown mass made by heating rosin and aluminum hydroxide. Aluminum oleate, $Al(C_{18}H_{33}O_2)_3$, is a white salt of oleic acid used as a drier. Aluminum stearate, $Al(C_{18}H_{35}O_2)_3$, is a salt of stearic acid. It is repellent to water and is valued for waterproofing fabrics and as a drier, and in waterproofing concrete and stucco. It is also used to give adherence to dyes, and as a flux in soldering compounds. It is a white fluffy powder of 200 mesh, soluble in oils and in turpentine. Grades high in free fatty acid, up to 22%, do not gel readily and are useful as a flatting agent and suspending medium in paints. Grades low in free fatty acid have a thickening effect on solvents. Those with 5 or 6% are used in lubricating grease, and those with about 8% are used in paints.

**Aluminum powder.** Called Aluminum bronze powder when alloyed. The flaked powder used for paints is more properly termed Aluminum flake. A flake powder made by a stamping process, and used as a pigment in paints and printing inks, in silvering rubber articles, and in plastics. The powder has a high ratio of surface to volume, and the dry powder will ignite easily. All of the grades used for paint contain a major proportion of very fine, 300 to 400 mesh, and they are revolved in a drum with a lubricant to give luster and also leafing properties to form a metallic surface in the paint by capillary attraction. Aluminum powder burns with an intense heat, but the powder used in calorizing and for pyrotechnics and explosives is not flaked and polished, but consists of par-

ticles of spherical shape free from grease. This powder is called Granulated aluminum, although this designation is also given to larger Aluminum pellets marketed for metallurgical purposes. Aluminum powder is also used for making aerated or porous concrete, and for thermit welding. Aluminum pellets are made by blowing molten metal or by crushing aluminum.

**Aluminum-silicon alloy.** Many aluminum alloys contain some silicon, but in the United States the term aluminum-silicon alloy usually refers to casting alloys of two general classes, one containing about 5% silicon and the other 13% silicon. These high-silicon alloys are characterized by their ease of casting, corrosion resistance, lightness, and ease of welding. They cast well even in thin sections, but the strength decreases and they become more difficult to machine as the silicon increases. Additions of copper increase the strength and improve the machinability, and also add the property of age-hardening, but decrease corrosion and wear resistance. Slight additions of magnesium also give age-hardening by the formation of $Mg_2Si$. The 13% alloy has a specific gravity of 2.64, being lighter than aluminum. It has a tensile strength of 24,000 lb. per sq. in., and elongation of 5%. The alloys also have high thermal conductivity, which makes them suitable for engine pistons and cylinders. Bohnalite U, of the Bohn Aluminum & Brass Corp., is a 13% alloy.

The alloys are usually modified by the addition of sodium or an alkaline chloride to the melt, thus refining the grain, making a dense structure, and increasing the strength and ductility. The modification increases the strength of the 13% alloy to 32,000 lb. per sq. in., and the elongation to 10%. The Modified aluminum alloys were developed in Europe and were covered by patents. Alpax, invented originally by Aladar Pacz and produced by Lightalloys, Ltd., is a 13% alloy treated with sodium during the casting. Magnesium up to 0.50% may be included in the modified alloys to give heat-treating qualities, but the addition of copper decreases the corrosion resistance. The modified alloys were known in Germany as Silumin. Telectal is a German alloy modified with lithium. Italsil is an Italian modified alloy. English alloys of this class are Wilmil of William Mills, Ltd., Birmasil of the Birmingham Alumi-

num Casting Co., Ltd., and M.V.C. aluminum alloy of Metropolitan-Vickers. Alcoa 47, of the Aluminum Co. of America, is a 13% modified alloy.

Alcoa 13, with 12% silicon, is a die-casting alloy, and has a tensile strength of 33,000 lb. per sq. in., and elongation of 1.8%. Alcoa 32S, a wrought alloy with 12% silicon, also contains 0.8% of nickel, 1 magnesium, and 0.8 copper. It has a tensile strength of 52,000 lb. per sq. in. in heat-treated forgings. Alcoa 132, also known as Lo-Ex alloy, used for casting automotive pistons, has a low coefficient of expansion, about 0.0000105, nearly that of cast iron. The alloy contains 14% of silicon, 1 copper, 1 magnesium, and 2 nickel. The tensile strength is from 30,000 to 50,000 lb. per sq. in., and Brinell hardness 90 to 140, depending upon the heat-treatment. The specific gravity is 2.69. It has high wear resistance, and in the United States this type of alloy is preferred to the modified alloys used in Europe. Alloy No. 1003, of Aluminum Industries, Inc., is a similar casting alloy containing 1% iron.

Architectural aluminum is usually a 5% silicon alloy. It is corrosion-resistant, has an attractive white color, and casts well in fine detail. The 5% alloy has a tensile strength, when quenched and aged, of about 18,000 lb. per sq. in., with elongation of 3%. It melts at 1150°F. Alcoa 43 and A.S.T.M. alloy No. 3, are 5% silicon alloys. The die-cast alloy has a tensile strength of 29,000 lb. per sq. in., elongation 3.5%, and Brinell hardness 40, and the sand-cast metal has a tensile strength of 17,000 lb. per sq. in. and elongation 3%. Bohnalite S43 is a similar alloy in wrought form. Alcoa 356 has 7% of silicon and 0.3 magnesium. These alloys may also contain some copper or nickel. A small amount of iron may also be used to add strength, although it decreases ductility. Navy alloy 2 has 4.5 to 6% of silicon, 0.6 copper, 1 iron, and 0.2 manganese. The tensile strength is 17,000 lb. per sq. in. min. Where higher strength is needed, the copper may be increased to 5%. Alcoa 108, with 3% of silicon and 4 copper, has a tensile strength of 21,000 lb. per sq. in., sand-cast. Apex 400 alloy, formerly known as Perm-Brite, of the Apex Smelting Co., is a high-silicon alloy used for architectural and marine castings. The tensile strength is 25,000 lb. per sq. in., and Brinell hardness 55.

**Aluminum steel.** Any steel containing aluminum as the effective element. Aluminum in small quantities was first used in the Hadfield steels as a deoxidizer and to restrict grain growth by forming dispersed nitrides and oxides. It also increases the strength of the steel, but, if the residual aluminum remaining in the steel is considerable, the steel becomes brittle. Low-alloy steels containing a small amount of aluminum will develop high strength and hardness when heat-treated, but the steels are normally used only as Nitriding steel for casehardening by the nitriding process. The process and the special steel compositions required were developed at the Krupp Works, and the American patents are held by the Nitralloy Corp. of America. Any steel will absorb some nitrogen under special conditions, and in casehardening by cyanide part of the hardness of the case is due to nitrogen. But nitriding steels refer only to those intended to be subjected to nitriding atmospheres. A nitrided case is formed by heating the steel in an ammonia atmosphere to a temperature of 875°F. for a long period and quenching. The ammonia gas decomposes, and the liberated nitrogen combines with the steel, forming nitrides of aluminum, chromium, and molybdenum. The surface hardness of nitrided steel may be as high as 1,200 Brinell, and the steel has a tensile strength up to 190,000 lb. per sq. in.

A composition range of Nitralloy steel is 0.20 to 0.45% of carbon, 0.75 to 1.5 aluminum, 0.9 to 1.8 chromium, 0.4 to 0.70 manganese, 0.15 to 0.60 molybdenum, 0.3 max. silicon. Nitrided steels can be softened, or denitrided, by heating in a fused mixture of potassium and sodium chlorides, which frees the nitrogen as a gas. Nitralloy is marketed by various steel companies. Nitrard, of the Firth-Sterling Steel Co., is also the name of a nitriding steel. Nitralloy steel is used for tools, gages, gears, and shafts. Unlike the soft core of ordinary casehardened steels, it will have a tough core with hardness of 400 to 650 Brinell.

Steels containing aluminum are heat resistant and are used for heat-resistant parts and engine valves, but at low temperatures they are weak. Small amounts of aluminum may be added to the chromium steels for greater resistance to oxidation at high temperatures. A cast steel, Circle L18, of the Lebanon Steel Foundry, contains 7.5% aluminum, 37.5 chromium, and little carbon, but

this class of heat-resistant alloy is not usually classed with the steels. Alumetized steel is not an alloy steel, but is sheet steel having aluminum sprayed or dipped on the surface and the metal subsequently heat-treated to produce an alloyed surface. Alplate, of the Reynolds Metals Co., is an Aluminum-coated steel made by subjecting the heated steel to the action of a reducing gas and then passing it through an aluminum bath. Aluminized steel, of the American Rolling Mill Co., has an aluminum coating on a soft steel sheet. It will withstand a temperature of 1000°F., and is more corrosion-resistant than tin plate.

**Aluminum-zinc alloy.** An alloy containing a considerable proportion of zinc, although important characteristics may depend upon elements other than zinc. The casting alloys have found greater use in Europe than in the United States. Zinc is a hardener of aluminum, but the alloys are likely to be hot-short, and they do not cast as well as other aluminum alloys. With high zinc they are brittle. They were formerly employed for such uses as crankcases. The general class of these alloys contains from 10 to 14% of zinc, about 3% copper, and usually some silicon. Skleron, a German alloy, contains 12% of zinc, 3 copper, 0.6 manganese, 0.25 silicon, and a slight amount of lithium to form the compound $Li_3Si$ for added strength and hardness. Alneon contained 7 to 22% of zinc, 2 to 3 copper, and some nickel. British engineering specification B.E.S. 2L5 calls for 13% of zinc, 2.7 copper, and the reaminder aluminum. The tensile strength is 25,000 lb. per sq. in., and hardness 100. An early American alloy, Aero metal, was higher in zinc. Alcoa 145 contains 10% of zinc, 2.5 copper, and 1.2 iron. S.A.E. alloy 31 and B.E.S. alloy 363 contain 2.25 to 3.35% of copper and 12.5 to 14.5 zinc. These alloys have tensile strengths up to 30,000 lb. per sq. in., and Brinell hardness of 70. The weight is 0.108 lb. per cu. in.

Frontier 40E alloy, of the Frontier Bronze Co., contains 5.5% of zinc, 1 iron, 0.5 magnesium, 0.5 chromium, 0.4 copper, 0.2 titanium, 0.3 manganese, and 0.3 silicon. It is corrosion-resistant, has a tensile strength of 35,000 lb. per sq. in., elongation 4%, and Brinell hardness 70 to 80. The wrought structural alloys containing zinc developed during the war have high strength and good working

qualities. Alcoa 75S, of the Aluminum Co. of America, contains 5.1 to 6.1% of zinc, 1.2 to 2 copper, 2.1 to 2.9 magnesium, 0.1 to 0.3 manganese, 0.15 to 0.4 chromium, 0.2 max. titanium, 0.5 max. silicon, and 0.7 max. iron. In heat-treated sheet form it has a tensile strength of 77,000 lb. per sq. in., yield strength 67,000 lb. per sq. in., and elongation 12%.

**Amalgam.** A combination of a metal with mercury. The amalgams have the characteristic that when slightly heated they are soft and easily workable, and become very hard when set. They are used for filling where it is not possible to employ high temperatures. A native Silver amalgam found in South America contains 26 to 95% silver. Native Gold amalgams are found in California and Colombia, and contain about 40% gold. Although native amalgams are chemical combinations of the metals, some of the artificial amalgams are alloys and others are compounds. Dental amalgams are prepared by mixing mercury with finely divided alloys composed of varying proportions of silver, tin, and copper.

Cadmium amalgam was formerly employed for filling holes in metals and was called Evans' metallic cement. It is a silvery white compound of the composition $Cd_5Hg_8$, with about 74% mercury, the excess mercury separating out on standing. It softens at about 100°F., and can be kneaded like wax, remaining soft for a considerable time and then becoming hard and crystalline. It is made by heating the mercury and introducing the cadmium in the form of thin sheet. Tin or bismuth may be added. Amalgams with an excess of cadmium are ductile and can be hammered into sheet. Bismuth amalgams are lustrous, very fluid combinations of mercury and bismuth, used for silvering mirrors. They are also added to white bearing metals to make them more plastic, and to fusible alloys to lower the melting point. Crilley metal is a self-lubricating bearing alloy containing mercury added as bismuth amalgam. The binary amalgams of mercury and bismuth are usually too fluid for ordinary use.

The usual quaternary alloy has equal parts of bismuth, mercury, tin, and lead, with the proportion of mercury increased to give greater fluidity. A bismuth amalgam containing bismuth, lead, and mercury was used for lead pencils. A Mercury-thallium amalgam,

with 8.5% thallium, which freezes at −76°F., is used for thermometers for low readings. Mackenzie's amalgam is a two-part amalgam in which each part is a solid but becomes fluid when the parts are ground together in a mortar at ordinary temperatures. One part contains bismuth and mercury, and the other part contains lead and mercury. Sodium amalgam contains from 2 to 10% sodium. It is a silvery-white mass which decomposes water and can be used for producing hydrogen. Potassium amalgam, made by mixing sodium amalgam with potash, is a true chemical compound, and is used for amalgamating with other metals.

**Amber.** A fossil resin found buried in the countries along the Baltic Sea and in Madagascar. It is employed for making varnishes and lacquers and for ornaments. The original German name for the material was Glassa, and in early writings it is referred to by the Greek word Elektron and the Persian name Karaba. It was called Vernice by the Italian painters who used it as a varnish resin. Amber came from a coniferous tree, *Pinus succinifera,* now extinct. It is hard, brittle, tasteless but with an aromatic odor, and dissolves in acids. It is sometimes transparent, but usually semitransparent or opaque with a glossy surface, yellow or orange in color. It takes a fine polish. When rubbed, it becomes electrically charged. Amber contains succinic acid in a complex form, and the finest specimens are known as Succinite, although this is the name of an amber-colored garnet. The amber of Madagascar is prized for necklaces and pipe mouthpieces. It is semitransparent, wave-streaked, and honey-colored. Synthetic amber is a plasticized phenol-formaldehyde or other synthetic resin. Amberoid is reclaimed scrap amber pieces compressed into a solid, sometimes mixed with pieces of copal or other resin. It has the same uses as amber. Amber oil, distilled from scrap amber, is a mixture of terpenes, and is used in varnish. Ambergris has no relation to amber, but is a solid, fatty, inflammable substance of grayish to black color found in the intestines of some sperm whales or found floating in the ocean. It has a peculiar sweet fragrance and is highly valued as a fixative in perfumes. In Asia it is used as a spice. Lumps weigh up to 150 lb.

**Amethyst.** A violet or purple transparent quartz. The color is due to manganese and iron oxides, and becomes yellow on heating. It has a density of 2.65, and hardness of 7 Moh. Amethyst is composed of alternate right- and left-hand crystals, and breaks with a rippled fracture instead of the conchoidal fracture of ordinary quartz. The crystals are doubly refractive. It is used for making pivot bearings for instruments, and for needles in recording machines. It is the most esteemed of the quartzes for cutting into gemstones, but only the deep and uniformly colored stones are used as gems and they are not common. Any large amethyst of deep and uniform color is likely to be synthetic. The chief production of amethyst is in Brazil and Uruguay with some from Montana.

**Ammonia.** A gaseous compound of the formula $NH_3$. It was originally called Alkaline air and Volatile alkali, and later in water solution by the name of Spirits of hartshorn. Ammonia is a by-product in the distillation of coal, but is now produced by passing nitrogen and hydrogen gases and a catalyst through an electric arc. It is readily absorbed by water, which at 60°F. takes up 683 times its own volume of the gas, forming a liquid commonly called ammonia, but which is Ammonium hydroxide, a colorless, strongly alkaline and pungent liquid of the composition $NH_4OH$ with a boiling point of 38°C. At 80°F. it contains 29.4% of ammonia, $NH_3$, in stable solution. It is also known as Ammonium hydrate and Aqua ammonia. It is used for the saponification of fats and oils, as a deodorant, for cleaning, as a bleaching agent, for etching aluminum, and in chemical processing. Ammonia gas is used in refrigeration, in nitriding steels, and in the manufacture of chemicals. Anhydrous ammonia is purified ammonia gas liquefied under pressure and put up in cylinders. At 20°C. the liquid has a vapor pressure of 122.1 lb. per sq. in. Chlorine unites with ammonia to form Chloramines which are used as solvents and chlorinating agents and as disinfectants. Ammonia does not burn in the air, but a mixture of ammonia and oxygen explodes when ignited.

Commercial Smelling salts, sometimes referred to as ammonia, is Ammonium carbonate, $(NH_4)_2CO_3 \cdot H_2O$, forming in colorless or white crystals. Methylamine, $CH_3NH_2$, a derivative of ammonia, is used in the tanning industry for unhairing skins, and as a

catalyst and solvent in the manufacture of synthetic resins. It is a gas and, like ammonia, is soluble in water and handled in water solution. It is more inflammable than ammonia, a 40% solution having a flash point of 20°F., and the vapors are explosive in air. Another form, Dimethylamine, is more effective for unhairing. In water solution a hydrate is formed, $(CH_3)_2NH \cdot 7H_2O$, which has a low freezing point, −16.8°C. Isopropylamine, $(CH_3)_2CHNH_2$, is used as a replacement for ammonia for many chemical uses, and as a solvent for oils, fats, and rubber. It is a clear liquid of specific gravity 0.686, boiling point 31.9°C., freezing point −101°C., and flash point −15°F.

The ammonium radical, $-NH_4$, has the chemical reaction of an alkali metal and forms many important chemicals. The fertilizer, Ammonium nitrate, is made by the action of nitric acid on ammonium hydroxide. It is a colorless to white crystalline hygroscopic powder of the composition $NH_4NO_3$, specific gravity 1.725, melting point 170°C., decomposing at 210°C., and soluble in water, alcohol, and alkalies. It is also used in pyrotechnics, dental gas, insecticides, freezing mixtures, and explosives. The British explosive Amatol is a mixture of ammonium nitrate and TNT, which explodes violently on detonation. The 50-50 mixture can be melted and poured, while the 80-20 mixture is like brown sugar and was used for filling large shells. Ammonium perchlorate is another explosive made by the action of perchloric acid on ammonium hydroxide. It is a white crystalline substance of the composition $NH_4ClO_4$, specific gravity 1.95, is soluble in water, and decomposes on heating. Nitrogen trichloride, $NCl_3$, which forms in reactions of chlorine and ammonia when there is an excess of chlorine, is a yellow oil of specific gravity 1.653, which is highly explosive.

Ammonium chloride, or Sal ammoniac, $NH_4Cl$, is a white crystalline powder of specific gravity 1.52, used in electric batteries, textile printing, as a soldering flux, and in making other compounds. Many salts and metallic soaps are also formed in the same manner as with the alkali metals. Ammonium vanadate, $NH_4VO_3$, is a white to yellow crystalline powder used as a paint drier, in inks, as a mordant for textiles, and in pottery mixes to produce luster. The specific gravity is 2.326, and it decomposes at 210°C. Ammonium

lactate, $CH_3CHOHCOONH_4$, is a colorless to yellowish sirupy liquid with a slight odor of ammonia, used in leather finishing.

**Ammoniac.** A gum resin from the stems of the *Dorema ammoniacum,* a desert perennial plant of Persia and India. It forms in hard, brittle, brownish-yellow tears, and has a peculiar fetid odor and an acrid taste. It is used in adhesives, in perfumery, and as a stimulant in medicine. In pharmacy it is called Ammoniacum. Oil ammoniac is a yellow liquid distilled from the gum. The specific gravity is 0.890, boiling point 275°C., and it is soluble in alcohol and benzol.

**Ammonium thiocyanate.** Also called Ammonium sulphocyanide. A white crystalline powder used as a mordant in dyeing cellulose and animal fibers, to increase the strength of weighted silks, in the production of plastics, in plating metals to produce Black nickel coatings, and as a weed killer. The composition is $NH_4SCN$, specific gravity 1.305, melting point 150°C., and decomposing point 170°C. It is soluble in water and in alcohol.

**Amyl acetate.** Called Banana oil because of the odor of bananas. A colorless liquid of the composition $CH_3COOC_5H_{11}$, made by the action of acetic acid on amyl alcohol. The specific gravity is 0.896, boiling point 141°C., and it is soluble in alcohol and ether but insoluble in water. It is a good solvent and plasticizer for cellulose plastics, and is also used as a solvent and plasticizer in varnishes, lacquers, and adhesives, as a bonding agent in artificial leather, linoleum, and oilcloth, and as an artificial banana flavor.

**Amyl alcohol.** A group of monohydroxy, or simple, alcohols, which are colorless liquids and have the general characteristic that they have five carbon atoms in the molecular chain. Normal amyl alcohol, $CH_3(CH_2)_4OH$, called also Fusel oil, Grain oil, Pentanol, and Fermentation amyl alcohol, has a specific gravity of 0.82 and boiling point of 137°C. It is only slightly soluble in water. It is used as a solvent for oils, resins, varnishes, in the manufacture of amyl acetate, and in rubber vulcanization. Secondary amyl alcohol has a differently arranged molecule, $CH_3CHOH(C_3H_7)$. The specific gravity is 0.82, and flash point 80°F. It is used in the manufacture of secondary amyl acetate for lacquers, and in chemical

manufacture. Tertiary amyl alcohol has the formula $(CH_3)_2C(OH)C_2H_5$, and a camphorlike odor. The specific gravity is 0.81 and boiling point 102°C. It is slightly soluble in water, but soluble in alcohol and ether. It is used as a flavor, and as a plasticizer in paints, varnishes, and in cellulose plastics. Isoamyl alcohol, or Isobutyl carbinol, $(CH_3)_2CHCH_2CH_2OH$, has a flash point above 80°F. It is used in the manufacture of pharmaceuticals.

**Angico.** The wood of the tree *Piptadenia rigida* of Brazil, also known as Queen wood and Angico vermelho. It is very hard, with a dense, close grain. The color is reddish brown, and the weight is 70 lb. per cu. ft. It is employed where a hard, heavy wood is required, and in cabinetmaking.

**Aniline.** Also known as Aminobenzene and Phenylamine. A slightly yellowish, oily liquid used in the production of dyestuffs, drugs, perfumes, explosives, plastics, flavors, and many chemicals. It is found in coal tar and bone oil, or is made by the reduction of nitrobenzene. The composition is $C_6H_5 \cdot NH_2$, boiling point 182 to 185°C., solidifying point −6.2°C., and specific gravity 1.022. It is soluble in alcohol, ether, benzene, and hydrochloric acid. It turns brown in the air, finally oxidizing into a resin. It is marketed +99.5% pure. The vapors of aniline are toxic, and it is poisonous in contact with the skin. It has a powerful effect on the nervous system, and causes decomposition of the blood.

**Animi gum.** A gum resin obtained from the stem of the plant *Hymenaca courbarii* of Zanzibar and East Africa, and employed in varnishes. It belongs to the group of East African copals, but is distinguished from copal by the ease of solubility in alcohol. The specific gravity is 1.062 to 1.068 and melting point about 245°C. It is also called Gum Zanzibar.

**Anise seed.** The seeds of the annual plant *Pimpinella anisum* grown in the Mediterranean countries and in India. The best grades come from Spain. The seed is used in flavoring in the baking industry. The distilled oil, Anise oil, is used in perfumes and in soaps, and in the liqueur known as Anisette. The oil contains choline, and is used in medicine as a carminative, heart stimulant, and expectorant.

**Annatto.** One of the chief Food colors. Any food color used commercially in the United States must be nontoxic in the quantities employed, and must be approved under the Food and Drugs Act. Annatto is a salmon-colored dye made from the pulp of the seeds of the tree *Bixa orellana* of the West Indies and tropical America and Africa. It contains Bixin, $C_{25}H_{30}O_4$, a dark-red crystalline material, and also Bixol, $C_{18}H_{30}O$, a dark-green oily alcohol. Annatto is sometimes called Bixine, and in West Africa it is called Rocou. It is soluble in oils and in alcohol. Annatto paste is used as a food color especially for butter, cheese, and margarine. It is also used as a stain for wood and for dyeing silk. It was one of the original dyes used by the Indians. A substitute for annatto for coloring butter and margarine, having the advantage that it is rich in vitamin A, is Carrot oil obtained from the common carrot. The concentrated oil has a golden-yellow color and is odorless and tasteless. Carex is a name for carrot oil in cottonseed oil solution used for coloring foods.

A beautiful water-soluble yellow dye used to color foods and medicines is Saffron, extracted from the dried flowers and tips of the saffron crocus, *Crocus sativas,* of Europe, India, and China. It is expensive, as about 4,000 flowers are required to supply an ounce of the dye. Saffron contains Crocin, $C_{44}H_{70}O_{28}$, a bright-red powder soluble in alcohol. Another nonpoisonous dyestuff used for coloring foods and in soaps is the green dye Chlorophyll. It is the characteristic coloring matter of all green plants, and is obtained by solvent extraction from the leaves of various plants. It is a complex chemical forming a crystalline powder soluble in alcohol and melting at 183°C. Safflower, from the orange-colored thistlelike heads of the plant *Carthamus tinctorius,* which are dried and pressed into cakes, produces both red and yellow colors. Besides its use as food color, it is employed for dyeing textiles and cosmetic rouge. The plant is grown in France and in India, and in the latter country it is produced on a large scale for safflower seeds which yield a clear yellow oil used for food, illuminants, and leather dressing.

**Anode metals.** Metals used for the positive terminals in electroplating. They provide in whole or in part the source of the metal to be plated, and they are as pure as is commercially possible, uni-

form in texture and composition, and have the skin removed by machining. They may be either cast or rolled, with the manufacture controlled to obtain a uniform grade and to exclude impurities, so that the anode will corrode uniformly in the plating bath. In addition to pure single metals, various alloys are marketed in anode form. The usual brass anode is 80% of copper and 20 zinc, but other compositions are used, some containing 1 to 2% of tin. Brass anodes are called Platers' brass. Copper anodes for metal plating are usually hot-rolled oval-shaped bars, 99.9% pure, while those for electrotype deposits may be hot-rolled plates, electrodeposited plates, or cast plates. Zinc anodes are 99.9% pure. Nickel anodes are 99+%, rolled or cast in iron molds, or 95 to 97% sand-cast. Lead anodes have low current-carrying capacity, and may be made with a saw-tooth or multiple-angled surface and ribs to provide more area and give greater throwing power. Anodes of other metals are also made with sections gear-shaped, fluted, or barrel-shaped to give greater surface area and higher efficiency. Special anode metals are marketed under trade names, usually accenting the color, hardness, and corrosion resistance of the deposited plate, such as Spekwite, of the Special Chemical Corp., which gives a white plate harder than nickel. Chilex is the name of a copper-silicon-lead-iron-tin alloy used for anodes in copper refineries. It is insoluble in the acid bath.

**Anthracite.** Also called Hard coal. A variety of mineral coal found in Wales, France, and Germany, but in greatest abundance in an area of about 500 sq. mi. in northeastern Pennsylvania. It is distinguished by its semimetallic luster, high carbon content, and high specific gravity, which is about 1.70. The carbon content may be as high as 95%, but the usual fixed carbon content is from 78 to 84%. It should give 13,200 B.t.u. per lb. In theory the best grades of anthracite should have 90% of carbon, 3 to 4.5 hydrogen, 2 to 5.5 oxygen and nitrogen, and only 1.7 ash. Anthracite, when pure and dry, burns without smoke or smell, and is thus preferred to bituminous coal for household furnaces. But the coal will absorb a high proportion of water, and commercial coal may be wetted down to add to the weight, thus lessening its efficiency. Hard coal is graded as anthracite and Semianthracite, depending

upon the ratio of fixed carbon to volatile matter. When the ratio is 10 to 1, it is anthracite.

The commercial gradings of anthracite are chiefly by size, varying from three sizes of very fine grains called silt, rice, and buckwheat, to the large size of furnace, or lump, coal. Standard A.S.T.M. sizes for anthracite are: broken, 4⅜ to 3¼ in.; egg, 3¼ to 2 7/16 in.; stove, 2 7/16 to 1⅝ in.; chestnut, 1⅝ to 13/16 in.; pea, 13/16 to 9/16 in.; No. 1 buckwheat, 9/16 to 5/16 in.; No. 2 buckwheat (rice), 5/16 to 3/16 in.; No. 3 buckwheat (barley), 3/16 to 3/32 in. As the coal comes from the breaker, the proportions are about 8% silt, 9 rice, 15 buckwheat, 10 pea, 24 chestnut, 23 stove, and 8 egg. Artificial anthracite, used extensively in Europe, is briquetted coals with a waterproof coating. It burns uniformly.

**Antifreeze compounds.** Materials employed in the cooling systems and radiators of internal-combustion engines to ensure a liquid circulating medium at low temperatures to prevent damage from the formation of ice. The requirements are that the compound must give a freezing point below that likely to be encountered without lowering the boiling point much below that of water, that it must not corrode the metals or deteriorate rubber connections, that it must be stable up to the boiling point, and that it must be readily obtainable commercially. Calcium chloride was early used for automobile radiators but corroded the metals. Oils were also used, but the high boiling points permitted overheating of the engine, and the oils soften rubber. Denatured ethyl alcohol is widely used for automobile radiators. Methanol, or wood alcohol, is less corrosive, but is normally not as available. A 30% solution of ethyl alcohol in water has a freezing point of about 5°F., and a 50% solution freezes at −24°F., which is sufficiently low for winter use in most localities in the United States. Alcohol, however, has a low boiling point, and requires to be renewed frequently because of loss by evaporation.

Glycerol is also used as an antifreeze, a 40% solution in water lowering the freezing point to about 0°F., and a 50% solution to −15°F. It has the disadvantage of high viscosity, requiring forced circulation at low temperatures, but it does not evaporate easily. Ethylene glycol lowers the freezing point to a greater extent than

alcohol and has a high boiling point so that it is not lost by evaporation, but it has a higher first cost and will soften ordinary natural rubber connections. Acetamide in water solution may also be used as an antifreeze. Antifreezes are sold under various trade names. Zerone, of E. I. duPont de Nemours & Co., Inc., has a methanol base, while Zerex has a base of ethylene glycol. Prestone, of the Union Carbide & Carbon Corp., is ethylene glycol antifreeze. Pyro is an antifreeze of the U.S. Industrial Chemicals, Inc., with a low freezing point. Calcium chloride is used as an antifreeze in fire tanks, sodium chromate being added to retard corrosion.

**Antimonial lead.** An alloy containing up to 25% of antimony with the balance lead, used for storage-battery plates, type metal, bullets, tank linings, pipes, cable coverings, bearing metals, roofing, collapsible tubes, toys, and small cast articles. The alloy is produced directly in the refining of some lead ores, but much is also made by adding antimony to soft lead. The alloy is also known as Hard lead, and in England is called Regulus metal. At least 75% of the total use of lead in the United States is in the form of antimonial lead. The antimony hardens the lead and increases the tensile strength. The usual alloy contains 4 to 8% of antimony and has about twice the tensile strength of pure lead. Up to about 0.10% of arsenic stabilizes and hardens the alloy, and from 0.25 to 1% of tin may be added to improve the casting properties. Antimonial lead of the National Lead Co. for chemical linings contains 6 to 8% antimony, weighs 0.398 lb. per cu. in., and melts at 475 to 555°F.

A hard lead with 10% of antimony and 90% lead has a tensile strength of 8,800 lb. per sq. in., elongation 17%, Brinell hardness 17, and melting point 486°F. Cable lead, used for cable sheathing, contains about 1% of antimony. The alloy for collapsible tubes usually contains 2% of antimony. Antimonial lead may be used for machine bearings, but for this purpose it usually contains considerable tin and is classed with the babbitt metals. Hoyt metal, used for bearings, contains 6 to 10% of antimony. Alloys containing from 70 to 90% of lead, 5 to 20 antimony, and 2 to 20 tin, have been used for railway car bearings under the name of Lining

metal. Dandelion metal, used for locomotive crosshead linings by one railroad, is given as 72% of lead, 18 antimony, and 10 tin.

**Antimony.** A bluish-white metal, symbol Sb, having a crystalline scalelike structure. It is brittle and easily reduced to powder. It is neither malleable nor ductile and is used only in alloys or in its chemical compounds. Like arsenic and silicon it is sometimes referred to as a Metalloid having the physical properties of a metal and the chemical properties of a nonmetal. The chief uses in metals are for battery plates, bearings, pipes, cable coverings, solder, and type metals. The specific gravity of the metal is 6.62, and melting point 824°F. It burns with a bluish light when heated to redness in the air. Antimony imparts hardness and a smooth surface to soft-metal alloys, and alloys containing antimony expand on cooling, thus reproducing the fine details of the mold. This property makes it valuable for type metals. When alloyed with lead, tin, and copper it forms the babbitt metals used for machinery bearings. It is also much used in white alloys for pewter utensils. Its compounds are used widely for pigments.

The chief antimony ore is stibnite, but much antimony is obtained from lead ores and is not separated but is left in the lead as hard lead. The metal antimony is marketed in flat cakes or in broken lumps. The highest grade of pure refined antimony is known as Star antimony because of the glittering spangled appearance on the surface, but the starring is done with lower grades of antimony by special cooling of the ingots. Crude antimony is not antimony metal, but is beneficiated ore, or ore matte, containing 90% or more of metal. High-grade antimony is +99.8% pure, Standard grade is 99 to 99.8% pure, and Chinese is 99% pure.

**Antimony ores.** The chief ore of the metal antimony is Stibnite, an impure form of antimony trisulphide, $Sb_2S_3$, containing theoretically 71.4% of antimony. The usual content of the ore is 45 to 60%, which is concentrated to an average of 92% for shipment as matte. Sometimes gold or silver is contained in the ore. Stibnite occurs in slender prismatic crystals of a metallic luster and lead-gray color with a hardness of 2 Moh. The metal is obtained by melting the stibnite with iron, forming FeS and liberating the antimony, or by roasting the ore to produce the oxide which is then re-

duced with carbon. For pyrotechnic uses stibnite is liquated by melting the mineral and drawing off the liquid, which on cooling and solidifying is ground. Stibnite comes from China, Mexico, Japan, Germany, Bolivia, Alaska, and Western United States.

Senarmorite, found in Mexico, Nevada, and Montana, is Antimony oxide, $Sb_2O_3$, occurring in cubic crystals with a yellow color. The specific gravity is 5.2, hardness 2.5, and theoretical metal content 83.3%. Valentinite, also found in the same localities, has the same theoretical formula and antimony content as senarmorite, but has a rhombic crystal structure, a hardness of 3, and a specific gravity of 5.5. These oxides are used as opacifiers in ceramic enamels. Cervantite, found in Mexico, Nevada, and Montana, is Antimony tetraoxide, $Sb_2O_4$. It has a grayish-yellow color, a specific gravity of 5, hardness of 4.5, and contains theoretically 79.2% of antimony. Stibiconite, from the same area, is a massive pale-yellow mineral of the composition $Sb_2O_4 \cdot H_2O$, with a specific gravity of 5.1, hardness 4.5, and antimony content 71.8%.

Kermesite, known as Red antimony, found in Mexico and Italy, is a mineral resulting from the partial oxidation of stibnite. The composition is $Sb_2S_2O$, and when pure it contains 75% of antimony and 20 sulphur. It occurs in hairlike tufts, or radiating fibers of a dark-red color and metallic luster, with a hardness of 1.5 and a specific gravity of 4.5. Another sulphide ore of antimony is Jamesonite, $Pb_2Sb_2S_5$, found in Mexico and Western United States. It has a dark-gray color, specific gravity of 5.5, hardness 2.5, and contains 20% antimony. When the ore is silver-bearing, it can be worked profitably for antimony. Stephanite is classed as an ore of silver, but yields antimony. It is a Silver sulphantimonite, $Ag_5SbS_4$, containing 68.5% of silver and 15.2 antimony. It occurs massive or in grains of an iron black color with a hardness of 2 to 2.5 and specific gravity 6.2 to 6.3. It is found in Nevada, Mexico, Peru, Chile, and central Europe.

**Antimony red.** The common name of Antimony trisulphide, $Sb_2S_3$, found in impure form in the mineral stibnite, but produced by precipitation from solutions of antimony salts. It comes in orange-red crystals with a specific gravity of 4.56 and melting point 546°C. It is also known as Antimony sulphide and Antimony

sulphuret, and is used as a paint pigment, for coloring red rubber, and in safety matches. Antimony pentasulphide, $Sb_2S_5$, an orange-yellow powder, was once used for vulcanizing rubber and it colored the rubber red. It breaks down easily when heated, yielding sulphur and the red pigment antimony trisulphide.

**Antislip metals.** Metals with abrasive grains cast in them, used for floor plates, stair treads, and car steps. They may be of any metal, but are usually iron, bronze, or aluminum. The abrasive may be sand, but it is more usually a hard and high-melting-point material such as aluminum oxide. In standard cast forms antislip metals are marketed under trade names. Alumalun is the name of an aluminum alloy cast with abrasive grains, made by the American Abrasive Metals Co. Bronzalum is a similar product made of bronze.

**Antler.** The bony, deciduous horns of animals of the deer family, used for making handles for knives and other articles. Antlers are true outgrowths of bone, and are not simply hardenings of tissue as are the horns of other animals. Unlike horn, antlers are solid, and have curiously marked surfaces. They are of various shapes and sizes, and are usually found on the male during the mating season, although both sexes of reindeer and American caribou possess them. They grow in from 3 to 4 months, and are shed annually. Antler is imitated by machine carving bone to reproduce the indented surface.

**Aqua regia.** The common name of a mixture of 3 parts of hydrochloric acid and 1 part of nitric acid, or the product obtained by dissolving sal ammoniac in nitric acid. It is a yellow volatile liquid with suffocating fumes, employed chiefly for dissolving or testing gold, platinum, and palladium.

**Argentite.** An important ore of silver, also called Silver glance. It has the composition $Ag_2S$, containing theoretically 87.1% of silver. It usually occurs massive, streaked black and lead gray, with a metallic luster and a hardness of 2 to 2.5. It is found in Nevada, Arizona, Mexico, South America, and Europe. Argyrodite is another silver ore found in Bolivia, remarkable as a source of the rare metal germanium. When pure, it has the composition $4Ag_2S \cdot GeS_2$,

and contains 5 to 7% of germanium. A similar mineral, Canfieldite, found in Bolivia, has 1.82% of germanium and some tin.

**Argols.** Also called Wine lees. A reddish crust or sediment deposited from wine, employed for the production of tartaric acid, cream of tartar, and rochelle salts. It is crude Potassium acid tartrate, or Cream of tartar, $KH(C_4H_4O_6)$. When grape fermentation is complete, the wine is drawn off and placed in storage tanks where the Lees settles out. The amount of tartrate varies in different types of wine, from 0.1 to 1.0 lb. of cream of tartar per gallon. From wines clarified by refrigeration, as much as 1 to 3 lb. per gal. of tartrate crystallizes out. Cream of tartar is also obtained from Grape pomace, which is the residue skins, seeds, and pulp, containing 1 to 5% of tartrate. The grape pomace is used for fertilizer and animal feed. Wine stones is the name of the cream of tartar, 70 to 90% pure, which crystallizes on the walls of wine storage tanks. Purified cream of tartar is a colorless to white crystalline powder of specific gravity 1.956, soluble in water, used in baking powders.

Tartaric acid is a colorless crystalline product of the composition $HOOC(CHOH)_2COOH$, with melting point 170°C. and soluble in water and in alcohol. It has a wide variety of uses in pharmaceuticals, and in effervescent beverages, and as a mordant in dyeing. Rochelle salts is Potassium sodium tartrate, $KNa(C_4H_4O_6)\cdot 4H_2O$, a colorless to bluish-white crystalline solid of specific gravity 1.79, melting point 75°C., and soluble in water and in alcohol. It is used in medicines and in silvering mirrors. Like quartz, it has the property of separating wave lengths, and is used in piezoelectric devices.

**Argon.** A gaseous element, symbol A, occurring free in the atmosphere to the extent of 0.935%. Its liquefying point is about −187°C. It is obtained by passing atmospheric nitrogen over red-hot magnesium, forming magnesium nitride and free argon. The density is about one and one-half that of air. It is an inactive element and forms no known compounds. Argon is employed in incandescent lamps to give increased light and to prevent vaporization of the filament.

**Arsenic.** A soft, brittle, poisonous element of steel-gray color and metallic luster, symbol As. The melting point is 850°C., and specific gravity 4.8. It is allotropic, with metallic and nonmetallic properties, and forms many compounds. When heated in the air, it burns to Arsenious anhydride with white odorous fumes. The bulk of the arsenic used is employed in insecticides, rat poisons, and weed killers, but it has many industrial uses, especially in pigments. It is also used in poison gases for chemical warfare. The white, poisonous powder commonly called arsenic is Arsenic trioxide, or Arsenious oxide, $As_2O_3$, also known as White arsenic. When marketed commercially, it is colored pink to designate it as a poison. White arsenic is marketed as Refined, +99% pure, High-grade, 95 to 99%, and Low-grade, −95%. Arsenic is added to antimonial lead alloys and white bearing metals for hardening and to increase fluidity, and to copper to increase the annealing temperature for such uses as radiators. It is also used in lead shot to diminish cohesion. The common ores of arsenic are the arsenical iron pyrites, realgar, smaltite, and orpiment. It is also a by-product from copper smelters, recovered by distillation.

**Arsenic acid.** A white crystalline solid of the composition $(H_3AsO_4)_2 \cdot H_2O$, produced by the oxidation of white arsenic with nitric and hydrochloric acids. It is soluble in water and in alcohol, has a specific gravity of 2 to 2.5, and a melting point of 35.5°C. Arsenic acid is sold in various grades, usually 75% pure, and is used in glass manufacture, in printing textiles, and in insecticides.

**Arsenic disulphide.** Also known as Ruby arsenic, Red arsenic glass, and Red orpiment. It is an orange-red, poisonous powder with specific gravity of 3.5, and melting point 307°C., obtained by roasting arsenopyrite and iron pyrites. The composition is $As_2S_2$. It is employed in fireworks, as a paint pigment, and in the leather and textile industries. Another arsenic sulphur compound used as a pigment is Orpiment, found as a natural mineral in Utah, Peru, and in central Europe. It is an Arsenic trisulphide, $As_2S_3$, containing 39% of sulphur and 61 arsenic. The mineral has a foliated structure, a lemon-yellow color, and a resinous luster. The specific gravity is 3.4, hardness 1.5 to 2, and melting point 300°C.

Artificial arsenic sulphide is now largely substituted for natural orpiment, and as a pigment is referred to as King's yellow.

**Arsenic ores.** Arsenopyrite, also called Mispickel, is the most common ore of arsenic. It is used also as a source of white arsenic, and directly in pigments and as a hide preservative. The composition is FeAsS. It occurs in crystals or massive, of a silvery-white to gray-black color and a metallic luster. The specific gravity is 6.2 and hardness 5.5 to 6. Arsenic is usually not a primary product from ores, but is obtained as a by-product in the smelting of copper, lead, and gold ores. A source of white arsenic is the copper ore, Enargite, $Cu_2S \cdot 4CuS \cdot As_2S_3$, containing theoretically 48.3% of copper and 19.1 arsenic. It occurs in massive form with a hardness of 3, specific gravity of 4.45, and is gray, with a pinkish variety known as Luzonite. The mineral is commonly intertwined with Tennantite, $5Cu_2S \cdot 2(CuFe)S \cdot 2As_2S_3$, a mineral of a gray to greenish color. Realgar, known also as Ruby sulphur and Red orpiment, is a red or orange arsenic disulphide, $As_2S_2$, occurring with ores of lead and silver in monoclinic crystals. The hardness is 1.5, and specific gravity 3.55. It has been used as a pigment. Another ore is Smaltite, or Cobalt pyrites, $CoAs_2$, occurring in gray masses of specific gravity 6.5 and hardness 5.5. It occurs with ores of nickel and copper. It may have nickel and iron replacing part of the cobalt, but it is also an ore of cobalt.

**Asbestos.** The commercial name for several varieties of fibrous minerals, the fibers of which are valued for their heat-resistant and chemical-resistant properties, and are made into fabrics, paper, insulating boards, and insulating cements. The long fibers are used for weaving into fireproof garments, curtains, shields, and brake linings. The short fibers are compressed with binders into various forms of insulating boards, shingles, pipe coverings, paper, and molded products. The original source of asbestos was the mineral Actinolite, but the variety of Serpentine known as Chrysotile now furnishes most of the commercial asbestos. Actinolite and Tremolite, which furnish some of the asbestos, belong to a great group of widely distributed minerals known as Amphiboles which are chiefly metasilicates of calcium and magnesium with iron sometimes replacing part of the magnesium. They occur granular, in

crystals, compact such as Nephrite which is the Jade of the Orient, or in silky fibers as in the iron Amphibole asbestos mined in the United States. The color varies from white to green and black. This type is more resistant to high temperatures than chrysotile asbestos.

Chrysotile is a highly fibrous variety of serpentine. It is a hydrated silicate of magnesia, $2SiO_2 \cdot 3MgO \cdot 2H_2O$, and has a silky, strong fiber that can be spun and woven into fabrics. The color is white to greenish. The fibers from different mines vary in diameter and flexibility, but the very thin flexible ones can be separated out readily for weaving into light fabrics. Chrysotile is mined chiefly in Vermont, Quebec, Arizona, and Rhodesia. Only about 8% of the total mined is long spinning fiber, the remainder being too short for fabrics or rope. Blue asbestos, from South Africa, is the mineral Crocidolite, $NaFe(SiO_3)_2 \cdot FeSiO_2$. The fiber has high tensile strength and is acid-resistant, and is used in packings and in asbestos-cement pipe.

The classes of Cape asbestos from South Africa are chrysotile, Amosite, and Transvaal blue. Amosite has a coarse, long, resilient fiber, and is used chiefly in insulation as it is difficult to spin. It comes in white and dark grades, and the fibers are graded also by length from ⅛ to 1½ in. It is a type of crocidolite. The name amosite was originally a trade name for South African asbestos, but now refers to this type of mineral. Transvaal blue is a whitish, iron-rich Anthophyllite, $(MgFe)SiO_3$, noted for the length of its fiber. The best grades are about 1½ in. in length. The fibers are resistant to heat and to acids, and the stronger fibers are used for making acid filter cloth and for fireproof garments. This type of asbestos is also found in the Appalachian range from Vermont to Alabama. Canada produces more than half of all asbestos. Canadian, Vermont, and Arizona asbestos is chrysotile; that from Georgia and the Carolinas is anthophyllite. Asbestos is shipped as crudes, fibers, and shorts, more than half the production being shorts. The nonspinning fibers are graded as shingle stock, paper stock, cement stock, and shorts. Short-fiber asbestos is washed and ground for use as a resistant filler in molded plastics. In England this material is called Micro asbestos.

Asbestos fabrics are often woven mixed with some cotton. For brake linings and clutch facings the asbestos is woven with fine metallic wire. Asbeston, of the U.S. Rubber Co., is full asbestos fabric in various weaves and weights. The 8-oz. open-weave fabric is used for cable insulation. The close-woven 16-oz. cloth is used for aircraft air ducts. The 20-oz. fabric is used for fireproof clothing. Asbestos wick, used for calking, is made of strands of carded long asbestos fiber twisted in the form of a soft rope, usually ¼ in. in diameter. Asbestos rope is larger diameter material made by twisting or braiding several strands of wick. Asbestos felt, used for insulation, is usually made by saturating felted asbestos with asphalt, although synthetic rubber or other binder may be used. Asbestos shingles, for fireproof roofing and siding of houses, are normally made of asbestos fibers and portland cement formed under hydraulic pressure. They are in the natural gray color or are colored with black or green pigments. Another type of asbestos used for some insulation is Paligorskite, known as Mountain leather, found in Alaska. It is a complex mineral which may be an alteration product of several asbestos minerals. It absorbs moisture, and is thus not suited to the ordinary uses of asbestos, but it can be reduced to a smooth pulp which is molded with a resistant plastic binder into a lightweight insulating board.

**Asbestos board.** A construction or insulating material in sheets made of asbestos fibers and portland cement molded under hydraulic pressure. Ordinary board for the siding and partitions of warehouses and utility buildings is in the natural mottled-gray color, but pigmented boards are also marketed in various colors. The specific gravity of asbestos board is about 2.0, and it will withstand temperatures to about 1000°F. The boards are dense and rigid, but can be worked easily with carpenters' tools. Usual thicknesses are 3/16, ¼, and ⅜ in. Asbestos board is marketed under trade names such as Industal, Apac board, and Linabestos, of the Keasbey & Mattison Co., and Transite of Johns-Manville. Sheetflextos, of the former company, is a flexible asbestos-cement wallboard in ⅛ in. thickness in natural gray or waxed decorative colors. Corrugated asbestos, used for roofing and siding of industrial build-

ings, has a thickness of ⅜ in., and the usual corrugation of the sheet has a pitch of 4.2 in. The weight is 3.75 lb. per sq. ft.

Asbestos lumber is asbestos-cement board molded in the form of boards for flooring and partitions, usually with imitation wood grain molded into the surface. Asbestos siding, for house construction, is grained to imitate cypress or other wood and is pigmented with titanium oxide to give a clear white color. Asbestos roofing materials may also be made with asphalt or other binder instead of cement. Fiberock, of the Philip Carey Co., is a roofing board composed of asbestos fibers impregnated with asphalt. Asbestos millboard is asbestos fibers compressed into sheets with a small amount of binder. Copperclad, of Johns-Manville, is a roofing material consisting of 2-oz. electro-sheet copper bonded to asbestos felt. Asbestos ebony, of this company, is an electrical panel board made of asbestos cement bonded under high pressure with an insulating compound. It has good dielectric strength, will withstand temperatures to 300°F., and has a specific gravity of 2.05. Ebonized asbestos, of the Ambler Asbestos Shingle & Sheathing Co., is asbestos molded into sheets with an asphalt binder, and used for instrument panels.

**Asbestos paper.** A thin asbestos sheeting made of asbestos fibers bonded usually with a solution of sodium silicate. It is strong, flexible, white in color, and is fireproof and a good heat insulator. For covering steam pipes and for insulating walls it is made in sheets of two or three plies. For wall insulation it is also made double with one corrugated sheet to form air pockets when in place. Thin sheets, 6 lb. per 100 sq. ft., up to 32 lb., or 1/16 in. thick, are employed for gaskets and electrical insulation. Crimped asbestos paper is also used for pipe insulation to give dead air spaces between layers. Amblerite, of Keasbey & Mattison Co., is thin sheet made of asbestos fibers with a resilient binder, used for packing for superheated steam and chemical fittings. Uni-Syn sheet packing, of this company, is made by treating long asbestos fibers with Buna-S rubber and felting under pressure. It is resilient and resistant to chemicals. Prenite, of the B. F. Goodrich Co., is Neoprene-bonded asbestos sheet used for chemical packings.

**Ash.** The wood of a variety of species of ash trees valued for uses where strength, hardness, stiffness, and shock resistance are important. Most of the species give dense, elastic woods that polish well, but they do not withstand exposure well. The color is yellowish, which turns brown on exposure. The woods from the different species vary in their qualities, and are likely to be mixed in commercial shipments, but the general quality is high. Ash is used for quality cooperage such as food tubs, flooring, veneer, vehicle parts, tool handles, bearings, and trim lumber. American ash and Canadian ash, also called Cane ash and White ash, come chiefly from the tree *Fraxinus americana* which grows over a wide area east of the Mississippi River. Arkansas ash is from *F. platycarpa;* Japanese ash, also called Tamo, is from *F. mandschurica;* and European ash is from *F. excelsior.* European ash is heavier than American ash, and is tough and elastic. It is valued for hockey sticks, tennis rackets, and tool handles. Japanese ash is a close-grained wood, and is browner in color than American ash.

White ash weighs 41 lb. per cu. ft. dry; Red ash, *F. pennsylvanica,* 39 lb. per cu. ft.; and Green ash, *F. pennsylvanica lanceolata,* also called Water ash and Swamp ash, 44 lb. This latter tree grows over the widest area throughout the states east of the Rockies, and is commercially abundant in the Southeast and Gulf states. All of these woods vary in tensile strength from 11,000 to 17,000 lb. per sq. in. White ash has a compressive strength perpendicular to the grain of 2,250 lb. per sq. in. Mountain ash and Black ash, *F. nigra,* are also species of American ash. The latter, also called Brown ash and Hoop ash, is a northern tree and was formerly used in aircraft construction. It has a specific gravity of 0.53 when oven-dried, a compressive strength perpendicular to the grain of 1,260 lb. per sq. in., and a shearing strength parallel to the grain of 1,050 lb. per sq. in. Oregon ash, *F. oregona,* is somewhat lighter and not as strong as white ash. It grows along the west coast of Canada. Blue ash, *F. quadrangular,* grows in the Central states. Pumpkin ash, *F. profunda,* grows in the lower Mississippi Valley and in Florida. A wood that has similar uses to ash, for handles, levers, and machine parts, but is harder than ash, is Hornbeam. It is from the tree *Ostrya virginiana* of the Eastern states of the United States. The

wood is very hard, tough, and strong, but is available only in limited quantities.

**Aspen.** The wood of the aspen tree, *Populus tremula,* used chiefly for match stems and for making excelsior, but also for some inside construction work. The color is yellowish, and it is tough and close-grained. The tree is native to Europe. The American aspen is from the tree *P. tremuloides,* called also American poplar, and from the Largetooth aspen, *P. grandidentata.* Both species are also called Poplar, and the lumber may be mixed with poplar and cottonwood. The trees grow in the Lake and Northeastern states and in the West. The heartwood is grayish white to light brown with a lighter colored sapwood. It is straight-grained with a fine and uniform texture, but is soft and weak. It has a disagreeable odor when moist. The wood is largely used for excelsior and for paper pulp. The pulp is easily bleached and is suitable for chemical use. Salicen is extracted from the bark of the tree.

**Asphalt.** A bituminous, brownish to jet-black substance, solid or semisolid, found in various parts of the world. It consists of a mixture of hydrocarbons, is fusible and largely soluble in carbon disulphide. It is also soluble in petroleum solvents and in turpentine. The melting points range from 32 to 38°C. Large deposits occur in Trinidad and Venezuela. Asphalt is of animal origin as distinct from coals of vegetable origin. Native asphalt usually contains much mineral matter, and crude Trinidad asphalt has a composition of about 47% of bitumen, 28 clay, and 25 water. Artificial asphalt is a term applied to the bituminous residue from coal distillation mechanically mixed with sand or limestone. Asphalt is used for roofings, road surfacing, insulating varnishes, acid-resistant paints, and for cold-molded products. The material has been known and used since earliest times, the clay bricks of the buildings of Babylon having been cemented with asphalt. The Greek word for native asphalt was Asphaltos, and the Latin word Bitumen. The latter word now means the asphalt clean of earthy matter. The word comes from the original Sanskrit word Gwitu-men, meaning pitch, and the word Pitch now applies chiefly to tars used as roofing or coating materials. In general, bitumens have the characteristics that they are fusible and are totally soluble in carbon disulphide, as

distinct from the Pyrobitumens, albertite, elatarite, and coals, which are infusible and relatively insoluble in carbon disulphide. Pyrogenous asphalts are the residues from the distillation of petroleum or from the treatment of wurtzilite. Asphaltite is a general name for the bituminous asphaltic materials which are difficultly fusible, such as gilsonite and grahamite.

Rock asphalt, or Bituminous rock, is a sandstone or limestone naturally impregnated with asphalt. The asphalt can be extracted from it, or it is used directly for paving and flooring. Kyrock is a rock asphalt from Kentucky consisting of silica sand of sharp grains bound together with a bituminous content of about 7%. The crushed rock is used as a paving material. Albertite is a type of asphalt found originally in Albert County, New Brunswick, and first named Albert coal. It belongs to the group of asphalts only partly soluble in carbon disulphide, infusible, and designated as Carboids, although they are true asphalts and not of vegetable origin. The commercial albertite is a type called Stellarite from Nova Scotia. It is jet-black, brittle, contains 22 to 25% of fixed carbon, and yields oil and coke when distilled. It is easily lighted with a match, and burns with a bright, smoky flame, throwing off sparks. The albertite found in Utah is called Nigrite and contains up to 40% of fixed carbon. A species found in Angola is called Libollite. These materials are weathered asphalts. Ipsonite is a final stage of weathered asphalt. It is black in color, infusible, only slightly soluble in carbon disulphide, contains 50 to 80% of fixed carbon, and is very low in oxygen. It is found in Oklahoma, Arkansas, Nevada, and in various places in South America. The Rafaelite found in large beds on the eastern slopes of the Andes Mountains in Argentina is a form of ipsonite.

Cutback asphalt is asphalt liquefied with petroleum distillates, used for cementing down floor coverings and for waterproofing walls. Emulsified asphalt is an asphalt emulsion in water solution, used for floor surfacing, painting pipes, and waterproofing concrete walls. Emulsified asphalts may be marketed under trade names such as Elastex of the Truscon Laboratories, and Ebontex of the Philip Carey Co. Thermotex, of the latter company, is an emulsified asphalt mixed with asbestos fibers, used for painting steam pipes. Amiesite, of the Amiesite Asphalt Co., is asphalt

mixed with rubber latex, or is a premixed asphalt with an aggregate employed for road filling. Flooring blocks and Asphalt tiles are made in standard shapes and sizes from mixtures of asphalt with fillers and pigments. Elastite, of the Philip Carey Co., is a block made of about 35% of asphalt, 15 fiber, and 50 mineral filler. It is used for factory floors. Accotile, of the Armstrong Cork Products Co., is a resilient and chemical-resistant floor tile made of asbestos fibers, mineral pigments, and asphalt binder. Asphalt is also used for cold-molded products, such as Gummon of the Garfield Mfg. Co., which is composed of asbestos fibers molded with an asphalt binder. Oil asphalt, Petroleum pitch, or Asphalt oil, is the heavy black residue left after removing the tar tailings in the distillation of petroleum. It contains 99% bitumen, is not soluble in water, and is durable. As it adheres well to metals, wood, or paper, and forms a glossy surface, it is used in roofings, or mixed with natural asphalt for paints and coatings. It is also used for roads.

**Babassu oil.** An oil similar to coconut oil obtained from the kernels of the nut of the palm tree *Attalea orbignya* which grows in vast quantities in northeastern Brazil. Most of the commercial nuts come from Maranhão. There are 2 to 5 long kernels in each nut, the kernel being only 9% of the heavy-shelled nut, and these kernels contain 65% of oil. A bunch of the fruits contains 200 to 600 nuts. The oil is very high in lauric acid, and is a direct substitute for coconut oil for soaps, as an edible oil, and as a source of lauric, capric, and myristic acids. The melting point of the oil is 22 to 26°C., specific gravity 0.868, iodine value 15, and saponification value 246 to 250. Tucum oil, usually classed with babassu but valued more in the bakery industry because of its higher melting point, is from the kernels of the nut of the palm *Astrocaryum tucuma* of northeastern Brazil. The oil is similar in characteristics but slightly heavier with melting point up to 35°C. In Colombia it is called Guere palm.

Another similar oil is Murumuru oil, from the kernels of the nut of the palm *A. murumuru,* of Brazil. The name is a corruption of the two Carib words marú and morú, meaning bread to eat. The oil contains as much as 40% of lauric acid, with 35% myristic acid, and some palmitic, stearic, linoleic, and oleic acids. It is

usually marketed as babassu oil. The Awarra palm, *A. janari*, of the Guianas, yields nuts with a similar oil. Cohune oil is a white fat from the kernels of the nut of the palm *Attalea cohune* of Mexico and Central America. It is a small tree yielding as many as 2,000 nuts a year. The oil has the appearance and odor of coconut oil, and contains 46% of lauric acid, 16 myristic, 10 oleic, with also stearic, capric, and linoleic acids. All of these oils yield a high proportion of glycerin which is in combination with the fatty acids. Cohune oil has a melting point of 18 to 20°C., saponification value 252 to 256, iodine value 10 to 14, and specific gravity 0.868 to 0.971. The cohune nut is much smaller than the babassu but is plentiful and easier to crack. Curua oil is from the nut of the palm *A. spectabilis* of Brazil. It is similar to cohune oil and is used for the same purposes in soaps and foods. Mamarron oil is a cream-colored fat with the odor and characteristics of coconut oil, obtained from another species of *Attalea* palm of Colombia. Another oil high in lauric acid, and similar to babassu oil, is Corozo oil obtained from the kernels of the nuts of the palm *Corozo oleifera* of Venezuela and Central America. Macanilla oil is a similar oil from the kernels of the nuts of the palm *Guilielma garipaes* of the same region. Buri oil is from the nuts of the palm *Diplothemium candescens* of Brazil.

**Babbitt metal.** The original name for tin-antimony-copper white alloys used for machinery bearings, but the term now applies to almost any white bearing alloy with either tin or lead base. The original babbitt, named after the inventor, was made by melting together 4 parts by weight of copper, 12 of tin, and 8 of antimony, and then adding 12 parts of tin after fusion. It consisted, therefore, of 88.9% of tin, 7.4 antimony, and 3.7 copper. This alloy melts at 462°F. It has a Brinell hardness of 35 at 70°F., and 15 at 212°F. As a general-utility bearing metal, the original alloy has never been improved greatly, and makers frequently designate the tin-base alloys close to this composition as Genuine babbitt. Some of the early competitive alloys varied in composition, but usually for the purpose of conserving tin. Thurston's bearing metal contained 9 to 10% copper, 20 antimony, and the balance tin. Jacana metal had 70% lead, 10 tin, 19 antimony, and a small amount of bismuth.

Husman's alloy, used originally on the German railways, had about 74% of tin, 11 antimony, 4 copper, 10 lead, and 0.4 zinc. Karmash's alloy contained considerable zinc.

Commercial white bearing metals now known as babbitt are of three general classes: Tin-base, with more than 50% of tin hardened with antimony and copper, and used for heavy, pounding service; Intermediate, with 20 to 50% of tin, having lower compressive strength and more sluggish as a bearing; Lead-base, made usually with antimonial lead with smaller amounts of tin together with other elements to hold the lead in solution. These Lead-base babbitts are lower in cost and also serve to conserve tin in times of scarcity of that metal, but they are suitable only for light service, although many ingenious combinations of supplementary alloying elements have sometimes been used to give hard, strong bearings with little tin. The high-grade babbitts, however, are usually close to the original babbitt in composition. S.A.E. babbitt for connecting-rod bearings has 86% of tin, 5 to 6.5 copper, 6 to 7.5 antimony, and not over 0.35 lead. A babbitt of this kind will have a compressive strength up to 20,000 lb. per sq. in., while the high-lead alloys have only 15,000 lb. per sq. in.

Copper hardens and toughens the alloy and raises the melting point. Lead increases the fluidity and raises the antifriction qualities, but softens the alloy and decreases its compressive strength. Antimony hardens the metal and forms hard crystals in the soft matrix which improves the alloy as a bearing metal. Only 3.5% of antimony is normally dissolved in tin. In the low-antimony alloys copper-tin crystals from the hard constituent, and in the high-antimony alloys antimony-tin cubes are also present. Alloys containing up to 1% of arsenic are harder at high temperatures and are fine-grained, but arsenic is used chiefly for holding lead in suspension. Zinc increases hardness but decreases frictional qualities, and with much zinc the bearings are inclined to stick. Even minute quantities of iron harden the alloys, and iron is not used except when zinc is present. Bismuth reduces shrinkage and refines the grain, but lowers the melting point, and lowers the strength at elevated temperatures. Cadmium increases the strength and fatigue resistance, but any considerable amount lowers the frictional qualities, lowers the strength at higher temperatures, and causes corrosion.

Nickel is used to increase strength but raises the melting point. The normal amount of copper in babbitts is 3 to 4%, at which point the maximum fatigue-resisting properties are obtained with about 7% of antimony. More than 4% of copper tends to weaken the alloy, and raises the melting point. When the copper is very high, tin-copper crystals are formed and the alloy is more a bronze than a babbitt. Parson's white brass is a hard tin-base white alloy with both SnSb and SnCu crystals in the matrix.

Babbitts are marketed under many trade names, and some makers class the high-lead alloys as Antifriction metal rather than as babbitt. The antifriction metal of the Bunting Brass & Bronze Co. contains 75% of lead, 15 antimony, and 10 tin. Leantin, of the Lumen Bearing Co., is a high-lead alloy; Cosmos metal is a lead-base alloy with small amounts of tin and antimony; Stannum metal is a high-tin alloy for hard-service bearings; Lubeco metal is a medium-composition babbitt; and Lotus metal, for motor bearings, is a lead-base alloy with higher percentages of tin and antimony. Hoo Hoo metal, of the National Bearing Metals Corp., contains no lead, but is a tin-base alloy with copper, nickel, and antimony. Nickel babbitt, of this company, is a tin-copper-nickel alloy with a compressive strength of 24,600 lb. per sq. in., and a Brinell hardness of 29. A grade of Rex babbitt, developed by this company as a substitute for high-tin babbitt during the war, contains only 10% of tin together with antimony, copper, and lead in proportions to give strength and frictional properties. The compressive strength is 17,500 lb. per sq. in., Brinell hardness 25, and pouring temperature 625 to 675°F. Copaloy, of the Michigan Smelting & Refining Co., is a lead-tin-antimony alloy with a small percentage of copper. Bearingoy, of the Williams Alloy Products Co., is a soft lead alloy used where lubrication is poor. Glyco is the name of a group of lead-base alloys of Joseph T. Ryerson & Son, Inc. Satco, of the National Lead Co., is a high-melting-point alloy for heavy service. It melts at 788°F. Tinite, of the Ajax Metal Co., is a tin-base metal hardened with copper. Ajax bull, of this company, contains 76% of lead, 7 tin, and 17 antimony.

**Bagasse.** The residue left after grinding sugar cane and extracting the juice, employed in making paper and fiber building boards.

In England it is called Megass. The fibers are long, and mat together to form a strong, tough, light, absorptive board. The finer fibers of bagasse in Cuba and Jamaica are soaked in molasses and used as a cattle feed under the name of Molascuit. Celotex is the trade name of the Celotex Corp. for wallboard, paneling, and acoustical tile made from bagasse fibers. Ferox-Celotex is the material treated with chemicals to make it resistant to fungi and termites. Celo-Rock is the trade name for Celotex-gypsum building boards. Acousti-Celotex is Celotex perforated to increase its sound-absorbing efficiency.

**Balata.** A nonelastic rubber obtained chiefly from the tree *Manilkara bidentata* of Venezuela, Brazil, and the Guianas. It is similar to gutta-percha and is used as a substitute, but the tree has not been cultivated. The material contains a high percentage of gums and is more tacky than rubber, but it can be vulcanized in the same manner as rubber. Balata has been used principally for transmission and conveyer belts. For conveyer belts heavy duck is impregnated with balata gum solution and vulcanized. The belts have high tensile strength, good flexibility, and wear resistance. The wood of the balata tree is used for cabinetwork and for rollers and bearings. It is called Bulletwood in the Guianas, but this name is also applied to the wood of the gutta-percha trees of Asia which have about the same characteristics. The wood is extremely hard, durable, and weighs 66 lb. per cu. ft. It has a deep-red color and a fine, open grain.

**Balloon cloth.** A plain-woven cotton fabric used originally as a base material in making coated fabrics for the construction of balloons, but now used also in many industries under the same name. The various grades differ in weight, thread count, and strength. Grade HH, having 120 threads per in. in each direction, is most widely used. A Navy fabric has a weight of 2.05 oz. per sq. yd. and a tensile strength of 38 lb. per sq. in. in each direction. When several layers are built up and rubberized or plastic-coated, they may be on the bias, and the outside layer coated with aluminum paint to reduce the heat absorption. Gas cell fabric is a single-ply, coated balloon cloth. Airplane cloth, used for fabric-covered training planes, is a plain-woven cotton fabric of 2-ply combed yarns mer-

cerized in the yarn. It is usually 4 oz. per yd., but wide fabrics may be 4.5 oz. The cotton is 1½ in. min. staple, and the threads per inch are 80 to 84.

**Balsa wood.** The wood of large and fast-growing trees of the genus *Ochroma* growing from southern Mexico to Ecuador and northern Brazil. It is the lightest of the commercial woods and combines also the qualities of strength, stiffness, and workability. It is about one-fourth the weight of spruce, with a structural strength only half that of spruce. The crushing strength is 2,150 lb. per sq. in. The wood is white to light yellow or brownish and weighs about 8 lb. per cu. ft. from a 4-year-old tree. Wood from a 6-year-old tree weighs 10 to 12 lb. per cu. ft. Its peculiar cellular structure makes it valuable as an insulating material for refrigeration. It is also used for life preservers, buoys, floats, paneling, vibration isolators, insulating partitions, and inside trim of aircraft. The small pieces are used for model airplanes. Balsa sawdust is valued as a lightweight filler for plastics. Much of the commercial wood is from the tree *O. grandiflora* of Ecuador. The Barrios balsa, *O. concolor,* grows from southern Mexico through Guatemala and Honduras. Limon balsa is from the tree *O. limonensis* of Costa Rica and Panama, and the Santa Marta balsa is the *O. obtusa* of Colombia. Red balsa is from the *O. velutina* of the Pacific coast of Central America. A Japanese lightweight wood used for floats, instruments, and where lightness is required is Kiri, from the tree *Paulownia tomentosa.* It weighs 20 lb. per cu. ft.

**Balsam fir.** The wood of the coniferous tree *Abies balsamea,* of the United States and Canada. It is brownish white in color, soft, and has a fine, even grain. It is not strong and not very durable, and is used chiefly for packing boxes and light construction. The weight is 26 lb. per cu. ft.

**Bamboo.** A genus of gigantic treelike grasses, of the order *Graminaceae,* of which the *Bambusa arundinacea* is the most common species. It grows most commonly in the East Indies and in southern Asia, but many species have been brought to Latin America and to the Southern United States. The stems of bamboo are hollow, jointed, and have an extremely hard exterior surface. They

sometimes reach more than 1 ft. in diameter and are often 50 ft. high, growing in dense masses. The *B. spinosa* of the Philippines grows as much as 10 ft. in one week. Bamboo is a material of innumerable uses. The stalks are used for making pipes, buckets, baskets, walking sticks, fishing poles, rug winding poles, lance shafts, window blinds, mats, arrows, and for building houses and making furniture. The weight is about 22 lb. per cu. ft. Tonkin bamboo is strong and flexible and is used for making fishing poles. Tali bamboo of Java, *Gigantochloa apus,* is used for construction. Betong bamboo is *G. asper,* and is one of the largest species. Giant bamboo, *Dendrocalamus gigantea,* of Ceylon, grows to a height of 100 ft. The fast-growing eeta bamboo is used in India as a source of cellulose for rayon manufacture.

**Barite.** Sometimes spelled Baryte, and also called Heavy spar, and in some localities known as Tiff. A natural Barium sulphate mineral of the theoretical composition $BaSO_4$, used chiefly for the production of lithopone, but also ground and used as a filler for paints, plastics, linoleum, rubber, cloth, and paper, and in chemical manufacture. For the latter purpose it is specified 90 to 95% pure $BaSO_4$, with not more than 1% of ferric oxide. Prime white and floated grades are used for coating paper. Artificial barite, Permanent white, and Blanc fixe are names for white, fine-grained precipitated paint grades. Micronized barite, for rubber filler, is a fine white powder of 400 to 1,000 mesh. Barite is widely distributed and especially associated with ores of various metals or with limestones. It occurs in crystals or massive. It may be colorless, white, or light shades of blue, red, and yellow, and transparent to opaque. Its hardness is 3 to 3.5, and specific gravity 4.4 to 4.8. It is insoluble in water. The mineral is produced in the Western states and from Virginia to Georgia. Large deposits of high-grade Barite occur in Nova Scotia. In the West much ground crude barite is used as a drilling mud in oil wells. The white pigment marketed by the American Zinc Sales Co. under the name of Azolite is 71% barium sulphate and 29% zinc sulphide in 325-mesh powder. Sunolith, of Wishnick-Tumpeer, Inc., is a similar product. A substitute for barite for some filler uses is Witherite, an alteration mineral of the composition $BaCO_3$, which is Barium carbonate, found asso-

ciated with barite. Precipitated barium carbonate is a white, tasteless, but poisonous powder used in rat poisons.

**Barium.** A metallic element of the alkaline earth group, symbol Ba. It occurs in combination in the minerals witherite and barite which are widely distributed. The metal is silvery white in color and can be obtained by electrolysis from the chloride, but it oxidizes so easily that it is difficult to obtain in the metallic state. It oxidizes on contact with the air and decomposes water at ordinary temperatures. Its melting point is 850°C., and specific gravity 3.78. The most extensive use of barium is in the form of its sulphate as a pigment. It is also used in chemical manufacturing, and its salts are employed for deoxidizing alloys of copper, tin, lead, and zinc. It is introduced into lead-bearing metals by electrolysis to harden the lead.

**Barium chloride.** A colorless, crystalline material of the composition $BaCl_2 \cdot 2H_2O$, or in anhydrous form without the water of crystallization. The specific gravity is 3.097, and melting point 860°C. It is soluble in water to the extent of 25% at 20°C. and 37% at 100°C. In the mechanical industries it is used for heat-treating baths for steel either alone or mixed with potassium chloride. The molten material is free from fuming and can be held at practically any temperature within the range needed for tempering steels. It is also used for making boiler compounds, for softening water, as a mordant in dyeing and in printing inks, in tanning leather, in photographic chemicals, and in insecticides Barium chlorate, $Ba(ClO_3)_2 \cdot H_2O$, is a colorless crystalline powder soluble in water. The melting point of the anhydrous material is 414°C. It is used in explosives as an oxygen carrier, and in pyrotechnics for green-colored light.

**Barium nitrate.** Also called Nitrobarite. A white, crystalline powder of the composition $Ba(NO_3)_2$, with specific gravity of 3.24, melting at 592°C., and decomposing at higher temperatures. It is a barium salt of nitric acid obtained by roasting barite with coke, leaching out the precipitated barium sulphide, precipitating as a carbonate by the addition of soda ash, and then dissolving in dilute nitric acid. It has a bitter metallic taste and is poisonous. Barium

nitrate is used in ceramic glazes, but its chief use is in Pyrotechnics. It gives a pale-green flame in burning, and is used for green signals and flares, and for white flares in which the delicate green is blended with the light of other extremely luminous materials. It is also used as an oxygen carrier in Flare powders and to control the time of burning of the aluminum or magnesium. Sparklers are composed of aluminum powder and steel filings with barium nitrate as the oxygen carrier. Barium oxalate, $BaC_2O_4$, another barium salt, is also used in pyrotechnics as a combustion retarder.

**Barley.** The seed grains of the annual plant *Hordeum vulgare* of which there are many varieties. It is one of the most ancient of the cereal grains, and was the principal source of bread flour until the sixteenth century. The plant is hardy, with a short growing season, and can be cultivated in cold latitudes and at high altitudes, giving high yields per acre. The grains grow in a dense head with three spikelets, and the six-rowed variety has a high protein content, but has low gluten, thus making a poor breadstuff. Pearl barley is the husked and polished grain. About two-thirds of the barley grown in the United States is now used for animal feed as it produces lean meat in cattle. The chief industrial use is for making Malt, for which the two-rowed varieties with low protein and thin husk are used. Malt is barley that has been germinated by moisture and then dried. Malting develops the diastase enzyme, which is capable of converting the insoluble starch into soluble starch and then into sugars. It is used for brewing beer and for malt extracts. Caramel malt is browned with high-temperature drying, and is used for the dark-colored Bock beer. Barley straw is employed in Europe and Asia for making braided plaits for hat making. In America barley straw is used for packing.

**Basalt.** A dense, hard, dark-brown to black igneous rock, consisting of feldspar and augite and often containing crystals of green olivine. It occurs as trap or as volcanic rock. The specific gravity is 2.87 to 3, and it is extremely hard. Masses of basalt are frequently found in columns or prisms, as in the celebrated basalt cliffs of northern Ireland. The rock is often wrongly classed as a granite. Basalt is used in the form of crushed stone for paving, as a building stone, and for making rock wool. A Russian cast basalt used for

electrical insulators is called Angarite. In Germany cast basalt has been used as a building stone, for linings, and for industrial floors. It is made by melting the crushed and graded basalt, and then tempering by slow cooling. The structure of the cast material is dense with needlelike crystals, and has a hardness of 8 to 9 Moh. Basalt glass is not basalt, but is pumice.

**Basswood.** The wood of several species of lime trees, *Tilia americana, T. heterophylla, T. glabra,* and *T. pubescens,* all native to the United States and Canada. The European Lime wood, from the tree *T. cordata,* is not called basswood. The wood of the *T. glabra,* called in the Eastern states the Lime tree, Linden, and White basswood, is important commercially. It is soft, light in weight, and has a fine, even grain, but is not very strong or durable on exposure. The white sapwood merges gradually with the yellow-brown heartwood. The specific gravity is 0.40 when oven-dried, and the compressive strength perpendicular to the grain is 620 lb. per sq. in.

**Bate.** A term employed in the leather industry for materials used to free the skins of lime and to make them soft and flaccid before tanning. Since ancient times dung has been used for this purpose, and until very recently the American tanning industry imported dog dung from Asia Minor for bating leather. Artificial bates are now used because of their greater uniformity and cleanliness. Boric acid is sometimes used for deliming, and gives a silky feel to the leather, but most bates have both a deliming and an enzyme action. Trypsin is a group of enzymes from the pancreatic glands of animals, and its action on skins is to dissolve the protein. Oropon, of Rohm & Haas Co., Inc., is this material carried in wood flour and mixed with a deliming salt. Sulphamic acid is also used as a bate.

**Bauxite.** A noncrystalline, earthy white to reddish mineral, massive or in grains, having a composition $Al_2O_3 \cdot 2H_2O$, containing theoretically 74% of alumina. It is the most important ore of aluminum, but is also used for making aluminum oxide abrasives, for refractories, white cement, and for decolorizing and filtering. The chief production in the United States is in Arkansas, Georgia, and Alabama, but less than 15% of the world output is in the

United States. The important producing countries are the Guianas, Hungary, France, and Italy, but large deposits are found in other places. Bauxite is graded on the $Al_2O_3$ content. High-grade bauxite, Grade A, contains a minimum of 55% of $Al_2O_3$, and a maximum of 8% silicon. Grade B contains a minimum of 50% of $Al_2O_3$ with a silicon content from 8 to 16%. Chemical grades should have less than 2.5% of $Fe_2O_3$. Grades appearing in price quotations with up to 84% alumina content are calcined and are based on the dehydrated alumina content of the ore. One long ton of crude bauxite yields 0.87 long ton of dried bauxite, which is sufficient to produce one short ton of alumina, which in turn yields 1,000 lb. of aluminum metal.

Cement-making white bauxite from Greece ranks very high in alumina content. Brazilian, Arkansas, and Indian ores also contain some titanium oxide, and the Surinam ore has as high as 3% of $TiO_2$. Two kinds of bauxite are found in Italy, a dark-red variety containing 54 to 58% of $Al_2O_3$, and only 2 to 4% $SiO_2$, but having 22 to 26% of $Fe_2O_3$, and 2 to 3% $TiO_2$, and a light-red variety containing 60 to 66% of $Al_2O_3$, 5 to 9 silica, 10 to 16 iron oxide, and 3 to 5 titanium oxide. The best French white bauxite contains 66 to 74% of alumina, 6 to 10 silica, 2 to 4 iron oxide, and 3 to 4 titanium oxide. It is preferred for ceramic and chemical purposes, while the best grade of the red variety is used for producing aluminum, and the inferior grades for refractories and for cement manufacture. American bauxite has usually a round, pebblelike structure, of white, gray, yellow, or reddish color, and is valued for aluminum production because of its low silica content. Bauxite melts at 1820°C., and can be used directly as a refractory. Diaspore, $Al_2O_3 \cdot H_2O$, mined in Missouri, and Gibbsite, $Al_2O_3 \cdot 3H_2O$, from the Guianas, are forms of bauxite used for refractories. Filter bauxite, or Activated bauxite, is bauxite that has been crushed, screened, and calcined, and is usually in 20 to 60 and 30 to 60 mesh grades. It may be sold under trade names such as Porocel and Florite. It is preferred to fuller's earth for oil-refinery filtering because it can be revivified indefinitely by calcining. Calcined bauxite for the abrasive industry is burned bauxite and contains 78 to 84% alumina. Laterite is a high-iron bauxite found in Oregon.

**Bearing bronze.** Any bronze used for bearing purposes, but usually referring to bronzes containing considerable lead. As an element in bearing metals lead has been called the wax of metals, forming the soft matrix or foundation for the hard crystals, but lead is not easy to keep in solution and the alloys require controlled casting. A high lead content in bronzes improves the antifriction qualities, but reduces the strength and hardness. Bronzes with about 30% of lead are called Plastic bronze. They are superior in strength to the babbitt metals, and are used for heavy mill bearings. The so-called Bearing brasses, used for railway-car journals, are not brasses, but are lead bronzes with about 65% of copper, 5 to 10 tin, and up to 30 lead. They seldom contain zinc, but the railway bearing metal called in England by the name of Bush metal contains 72% of copper, 14 tin, and 14 yellow brass ingot metal. The Journal bronze of the U.S. Navy contains 82 to 84% of copper, 12.5 to 14.5 tin, 2.5 to 4.5 zinc, and 1 lead. The A.S.T.M. bearing bronzes have from 70 to 85% of copper, 5 to 10 tin, and 5 to 25 lead, with the zinc kept below 0.50% as an undesirable element. The 85-10-5 bronze has a tensile strength of 28,000 lb. per sq. in., a compressive deformation limit of 18,000 lb. per sq. in., and a Brinell hardness of 60. The 70-5-25 bronze has a tensile strength of 15,000 lb. per sq. in., and a hardness of 40. Zinc is used, however, where higher strengths are needed, if the copper-tin is high and the zinc remains alloyed with the copper in the softer matrix. S.A.E. alloy 660, and Bunting bronze 72, used for electric motor bearings, contain 83% of copper, 7 tin, 7 lead, and 3 zinc. This alloy has a tensile strength of 34,000 lb. per sq. in., compressive limit of 22,000 lb. per sq. in., and Brinell hardness of 58.

Bearing bronzes are marketed under a variety of trade names. Ajax metal, of the Ajax Metal Co., and Johnson bronze, of the Johnson Bronze Co., are group names for bearing bronzes of various compositions. An addition of small amounts of nickel to bearing bronzes helps to keep the lead in solution and improves the resistance to compression and shock. Iron up to 1% increases the resistance to pounding and hardens the bronze, but reduces the grain size and tends to segregate the lead. Some early bearing bronzes were made with antimony instead of lead, but the binary Copper-antimony alloys are highly crystalline, and the crystalline

purple-colored material called by the alchemists Regulus of Venus was a 50-50 copper-antimony alloy. An early bearing bronze contained 16% of lead, 7 antimony, and small amounts of nickel and tin. A copper-antimony alloy used by the Hamilton Gear & Machine Co. for worm gears contains 7 to 8% of antimony, 1.5 to 2.5 nickel, and the balance copper. It casts well and has a triplex structure that makes a good bearing metal. The tensile strength, sand-cast, is 32,000 lb. per sq. in., with elongation of 7%.

**Bearing materials.** White metals and bronzes are most frequently used for machine bearings, but wood, glass, plastics, and other materials are also employed. Wood is one of the oldest of bearing materials, and is still considered an excellent material for large, low-pressure, and slow-speed bearings. The hardwoods are used, and since they absorb oil and grease little attention is required for lubrication. Lignum vitae was widely used for large marine main-shaft bearings until the introduction of molded, laminated, plastic bearings. The laminated plastic bearings with fabric base have a low coefficient of friction, and will operate with only water as the lubricant. Plastic bearings are also employed where electrical insulation is required. These materials have a compressive strength up to 36,000 lb. per sq. in. Almost any commercial metal can be used for bearings, but certain metals and alloys are particularly suited for bearings, chiefly because of the fact that a proportion of hard crystals occurs in a background, or matrix, of softer metal, thus supporting the shaft and permitting the free circulation of the lubricant. In the soft babbitt metals these crystals are formed largely by the antimony, while in the bronzes the crystals consist of a chemical compound of copper and tin.

Cast iron is an excellent bearing metal because of the hard carbides, a soft background of iron, and considerable graphitic carbon which acts as a lubricant. The stainless steels are poor bearing metals and tend to stick and seize. Brass is not much used for bearings since zinc causes sticking, but a bearing alloy known as Tissier's metal was a high-copper brass with 1% of arsenic to give a crystalline structure. The alloy marketed by the Buckeye Brass & Mfg. Co. under the name of Hy-speed for high-speed bearings, contains 88% of copper, 7 tin, and 5 zinc. In white metals the

formation of the structure is affected by the melting times, and a well-cast alloy of inferior composition may result in a better bearing than a high-grade alloy that is poorly cast.

Unlike metals are invariably used for shaft and bearing, and the wear is taken in the bearing. The choice of a bearing metal is usually a compromise of hardness, compressive strength, coefficient of friction, and degree of lubrication. In general, the tin-base alloys have low coefficients of friction and are tough and capable of withstanding shocks, but the copper bronzes are capable of withstanding heavier loads. Between the two, almost any desired combination can be obtained, depending upon the proportions of copper, tin, antimony, and lead. Some constituents of the alloys have a catalytic action on the lubricants. Tin in a bearing metal reduces the tendency of the lubricating oil to sludge, but the presence of an alkali metal may have an injurious effect on the oil. Self-lubricating bearings may be porous white metals or bronzes impregnated with oils or graphite, or they may be oil-impregnated wood.

Widely various trade names are used to designate bearing materials. Ryertex is the name of a laminated plastic bearing material, and Aqualite, of the National Vulcanized Fibre Co., is the name of laminated plastic marine bearings. Parock, of Raybestos-Manhattan, Inc., is an oilless bearing made with graphite bonded with vulcanized rubber. Nolu is an oil-impregnated wood bearing of the Nolu Oilless Bearing Co., and Woodex is an impregnated wood bearing of the Neveroil Bearing Co. These woods are normally maple, but lignum vitae may be used. Phosphor lignum, of the latter company, is a hardwood oil-impregnated bearing. The self-lubricating wood bearings are valued for textile machinery where there is danger of oil dripping on the fabrics from other types of bearings.

**Beech.** The wood of several species of beech trees, *Fagus atropunicea, F. ferruginea,* and *F. grandifolia,* common to the eastern parts of the United States and Canada. The wood is strong, compact, fine-grained, durable, and of a light color similar in appearance to maple. The weight is 47 lb. per cu. ft. It is employed for tool handles, shoe lasts, gunpowder charcoal, veneer, cooperage, pulpwood, and for small wooden articles such as clothespins. The

beech formerly used for aircraft, *F. grandifolia,* has a specific gravity, oven-dried, of 0.66, a compressive strength perpendicular to the grain of 1,670 lb. per sq. in., and a shearing strength parallel to the grain of 1,300 lb. per sq. in. The wood may be obtained in large pieces as the tree grows to a height of 100 ft. and a diameter of 4 ft. It grows from the Gulf of Mexico northward into eastern Canada. White beech refers to the light-colored heartwood. Red beech is from trees with dark-colored heartwood. The sapwood of beech is white tinged with red and is almost indistinguishable from the heartwood. The wood is noted for its uniform texture and its shock resistance.

Antarctic beech, *F. antarctica,* known locally as Rauli, grows extensively in southern Chile. It has a coarser grain than American beech, and is used for cooperage and to replace oak. European beech, *F. sylvatica,* is reddish in color, has a close, even texture, is not as heavy as American beech, but is used for tools, furniture, and small articles. New Zealand beech, known as Red beech and Tawhai, is from the very large tree *Nothofagus solandri.* The wood weighs 44 lb. per cu. ft., is brown in color, and has high strength and durability. Silver beech, of New Zealand, is *N. menziesii.* The trees grow to a height of 80 ft. and a diameter of 2 ft. The wood is light-brown, straight-grained, strong, and weighs 34 lb. per cu. ft. It is used for furniture, implements, and cooperage.

**Beef.** The edible meat from full-grown beef cattle, *Bos taurus.* The meat from the younger animals that have not eaten much grass is called Veal and is lighter in color and softer. The production of beef and beef products is one of the great industries of the world. In the industrial countries, much of the beef is prepared in organized packing plants, but also the production from city slaughterhouses is important. After slaughter and preparation of the animal, the beef is marketed in animal quarters either chilled or frozen. Fresh-killed beef from local slaughterhouses is also chilled to remove animal heat before marketing. The amount of marketable beef averages 55 to 61% of the live weight of the animal. The hide is from 5 to 7%, the edible and inedible fat and tallow is 3.5 to 7.5%, and the bones, gelatin, and glue material is 2.8 to 4.9%. The average live weight of cattle slaughtered in

American packing plants is 980 lb. From 10 to 17% of the live weight may be shrinkage and valueless materials, although the Tankage, which includes entrails and scraps, is sold as fertilizer. Offal includes tongues, hearts, brains, tripe (stomach lining), livers, tails, and head, and may be from 3 to 5.5% of the live weight. The Glands are used for the production of insulin.

Canned beef, which includes Corned beef, Canned hash (beef mixed with potatoes), and various Potted meats, is not ordinarily made from the beef of animals suitable for sale as chilled or frozen beef, but is from tough or otherwise undesirable meat animals, or from animals rejected by Government inspectors as not suitable for fresh beef. In the latter case the beef canned is held at high temperature for a sufficient length of time to destroy any bacteria likely to be in the fresh meat. Federal specifications for canned corned beef require freedom from skin, tendons, and excessive fat, and a maximum content of not more than 3.25% of salt and 0.2 saltpeter. Beef extract was first made by Prof. Justus von Liebig in 1840 as a heavy concentrated paste that could be kept indefinitely. It is now made on a large scale in both paste and cube forms, and used for soups and hot beverages. Dehydrated beef is lean beef dried by mechanical means into flake or powder forms. It is semicooked and, when wet with water, resumes its original consistency but with a somewhat cooked taste. Its advantage is the great saving in shipping space. Beef is also marketed in the form of Dried beef, usually sliced and salted. Jerked beef, or Tasajo, is beef that has been cut into strips and dried in the sun. It is widely used in some Latin-American countries, but has a strong taste.

**Beeswax.** The wax formed and deposited by the honey bee, *Apis mellifica*. The bees build combs for the reception of the honey, consisting of two sheets of horizontal, six-angled prismatic cells formed of wax. After the extraction of the honey, the wax is melted and molded into cakes. New wax is light yellow, but turns brown with age. It may be bleached with sunlight or with acids. It is composed largely of a complex long-chain ester, Myricil palmitate, $C_{15}H_{31}COOC_{30}H_{61}$, and Cerotic acid, $C_{25}H_{51}COOH$. The specific gravity is 0.965 to 0.969, and the melting point 63°C.

It is easily colored with dyes, and the Germans marketed powdered beeswax in various colors for compounding purposes. Beeswax is used for polishes, candles, leather dressings, adhesives, cosmetics, molded articles, as a protective coating for etching, and as a filler in thin metal tubes for bending. It is frequently adulterated with paraffin, stearin, or vegetable waxes, and the commercial article may be as low as 50% pure. The standards for the Toilet Goods Assoc. require that it shall contain no carnauba wax, stearic acid, paraffin, or ceresin, and shall not show more than 0.01% ash content. Beeswax is produced in many parts of the world as a by-product of honey production from both wild and domesticated bees, the honey being used as a sweetening agent or for the making of alcoholic beverages. The honey varies greatly in flavor owing to the different flowers upon which the bees feed, but the chemical properties of both the honey and the wax vary little. The honey is composed largely of fructose. West Africa produces much wax from wild bees. Abyssinia is a large producer of beeswax, where the honey is used for making Tej, an alcoholic drink. The ancient drink known as Mead was fermented honey. Scale wax is produced by removing the combs from the hives, thus forcing production of wax which is dropped in scales or particles by the bees and prevented from being picked up by a screen.

**Bell metal.** A bronze used chiefly for casting large bells. The composition is varied to give varying tones, but the physical requirements are that the castings must be uniform, compact, and fine-grained. The standard is 78% copper and 22 tin, which alloy weighs 0.312 lb. per cu. in., is yellowish red, has a fine grain, is easily fusible, and gives a clear tone. Increasing the copper slightly increases the sonorous tone. Large bells of deeper tone are made of 75% of copper and 25 tin. Big Ben, at Westminster, cast in 1856, contains 22 parts copper and 7 tin. Another bell metal, containing 77% of copper, 21 tin, and 2 antimony, is harder, giving a sharper tone. An alloy for fire-engine bells contains 20% of tin, 2 nickel, 0.1 silicon for deoxidation, and the balance copper. The nickel reduces the tendency to embrittlement from pounding. A bell metal marketed by the Lumen Bronze Co. contains 80% of copper and 20 tin, deoxidized with phosphorus. Silver bell metal, for bells

of silvery tone, is a white alloy containing 40% of copper and 60 tin. This type of alloy, with tin contents up to as high as 60%, is also used for valves and valve seats in food machinery.

**Belt dressings.** Compounds employed to soften and improve the surface of belts used to drive machinery. They are usually compounded of waxes, degras, fats, tallow, castor oil, fish oil, or corn oil, and may contain sulphonated oils or rosin. Vegetable oils, neatsfoot oil, and fish oils act as lubricants for the leather, but mineral oils dissolve and soften the leather. Rosin is used to give grip to the belt, but it makes the leather dry and fills the pores so that the belt cannot be lubricated. Belt dressings are marketed under many trade names.

**Ben oil.** A colorless to yellow oil obtained from the seeds of trees of the genus *Moringa,* notably *M. aptera, M. oleifera,* and *M. Pterygosperma,* of Arabia, Egypt, India, and the Sudan. The latter species is also grown in Jamaica. The seeds contain 25 to 34% of oil varying from a liquid to a solid, with specific gravity 0.898 to 0.902, saponification value 179 to 187, and iodine value 72 to 113. The oil is used as a food, in cosmetics, and as a lubricant for fine mechanisms.

**Bentonite.** Also known as Wilkinite. A Colloidal clay which has the property of being hydrophilic, or water swelling, some clay absorbing as much as five times its own weight of water. It is used in emulsions, adhesives, for oil-well drilling mud, to increase plasticity of ceramic clays, and as a bonding clay in foundry molding sands. In combination with alum and lime it is used in purifying water as it captures the fine particles of silt. Because of its combined abrasive and colloidal properties it is much used in soaps and washing compounds. The Wyoming type, from Wyoming and South Dakota, has a soapy feel. It is a hydrous silicate of alumina containing about 62% of $SiO_2$, 22 of $Al_2O_3$, 4 iron oxide, 4 of magnesia and calcia, and 2 of alkali metal oxides. The Mississippi type from the South differs only in physical properties. It does not swell like the Wyoming, and is much used for filtering and decolorizing oils.

**Benzene.** Also called by the German name Benzol. A colorless, highly inflammable liquid of the composition $C_6H_6$. It is an aromatic hydrocarbon product of coal tar obtained as a by-product of coke ovens or in the manufacture of gas. Its molecular structure is the closed benzene ring with six CH groups in the linkage, which forms a convenient basic chemical for the manufacture of a great variety of other chemicals. It is also an excellent solvent for waxes, resins, rubber, and other organic materials, although the fumes are toxic. It is also employed as a fuel or for blending with gasoline or other fuels. Industrially pure benzene has a distillation range from 78.1 to 82.1°C., a specific gravity of 0.875 to 0.886, and a flash point below 0°F. The pure nitration grade, used for nitrating and for the manufacture of organic chemicals, has a 1°C. boiling range starting not below 79.2°C., and a specific gravity of 0.882 to 0.886. Benzene has a characteristic odor, is soluble in alcohol but insoluble in water.

Nitrobenzene, $C_6H_5NO_2$, is a highly poisonous and inflammable liquid made by the action of nitric and sulphuric acids on benzene, used in soaps and cosmetics. It is called Myrbane oil as a perfuming agent. Benzyl alcohol, $C_6H_5CH_2OH$, is a colorless liquid soluble in water, having a boiling point of 205.2°C. and a freezing point of −15.3°C. It is also called Phenylcarbinol, and is used as a solvent for resins, lacquers, and paints. Benzyl chloride, $C_6H_5$-$CH_2Cl$, is a colorless liquid of specific gravity 1.103 and boiling point 179°C., which was used as a lachrymatory poison gas in chemical warfare, and is employed in the production of molding plastics. Benzyl cellulose is a thermoplastic molding plastic of the Imperial Chemical Industries, Ltd., produced by the action of benzyl chloride and caustic soda on cellulose. The plastic is noninflammable, resistant to acids, can be molded easily, and is produced in various grades by different degrees of benzylation. Benzyl dichloride, $C_6H_5CH \cdot Cl_2$, is a liquid heavier than benzyl chloride and has a higher boiling point, 212°C., but was also used as a war gas and disseminated as a poisonous mist.

**Beryllium.** A steel-gray, lightweight, very hard metallic element, symbol Be, formerly known as Glucinum. The specific gravity is 1.84, melting point 1285°C., and hardness 6 to 7 Moh, or

hard enough to scratch glass. The metal produced by the Goldschmidt electrolysis process is 99.5% pure, but is brittle and crystalline and can only be rolled hot. It does not corrode easily as an oxidized film protects it from further oxidation. The pure metal is expensive, but has a few uses, such as electrodes in neon signs, and for windows in X-ray tubes and atom-smashing cyclotrons as it will transmit certain short waves. Small amounts of beryllium will harden 18-carat gold to 300 Brinell. It combines with iron, and can be used for casehardening iron and steel. Its chief use is for hardening copper, producing the hard alloys known as beryllium bronze. The metal is marketed usually as a master alloy of Beryllium copper, with 12% of beryllium and 88 copper, for making alloys.

Beryllium occurs very widely distributed in many minerals, but the chief ore is the mineral Beryl, and the high-grade ore comes mostly from Brazil, Argentina, India, Australia, and South Africa. The metal is expensive to reduce. Beryl, $3\,BeO \cdot Al_2O_3 \cdot 6SiO_2 \cdot H_2O$, occurs in pale-yellow rhombic crystals in pegmatic dikes. The crystals are ¼ to ½ in. in diameter, with a specific gravity of 2.63 to 2.90, and a hardness of 7.5 to 8. The ore may contain up to 12% of beryllium oxide, but most ore averages 4% of metal. The Indian ore contains a minimum of 12%BeO, and the beryl of Ontario has 14% of BeO, or 5 metallic beryllium. The rose-pink and rose-red variety of flawless beryl crystals found in Madagascar and known as Morganite is cut into gem stones. The Emerald is a flawless beryl-colored green with chromium. Emeralds have been found at only one place in the United States, in North Carolina. Synthetic beryl is made in Europe for use as bearings in watches and instruments. Igmerald is a German synthetic emerald. The secondary ores of beryllium, Bertrandite, Herderite, and Beryllonite contain only slight quantities of the metal and are not commercial. Helvite is a complex mineral found associated with garnet in New Mexico and contains considerable beryllium. It has the composition $3\,(Be,Mn,Fe)_2SiO_4(Mn,Fe)S$, is in cubical crystals of various colors from yellow through green to dark brown, and has the appearance of garnet. The specific gravity is 3.3, and hardness 6.5.

Artificial Beryllium oxide, a colorless to white crystalline powder of the composition BeO, has a specific gravity of 3.025, and a very

high melting point, 4660°F. The oxide is known as Beryllia, and in mineralogy as Bromellite. It is used for refractories that must withstand great thermal shock. Because of its insulating value at high temperatures it is used for high-frequency insulators, and because of its great hardness it is valued as a grinding and polishing powder for hard metals. It is also used in fluorescent lamps, and in the nuclear reactions in the production of plutonium. The oxide has the property of transforming radiation of a given wave length into radiation of a longer wave length. Thin films of beryllia deposited on silver by cathodic treatment from a solution of beryllium salts are used to protect the silver from discoloration. The thin films are invisible, but heavier films give a faint iridescent coloring.

**Beryllium bronze.** Alloys of copper and beryllium containing usually not more than 3% of beryllium. They are sometimes designated as beryllium copper, although this term is more generally used to mean the master foundry alloys. The alloys are tough, hard, and have a bronzelike crystalline structure. They are noted for their fatigue resistance, and were first employed in Germany for locomotive bearings and for springs. Beryllium bronze is now employed for springs, nonsparking tools, plastic molds, and strong mechanical parts. Silicon in small amounts is added to beryllium bronze to harden and strengthen the alloy further by the formation of $Be_2Si$. Nickel and cobalt also form chemical compounds with beryllium. A small amount of nickel refines the grain and increases the ductility. It is especially useful for this purpose in castings. A very small amount of iron, 0.25%, improves the structure and increases the hardness. A cast beryllium bronze produced by Ampco Metals, Inc., has 2.5% of beryllium, and has a hardness of 325 to 375 when heat-treated. Alloys for plastic molds usually have about 2% of beryllium, and will harden to 365 Brinell. The wrought alloy called beryllium copper by the American Brass Co. has 2 to 2.5% of beryllium and 0.25 to 0.50 nickel. The soft material has a tensile strength of 70,000 lb. per sq. in., elongation 45%, and hardness 110 Brinell, while the heat-treated alloy has a tensile strength of 193,000 lb. per sq. in., elongation 2%, and hardness 365 Brinell. It is valued for springs. Beryllium copper of this kind is also used for spot-

welder contacts, and about 1.5% of titanium may be added to give hardness stability at elevated temperatures. Wrought beryllium bronze is marketed regularly in the form of rods, wire, and strip.

A Beryllium-cobalt alloy intermediate in physical characteristics between beryllium bronze and phosphor bronze contains only 0.5% of beryllium, with 2 to 3% cobalt, and the balance copper. The heat-treated alloy has a hardness of 92 to 98 Rockwell B, and an electrical conductivity 50 to 60% that of copper. A much used alloy contains 2% beryllium, 0.3 cobalt, and the balance copper. When heat treated it has a tensile strength of 170,000 lb. per sq. in., and a hardness of 37 Rockwell C.

An alloy with 2.5% of beryllium and the balance nickel hardens to 600 Brinell when heat-treated. A beryllium nickel alloy for springs has 1.9% of beryllium, 0.50 manganese, and the remainder nickel. The tensile strength, cold-rolled and heat-treated, is 200,000 lb. per sq. in., with elongation of 6%. It is noted for high torsional endurance. The fatigue-resistant properties of beryllium-copper alloys have been utilized in such uses as setting diamonds in drill bits. Vankalite is a trade name of a beryllium-copper alloy used for this purpose. Viculoy is the name of a group of beryllium bronzes of the Akron Bronze & Aluminum Co. for high-strength castings to replace aluminum bronze and manganese bronze for gears and corrosion-resistant marine parts.

**Bessemer steel.** Steel made by blowing air through molten iron. The process was developed by Henry Bessemer in England in 1860 and made possible for the first time the production of steel on a large scale. The process is also now employed as a preliminary step in the production of other steels. In the process the chemical action between the oxygen of the air and the molten mass increases the temperature, and the air then forms the chief fuel as the carbon is oxidized and driven off. The blowing requires only a few minutes, and the carbon is reduced to 0.04% or less. The carbon desired in the steel is then regulated by the addition of carbon to the melt. Plain bessemer steels have a wide usage for general purposes. The two processes known as acid and basic differ in the type of refractories employed for lining the converters, and there is a difference in the resulting steel since the acid process does not re-

move as much sulphur and phosphorus. The acid process is used principally in the United States, and the basic process is employed in Europe where the product is called Thomas steel. The lining of an acid converter is made of highly refractory acid material, usually ganister or mica schist. The converters are normally of 5 to 25 tons capacity. Acid Bessemer pig iron should contain about 1% of silicon, but the sulphur and phosphorus must be low. An acid bessemer steel to be free cutting has a content of 0.09 to 0.13% of phosphorus and 0.075 to 0.15 sulphur, but these amounts are too high for structural steels, so that bessemer steel is mostly employed in rod form for making screw machine products. A good quality acid bessemer steel contains about 0.15% of carbon, 0.40 to 0.80 manganese, and up to 0.08 each of sulphur and phosphorus. For basic bessemer steel the converter has a basic lining of burned dolomite, and the Bessemer pig iron has less silicon to avoid the production of much silica. The high-phosphorus pig irons of Europe are made into steel by this process as the basic lining aids in the elimination of the phosphorus and sulphur, although lime is also added at the beginning of the blow. During the war, Synthetic steel scrap to replace ordinary steel scrap for open-hearth steel, was made in bessemer converters by partly blowing and then casting into ingots for the furnace charge.

**Birch.** The wood of the birch trees, of which more than 15 varieties grow in the Northeastern and Lake states of the United States and in Canada, and other varieties in Europe and north Asia. The birch of north Europe is called Russian maple. The wood of the American birches has a yellow color, is tough, strong, hard, and close-textured, and polishes well. It has a fine wavy grain sometimes beautifully figured, and can be stained to imitate cherry and mahogany. Birch is used in construction work for trim and paneling, for furniture, and for turned articles such as handles, shoe pegs, clothespins, toys, and woodenware. The lumber usually includes the wood of several species. It has a specific gravity, oven-dried, of 0.68, a compressive strength perpendicular to the grain of 1,590 lb. per sq. in., and a shearing strength parallel to the grain of 1,300 lb. per sq. in. Yellow birch, *Betula lutea*, is the most abundant. It is also called Silver birch and Swamp birch. The commercial wood

includes that from the Gray birch, *B. populifolia.* Sweet birch, *B. lenta,* ranks next in importance. It is also called Black birch, Cherry birch, and Mahogany birch, and may be marketed together with yellow birch. Sweet birch may also include River birch, *B. nigra,* but sweet birch is a heavier and stronger wood. Paper birch, *B. papyrifera,* is the variety known as Canoe birch because the silvery-white flexible bark was used by the Indians in making canoes. It is also referred to as Silver birch, and is much used for pulpwood. It is similar to and mixed with White birch, *B. alba,* the wood of which is strong, elastic, and uniform, and is much used in Vermont and New Hampshire for making spools, bobbins, handles, and toys. Yellow birch of the Canadian border reaches a height of 60 to 80 ft. and a diameter up to 2 ft. A 50-year-old tree has a diameter of about 5 in. and a height of 40 ft.

**Birch oil.** A viscous, yellowish, poisonous oil with a characteristic birch odor, obtained by distillation from Birch tar, which is a product of the dry distillation of the wood of the white birch tree. Birch oil has a specific gravity of 0.956. It contains phenols, cresol, and xylenol, and is used in disinfectants and in pharmaceuticals. It is also called Birch tar oil, and in pharmacy is known as Oil of white birch. Sweet birch oil, also known as Betula oil, is a lighter volatile oil distilled from the steeped bark of the *B. lenta,* or sweet birch. It contains methyl salicylate, and is used as a flavoring agent, in perfumes, in dressing fancy leathers, in cleaning solutions and soaps, and as a disinfectant to neutralize odors of organic compounds.

**Bismuth.** An elementary metal, symbol Bi, sometimes occurring native in small quantities. American bismuth is obtained chiefly as a by-product in the refining of lead and copper. Foreign bismuth comes largely from the mineral bismuthinite. The chief production of bismuth is in the United States, Peru, Canada, Bolivia, and Mexico. The metal has a grayish-white color with a reddish tinge, is very brittle, and powders easily. It thus has few uses in its pure state. The specific gravity is 9.75, melting point 271°C., and hardness 73 Brinell. The thermal conductivity is less than any other metal except mercury, and the coefficient of expansion is 0.00000731 per deg. F. It is nonradioactive and is the most diamagnetic of all

the metals. It has the property of expanding 3.32% when changing from the liquid to the solid state, which makes it valuable in type-metal alloys and in making small castings where sharp impressions of the mold are needed. The metal imparts to lead and tin alloys hardness, sonorousness, luster, and a lowered melting point. By regulating the amount of bismuth the alloys can be cast to fill the mold without expansion or contraction on cooling. It is used in white alloys for molds for casting plastics, and because of the property of lowering of the melting point it is valued in fusible alloys and in soft solders. Very fine Bismuth wire used for thermocouples is drawn in glass tubes.

Bismuth steel, with a very small content of bismuth, is used for transformer sheets. It has increased electrical resistance without diminished electrical permeability and lowered hysteresis. About 0.5% of bismuth is used in some 18-8 stainless steels instead of selenium to add machinability without impairing the corrosion resistance. Bismuth is also used in amalgams, and is employed in the form of its salts in pigments, in pharmaceuticals as an antacid, and in many chemicals. For medicinal purposes bismuth must be completely free of traces of arsenic. About 45% of the total bismuth production is used in pharmaceuticals, and about 30% in solders and white metals. The paint pigment known as Pearl white is Bismuth oxychloride, BiOCl, a white crystalline powder of specific gravity 7.717, insoluble in water. Another bismuth pigment is Bismuth chromate, $Bi_2O_3 \cdot 2CrO_3$, a water-insoluble orange-red powder.

**Bismuthinite.** An ore of the metal bismuth, found in Bolivia, Peru, central Europe, Australia, and Western United States. It is Bismuth trisulphide, $Bi_2S_3$, containing theoretically 81.3% of bismuth. The richest Bolivian ores contain more than 25% of bismuth, and concentrates from northwest Argentina contain 40 to 48% of bismuth. The mineral has a massive foliated structure with a metallic luster, a lead-gray streaked color, and a hardness of 2. The concentrated ore is roasted and smelted with carbon, and the resulting impure bismuth is refined by an oxidizing fusion. Other bismuth ores are Bismite, or Bismuth ocher, $Bi_2O_3 \cdot 3H_2O$, containing theoretically 80.6% of bismuth, and Bismutite, $Bi_2O_3$-

$CO_3 \cdot H_2O$, containing theoretically 78.3% of bismuth, both of which are widely distributed minerals.

**Bituminous coal.** Also called Soft coal. A variety of coal with a low percentage of carbon, and easily distinguished from anthracite by the property of losing moisture and breaking up into small pieces. Because of its cheapness it is the coal used most extensively for industrial fuel, but is not preferred for household use because of its smoke and odor. However, considerable of the fine or powdered coal called Slack coal is used in making fuel briquettes. Bituminous coal is widely distributed in many countries, and is found in 28 states of the United States. The estimated American reserves are 1,400 billion tons, with a normal production exceeding 350 million tons annually. Much bituminous coal is used for the production of coke, coal tar, and chemicals. The bituminous coals vary in quality from near lignite to the hard grades near anthracite, called Semibituminous coal, depending upon their geologic age. They are not true bitumens. The specific gravity of clean bituminous coal is 1.75 to 1.80. The best steam coals are the semibituminous grades from West Virginia, Virginia, Pennsylvania, and some parts of the Middle West. The latter is very compact and is extracted in large blocks, called Block coal. Good coals for industrial use should give 13,500 to 14,500 B.t.u. per lb., have from 55 to 60% of fixed carbon, and 30 to 37 volatile matter. The best grades are in lumps. The Coking coals are the higher-carbon grades low in sulphur, and with capacity to leave the residue coke in large firm lumps.

**Blackbutt.** The wood of several species of fast-growing eucalyptus trees native to Australia but now grown in other countries and sometimes used as a substitute for oak. The trees include *Eucalyptus pilularis* and *E. patens*. The wood is gray to brown in color, is hard, close-grained, tough and durable, but is inclined to warp and crack. The weight is about 58 lb. per cu. ft.

**Blackfish oil.** A pale-yellow waxy oil extracted from the Pilot whale or Blackfish, *Globicephala melas*, found off the North Atlantic coasts as far south as New Jersey, and the *G. ventricosa* of other seas. The blackfish averages 15 to 18 ft. in length, with a

weight of about 1,000 lb. The oil has a saponification value of 290, iodine value 27, and specific gravity 0.929. The Dolphin oil, of the common dolphin, *Delphinus delphis,* of all seas, is also classed as blackfish oil, as is also the oil of the Killer whale, *Grampus orca,* of all seas. The oil is used as a lubricant for fine mechanisms, in cutting oils, and for treating leather. The product from the head and jaw is of the best quality, and is known as Jaw oil, although the best grade of sperm oil is also called jaw oil. The jaw oil from blackfish does not oxidize easily, and is free flowing at low temperatures, having a pour point of −20°F. It consists of 71% mixed acids, of which 86% is Valeric acid, $C_4H_9COOH$, and 13% oleic and palmitic acids.

**Boiler plate.** Originally, a high-grade plain iron or steel plate of $\frac{9}{64}$ in. thickness or heavier, used for making steam boilers, but the term came to mean plate of this kind for any purpose, and plates $\frac{1}{4}$ in. thick or thinner are referred to as sheet. Actually, boiler plates for boilers, tanks, and chemical equipment, and Flange plates for dished ends, are now made in various alloy steels to incorporate high strength, corrosion resistance, and creep resistance, and also in clad steels. Ordinary boiler plate is divided into firebox, flange and extra-soft. A plain steel firebox plate contains not more than 0.30% of carbon, 0.30 to 0.50 manganese, and not more than 0.40 each of sulphur and phosphorus. Flange plates contain less carbon. The tensile strength of such steels is from 55,000 to 65,000 lb. per sq. in.

**Bone black.** Also called Animal charcoal and Bone char. Charred bone ground to a fine silky powder for use as a pigment or as a decolorizing agent for sugar and oils. It has a deep, dense, bluish-black color especially valued for engraving inks of depth and tone, and also to give a dull velvety black finish to coated paper. Its covering power, however, is inferior to that of carbon black, as it has only about 10% of carbon and has a very high ash content. The best blacks may be treated with acid to remove the lime salts. Federal specifications for bone black for pigment require that 97.5% shall pass through a 325-mesh screen. For filtering, the material is used from 4 to 16 mesh. The specific gravity is 2.6 to 2.8. Bone black is made by calcining dried bones in airtight retorts

after they have been freed from fat and ground to a coarse powder. One short ton of dried bones yields about 700 lb. of bone black. About 75% of the bone black production is used for refining sugar and sirups. It may be sold under trade names such as Filt-char. Drop black is the spent bone black from the decolorizing of sugar, which has been washed and reground for pigment use. Ivory black, having the same uses as bone black, is made by heating the refuse of ivory-working in a closed retort and then grinding to a fine powder.

**Bones.** The dried bones from cattle and from Asiatic buffalo form an important item in international commerce. In general, organized packing plants do not ship much bone, but utilize it for the production of glue, gelatin, bone meal, and fertilizer. The bones shipped from packing plants are called Packer bones, but the source of much commercial bone is from slaughterhouses, local retail meat shops, and the bones from farms and fields known as Prairie bones and Camp bones, the latter name being from the Argentine word campo, meaning field. Tabulated production of commercial bone in the United States is less than 50,000 short tons annually, which is only a small part of bone available from animal slaughter, but in Europe the production of commercial bone more nearly approaches the available bone. American imported bone comes from Argentina, Canada, Cuba, Uruguay, Brazil, South Africa, and India. Selected flat shinbones are used for making buttons, knife handles, novelties, and artificial antler. Large quantities were formerly used for making brush handles, but for this use plastics are now employed.

In processing bones for buttons and handles about 90% of the bone is scrap pieces and sawdust which is made into Raw bone meal for packing steel for heat-treatment, for making gelatin, and for fertilizer. Casehardening bone, for carbonizing steel, and Bone meal, for animal feed, are processed to remove fats and prevent rancidity, and also steam-sterilized. Fertilizer bone is bone meal that is of too fine mesh for carbonizing use or for making bone black, but it is not cooked or processed, and has an analysis of about 45% ammonia and 50% phosphate of lime. Knucklebones, and also the hard shin bones, are preferred for gelatin manufacture.

Dissolved bone, used for fertilizer, is ground bone treated with sulphuric acid, or the residue bone after dissolving out the gelatin with acid. The Steamed bone meal produced as a residue by-product of the glue factories and soup factories, is suitable only for fertilizer, but it contains only 1% of ammonia. The steamed bone meal for animal feed is merely steam-sterilized raw bone.

**Borax.** A white or colorless crystalline mineral used in glass and ceramic enamel mixes, as a scouring and cleansing agent, as a flux in melting metals and in soldering, as a corrosion inhibitor in antifreeze liquids, as a constituent in fertilizers, in the production of many chemicals and pharmaceuticals, and as a source of boron. Borax is a hydrous Sodium borate, or tetraborate, first obtained from Tibet under the Persian name Borak, meaning white. Tincal is the natural borax, $Na_2O \cdot 2B_2O_3 \cdot 10H_2O$, obtained originally through Persia from Tibet, and later found in quantity in Western United States. The specific gravity is 1.75, hardness 2 to 2.5, and melting point 1125°F. It contains 47.2% of water, and is readily soluble in water. The borax from California and Nevada known as Colmanite is Calcium borate, $2CaO \cdot 3B_2O_3 \cdot 5H_2O$. That known as Kernite, or Rasorite, is another variety of Sodium borate of the composition $Na_2O \cdot 2B_2O_3 \cdot 4H_2O$. Ulexite, or Boronatrocalcite, is found in Western United States, Chile, Bolivia, and Peru, and has the composition $Na_2O \cdot 2CaO \cdot 5B_2O_3 \cdot 16H_2O$, but the ulexite of Chile and Bolivia is also mixed with sodium and calcium sulphates and sodium and magnesium chlorides. The dried mineral contains 45 to 52% of boric acid. Priceite, or Pandermite, from Asia Minor, is $5CaO \cdot 6B_2O_3 \cdot 9H_2O$. Borax is found in great quantities in the desert regions of the Western states, and in the Andean deserts of South America. The colmanite is usually associated with ulexite, shale, and clay, and is concentrated to 40% $B_2O_3$. Kernite ore from Kern County, California, contains about 29% $B_2O_3$ and is concentrated to 45%. Federal specifications for borax call for not less than 99.5% of hydrous sodium borate in three grades from large crystals to fine white powder. Pyrobar is a crystalline anhydrous borax of the American Potash & Chemical Co., produced from the brine of Searles Lake.

**Boric acid.** Also called Boracic acid and Orthoboric acid. A white, crystalline powder of the composition $B_2O_3 \cdot 3H_2O$, derived by adding hydrochloric or sulphuric acid to a solution of borax and crystallizing. It is also obtained from the boron ores of California, Chile, Bolivia, and Peru as one of a number of chemicals. It occurs naturally in volcanic fissures in Italy as the mineral Sassolite, $B_2O_3 \cdot 3H_2O$. The specific gravity is 1.435 and melting point 1050°F. It is soluble in water and in alcohol. Boric acid is used as a preservative and weak antiseptic, in glass and pottery mixes, in the tanning industry for deliming skins by forming calcium borates soluble in water, as a flux in soldering and brazing, for surface-hardening steels, and in cosmetics and pharmaceuticals.

**Borneo tallow.** A hard, brittle, yellowish-green solid fat obtained from the seed nuts of trees of the family *Dipterocarpaceae* of Borneo, Java, Sumatra, and Malaya. They include the *Shorea aptera, S. robusta, S. stenoptera, Hopea aspera,* and *Pentacme siamensis,* which trees also produce copals and valuable woods. The kernels of the nuts of the *S. stenoptera* contain 45 to 60% of fat, which is used chiefly as a substitute for cocoa butter. It contains 39% of stearic acid, 38 oleic, 21.5 palmitic, and 1.5 myristic acid. The specific gravity is 0.852 to 0.860, saponification value 185 to 200, iodine value 29 to 38, and melting point 34 to 39°C. The seeds are exported as Sarawak illipé nuts or Pontianak illipé, but they are not the same as the Illipé nuts and Illipé tallow from the species of *Bassia* of India. Illipé butter, also called Mowrah butter and Bassia butter, is from the seed nuts of the trees *B. longifolia* and *B. latifolia,* of India. The oil content of the seeds is 50 to 60%. The crude fat is yellow to green in color, but the refined product is colorless with a pleasant taste. It is used as a food, and in soaps and candles. Phulwa butter, or Indian butter, is from the seed nuts of the *B. butyracea* of India. It is white, stiffer than lard, and is used as a food. Siak tallow is from the *Palanquium oleosum* of Malaya. The fat is yellow to greenish, and is used as a substitute for cocoa butter. Jaboty fat is a similar heavy oil from the kernels of the fruit of the tree *Erisma calcaratum* of Brazil. It contains 44% palmitic acid, 28 myristic, and 4 stearic acid, and has a melt-

ing point of 40 to 46°C. The tropical forests of Brazil, Africa, and southern Asia abound in trees that produce a great variety of nuts from which useful fats and oils may be obtained.

**Borneol.** Also called Borneo camphor. A white, crystalline product with an aromatic pepperlike odor obtained from the tree *Dryobalanops camphora* of Borneo and Sumatra. It has a composition $C_{10}H_{17}OH$, a specific gravity of 1.01, sublimes at 212°C., is soluble in alcohol and slightly soluble in water. Under pressure it will melt at 208°C. Borneol is used as a substitute for camphor in cellulose plastics.

**Boron.** A metallic element, symbol B, closely resembling silicon. When pure, it is in the form of hard red crystals of specific gravity 2.45, or a brownish amorphous powder of specific gravity 1.73. At about 600°C. it ignites and burns with a brilliant green flame, but its melting point in a nonoxidizing atmosphere is about 2300°C. It is obtained by the electrolysis of fused boric oxide from the mineral borax, but it is used only in its compounds, the most widely used of which are borax and boric acid. Minute quantities of boron are used in steels for casehardening by the nitriding process to form a boron nitride, and in other steels to increase strength and hardness penetration. In these steels as little as 0.003% is beneficial, forming an iron boride, but above about 0.008% the steel becomes brittle and hot-short. Boron steels are used for crankshafts and for hot-rolled spring steels. In cast steels for hard tools as much as 1.5% of boron may be used, but these steels cannot be forged or machined. In cast iron, boron inhibits graphitization and serves as a deoxidizer. It is added to iron and steel in the form of ferroboron made by reducing boric acid in molten iron. Electromet ferroboron, of the Electro Metallurgical Co., has 18 to 25% boron and 3% max. each of silicon and aluminum. Boron compounds are employed for fluxes and deoxidizing agents in melting metals. In combination with carbon boron forms the hard abrasive boron carbide, and in combination with chromium it forms the hard diamondlike abrasive Chromium boride, CrB, marketed under the name of Colmonoy for oil-well drilling.

**Boron carbide.** A fine, black, crystalline powder of great hardness used as an abrasive or compressed into drawing dies, gages, and pestles for pharmaceutical mortars. It is made by fusing together boric acid and carbon in an electric furnace. The composition is either $B_6C$ or $B_4C$. The boron carbide of the first composition is extremely hard and crystalline, but it contains an excess of flake graphite mixed with the carbide. It can be used thus as a deoxidizing agent for casting copper, and also as a lapping abrasive since the graphite acts as a lubricant. Boroflux, of the General Electric Co., is boron carbide with flake graphite used as a flux. The boron carbide marketed by the Norton Co. under the name of Norbide is $B_4C$, and is free of graphite. It is used as a hard abrasive, and in molded form for plug and ring gages. Boron carbide molded without a binder has a compressive strength of 300,000 lb. per sq. in., and for gages gives an extremely long wear life since the hardness is above 9 Moh, or nearly equal to that of the diamond. The coefficient of expansion is 0.0000045 per deg. C., or only one-third that of steel, and it has a density of 2.52, or less than that of aluminum. The melting point is about 2450°C. Boron carbide powder for grinding and lapping comes in standard mesh sizes up to 240, and in special finer sizes up to 800. The usual grinding powders are 220 and 240, and the finishing powder is 320.

**Boxwood.** The wood of the Turkish boxwood tree *Buxus sempervirens,* native to Europe and Asia but also grown in America. It is used for rulers, instruments, engraving blocks, and inlay work. The wood is light-yellow, hard, and has a fine grain and a dense structure that does not warp easily. The weight is about 65 lb. per cu. ft. African boxwood, or Cape boxwood, comes from the tree *B. macowani,* of South Africa, and is similar to boxwood but is softer. Kamassi wood is a hard, fine-grained wood from the tree *Gonioma kamassi,* of South Africa, sometimes substituted for boxwood, but it does not have the straight grain of boxwood. It is valued for loom shuttles. Coast gray boxwood, or Gippsland boxwood, of New South Wales, is from the tree *Eucalyptus bosistoana.* It is a durable wood of uniform texture but it has an interlocking grain. The Maracaibo boxwood, or Zapatero, which comes chiefly from Venezuela, is from the tree *Casearia praecox.* It comes in

straight knotless logs 8 to 10 ft. long and 6 to 10 in. in diameter. The light-yellow wood has a fine uniform texture and straight grain. It replaces Turkish boxwood for all purposes except for wood engravings.

**Brake lining.** A term generally referring to the treated and compressed fabric materials for lining the brake bands of motor vehicles and machinery, and not including wood block linings. Brake linings may be impregnated woven fabrics, or they may be compressed fibers cemented together with a heat-resistant binder. The binder may be rubber, synthetic rubber, plastic, or a silicate. The coefficient of friction of asbestos fabric against steel is from 0.27 to 0.38, as compared with 0.16 for cast iron against steel. This coefficient may be increased still further with treated binders, or it may be reduced with interwoven wire. A typical brake lining is made by twisting asbestos yarns with fine wire strands, treating with silicate of soda solution, and then weaving into a fabric which is impregnated with rubber or other frictional binder and subjected to heat and pressure. In Germany, aluminum or steel wire of a diameter of 0.03 mm. was used as a substitute for asbestos and bonded with synthetic rubber. Brake linings are usually marketed under trade names. Raybestos, of Raybestos-Manhattan, Inc., is the trade name of brake lining and Clutch lining of various grades made of asbestos fibers and fine wire impregnated and bonded under pressure. The coefficient of friction is 0.45. Autobestos, of the Keasbey & Mattison Co., is made of chrysotile fiber molded with a binder.

**Brass.** An alloy of copper and zinc, although some brasses also contain other elements. The brasses constitute one of the most important groups of alloys because of their ease of working, corrosion resistance, and attractive appearance. They are more ductile than corresponding copper-tin alloys, or bronzes, but are not as hard and do not contain the hard crystals that make bronzes valuable as bearing metals. Zinc added to copper causes a progressive lowering of the melting point from the 1949°F. of the 95-5 brass to the 1616°F. of the 50-50 brazing metal. Ten per cent of zinc gives a bronze color; 15%, golden; from about 20 to 38% the color is yellow. When the zinc exceeds 45%, the color be-

comes silvery white, and the alloy is brittle, rapidly losing the characteristics of brass. The maximum tensile strength is reached at 55% of copper, and the maximum ductility at about 70% copper content.

Alpha brass is the form of brass having less than 36% of zinc all dissolved in the copper, and the alloy has the same structure as copper. It is easily cold-worked. Beta brass, with the zinc between 36 and 45%, contains the compound CuZn. It is the best brass for hot working. Gamma brass, with the zinc above 45%, has $Cu_2Zn_3$ crystals in the alloy, and is not easily worked either hot or cold. More than 75% of all commercial wrought brass is the alpha brass known as high brass with 65% of copper and 35 zinc, but the 70-30 alpha alloy called cartridge brass is widely used for deep drawing. The standard red brass of the mills, containing 85% of copper and 15 zinc, is much used for hot-water pipes for corrosive conditions. The 80-20 alloy known in the mills as low brass is very ductile, easily drawn, and has a fine golden-yellow color. It is much used for cheap jewelry and novelties.

Although the tensile strength of cold-worked brass is high, 85,000 lb. per sq. in. for the 60-40 muntz metal, the modulus of elasticity is much lower, proportionally, than that of steel. Brass is annealed for drawing and bending by quenching in water from a temperature of about 1000°F. Simple copper-zinc brasses are made in standard degrees of temper, or hardness. This hardness is obtained by cold rolling after the first annealing, and the degree of hardness depends upon the percentage of cold reduction. When the thickness is reduced one number of the Brown & Sharpe gage, or about 10.9% reduction, the resulting sheet is known as ¼ hard. The other grades are ½ hard, hard, extra hard, spring, and finally extra spring, which is a reduction of 10 numbers on the Brown & Sharpe gage, or about 68.7% reduction without intermediate annealing. Degrees of softness in annealed brass are measured by the grain size, and annealed brass is furnished in grain sizes from 0.010 to 0.150 mm. The A.S.T.M. standard grain sizes are: 0.015 to 0.025 mm. for light anneal, 0.035 mm. for drawing or rod anneal, 0.050 mm. for intermediate anneal, 0.70 mm. for soft anneal, and 0.120 for dead-soft anneal. Brasses with smaller grain sizes are not

as ductile as with larger grain sizes, but they have smoother surfaces and require less polishing.

Even slight additions of other elements to brass alter the characteristics drastically. Slight additions of tin change the structure, increasing the hardness, but adding to the brittleness and reducing the ductility. The so-called Naval brasses are made with some tin. Lead in small amounts improves the cutting qualities of brass, but reduces the ductility and the impact strength. The alloys known as clock brass contain lead. Iron hardens the alloy and reduces the grain size, making it more suitable for forging, but making it difficult to machine. Manganese increases the strength, increases the solubility of iron in the alloy, and promotes the stabilization of aluminum, but makes the brass extremely hard. Such alloys are called manganese bronze rather than brass. Slight additions of silicon increase the strength of brass, but large amounts promote brittleness, loss of strength, and danger of oxide inclusions. Nickel increases strength and toughness, but when any silicon is present the brass becomes extremely hard and more a bronze than a brass.

Casting brasses are usually made from brass ingot metal and are seldom plain copper-zinc alloys. The most widely used alloy is the one usually designated as composition metal, containing 85% of copper, 5 tin, 5 zinc, and 5 lead. In melting brass for casting, any overheating causes loss of zinc by vaporization, thus lowering the zinc content. Small amounts of antimony, or some arsenic, are used to overcome this dezincification. The casting brasses are roughly divided into two classes as red casting brass and yellow casting brass, which are various compositions of copper, tin, zinc, and lead to obtain the required balance of color, ease of casting, hardness, and machining qualities.

**Brass ingot metal.** Commercial ingots made in standard composition grades and employed for casting various articles designated as brass and bronze. They are seldom true brasses, but are composition metals intermediate between the brasses and the bronzes, and their selection for any given purpose is based on a balance of the requirements in color, strength, hardness, ease of casting, and machinability. Brass ingot metal is usually made from secondary metals, but, in general, the grading is now so good that they will

produce high-grade uniform castings. In producing the ingot metal there is careful sorting of the scrap metals, and the impurities are removed by remeltings. An advantage of ingot metal over virgin metals is the ease of controlling mixtures in the foundry. The A.S.T.M. designates eight grades for brass ingot metal. No. 1 grade, the highest in copper, contains 88% of copper, 6.5 zinc, 1.5 lead, and 4 tin, with only slight percentages of impurities. The No. 8 grade contains 63.5% of copper, 34 zinc, 2.5 lead, and no tin. The Red brass ingot, of H. Kramer & Co., contains 80 to 82% of copper, 3 to 4 tin, 5 to 7 lead, and the balance zinc. Yellow ingot, for plumbing fixtures, contains 65% of copper, 1 tin, 2 lead, and the balance zinc. The most widely used ingot metal is the A.S.T.M. alloy No. 2, which is the 85-5-5-5 alloy known as composition metal. Yellow brass, or Yellow casting brass, is frequently cast from A.S.T.M. ingot No. 6, which contains 72% of copper, 22 zinc, 4 lead, and 2 tin. It has a tensile strength of 20,000 to 25,000 lb. per sq. in., elongation 15 to 20%, Brinell hardness 40 to 50. It is yellow in color, and makes clean, dense castings suitable for various machine parts except bearings.

**Brazil nuts.** Also called Para chestnut. The nuts of the large tree *Bertholletia excelsa* growing wild in the Amazon Valley. The trees and nuts are called Tacarí in Brazil and Toura in French Guiana. The tree begins to bear in 8 years and yields up to 1,000 lb. of large round fruit pods containing 18 to 24 hard-shelled kernels which are the commercial nuts. The shelled kernels are several times the size of the large Virginia type of peanut, and have a pleasant nutty flavor. The kernels contain 67% of a pale yellow oil of specific gravity 0.917, saponification value 192 to 200, and iodine value 98 to 106. The oil contains 51% of oleic acid, 19 linoleic, 2 myristic, 3 stearic, and 12 palmitic. It is a valuable food oil, and is also a good soap oil, but is normally too high in price for this purpose as the nuts are more valued for eating as a nut or for confections.

**Brazilwood.** The wood of the trees *Caesalpinia brasiliensis, C. crista,* and *C. echinata,* of tropical America, and *C. sappan,* of Ceylon, India, and Malaya. The latter species is called Sappanwood. Brazilwood formerly constituted one of the most valuable exports

from Brazil to Europe as a dyewood. It produces purple shades with a chrome mordant and crimson with alum. Brazilwood extract is still valued for silk dyeing, wood staining, and for inks. The wood is prized for such articles as violins and fine furniture. It has a rich bright-red color, and takes a fine, lustrous polish.

**Brazing metal.** A common name for high-copper brass used for the casting of such articles as flanges that are to be brazed on copper pipe. Federal specifications for brazing metal call for 84 to 86% of copper and the balance zinc. Brazing brass, of the American Brass Co., has 75% of copper and 25 zinc. Some alloys also contain up to 1% of lead for ease of machining. It also makes the metal easier to cast, as the high-copper brasses are difficult to cast. A brazing brass of the U.S. Navy contains 0.3% of lead. The term brazing metal is also applied to Brazing rods of brass or bronze used for joining metals. The joining of iron or steel by brazing is essentially different from welding in that the brazing metal has a lower fusion point than iron, and the base metal is not fused. It is a type of high-temperature soldering, although there is some surface alloying between the brazing metal and the base metal. A common brazing rod is the 50-50 brass alloy with a melting point of 1616°F. The S.A.E. designates this alloy as Spelter solder. The joints made with it are inclined to be brittle. Brazing wire, of the Chase Brass & Copper Co., contains 59% of copper and 41 zinc, while the Brazing solder, for brazing high-zinc brasses, has 51% of copper and 49 zinc. The Phos-copper, of the Westinghouse Electric Corp., is a phosphor copper which gives joints with 98% the electrical conductivity of copper. It flows at 1382°F.

Brazing rods for brazing brasses and bronzes are usually of a composition similar to that of the base metal. For brazing cast iron and steel, various bronzes, naval brass, manganese bronze, or silicon bronze may be used. Brass rods may contain some silicon to lessen the vaporization by forming a film. Sifbronze, an English brazing rod, contains some ferromanganese and tin. It gives high-strength joints. Small amounts of silver added to the high-copper brazing metals give greater fluidity and better penetration into small openings. A series of brazing alloys of varied compositions to give a range of colors, hardnesses, and strengths, is marketed by the

Eutectic Welding Alloys, Inc., under the trade names Eutechrom, Eutecrod, and Bronzochrom.

**Brick.** The most ancient of all artificial building materials. Bricks in some countries are still made by baking in the sun, but commercial bricks in the United States and in Europe are all of hard-burned clay. They are used for buildings, walls, and paving, and are classified apart from the bricks of fireclays used for refractories. Brick clays are of two general classes. The first consists of noncalcareous clays or shales composed of true clay with sand, feldspar grains, and iron compounds, which when fired become buff, or salmon in color. The second class comprise calcareous clays containing up to 40% of calcium carbonate, and are called Marls. When fired, they are yellowish. Brick clays of the first type are widely distributed. Iron oxide in them varies from 2 to 10%, and the red color of common brick depends largely on this content. In practice the composition of bricks varies widely, but much of the difference is also in the burning as well as in the method of pressing. Pressed brick is a stiff mud brick made under high pressure. It is homogeneous, and has increased density and strength. Building brick made by machine of ground and tempered clay has great uniformity of strength and color. Such brick is made by pressing soft, stiff, or dry. The burning is done in kilns at temperatures from 900 to 1250°C. The calcareous clays require a temperature of 1200°C. to bring about chemical combination. The bricks are sorted according to hardness and color, both largely resulting from their position in the kiln. The hardest bricks are used for paving, and Paving brick is usually a hard-burned common brick. Floor brick is highly vitrified brick. The common hard brick for building has a crushing strength of 5,000 to 8,000 lb. per sq. in., and weighs 125 lb. per cu. ft. The common standard for building brick size is 8¼ by 4 by 2½ in.; other sizes are also used, especially 8 by 3⅞ by 2¼. Specially sized paving bricks are 8½ by 4 by 3 or 8½ by 4 by 3½ in. Sand-lime bricks for fancy walls are of sand and lime pressed in an atmosphere of steam. They are not to be confused with the sand-lime bricks used for firebrick, which are of refractory silica sand with a lime bond. Various types of ceramic

glazes and semiglazes are used on some building bricks, especially on the yellow bricks.

**Bristles.** The stiff hairs from the back of the hog, used chiefly in making brushes. The best brush bristles do not include hair from the sides of the animals, nor the product from the fat meat animals killed in the slaughterhouses. They come mostly from types of semiwild swine grown in cool climates, notably northern China and Russia. Bristles are in form similar to a tiny tube outwardly covered with microscopic scales and filled with a fatty substance. The so-called flag, or split end, gives the valuable paint-carrying characteristic for brushes. The taper of the bristle gives the brush stiffness at the base and resiliency toward the end. Quality varies according to the type of animal, climate, and feeding. The colors are white, yellow, gray, and black. They are graded by locality, color, and length, and in normal times the name of the place at which they are graded, such as Tsingtao, Hankow, and Chungking, is an indication of the grade. The best fibers are more than 3 in. in length. American bristles from Chester hogs are light in color and are of high quality. Bristles from the Duroc hog are bronze in color, are stiff, and are superior to most Chinese grades. Those from the Poland China hogs are black and stiff, but they have a crooked flag and are of poor quality. Artificial bristles of high quality are made of nylon fibers. Casein bristles are made by extruding a solution of acid casein, stretching the fiber, and hardening with quinone and formaldehyde. These fibers have good paint-carrying capacity and good wear resistance. The very short-length bristles, rejects, and scrap pieces are used for filler in molded plastics.

**Bromine.** An elementary material, symbol Br. It is a reddish-brown liquid having a specific gravity of 2.928 and boiling point of 58°C. It gives off very irritating fumes, and is highly corrosive. It belongs to the halogen group of elements, is less active than chlorine but more so than iodine. It is soluble in water. Bromine never occurs free in nature, but is obtained by electrolysis of salt solutions. It occurs in sea water to the extent of 60 to 70 parts per million, or 0.006%. A pound of bromine is obtained from 2,000 gal. of sea water. It is also produced as a by-product from the brine wells of Michigan, and from the production of chemicals at Searles Lake,

California, at which lake the bromine concentration is 12 times that of sea water. It is used in the manufacture of dyes, photographic chemicals, poison gases for chemical warfare, pharmaceuticals, ethyl fluid for gasoline, disinfectants, and in many chemicals. It is also employed in the extraction of gold.

**Bronze.** An alloy of copper and tin, but the name is now applied to many copper alloys that have the crystalline, bronzelike structure, such as silicon bronze, aluminum bronze, and manganese bronze. In the true bronzes, tin is the predominating alloying element with the copper, but some brasses are called bronzes because of their color, or because they contain some tin. Most commercial copper-tin bronzes are now modified with zinc, lead, or other elements. Bronze is essentially a casting metal, while brass is used mostly in wrought forms. Unlike zinc, the tin forms a crystalline structure valued for bearing metals. But tin does not deoxidize copper, and the tin oxide stays in the melt. Small amounts of phosphorus are used to reduce the oxide to give stronger castings. Aluminum is sometimes used as a deoxidizer, but not more than 0.25% can be added without increasing the hardness and reducing the working properties. Small amounts of zinc are added to give sharper castings free from blow holes. Small amounts of lead make the castings easier to machine, but it reduces the strength.

A copper-tin bronze is hard in proportion to the amount of $Cu_4Sn$ crystals it contains, which depends upon the amount of tin and the rate of solidification. The hard crystals are formed at high temperatures and by chilling; softer $Cu_2Sn_2$ crystals are formed at low temperatures. Bronzes containing more than 90% of copper are reddish; below 90% the color changes to orange-yellow which is the typical bronze color. The maximum strength is with 80% of copper and 20 tin. Ductility rapidly decreases with the increase of tin up to 20%, after which it practically disappears until 80% is reached, when it again increases. Above 20% of tin the alloy rapidly becomes white in color and loses the characteristics of bronze. The high-tin alloys are also subject to what is known as tin sweat. The amount of tin used in bronzes seldom reaches 20%. The Copper-tin alloy known as Cothias metal, containing 67% of copper and 33 tin, is a master alloy used for adding copper and tin

to zinc-base alloys. Bronzes have a lower thermal conductivity than brasses. The average coefficient of expansion is 0.0000098. A 90-10 bronze weighs 0.317 lb. per cu. in.; an 80-20 bronze weighs 0.315 lb. per cu. in. The 80-20 bronze melts at 1868°F., and a 95-5 bronze melts at 2480°F.

In a modified 90-10 type of bronze, the zinc is usually from 2 to 4%, and the lead up to 1%. A cast bronze of this type will have a tensile strength of about 40,000 lb. per sq. in., an elongation of 15 to 25%, and a hardness of 60 to 80 Brinell, those high in zinc being the stronger and more ductile, those high in lead being weaker. Bronzes of this type are much used for general castings and are classified as composition metal in the United States. In England they are called Engineer's bronze. An alloy designated as Hard bronze by one automotive company contains 88% of copper, 7 tin, 3 zinc, and 2 lead. It makes clean, dense castings and machines well. The tensile strength is 30,000 lb. per sq. in., and elongation 12%. An alloy designated as special hard bronze contains 88% copper, 10 tin, and 2 zinc. It is stronger and harder, and is used for gears and heavy-duty castings, but it is difficult to machine. Merco bronze, of the Merco Nordstrom Valve Co., has 88% of copper, 10 tin and 2 lead, deoxidized with phosphorus. It machines well, and has a tensile strength of 42,000 lb. per sq. in., and elongation of 17%.

Architectural bronze, or Art bronze, is formulated for color and is very high in copper. One foundry formula for art bronze of a dull-red color calls for 97% of copper, 2 tin, and 1 zinc. For ease of casting, however, they are more likely to contain lead, and a Gold bronze for architectural castings contains 89.5% of copper, 2 tin, 5.5 zinc, and 3 lead. In leaded bronze the hard copper-tin crystals aid in holding the lead in solution. These bronzes are resistant to acids and are grouped as valve bronze, or as bearing bronze because of the hard crystals in a soft matrix. Federal specifications for bronze give 10 grades in a wide variation in tin, zinc, and lead. The A.S.T.M. designates five grades of bronze casting alloys. Alloy No. 1 contains 85% of copper, 10 tin, and 5 lead; Alloy No. 5 contains 70% of copper, 5 tin, and 25 lead. The British Coinage copper is a bronze containing 95.5% of copper, 3 tin, and 1.5 zinc.

**Bronze powder.** Pulverized or powdered bronze or brass made in flake form by stamping from sheet metal. It is used chiefly as a paint pigment and as a dusting powder for printing. In making the powder the sheets are worked into a thin foil which becomes harder under the working and breaks into small flakes. Lubricant keeps the flakes from sticking to each other. Usually stearic acid is used, but in the dusting powder hot water or nonsticky lacquers are used. The powder is graded in standard screens, and is then polished in revolving drums with a lubricant. This gives it the property of leafing, or forming a metallic film in the paint vehicle. The leaf is also called Composition leaf, or Dutch metal leaf, when used as a substitute for gold leaf. Flitters are made by reducing thin sheets to flakes, and are not as fine as bronze powder.

The compositions of bronze powder vary, and seven alloys form the chief commercial color grades from the reddest, called pale gold, which has 95% of copper and 5 zinc, to the rich gold which has 70% of copper and 30 zinc. Colors are also produced by heating to give oxides of deep red, crimson, or green-blue. The powder may also be dyed in colors, using tannic acid as a mordant, or treated with acetic acid or copper acetate to produce antique finish. The color or tone of bronze powders may also be adjusted in paints by adding a proportion of mica powder. A white bronze powder is made from aluminum bronze, or the silvery colors are obtained with aluminum powder. The bronze powder of 400 mesh used for inks is designated as extra fine. The fine grade, for stencil work, is 325 mesh. Medium fine, for coated paper, has 85% of the particles passing through a 325-mesh screen and 15% retained on the screen. Near mesh, for paint pigment, has 30% passing through a 325-mesh screen. A 400-mesh powder has 500 million particles per gram. The old name for bronze powder is Gilding powder. It is also called Gold powder when used in cheap gold-colored paints, but bronze powders cannot replace gold for use in atmospheres containing sulphur, or for printing on leather where tannic acid would corrode the metal.

**Broomcorn.** A plant of the sorghum family, *Holcus sorghum*, grown in the Southwest, in Illinois and Kansas, and in Argentina and Hungary. It is used for making brushes and brooms, and for

the stems of artificial flowers. The jointed stems of the dwarf variety grown in the semiarid regions are 12 to 24 in. long, but the standard brush corn is up to 30 in. long. The fibers are yellow in color and, when dry, are coarse and hard. They are easily cleaned and readily dyed. As a brush material they have the objection that they break easily, and are therefore unsuited for mechanical brushes for hard service. Broom root, or Rice root, is similar to broomcorn, and is suitable for mixing with it or for coarse brushes. It is from a type of grass, *Epicampes macroura,* of Mexico and Guatemala. The fiber is obtained from the shredded roots.

**Brush fibers.** Industrial brushes are made from a wide variety of fibers, varying from the fine and soft camel's hair to the hard, coarse, and brittle broomcorn. Bristles from the hog form one of the most common, but tampico and piassava fibers are important for polishing brushes. The Vegetable fibers used for brushes are tough and stiff as compared with the finer flexible and cohesive fibers used for twine and for fabrics. They may, however, come from the same plant, or even from the same leaf, as the textile fibers, but be graded out for stiffness. Palmetto fiber, for stiff floor sweeps, is from the cabbage palm tree of Florida. Arenga fiber is a stiff, strong fiber from the leaves of the palm tree *Arenga saccharifera* of the East Indies. The finest grades resemble horsehair. Kittool is a similar strong, elastic fiber from the large leaves of the palm tree, *Caryota urens,* of India and Ceylon. It is very resistant, and is valued for machine brushes. Gomuti fiber and Chinese coir are fibers from other species of this palm. Bass, or Raphia, is a coarse fiber used for hard brushes and brooms. The heavier piassava fibers are also known as bass, but bass is from the leaves of the palm tree, *Raphia vinifera,* of West Africa. Crin is from the leaves of a palm tree of Algeria, although the word crin originally referred to horsehair. Crin vegetal, or Vegetable crin, is fiber from the leaf of the Yatay palm, *Diplothemium littorale,* of Corrientes Province, Argentina. Horsehair, from the manes and tails of horses, is used for brushes.

Vegetable and animal fibers are not resistant to alkalies or acids and cannot be wetted with them. The artificial fibers of plastics such as nylon are resistant to many chemicals. For hard-service

mechanical brushes, and for resistance to strong chemicals, brush fibers are of steel, brass, or aluminum wire. Brush wire for rotary-power brushes for metal brushing is soft to hard-drawn steel wire usually 0.005 in. in diameter, but finer wire is used to give a soft brush. Brush wire used by the Osborn Mfg. Co. for soft rotary brushes is a soft steel wire 0.0025 in. in diameter with 242,144 wires in a 1½ in. diameter brush 2 in. long.

**Buckram.** A coarse, plain-woven open fabric similar to cheesecloth, but heavily sized with gums or water-resistant stiffening material. It is usually of cotton, but may be of linen. It may be white or in plain colors, and is employed as a stiffening material, for bookbindings, shoe inner soles, and interlinings for leather goods.

**Buffing compositions.** Materials used for buffing or polishing metals, consisting usually of dolomitic lime with from 18 to 25% of saponifiable grease as a bond. The lime acts as the abrasive, and in some compositions is partly replaced by other abrasives such as emery flour, tripoli, pumice, silica, or rouge. Harsher abrasives are used in the compositions employed for the cutting-down, or buffing, operations. Abrasive grains are selected for combinations of hardness, toughness, and sharpness, from the soft iron oxide to the hard and sharp aluminum oxide. Buffing compositions are usually sold under trade names for definite uses rather than by composition. Metal polishes for hand use are now usually liquids. The pastes, formerly known as Putz cream and Brass polish, contained tripoli or pumice with oxalic acid and paraffin. The liquid polishes now generally contain finer abrasives such as pumicite or diatomite, in a soap detergent, together with a solvent such as naphtha, and sometimes pine oil or an alkali.

**Building sand.** Selected sand used for concrete, for mortar for laying bricks, and for plastering. Early specifications called for sand grains to be sharp, but rounded grains are now preferred because of fewer voids in the mixture. Building sand is normally taken from deposits within a reasonable haul of the site of building, and is not usually specified by analysis, but should be a hard silica sand that will not dissolve. Pure white sand for finish plaster is made by grinding limestone. Building sand is required to be

clean, with not more than 3% of clay, loam, or organic matter. A.S.T.M. requirements are that all grains must pass through a ⅜-in. sieve, 85% through a No. 4 sieve, and not more than 30% through a No. 50 sieve. For brick mortar all of the sand should pass through a ¼-in. sieve. For plaster, not more than 6% should pass through a No. 8 sieve. Flooring sand for mastic flooring is a clean sand passing through a No. 3 sieve, with 7% passing through a No. 100 sieve. Roofing sand is a fine white silica sand. Paving sand is divided into three general classes: that for concrete pavements, that for asphaltic pavements, and that for grouting.

The U.S. Bureau of Public Roads requires that sand for concrete pavements should all pass through a ¼-in. sieve, 5 to 25% should be retained on a No. 10 sieve, from 50 to 90% on a No. 50 sieve, and not more than 10% should pass through a No. 100 sieve. Not more than 3% of the weight should be matter removable by elutriation. For asphaltic pavements small amounts of organic matter are not objectionable in the sand. All should pass through a ¼-in. sieve, 95 to 100% through a No. 10 sieve, and not more than 5% through a No. 200 sieve. Grouting sand should all pass through a No. 20 sieve, and not more than 5% through a No. 200 sieve. Chat sand, used for concrete pavements, is a by-product of zinc and lead mines. It is screened through a ⅜-in. sieve.

**Building stone.** Any stone used for building construction may be classed as building stone, but the stones, in order of importance, used in the United States for building are limestone, granite, sandstone, basalt, and marble. Granite and limestone are among the most ancient of building materials and are extremely durable. Two million limestone and granite blocks, totaling nearly 8 million long tons, were used in the pyramid of Ghizeh built about 2980 B.C., the granite being used for casing. Availability, or a near supply, may determine the stone used in ordinary building, but for public buildings stone is transported long distances. Some sandstones, such as the red sandstone of the Connecticut Valley, weather badly, and are likely to scale off with penetration of moisture and frost. Granite will take heavy pressures and is used for foundation tiers and columns. Limestones and well-cemented sandstones are employed extensively above the foundations. Nearly half of all the

limestone used in the United States in block form is Indiana limestone. Marble has a low crushing strength and is usually an architectural or facing stone.

Crushed stone is used for making concrete, for railway ballast, and for road making. The commercial stone is quarried, crushed, and graded. Much of the crushed stone used is granite, limestone, and Trap rock. The latter is a term used to designate basalt, gabbro, diorite, and other dark-colored fine-grained igneous rocks. Graded crushed stone usually consists of only one kind of rock and is broken with sharp edges. The sizes are from ¼ to 2½ in., although larger sizes may be used for massive concrete aggregate. Screenings below ¼ in. are employed largely for paving. Granite granules for making hard terrazzo floors are marketed in several sizes, and in pink, green, and other selected colors. Roofing granules are graded particles of crushed rock, slate, slag, porcelain, or tile, used as surfacing on asphalt roofing and shingles. Granules have practically superseded gravel for this purpose. Ceramic granules are produced from clay or shale fired and glazed with metallic salts. They are preferred because the color is uniform. Slate granules are used for surfacing prepared roofing.

**Bunting.** A lightweight worsted fabric, plain-woven, and dyed in solid colors. It is employed mostly for making flags, for box lining, and other industrial uses. It wears well, and does not fade easily. Cotton bunting is a thin, soft, flimsy fabric of closer weave than cheesecloth. It is dyed in solid colors, or printed, and usually fades easily. It is used for cheap flags, decorations, and industrial linings and coverings.

**Burlap.** A coarse, heavy cloth made of plain-woven jute, or jutelike fibers, and used for wrapping and bagging bulky articles, for upholstery linings, and as a backing fabric for linoleum. Finer grades are also used for wall coverings. The standard burlap from India is largely from jute fibers, but some hibiscus fibers are used. For bags and wrappings, the weave is coarse and irregular, and the color is the natural tan. The coarse grades such as those used for wrapping cotton bales are sometimes called gunny in the United States, but Gunny is a general name for all burlap in Great Britain. Dundee, Scotland, is the important center of burlap manufacture

outside of India, but considerable quantities are made from native fibers in Brazil and other countries. Burlap is woven in widths up to 144 in., but 36, 40, and 50 in. are the usual widths. Hessian is the name of a 9½-oz. plain-woven finer burlap made to replace an older fabric of the same name woven from coarse and heavy flax fibers. When dyed in colors it is used for linings, wall coverings, and upholstery. Brattice cloth is a very coarse, heavy, and tightly woven jute cloth, usually 20 oz. per sq. yd., used for gas breaks in coal mines, but a heavy cotton duck substituted for the same purpose is called by the same name. Most burlap for commercial bags is 8, 9, 10, and 12 oz., feed bags being 8 oz. and grain bags 10 oz.

**Butadiene.** Also called Bivinyl and Erythrene. A colorless gas of the composition $CH_2:CH\cdot CH:CH_2$ used in the production of synthetic rubber by polymerization with styrene or acrylonitrile. It unites easily with many reagents and is thus also a starting point for the production of many other compounds. In contact with air or oxygen it forms peroxides that are explosive, and is therefore safeguarded with inhibitors when shipped. Butadiene has a boiling point of $-3°C.$, and a specific gravity of 0.6272. Commercial butadiene is at least 98% pure, with normal butane and butenes as the impurities. It contains 0.01% of phenyl beta naphthylamine or other oxidation inhibitor. It is easily produced by the dehydrogenation of butane from natural gas or petroleum.

**Butter.** An edible fat made from cow's milk by curdling with bacterial cultures and churning. The production of butter is one of the large industries of the western nations, with an annual production exceeding 10 billion pounds, 30% of which is made in the United States. Other important producers are Germany, Holland, the Scandinavian countries, Australia, New Zealand, Canada, Ireland, and Argentina. More than 80% of the butter produced in the United States is made in factories as Creamery butter subject to Federal inspection, as distinct from Farm butter not subject to the regulations of interstate trade. Creamery butter is an important raw material in the bakery and confectionery industries. Federal regulations require that creamery butter shall be made exclusively from milk or cream, with or without salt and coloring matter, and shall contain not less than 80% by weight of milk fat, not over 15%

moisture, and not over 2.5% salt. Butter varies greatly in color and flavor from the feed of the animal, the processing, and the storage. The natural color is whitish in winter and yellow in summer when the animal feeds on green pasturage. Commercial butter is usually brought to a uniform yellow by coloring with annatto. Musty, garlicky, and fishy flavors may be caused by noxious weeds eaten by the animal; cheesy or yeasty flavors may be from stale cream; metallic, greasy, scorched, or alkaline flavors may be from improper processing. Almost all American butter is salted. Argentine butter is usually unsalted.

United States grades for creamery butter range from 93 score for the best butter of fine flavor and body down to 85 score for the lowest grade having pronounced obnoxious weed flavor and defects in body, color, or salt. The grading, or scoring, of butter is done by experts. The flavor is determined by the senses of taste and smell. The flavor, body, color, and salt are rated independently, and points, or scores, are subtracted for defects. The body and texture of the butter are determined by the character of the granules and their closeness. The most common body defects are gumminess, sponginess, crumbliness, and stickiness. The most common defect in color is lack of uniformity with waves or mottles. Defects in salting are excessive salt and undissolved salt grains. Butter held in storage at improper temperatures is likely to develop rancid or unpleasant flavors and acidity due to chemical changes, or it may absorb flavors from surrounding products. High-grade butter can be held in well-regulated cold storage for long periods without appreciable deterioration.

An important substitute for butter is Margarine, sometimes called by the name of an older product, Oleomargarine, now no longer manufactured. Margarine is made from a mixture of about 80% of vegetable oils and 20 milk in the same manner as butter. It has a slightly lower melting point than butter, 22 to 27°C., and is somewhat more greasy. The margarine of lower melting points is used in the bakery industry, and the grades with higher melting points are for table use. From 2.5 to 4% of salt is used, together with vitamins A and D, lecithin, annatto coloring, and sometimes phosphatides to prevent spattering when used for frying. Biacetyl, $C_4H_6O_2$, a colorless, pungent sweet liquid which gives the character-

istic flavor to butter is also added. The food value is in general higher than that of butter, but because of the competition with butter various Federal and state regulations and taxes restrict its use. Soya butter is made from emulsified soybean and, when fortified with butyric acid, the characteristic acid of butter, is practically indistinguishable from butter. It is, however, subject to restrictive regulations and taxes. Ghee butter, used in India, is made from buffalo milk, sometimes mixed with cow's milk. It is clarified by melting the butter over a slow fire and separating off the opaque white portion.

**Butyl alcohol.** A colorless liquid used as a solvent for paints and varnishes, and in the manufacture of dyes, plastics, and many chemicals. There are four forms of this alcohol, but the normal, or primary, butyl alcohol is the most important. Normal butyl alcohol, $CH_3(CH_2)_2CH_2 \cdot OH$, has a specific gravity of 0.814, and boiling point of 117°C.

**Cadmium.** A silvery-white crystalline metal, symbol Cd. It has a specific gravity of 8.6, is very ductile, and can be rolled or beaten into thin sheets. It resembles tin and gives the same characteristic cry when bent, but is harder than tin. A small addition of zinc makes it very brittle. It melts at 608°F., and boils at 1580°F. Cadmium is employed as an alloying element in soft solders and in fusible alloys, for hardening copper, as a white corrosion-resistant plating metal, and in its compounds for pigments and chemicals. The metal is marketed in small round sticks 12 in. long, and in variously shaped anodes for electroplating. Electrolytic cadmium is 99.95% pure. It is obtained chiefly as a by-product of the zinc industry by treating the flue dust and fumes from the roasting of the ores. Flue dust imported from Mexico averages 0.66 ton of cadmium per ton of dust. About half the world production is in the United States. Other important producers are Germany, Belgium, Canada, and Poland. The only commercial ore of the metal is Greenockite, CdS, which contains theoretically 77.7% of cadmium. This mineral occurs in yellow powdery form in the zinc ores of Missouri.

More than 85% of the consumption of cadmium is for electroplating. For a corrosion-resistant coating for iron or steel a cad-

mium plate of 0.0003 in. is equal in effect to a zinc coat of 0.001 in. The plated metal has a silvery-white color with a bluish tinge, and is harder than tin. Cadalyte is a trade name of E. I. duPont de Nemours & Co., Inc., for a cadmium salt and process for cadmium plating, and Udylite is the name of a salt and process of the Udylite Corp. Small amounts of cadmium added to copper give the copper higher strength, hardness, and wear resistance, but decreases the electrical conductivity. Copper containing 0.5 to 1.2% of cadmium is called Cadmium copper or Cadmium bronze. Hitenso is a cadmium bronze of the American Brass Co. used for overhead trolley wires. It has 35% greater strength than hard-drawn copper, and 85% the conductivity of copper. The cadmium bronze known in England as Conductivity bronze, used for electric wires, contains 0.8% of cadmium and 0.6 tin. The tensile strength, hard-drawn, is 85,000 lb. per sq. in., and the electrical conductivity is 50% that of copper.

**Caffeine.** An alkaloid which is a white powder when it has the composition $C_8H_{10}N_4O_2$, and occurs in crystalline flakes when it has one molecule of water of crystallization. The melting point is 235°C. It is soluble in water and in alcohol. Caffeine increases muscular contraction and stimulates to lessen fatigue, but in large amounts is highly toxic. Its prime use is in medicine, but most of the production is used in soft drinks. It is obtained from coffee, tea waste, kola nuts, or guarana by solvent extraction, or as a by-product in the manufacture of such noncaffeine coffees as Sanka, or in the processing of coffee for the production of oil and cellulose. Less than 1% of caffeine is obtained from coffee, about 2 from Tea waste, and 1.5 from kola nuts. Cocoa waste contains Theobromine, from which 0.2 to 0.5% of caffeine is derived. Theobromine is a more powerful stimulant than caffeine. Guarana contains the highest percentage of caffeine of all the beverage plants, about 3%. It comes from the seeds of the woody climbing plant *Paullinia cupana,* of the Amazon Valley. It is used by the Indians by grinding the seeds with water and mandioca flour and drying the molded paste with smoke. For use it is grated into hot water. The Kola nuts are the seeds of the fruit of the large spreading tree *Kola acuminata* native to West Africa and cultivated also in tropical America,

and the *K. nitida* of West Africa. The nuts of the latter tree contain the higher percentages of theobromine and caffeine. The white nuts are preferred to the pink or red varieties. Citrated caffeine, used in pharmaceuticals, is a white powder produced by the action of citric acid on caffeine, and contains about equal quantities by weight of anhydrous caffeine and citric acid. It is very soluble in water.

**Cajeput oil.** A greenish essential oil distilled from the leaves of the tree *Melaleuca leucadendron* growing chiefly in the East Indies. It contains the cineole of eucalyptus oil and also the Terpinol which is characteristic of the lilac. It has a camphorlike odor. It is used in medicine as an antiseptic and counterirritant, and in perfumes. Naouli oil is a similar oil from the leaves of the tree *M. viridi* of New Caledonia. Cajeput bark, from the same tree, is used as an insulating material in place of cork. The bark is up to 2 in. in thickness, is soft, light, resistant, and a good insulator.

**Calcite.** One of the most common and widely diffused minerals, occurring in the form of limestones, marbles, chalks, calcareous marls, and calcareous sandstones. It is a calcium carbonate, $CaCO_3$, and the natural color is white or colorless, but it may be tinted to almost any shade with impurities. The specific gravity is about 2.72 and hardness 3. Iceland spar, or Calc spar, are names for the perfectly crystallized, water-clear, flawless calcite crystals of optical grade used for the manufacture of Nicol prisms for polarizing microscopes, photometers, calorimeters, and polariscopes. It comes from Iceland, Spain, South Africa, and New Mexico, and some crystals have been found as large as 17 lb.

**Calcium.** A metallic element, symbol Ca, belonging to the group of alkaline earths. It is one of the most abundant materials, occurring in combination in limestones and calcareous clays. The metal is obtained 98.6% pure by electrolysis of the fused anhydrous chloride. By further subliming it is obtained 99.5% pure. Calcium metal is yellowish white in color. It oxidizes easily, and when heated in the air burns with a brilliant white light. The specific gravity is 1.55, melting point 810°C., and boiling point 1440°C. Its strong affinity for oxygen and sulphur is utilized as a cleanser

for nonferrous alloys. As a deoxidizer and desulphurizer it is employed in the form of lumps or sticks of calcium metal or in ferro-alloys and calcium-copper. Natural calcium compounds, such as dolomite, are used directly as a flux in melting iron. Calcium is also used to harden lead, and calcium silicide is used in making some special steels to inhibit carbide formation.

Many compounds of calcium are employed industrially, in fertilizers, foodstuffs, and medicine. It is an essential element in the formation of bones, teeth, shells, and plants. Edible calcium, for adding calcium to food products, is Calcium lactate, a white powder of the composition $Ca(C_3H_5O_3)_2 \cdot 5H_2O$, derived from milk. Calcium phosphate, used in the foodstuffs industry and in medicine, is marketed in several forms. Calcium diphosphate, known as Phosphate of lime, is $CaHPO_4 \cdot 2H_2O$, or in anhydrous form. It is soluble in dilute citric acid solutions, and is used to add calcium and phosphorus to foods, and as a polishing agent in tooth pastes. Calcium monophosphate is a stable, white, water-soluble powder, $CaH_4P_2O_8 \cdot H_2O$, used in baking as a leavening agent. Calcium triphosphate, $Ca_3(PO_4)_2$, is a white water-insoluble powder used to supply calcium and phosphorus to foods, as a polishing agent in dentifrices, and as an antacid. Calcium sulphite, $CaSO_3 \cdot 2H_2O$, is a white powder used in bleaching paper pulp and textiles, and as a disinfectant. It is only slightly soluble in water, but it loses its water of crystallization and melts at 100°C. Calcium silicate, $CaO \cdot SiO_2$, is a white powder used as a reinforcing agent in rubber. Silene EF, of the Columbia Chemical Div., is a precipitated calcium silicate for rubber.

**Calcium carbide.** A hard, crystalline substance of grayish-black color, used chiefly for the production of acetylene gas for welding torches and for lighting. It was discovered in 1892 and was widely employed for theater stage lighting and for early automobile headlights. It is made by reducing lime with coke in the electric furnace. It can also be made by heating crushed limestone to a temperature of about 1000°C., flowing a high-methane natural gas through it, and then heating to 1700°C. The composition is $CaC_2$, and specific gravity 2.26. It contains theoretically 37.5% of carbon. When water is added to calcium carbide, acetylene gas

is formed, leaving a residue of slaked lime. Pure carbide will yield 5.83 cu. ft. of acetylene per pound of carbide, but the commercial product is usually only 85% pure. Federal specifications require not less than 4.5 cu. ft. of gas per pound. Calcium carbide is marketed in four size grades from the lump, which is 3½ to 2 in., to the quarter, which is of a fineness below ¼ in.

**Calcium chloride.** A white, crystalline, lumpy or flaky material of the composition $CaCl_2$. The specific gravity is 2.512, melting point 722°C., and it is highly hygroscopic and deliquescent with rapid solubility in water. The commercial product contains 75 to 80% of $CaCl_2$, with the balance chiefly water of crystallization. Some is marketed in anhydrous form for dehydrating gases. It is also sold in water solution containing 40% calcium chloride. An important use for calcium chloride is for spreading on gravel or macadam roads to aid in surfacing and absorb dust, and to prevent cracking from freezing. It is also used for accelerating the setting of concrete and to prevent concrete mixtures from freezing in cold weather. More than 4% in concrete decreases the strength of the concrete. It is also employed as an antifreeze in fire tanks. Other uses are as a food preservative and in textile and paper sizes as a gelling agent. Calcium chloride is obtained from natural salt brines, or as a by-product in the Solvay process. Temperite, of the Truscon Laboratories, is calcium chloride for concrete.

**Calcium molybdate.** A salt of molybdenum, $CaMoO_4$, used in place of ferromolybdenum for adding molybdenum to steel. It is made by roasting molybdenite and adding lime. It contains about 60.7% of $MoO_3$ with the balance lime, and is sold on the basis of the molybdenum content. The specific gravity is 4.35. The calcium molybdate and flux mixture marketed by the Molybdenum Corp. under the name of Molyte is heavier and sinks in the molten steel.

**Calcium-silicon.** An alloy of calcium and silicon used as a deoxidizing agent, and for the elimination of sulphur in the production of steels and cast irons. It is marketed as low-iron, containing 22 to 28% of calcium, 65 to 70 silicon, and 5 max. iron, and as high-iron, containing 18 to 22% of calcium, 58 to 60 silicon, and

15 to 20 iron. It comes in crushed form and is added to the molten steel. At the temperature of molten steel all of the calcium passes off and leaves no calcium residue in the steel. Calcium-manganese-silicon is another master alloy containing 17 to 19% of calcium, 8 to 10 manganese, 55 to 60 silicon, and 10 iron.

**Cambric.** Originally, a fine, thin, hard-woven linen, but now usually a plain-woven strong cotton fabric of fine weave and hard-twist yarn. It is the standard material for making Varnished cambric and Varnished cloth for electrical insulation and cable winding. The coatings may be of insulating varnish or of synthetic resins. It comes in 36-in. widths in rolls or as tape, usually black or yellow. The thickness, including the varnish, ranges from 0.005 to 0.015 in., and the dielectric strength varies from 1,000 to 1,300 volts per mil. It has higher strength than the older Varnished silk which has become obsolete. For still higher strengths nylon may be substituted for the cambric.

**Camel's hair.** The fine woolly hair from the neck and back of the camel, employed industrially for fine brushes for painting. Most of the fiber is produced in Arabia and Persia, and the bulk of it is consumed locally for weaving into shawls, rugs, and fabrics. The natural color is light brown, and the finer grades of underhair are soft and silky. The fine body hairs are about 1 in. long and downy, but the beard hairs are coarse, strong, and tough. Beard hairs are up to 4 in. long, and are the ones most used for brushes. The color of these is a natural tan, with some white hair which is not preferred. The best hair is from the Bactrian animals.

**Camphor.** The white resin of the *Cinnamomum camphora,* an evergreen tree with laurel-like leaves, and reaching a height of 100 ft. The tree occurs naturally in China and southern Japan, and is also grown in Florida. Formosa is the center of the industry. Camphor, $C_{10}H_{16}O$, has a specific gravity of 0.986 to 0.996, and melts at 175°C. It is soluble in water and in alcohol. Much of the camphor is used for hardening nitrocellulose plastics, but it is also used in pharmaceuticals, in disinfectants, and in explosives and chemicals. It is contained in all parts of the tree, but is obtained almost entirely from the trunks, roots, and large branches by

steam distillation. From 20 to 40 lb. of chips produce 1 lb. of camphor. The crude camphor is pressed to obtain the Flowers of camphor and Camphor oil. The crude red camphor oil is fractionated into white and brown oils, the first of which is used in soaps, polishes, varnishes, cleaners, and pharmaceuticals. The brown oil is used in perfumery. The white camphor oil is a colorless liquid with a camphor odor, a specific gravity of 0.870 to 1.040, and soluble in ether or chloroform. Camphor oil may also be distilled from the twigs.

Artificial camphor is Bornyl chloride, $C_{10}H_{17}Cl$, a derivative of the pinene turpentine. It has a camphor odor, has the same industrial uses as camphor, but is optically inactive and is not used in pharmaceuticals. Synthetic camphor, made from turpentine, in refined form is equal to the natural product for medicinal use, and the technical grade is used in plastics. The camphor substitute Lindol, of the Celanese Chemical Corp., is Tricresyl phosphate, or Tolyl phosphate, $(CH_3C_6H_4)_3PO_4$, a colorless, odorless, viscous liquid which solidifies at $-20°C.$, or a solid that melts at $77°C.$ Like camphor, it hardens cellulose nitrate and makes it noninflammable. Dehydranone, of the Carbide & Carbon Chemicals Corp., is Dehydracetic acid, $C_8H_8O_4$, a white odorless solid with some of the properties of camphor, used in nitrocellulose and vinyl resins. Cyclohexyl levulinate, $CH_3CO(CH_2)_2COOC_6H_{11}$, is also used as a substitute for camphor in nitrocellulose, and also in vinyl resins and in chlorinated rubber. It is a liquid of specific gravity 1.025, boiling point $265°C.$, and freezing point $-70°C.$

**Camwood.** The wood of the tree *Baphia nitida,* native to West Africa, used for tool handles and for machine bearings. It will withstand heavy bearing pressures. The wood is exceedingly hard, has a coarse, dense grain, and weighs 65 lb. per cu. ft. It contains a red coloring matter known as Santalin, and was once valued as a dyewood for textiles. Barwood, from the tree *Pterocarpus santalinus,* of West Africa, is a similar reddish hardwood containing the same dye and used for the same purposes.

**Canada balsam.** Also called Canada turpentine. A yellowish, viscous oleoresin liquid of pleasant odor and bitter taste, obtained from the buds of the balsam fir *Abies balsamea* of the North-

eastern states and Canada. The specific gravity is 0.983 to 0.997. It is a class of turpentine, and is used as a solvent in paints and polishes, in leather dressings, adhesives, and perfumes. It is also referred to as Balm of Gilead for medicinal and perfumery use, but the original balm of Gilead, marketed as buds, was from the small evergreen tree *Balsamodendron gileadense* of the Near East.

**Canaigre.** A tanning material extracted from the roots of the low-growing plant *Rumex hymenosepalus* of northern Mexico and the arid Southwest of the United States. The plant is known locally as Sour dock, and the roots contain up to 50% of tannin. Canaigre extract contains 30% tannin. It produces a firm, orange-colored leather. Canaigre was the tanning agent of the Aztec Indians of Mexico. It is now cultivated.

**Canary seed.** The seeds of the Canary grass, *Phalaris canariensis,* native to the Canary Islands, but now grown on a large scale in Argentina for export, and in Turkey and Morocco for human food and for export. In international trade it is known by the Spanish name Alpiste. It is valued as a bird food because it contains phosphates, iron, and other minerals, and is rich in carbohydrates. It is, however, low in proteins and fats, and is usually employed in mixtures. Birdseed is an extensive item of commerce, but the birdseed that reaches the market in the United States is usually a blend of canary seed and millet, with other seeds to give a balanced food. Canary seed is small, pale-yellow in color, and convex on both sides. The term Spanish canary seed is applied to the choice seed regardless of origin. Niger seed, also valued as a birdseed, is from the plant *Guizotia abyssinica,* of the thistle, or *Compositea* family, grown in India, Africa, Argentina, and Europe. It is also known as Inga seed, Rantil, Kala til seed, and Black sesame. It is also called Gingelli in India, although this name and Til are more properly applied to sesame. The seed is high in proteins and fats.

**Candelilla wax.** A yellowish amorphous wax obtained by hot water or solvent extraction from the stems of the shrubs *Pedilanthus pavonis* and *Euphorbia antisyphilitica* growing in the semiarid regions of Texas and Mexico. The plants grow to a height of 3 to 5 ft. and consist of a bundle of stalks without leaves. The stems

yield 3.5 to 5% of a wax that consists of long-chain hydrocarbons with small amounts of esters. The wax has a specific gravity of 0.983, melting point 67 to 70°C., iodine value 37, and saponification value 45 to 65. The refined grade is purified by remelting, and contains not more than about 1% of water. It is soluble in turpentine, and is used for varnishes, polishes, leather finishes, as a substitute for carnauba wax, or to blend with carnauba or beeswax. About half the production goes into furniture and shoe polishes.

**Cannel coal.** A variety of coal differing from ordinary coal in properties and composition. It consists of coaly matter intimately mixed with clay and shale, often containing fossil fishes, and is supposed to have been derived from vegetable matter in lakes, having some of the characteristics of petroleum. It is close and compact in texture, dull-black in color, and breaks along joints, often appearing like black shale. It burns with a long, luminous, smoky flame, from which characteristic it derives its old English name, meaning candle. On distillation, cannel coal yields a high proportion of illuminating gas, up to 16,000 cu. ft. per ton, leaving a residue consisting mostly of ash. At low temperatures it yields a high percentage of tar oils. The proportion of volatile matter may be as high as 70%. It is found in Great Britain, and in the United States in Kentucky, Ohio, and Indiana. It is chiefly valued for its quick-firing qualities. Cannel coal from Scotland was originally called Parrot coal. Boghead coal is the name of a variety of streaky cannel coal of Scotland.

**Carbohydrates.** A group of materials, chiefly of vegetable origin, which are distinguished by the fact that they contain the elements carbon, hydrogen, and oxygen, and no others. Many chemical compounds, such as alcohols and aldehydes, also have these elements only, but the term carbohydrate refers only to the starches, sugars, and cellulose, and is more properly called Saccharides. They are best known for their use as foodstuffs, as carbohydrates compose more than 50% of all American food, but they are also used in many industrial processes. The digestible carbohydrates are the sugars and the starches. The indigestible carbohydrates are cellulose and hemicellulose, which form the chief constituents of wood, stalks, and leaves of plants, the outer covering of seeds, and the

walls of plant cells enclosing the water, starches, and other substances of the plants. Much cellulose is eaten as food, especially in the leaves of vegetables and in bran, but it serves as bulk rather than as food, and is beneficial if not consumed in quantity. The digestible carbohydrates are classified as Single sugars, Double sugars, and Complex sugars, chemically known as Monosaccharides, Disaccharides, and Polysaccharides. The single sugars, glucose, fructose, and galactose, require no digestion and are readily absorbed into the blood stream. The double sugars, sucrose, maltose, and lactose, require to be broken down by enzymes in the human intestine. Lactose is only slowly digested. It is produced from cow's milk, and is only one quarter as sweet as sucrose from cane sugar. Galactose is derived from lactose by hydrolysis.

The complex sugars are the starches, dextrines, and glycogen. These require digestion to the single stage before they can be absorbed in the system. The common starches are in corn, wheat, potatoes, rice, tapioca, and sago. Glycogen is animal starch stored in the liver and muscles of animals. The hemicelluloses are agar-agar, algin, and pectin. They differ chemically from cellulose and expand greatly on absorbing water. The hemicelluloses of wood, called Hexosan, consist of the Wood sugars, or Hexose, with six carbon atoms, $(C_6H_{10}O_5)_n$. They were used in Germany during the war to produce alcohol, glycerin, and other chemicals. The Pentosans are gums or resins occurring in nut shells, straw, and in the cell membranes of plants. They may be classed as hemicellulose and on hydrolysis yield Pentose, or Pentaglucose, a sugar containing 5 carbon atoms. Pectin is a yellowish, odorless powder soluble in water. It occurs in some fruits, and is produced by dilute acid extraction of the inner portions of the rind of citrus fruits or from apple pomace. It contains a complex acid, and the pectin molecule ranges in molecular weight from 150,000 to 300,000. The gelling strength depends upon the size of the molecule. Hemicellulose and pectin are valuable in the human system because of their ability to absorb and carry away irritants, but they are not foods in the normal sense of the term. Pectin is a blood coagulant, and is used in medicine in treating hemorrhage. Each of the saccharides has distinctive characteristics of value in the system, but each also in excess causes detrimental conditions. The metabolism,

or energy-yielding process, of carbohydrates as food is complex and varies greatly in the presence of, or lack of, various minerals, vitamins, nitrogen compounds, absorption of oxygen, and the acids and glycerides of fats. Carbohydrates are used in many industries. The sugars are employed for the manufacture of alcohols, the starches for adhesives and sizing, the celluloses for plastics and explosives, and the hemicelluloses as thickening agents.

**Carbon.** A nonmetallic element, symbol C, existing naturally in several allotropic forms, and in combination as one of the most widely distributed of all the elements. It is quadrivalent, and has the property of forming chain and ring compounds, and there are more varied and useful compounds of carbon than of all other elements. Carbon enters into all organic matter of vegetable and animal life, and the great branch of organic chemistry is the chemistry of carbon compounds. The black amorphous carbon has a specific gravity of 1.88; the black crystalline carbon known as graphite has a specific gravity of 2.25; the transparent crystalline carbon, as in the diamond, has a specific gravity of 3.51. Amorphous carbon is not soluble in any known solvent. It is infusible, but sublimes at 3500°C., and is stable and chemically inactive at ordinary temperatures. At high temperatures it burns and absorbs oxygen, forming the simple oxides CO and $CO_2$, the latter being the stable oxide present in the atmosphere and a natural plant food. Carbon dissolves easily in some molten metals, notably iron, exerting great influence on them. Steel, with small amounts of chemically combined carbon, and cast iron, with both combined carbon and graphitic carbon, are examples of this.

Carbon occurs as hydrocarbons in petroleum, and as carbohydrates in coal and plant life, and from these natural basic groupings an infinite number of carbon compounds can be made synthetically. Carbon, for chemical, metallurgical, or industrial use, is marketed in the form of compounds, or in master alloys containing high percentages of carbon, or as activated carbons, charcoal, graphite, carbon black, coal-tar carbon, petroleum coke, and as pressed and molded bricks or formed parts with or without binders or metallic inclusions. Natural deposits of graphite, coal tar, and petroleum coke are important sources of elemental carbon. Charcoal and acti-

vated carbons are obtained by carbonizing vegetable or animal matter. Carbon 13 is a variety of carbon containing an extra neutron in the nucleus of the atom. It is made only in very small quantities by a complicated isotope exchange process. It is used as a tracer in biologic research where its heavy weight makes it easily distinguished from other carbon.

Carbon brushes for electrical motors and generators, and Carbon electrodes, are made of carbon in the form of graphite, petroleum coke, lampblack, or other nearly pure carbon, sometimes mixed with copper powder to increase the electrical conductivity, and then pressed into blocks or shapes and sintered. Carbon brick, used as a lining in the chemical processing industries, is carbon compressed with a bituminous binder and then carbonized by sintering. If the binder is capable of being completely carbonized, the bricks are impervious and dense. Graphite brick, made in the same manner from graphite, is more resistant to oxidation than carbon bricks and has a higher thermal conductivity, but it is softer. The binder may also be a furfural resin polymerized in the pores. Karbate No. 1, of the National Carbon Co., Inc., is a carbon-base brick, and Karbate No. 2 is a graphite brick. Karbate has a crushing strength of 10,500 lb. per sq. in., and a weight of 110 to 120 lb. per cu. ft. The material is also used for lining chemical pumps, for valves, and for acid-resistant parts. Graphitar, of the U.S. Graphite Co., is a strong, hard carbon molded from amorphous carbon mixed with other forms of carbon. It has high crushing strength and acid resistance, and is used for sealing rings, chemical pump blades, and piston rings. Porous carbon is used for the filtration of corrosive liquids and gases. It consists of uniform particles of carbon pressed into plates, tubes, or disks without a binder, leaving interconnecting pores of about 0.001 to 0.0075 in. in diameter. The porosity of the material is 48%, tensile strength 150 lb. per sq. in., and compressive strength about 500 lb. per sq. in. Porous graphite has graphite instead of carbon particles, and is more resistant to oxidation but is lower in strength. Carbocell and Graphicell are trade names of the National Carbon Co., Inc., for these materials.

The so-called carbons used for electric-light arc electrodes are pressed from coal-tar carbon, but are usually mixed with other elements to bring the balance of light rays within the visible spectrum.

The Sunshine carbon, used in electric-light carbons to give approximately the same spectrum as sunlight, is molded coal-tar carbon with a core of cerium metals to introduce more blue into the light. Arc carbons are also made to give other types of light, and to produce special rays for medicinal and other purposes. B carbon, of the National Carbon Co., Inc., contains iron in the core and gives a strong emission of rays from 2,300 to 32 angstrom units, which are the antirachitic radiations. The light appears to the eye only one-fourth the actual radiation since the low rays are invisible. C carbon contains iron, nickel, and aluminum in the core, and gives powerful lower zone ultraviolet rays. It is used in light therapy and for industrial applications. E carbon, to produce penetrating infrared radiation, contains strontium.

**Carbon bisulphide.** Also called Carbon disulphide. A colorless liquid of the composition $CS_2$, made by heating together carbon and sulphur. It is inflammable and poisonous, but is a good solvent for oils, fats, resins, and waxes. The specific gravity is 1.263, boiling point 46.3°C., and solidifying point −111°C. It is a highly refractive liquid with a characteristic odor.

**Carbon black.** An amorphous powdered carbon resulting from the incomplete combustion of a gas, usually deposited by contact of the flame on a metallic surface, but also made by the incomplete combustion of the gas in a chamber. The carbon black made by the first process is called Channel black, taking the name from the channel iron used as the depositing surface. The carbon black made by other processes is called Soft black and is weaker in color strength. It is therefore not as useful as a pigment. Carbon black from clean artificial gas is a glossy product with an intense color, but all the commercial carbon black is from natural gas. Thermotomic black, a grade made by the thermal decomposition of the gas in the absence of oxygen, is preferred as a filler in rubber because it does not retard the vulcanization. Carbon black is used as a paint pigment, in stove polishes, carbon paper, and in printing and drawing inks. Its largest use is in rubber for automobile tires to give added wear resistance to the tire. The blacker blacks have a finer particle size than the grayer blacks, hence have more surface and absorptive capacity in compounding with rubber. Channel black is valued for

rubber mixtures because it adheres strongly to the rubber. Carbon black is produced largely in Louisiana, Texas, and Oklahoma. The yield per thousand cubic feet of gas is from 1.1 to 1.8 lb. Acetylene black is a carbon black made from acetylene. It is more graphitic than ordinary carbon black and is used in dry cells and liquid oxygen explosives. Carbon black grades are often designated by trade names for particular uses. Kosmovar, of the United Carbon Co., is a black with a slight bluish top tone used as a pigment for lacquers. The specific gravity is 1.72, and the mesh is 325. Gastex and Pelletex are carbon blacks of the General Atlas Carbon Co. used for rubber compounding. Statex, of the Columbian Carbon Co., is a colloidal furnace black for synthetic rubber compounding.

**Carbon dioxide.** Also called Carbonic acid and Carbonic anhydride, and in its solid state, Dry ice. A colorless, odorless gas of the composition $CO_2$, which liquefies at $-65°C.$ and solidifies at $-78.2°C.$ It is obtained as a by-product of distilleries, from burning lime, and from natural gas. In liquid form it is marketed in cylinders, and is used in fire extinguishers, spray painting, refrigeration, for inert atmospheres, for the manufacture of Carbonated beverages, and in many industrial processes. It is also marketed as Dry ice as a white snowlike solid used for refrigeration in transporting food products. Cardox is a trade name of the Cardox Corp. for liquid carbon dioxide in storage units at 300 lb. per sq. in. pressure for fire-fighting equipment.

**Carbon paper.** Paper used for duplicating typewriting, pencil, or pen writing. It is made by coating the paper with a mixture of a pigment and a medium. The pigments include carbon black, Prussian blue, and organic red, or blue and green lakes. The medium is likely to be a blend of waxes and oils to give a composition of the desired consistency and melting point but, to make a good carbon paper that will not be gummy and will not smear, a proper proportion of a high-melting true wax, such as carnauba, must be used. Paper of special texture, usually rag papers, are used.

**Carbon steel.** Any steel owing its distinctive properties to carbon chemically combined with the iron. If other elements in influencing proportions are in the steel, it is designated as an alloy

steel, except that up to 1.65% of manganese, 0.60 silicon, and 0.60 copper may be included without the steel being considered as alloyed. Likewise, small amounts of sulphur to give free-machining properties may be added without changing the name. When the carbon is below 0.15%, the metal may be called iron; when the carbon exceeds 0.60%, the steel is usually considered to be tool steel. However, there is no fixed dividing line, and carbon steels for general use may be high or low in carbon. The old shop names, Machine steel, or Machinery steel, for open-hearth carbon steel having a low carbon range, are still used to mean any easily worked low-carbon steel up to the tool steel range that requires only simple heat-treatment. Those of low carbon have tensile strengths from 35,000 to 45,000 lb. per sq. in., and those with 0.40 to 0.60% carbon have strengths up to 60,000 lb. per sq. in., or up to 120,000 lb. per sq. in. when hard-drawn. S.A.E. steel 1020, with 0.15 to 0.25% carbon, when cold-rolled or hard-drawn, has a tensile strength from 40,000 to 60,000 lb. per sq. in., with elongation of 30 to 40%. These steels do not contain enough carbon to harden fully, but they can be carburized and casehardened. When properly heat-treated, they have a fine grain, good wearing qualities on the outside, and a tough core. They will not withstand repeated shocks or stresses. Those with low carbon are ductile and are useful for deep drawing. The control of microstructure is important in this type of steel. They are used for shafts, forgings, gears, machine parts, and cheap dies and gages for small runs. They forge and machine easily. Up to 0.15% of sulphur, or up to 0.045% of phosphorus, makes them free-cutting and keeps the chips from curling, but reduces the strength.

Screw stock, or Free-cutting steel, in rod form, with sulphur or phosphorus, is produced regularly in the carbon range from 0.08 to 0.25%, designated as S.A.E. 1112 to S.A.E. 1120 steel. The carbon Rail steel, for railway rails, is characterized by an increase of carbon with the weight of the rail. A.R.E.A. standards call for 0.50 to 0.63% of carbon and 0.60 manganese in a 60-lb. rail, and 0.69 to 0.82% of carbon and 0.70 to 1.0 manganese in a 140-lb. rail. Sometimes a machinery steel may be required with a small amount of alloying element to give a particular characteristic and still not be marketed as an alloy steel, although trade names are usually

applied to such steels. Crow steel, of the Allegheny Ludlum Steel Corp., is a carbon steel with 0.50% of chromium to give greater depth of hardness. When annealed, it machines the same as the straight carbon Corinth steel of this company. Economo steel, of Wheelock, Lovejoy & Co., Inc., is a low-carbon steel containing 0.18% of molybdenum to produce a tough core when casehardened. Max-El 1B steel, of the Crucible Steel Co., has 0.20% of carbon, high manganese, and a small amount of molybdenum. Rytense AA machinery steel, of Joseph T. Ryerson & Sons, Inc., is a special-analysis steel with a tensile strength up to 115,000 lb. per sq. in., elongation 20%, and Brinell hardness 229. The so-called Hobbing steels, used for making plastic molds by pressing the hard model into the steel, may be plain carbon steel for casehardening, or they may be low-alloy steels. Press E-Z steel, of the Jessop Steel Co., is a hobbing steel containing 0.40 to 0.50% of carbon and 0.15 to 0.20 manganese with no alloying elements. It is marketed annealed to 100 Brinell, and when carburized and hardened has a hardness of 60 Rockwell C.

**Carbon tetrachloride.** A heavy colorless liquid of the composition $CCl_4$, also known as Tetrachloromethane, which is one of a group of chloronated hydrocarbons. It is an important solvent for fats, asphalt, rubber, bitumens, and gums. It is more expensive than the aromatic solvents and is toxic, but it is notable as a non-inflammable solvent for many materials sold in solution, and is widely used as a degreasing and cleaning agent in the dry-cleaning and textile industries. It is employed in such cleaning compounds as Carbona, and as a chemical in fire extinguishers such as Pyrene. It is also used as a disinfectant, and because of its high dielectric strength has been employed in transformers. It was first produced in 1839 and used in Germany as a grease remover under the name of Katharin. Carbon tetrachloride is obtained by the chlorination of carbon bisulphide. The specific gravity is 1.595, boiling point 76.8°C., and solidifying point −23°C.

**Carnauba wax.** A hard, high-melting lustrous wax from the fanlike leaves of the palm tree *Copernica cerifera* of the arid region of northeastern Brazil, sometimes referred to as Brazil wax or Ceara wax. It is composed largely of Ceryl palmitate, $C_{25}H_{51}COOC_{30}$-

$H_{61}$. The trees grow up to 60 ft. in height with leaves 3 ft. in length. The wax forms a protective coating on the leaves, and when the leaves are dried it flakes and is beaten off and melted into cakes. The wax comes in hard, vitreous, yellowish cakes or lumps that melt at about 85°C., and have a specific gravity of 0.995. It is soluble in alcohol and in alkalies. Olho wax is the wax from young yellow leaves and is whitish gray. Palha wax, from older green leaves, is of a deeper grayish-yellow hue. In melting, water is added to the palha to make the Chalky wax. No. 3 chalky contains up to 10% of water. Olho wax without water yields the prime yellow wax. Flora wax is the highest quality and is clear yellow. Fully 70% of the production of carnauba goes into the manufacture of floor waxes and carbon paper. It has the property of being self-polishing in liquid floor waxes. In carbon paper it is nongreasy and nonsmearing. Other uses are in shoe polishes, leather finishes, phonograph records, and for blending with other waxes for coating compounds. Burnishing wax, in the shoe industry, is carnauba wax blended with other waxes.

A wax quite similar to carnauba is Guaruma, or Cauassu wax, from the leaves of the *Calathea lutea,* a small plant with large leaves like those of the banana, growing in the lower Amazon Valley. Another similar wax is from the trunk of the Wax palm, *Ceroxylon andicola,* growing on the Andean slopes. A wax that is very similar to carnauba in properties and is more plentiful, but which contains the green leaf coloring difficult to bleach out, is Ouricury wax. The name is also spelled Urucury (Uru, the Carib name for a shell; O means leaf). The wax is from the leaves of the palm tree *Syagrus coronata,* or *Cocos coronata,* of northeastern Brazil. It is beaten off or boiled off the dried leaves and melted into blocks. The green color results largely from the method of preparation of the wax as it does not flake off the leaves like carnauba. Ouricury wax has a melting point of about 85°C., acid number 10.6, iodine value 16.9, and saponification value 78.8. It has the same uses as carnauba where color is not important, or it is used to blend with carnauba to increase the gloss. The nuts of the tree are called Licurí nuts, and are used to produce Licurí oil employed in soaps. The name Licurí wax is sometimes erroneously given to ouricury. Cotton wax, which occurs in cotton fiber to the extent of about

0.6% is very similar to carnauba wax. It is a combination of $C_{28}$ to $C_{32}$ primary alcohols with $C_{24}$ to $C_{32}$ fatty acids. It has not been produced commercially although some strains of cotton contain 15% of wax.

**Carnotite.** A mineral found in Utah and Colorado and employed as a source of uranium, radium, and vanadium. It is a vanadate of uranium and potassium, $V_2O_5 \cdot 2UO_3 \cdot KO \cdot 3H_2O$. It is found with other sands and gives them a pale-yellow color. The ore may contain 2 to 5% of uranium oxide and up to 6 of vanadium oxide, but it usually runs 2% of $V_2O_5$. The vanadium is produced by roasting the ore, leaching, precipitating the oxide with acids, and sintering. The production of radium from the residue ore is a complex process, and it requires 400 tons of ore to produce a gram of radium. Patronite, mined in Peru as a source of vanadium, is a greenish mineral of the composition $V_2S_9$ mixed with pyrites and other materials.

**Caroa.** Pronounced car-o-áh. The fiber from the leaves of the plant *Neoglaziovia variegata* of northeastern Brazil. It is more than twice as strong as jute and is lighter in color and lighter in weight, but is too hard to be used alone for burlap. It is employed as a substitute for jute for burlap when mixed with softer fibers, and also for rope, and in mixtures with cotton for heavy fabrics and suitings. Some summer suiting is made entirely of the finer caroa fibers. Fibrasil is a trade name in Brazil for fine white caroa fibers.

**Cartridge brass.** One of the standard alloys of the brass mills, containing 70% of copper and 30 zinc. Because of the general use of the alloy for making cartridges and for other deep drawing, the highest purity zinc is used and all lead is excluded. It has high ductility and an attractive yellow color, and is used for deep-drawn or spun articles such as lamp bases, horns, and cornets. It brazes well and electroplates easily. Hard-rolled sheet has a tensile strength of 84,000 lb. per sq. in., with elongation of 5%, while the annealed sheet has a strength of 49,000 lb. per sq. in. and elongation of 55%. The coefficient of expansion is 0.0000103 per deg. F., weight 0.308 lb. per cu. in., and electrical conductivity

27% that of copper. Revere alloy No. 160, of the Revere Copper & Brass, Inc., is this alloy. A slightly harder alloy, used for wire goods, is Eyelet brass, containing 68% of copper and 32 zinc. A grade produced by the American Brass Co. under the name of Spinning brass contains 67% of copper and 33 zinc. Lubaloy, of the Western Cartridge Co., contains some tin. Primer brass, for cartridge primers, may be the 70-30 alloy, or it may be cap copper.

**Casehardening materials.** Any material employed for adding carbon to the outside of low-carbon steels or to iron so that upon quenching a hardened case is obtained, the center of the steel remaining soft and ductile. The material may be plain charcoal, raw bone, or mixtures marketed as Carburizing compounds. A common mixture is about 60% of charcoal and 40 barium carbonate. The latter decomposes, giving carbon dioxide which is reduced to carbon monoxide in contact with the hot charcoal. If charcoal is used alone, the action is slow and spotty. Coal or coke can be used, but the action is slow, and the sulphur in these materials is detrimental. Salt is sometimes added to aid the carburizing action. By proper selection of the carburizing material the carbon content may be varied in the steel from 0.80 to 1.20%. The carburizing temperature for carbon steels is 1600°F., and for alloy steels about 1525°F. The articles to be carburized for casehardening are packed in metallic boxes for heating in a furnace, and the process is called pack hardening as distinct from the older method of burying the red-hot metal in charcoal. The principal liquid carburizing material is sodium cyanide, which is melted in a pot and the articles dipped in, or the cyanide rubbed on the hot steel. Cyanide hardening gives an extremely hard but superficial case. Nitrogen as well as carbon is added to the steel by this process. Gases rich in carbon, such as methane, may also be used for carburizing, by passing the gas through the box in the furnace. When ammonia gas is used to impart nitrogen to the steel, the process is not called carburizing but is referred to as nitriding. Casehardening compounds are marketed under a wide variety of trade names. These may have a base of hardwood charcoal or of charred bone, with sodium carbonate, barium carbonate, or calcium carbonate. Char, of the Char Prod-

ucts Co., is a carburizing material in which the particles of coal-tar carbon are surrounded by an activator and covered with a carbon coating.

**Casein.** A whitish to yellowish granular or lumpy protein precipitated from skim milk by the action of a dilute acid, or coagulated by rennet, or simply inoculated with whey from a previous batch. The precipitated material is then filtered and dried. Cow's milk contains about 3% of casein. It is insoluble in water or in alcohol, but is attacked by alkalies. Most of the production is by acid precipitation, and this material has a moisture content of not more than 10%, has not more than 2.25% of fat, and not over 4 ash. The casein made with rennet has higher ash content, up to 7.5%, less than 1% fat, and is less soluble in alkalies. It is the type used for making plastics. Rennet is an extract of an enzyme derived from the stomachs of calves and lambs and is closely related to pepsin. Argentina and the United States are the most important producers of casein, but production drops in the United States at times when milk products are in greater demand for food. France, Norway, and Holland are also large producers. Casein is employed for making plastics, adhesives, sizing for paper and textiles, washable interior paints, leather dressings, and as a diabetic food. Casein glue is a cold-work, water-resistant paste made from casein by dispersion with a mild base such as ammonia. With a lime base it is more resistant but has a tendency to stain. It is marketed wet or dry, the dry powder being simply mixed with water for application. It is used largely for low-cost plywoods and in water paints, but is not waterproof.

**Casein plastics.** A group of thermoplastic molding materials made usually by the action of formaldehyde on rennet casein. The process was invented in 1885, and the first commercial casein plastic was called Galalith, meaning Milkstone. Casein plastics are easily molded, machine easily, are noninflammable, will withstand temperatures up to 300°F., and are easily dyed to light shades. But they are soft, have high water absorption, 7 to 14%, and soften when exposed to alkalies. They are thus not suitable for many mechanical parts or for electrical parts. They are used for ornamental parts, buttons, and for such articles as fountain-pen holders. The specific

gravity of the material is 1.34, and the tensile strength is 8,000 lb. per sq. in. They are usually marketed under trade names. Some of these are Aladdinite, of the Aladdinite Co., Inc.; Inda, of the American Machine & Foundry Co.; Erinoid, of the Erinoid Co.; Lactoid, of the British Xylonite Co., Ltd.; Lactonite, of the British Lactonite Co.; Ameroid, of the American Plastics Corp.; and Karolith, of the Karolith Corp. Sicalite is a French casein plastic. Casein fiber is made by treating casein with chemicals to extract the albumen and salts and forcing it through spinnerets, and again treating it to make it soft and silklike. The fiber is superior to wool in silkiness and resistance to moth attack, but is inferior in general properties. It is blended with wool in fabrics and in hat felts. Lanitol was an early Italian casein fiber. Aralac fiber, of Aralac, Inc., is a translucent, white, silky casein fiber.

**Cashew-nut shell oil.** An amber-colored poisonous viscous oil obtained by extraction from the by-product shells of the cashew-nut industry of India and Brazil. For every pound of shelled nuts there are 3.55 lb. of by-product shells. The cashew nut grows on the distal end of the fruit of the tree *Anacardium occidentale*. The thin-skinned, yellow, pear-shaped fruit may be eaten or used in preserves. The kernel of the seed nut, known as the Cashew nut, is roasted and widely used as an edible nut or in confections. The kernel is crescent-shaped, and the nuts are graded by sizes from 200 per lb. to 400-450 per lb. On crushing, the nuts produce 45% of an edible oil, but the nuts are more valuable as a confection than for oil, and there is no commercial production of cashew-nut oil. One pound of shells yields 0.335 lb. of cashew-nut shell oil which contains largely Anacardic acid, a high phenol, very blistering to the skin. It is used for the production of plastics, drying oils, and insulating compounds. The oil reacts with formaldehyde to give a drying oil. With furfural it produces a molding plastic. Reacted with other chemicals it forms rubberlike masses used as rubber extenders and in electrical insulating compounds. On distillation, cashew-nut shell oil yields Cardanol, a light oily liquid of the composition $C_6H_4 \cdot OH(CH_2)_6CHCH(CH_2)_6CH_3$, with boiling point of 360°C. and freezing point of about −20°C. Cardanol polymerizes with formaldehyde to form a heat-resistant, chemical-re-

sistant, flexible resin of high dielectric strength valued for wire insulation. Small amounts of this resin also improve the chemical and electrical properties of the phenol resins.

**Cashmere.** A fine, soft, silky fabric made from the hair of the Cashmere goat raised on the slopes of the Himalayas of Asia. The hair is obtained by combing the animals, not by shearing, and the production is small. The hair is straight and silky, but not lustrous, and is difficult to dye. The fabrics are noted for warmth, and the production now goes mostly into the making of shawls and fine ornamental garments. Cotton cashmere is a soft, loose-woven cotton fabric made to imitate cashmere, or it may be a cotton and wool mixture, but it lacks the fineness of true cashmere.

**Cassiterite.** Also called Tin stone. It is the only commercial Tin ore, and is a Tin dioxide, $SnO_2$, containing theoretically 78.6% of tin. It is a widely distributed mineral, but is found on a commercial scale in only a few localities, notably in Malaya, East Indies, Bolivia, Cornwall, England, Nevada, Isle of Pines, and in Australia. The mineral occurs granular massive with a specific gravity of 6.8 to 7.1, and a hardness of 6 to 7, with a brown to black color. It is present in the ore usually in amounts of from 1 to 5%, and is found in veins, called Lode tin, or in placer deposits. The concentrated ore averages 65 to 70% of tin oxide. It is roasted to eliminate sulphur and arsenic, and then smelted in reverberatory furnaces.

**Cast iron.** A combination of iron with from 2 to 6% of carbon, receiving its name from the fact that it is readily cast into almost any desired shape in an ordinary sand mold. The A.S.T.M. definition is an iron containing so much carbon that it is not malleable at any temperature. The low limit is about 1.7%. Cast iron is of two kinds: White cast iron and Gray iron. The first is a chemical compound of most of the carbon with the iron; the second contains most of the carbon in the form of graphite mechanically mixed with the iron. Cast iron is brittle and not malleable. It is low in cost, easy to machine, and has a higher proportional fatigue than steel. It is used for the massive bodies of machines and for intricate castings that do not require high strength. White iron is made by chilling gray iron, and may be converted into gray iron

by heating to 1850°F. for several hours. Cast iron is made by melting pig iron and scrap iron in a cupola in contact with the fuel, which is usually coke. The pouring temperature is about 2460°F. With an electric furnace, scrap iron may be employed alone with carbon without pig iron, and the furnace may be operated continuously. The product is called Synthetic cast iron.

The specific gravity of gray iron is 7.10, and that for white iron is 7.50. The coefficient of expansion is 0.0000056. Tensile strengths of plain gray irons vary from 18,000 to 25,000 lb. per sq. in., and compressive strength from 60,000 to well over 100,000 lb. per sq. in. Ordinary cast iron contains 3.25 to 3.75% of carbon, about 2.5 silicon, 0.60 manganese, 0.06 sulphur, and 0.40 to 0.80 phosphorus. The chemically combined carbon governs the melting point. An iron with 4.2% combined carbon and 0.2 graphite melts at 1990°F., while one with 0.17% combined carbon and 3.57 graphite melts at 2260°F. If the combined carbon is above 0.75%, machining is difficult. At 1.50% machining is impossible with ordinary tools. At 1.75% the hardness may be as high as 477 Brinell, whereas soft iron is as low as 88 Brinell. Pure iron can take up to 4.6% of carbon in a chemically combined state. Manganese and chromium increase this saturation point, but silicon reduces it.

The combined carbon structure of cast iron is known as Austenite, and the structure with the iron-carbon compound $Fe_3C$, which forms when the austenite changes on cooling, is called Cementite. The term Ferrite is used for the iron crystals having no carbon. Pearlite, the most desirable structure of cast iron, consists of alternate layers of ferrite and cementite. The tensile strength of such a structure, if it could be obtained throughout, would be 100,000 lb. per sq. in., but a good average for plain gray iron is 22,000 lb. per sq. in., with a compressive strength of 100,000 lb. per sq. in. Gun iron, formerly used for casting cannon, was a fine-grained iron of uniform texture, low in sulphur and in total carbon, made with charcoal in an air furnace, and had tensile strengths equal to some modern high-test cast irons. Graphite is a weakening element in cast iron, and the high graphitic irons are desired only because of their ease of casting and machining. The lower the carbon, the stronger the cast iron. To obtain this result, steel scrap is used in the mix. Low-carbon steel of known chemical

content, such as plate and rod ends and rail croppings, is used. The amount of steel varies from 15 to 60%, and the product resulting from the larger additions is called Semisteel. Tensile strengths as high as 40,000 lb. per sq. in. can be obtained without great reduction in the casting and machining qualities of the cast iron. Semisteel castings can be softened and made more ductile by annealing at a temperature of about 800°F., but they then lose 25 to 35% of the tensile strength.

Phosphorus in cast iron increases fluidity, but more than 0.6% makes the iron hard. Sulphur is an undesirable impurity. Silicon goes into solid solution in iron to form iron silicides and precipitates graphite. Small amounts make the iron soft, but large amounts make it glassy hard. Copper is also used as a graphitizer and to increase the heat conductivity. Engine cylinder blocks of high heat conductivity and good strength contain about 0.75% of copper. Lithium-treated cast irons make sound, dense, and hard castings. The lithium cleans the iron and disperses the carbon. Nickel, chromium, and other elements are added to cast irons while molten to give additional strength, toughness, or hardness, but the iron is then generally known as Alloy cast iron. Manganese decreases the magnetic properties of cast iron. Nomag, an English nonmagnetic cast iron, contains 6% of manganese. Adding nickel makes this manganese iron machinable without changing its nonmagnetic quality. Small amounts of tungsten increase the tensile and transverse strength of cast iron, but reduce its hardness. A Tungsten cast iron, with 1.2% of tungsten has a tensile strength of about 40,000 lb. per sq. in. Casehardening of cast iron is done by using powdered ferromanganese on the mold surface. Nitrided cast iron, hardened by nitrogen treatment to give great wear resistance, must have a special composition. A typical composition for the Nitricastiron, as given by the Electro Metallurgical Co., is 2.9% of total carbon, 0.6 combined carbon, 2.7 silicon, 0.75 manganese, 1.3 chromium, 1 aluminum, 0.16 vanadium, 0.25 molybdenum, with sulphur and phosphorus below 0.07. It can be hardened to 800 to 1,000 Brinell to a depth of 0.004 to 0.006 in. Cast iron deteriorates rapidly when subjected to temperatures above 800°F., and the Heat-resistant cast irons for firebox castings and stove grates contain some chromium to stabilize the pearlite and cementite. A cast

iron containing 1.25% of chromium will withstand temperatures up to 1400°F. Trade names are used to designate cast iron made by special processes. Pomoloy, of the Pomona Pump Co., is an unalloyed cast iron with a tensile strength of 40,000 lb. per sq. in., and hardness of 215 Brinell. DeLavaud metal, of the U.S. Cast Iron Pipe & Foundry Co., is made by a centrifugal process in rotating steel molds. After annealing, the pipe has an outer layer of malleable iron, a center layer resembling steel, and an inner surface of gray iron. Hi-Tem iron, of the Bethlehem Foundry & Machine Co., is a corrosion-resistant cast iron used for processing vessels. Hi-Tem S is a high-manganese iron used for retorts.

High-test cast iron was originally cast iron that was superheated in the melting for pouring, poured in chilling molds, and then heat-treated, the only change in composition being to keep the silicon and manganese high. The term now means high-strength irons that are processed to give a careful balance of ferrite, pearlite, cementite, and carbon by the treatment, by additions of steel scrap, and by additions of nickel, chromium, and other elements that give strength to the metal by balancing the structure, but are not in sufficient quantities to classify the iron as an alloy cast iron. Tensile strengths above 50,000 lb. per sq. in. are obtained, and all of the high-test irons are fine-grained, and are not spongy like gray iron. Steel scrap gives a stronger and finer structure; nickel gives ease of machining and aids in the chilling; chromium gives hardness and resistance to growth; molybdenum raises the combined carbon and adds strength and hardness. Oxygenized iron is high-test cast iron made by blowing air through a part of the metal and then returning the blown metal to the cupola. There is no sharp dividing line between some of these processed irons and steel, and when the combined carbon is high and the graphitic carbon is well distributed in even flakes the metal is called Graphitic steel. High-test cast irons are used for brake drums, cams, rolls, and high-strength parts. In many cases they are substitutes for malleable iron. They are marketed under many trade names. Ermal is a pearlitic cast iron of the Erie Malleable Iron Co. with a tensile strength up to 70,000 lb. per sq. in. Perlit, of the Durson Corp., is another pearlitic cast iron. Aremite is a synthetic cast iron of Robbins & Myers, Inc. Jewell alloy, of the Jewell Steel & Malleable Co., is the name of a group of

high-strength and heat-resistant irons. Ermalite, of the Erie Malleable Iron Co., and Wearloy, of the Frank Foundries Corp., are high-strength, wear-resistant cast irons. Gunite, of the Gunite Corp., is a graphitic steel which, when quenched to a hardness of 477 Brinell, has a compressive strength of 200,000 lb. per sq. in. Arma steel, of the Saginaw Malleable Iron Div., General Motors Corp., is a graphitic steel, or arrested malleabilized iron of high strength and shock resistance, used for connecting rods, gears, and camshafts where both high strength and bearing properties are required. Meehanite metal, produced under license of the Meehanite Research Institute of America, is made in a wide range of high-strength, wear-resisting, corrosion-resisting, and heat-resisting castings for dies, hydraulic cylinders, brake drums, pump parts, and gears. The normal strengths range from 35,000 to 55,000 lb. per sq. in., compressive strengths from 135,000 to 175,000 lb. per sq. in., and hardnesses from 193 to 223 Brinell.

**Castor oil.** A light-yellow to brownish viscous oil obtained from the seed beans of the castor plant, *Ricinus communis*. In the tropics the plant grows to the proportions of a sturdy tree, but in temperate climates it is a small plant with a poor yield. Besides its original use as a purgative in medicine, castor oil is one of the most widely used industrial vegetable oils. When pure and fresh, the oil is nearly colorless and transparent. The hot-pressed oil is brownish. It has a characteristic acrid, unpleasant taste. The specific gravity is 0.960 to 0.970, iodine value 82 to 90, saponification value 147, and solidifying point $-10°C$. Castor seeds have the appearance of mottled colored beans, and are enclosed in hard husks which are removed before crushing. Fully 40% of the world production is in Brazil, and two classes are grown in that country. The large Zanzibar type has seeds 16 mm. long containing 30 to 35% of oil, and the Sanguineus type has seeds 10 mm. long containing up to 60% of oil. They are usually mixed in shipments, and the average yield is calculated as 0.45 lb. of oil from 1 lb. of beans. The oil obtained from the first cold pressing is used in medicine and in lubricants. The second and third grades of hot-pressed oil are the ones for general industrial use. Castor beans are also grown in India, Russia, Argentina, Haiti, Cuba, Japan, and China. Castor

oil is used in paints and varnishes usually in dehydrated form, as a hydraulic brake-cylinder oil, as a lubricating oil, for treating leather, in soaps, and for treating textiles. It increases the lathering power of soaps and their solubility in cold water. In lubricating oils and in cutting oils it has excellent keeping qualities and does not dry or gum on exposure.

When castor oil is chemically dehydrated by removing the hydroxyl groups in the form of water by means of a catalyst, a double bond is formed giving an oil of heavy viscosity, light color, and with iodine value 116, acid value 3.5, and saponification value 191. Dehydrated castor oil gives a better gloss in varnishes than tung oil with a softer and less brittle film, but it has less alkali resistance than tung oil unless mixed with synthetic resin. Sulphonated castor oil, known as Turkey red oil in the textile industry, is made by treating crude hot-pressed castor oil with sulphuric acid and neutralizing with sodium sulphate. It is miscible with water and lathers like a solution of soap. It is used for the preparation of cotton fibers to be dyed, and gives clearer and brighter colors. It is also employed in soaps and in cutting compounds. Sulphonated dehydrated castor oil is used in nonalkaline water-washable skin ointments. It has a softening point of 30°C., and an $SO_2$ content of 10%. Synthenol, of Spencer Kellogg & Sons, Inc., is a dehydrated castor oil for paints and varnishes. Castung, of the Baker Castor Oil Co., and Isoline, of the Woburn Degreasing Co., are dehydrated castor oils. Mannitan drying oil, of the Atlas Powder Co., is an ester of dehydrated castor oil that dries faster than linseed oil and has better resistance in paints.

A substitute for castor oil in medicine is Croton oil, a yellow-brown oil obtained from the dried ripe seeds of the small tree *Croton tiglium* of India and Ceylon. It has a burning taste and unpleasant odor, and is a more violent purgative than castor oil. The leaves and flowers of the tree are used like derris to kill fish. Curcas oil is a yellowish oil from the kernels of the seeds of the *Jatropha curcas* which grows in Central America. The kernels yield 50% of oil with a specific gravity of 0.920, iodine value 98 to 104, and saponification value 192. It has 10 times the purgative effect of castor oil, and is also a good soap oil but has an unpleasant odor.

**Cast steel.** Steel that has been cast into sand molds to form finished or semifinished machine parts or other articles. Steel castings are used to replace forgings where only small quantities are required that would not justify the cost of forging dies, and for large parts that could not be forged easily. Cast steel is stronger and tougher than malleable iron and, when heat-treated, will have a tensile strength above 70,000 lb. per sq. in., and elongation 15 to 20%. Federal specifications for cast steel call for 0.35% carbon in the soft grade, 0.45 in the medium grade, and 0.50 in the hard grade. The tensile strength of the soft is 60,000 lb. per sq. in., and of the hard 80,000 lb. per sq. in. The yield point is taken as 45% of the tensile strength. The shrinkage allowed for cast steel is ¼ in. per ft. British engineering standard specifications call for cast steel for general purposes to have 0.30% carbon, and a tensile strength of 26 tons per sq. in., with elongation 15 to 20%. Nickel, chromium, or a high percentage of manganese may be added to make special alloy castings, but the term cast steel alone generally means plain carbon steels. The carbon content of cast steel is not usually over 0.45%, and the manganese is usually 0.60 to 0.80%. Cast steel has the disadvantage in comparison with forged steel that it may contain blow holes, slag, sand holes, shrinkage cavities, or cold shuts, the last from pouring at too low a temperature. Thus, companies producing steel castings usually feature careful metallurgical control rather than merely chemical content of the steel, and the cast steels are generally sold under trade names, especially the alloy steels.

Aluminum, titanium, or other elements in the form of master alloys, are used to deoxidize and degasify alloy steels to produce homogeneous castings. Alloy steels for heavy-duty castings may be chromium steel, with 0.80 to 1.10% of chromium; vanadium, with 0.15 to 0.20 vanadium; chrome-vanadium; 1½ to 3½ nickel; nickel-chromium; or manganese, with either high or medium manganese content. One of the simplest alloy cast steels for parts subject to shock and fatigue stresses is the standard low-carbon and medium-carbon steel with 2% of nickel. It is used for mining and other heavy machinery parts, locomotive frames, and ship castings. The tensile strength is up to 85,000 lb. per sq. in., with yield point up to 55,000 lb. per sq. in., and elongation 25 to 32%. The nickel,

with manganese up to 0.90%, gives the steel greater shock resistance at low temperatures, as ordinary steel is brittle in cold climates or when used on refrigerating equipment. A 3 to 3½% nickel steel used for cast gears for rolling mills has a tensile strength of 110,000 lb. per sq. in., elongation of 20%, and hardness of 200 Brinell as cast. A nickel-chromium-molybdenum cast steel for heavy gears contains 1.5% of nickel, 0.75 chromium, 0.35 molybdenum, 0.70 manganese, and 0.35 carbon. The tensile strength is 145,000 to 160,000 lb. per sq. in.

**Catalyst.** A material used to cause or accelerate chemical action without entering into the chemical combination. Various metals, especially platinum and nickel, are used to catalyze or promote chemical action in the manufacture of synthetics. Acids may be used to aid in the polymerization of synthetic resins. Mineral soaps are used to speed up the oxidation of vegetable oils. Cobalt oxide is used for the oxidation of ammonia. Cobalt and thorium are used for synthesizing gasoline from coal. All of these are classed as Inorganic catalysts. Sometimes more complex chemicals are employed, silicate of soda being used as a catalyst for high-octane gasoline. In the use of Potassium persulphate, $K_2S_2O_8$, as a catalyst in the manufacture of some synthetic rubbers, the material releases 5.8% of active oxygen, and it is the nascent oxygen that is the catalyst. Sunlight or ultraviolet rays are also used as catalysts in some reactions. For example, chlorine and hydrogen combine very slowly in the dark, but combine with great violence when a ray of sunlight is turned on. Biologic catalysts are the Enzymes, which are Organic catalysts that are a form of life. They are sensitive to heat and light and are destroyed at 100°C. Enzymes are soluble in water, glycerin, or dilute saline solutions, and water must always be present for enzyme action. Their action may be stimulated or checked by other substances. Enzymes have various actions. Diastose, found in the seeds of barley and other grains, converts starch to maltose and dextrin. Cytase, found in seeds and fruits, decomposes cellulose to galactose and mannose. Zymose, found in yeast, hydrolyzes glucose to alcohol.

**Catechu.** An extract obtained from the heartwood and from the seed pods of the tree *Acacia catechu* of southern Asia. It is

used in tanning leather, and also as a dyestuff, giving brown, drab, and khaki colors. It is also used in medicine as an astringent for diarrhea and hemorrhage. The name is also sometimes applied to gambier, which also contains catechu tannin, $C_{15}H_9(OH)_5$. Catechu, or Cutch, comes either as a liquid which is a water solution, or as brownish, brittle, glossy cakes. The extract contains 25% of tannin, and the solid 50%. A ton of heartwood yields, by hot-water extraction, 250 to 300 lb. of solid cutch extract. It is a powerful astringent. When used alone as a tanning agent, the leather is not of high quality, being of a dark color, spongy, and water-absorbent. It is normally employed in mixtures. Burma cutch is from the *A. catechuoides.* Indian cutch is from the *A. sundra.* The latter is frequently adulterated with starch, sand, and other materials. Wattle is an extract from Australian and East African acacia, *A. dealbata,* and other species. Wattle bark contains 40 to 50% of tannin. It gives a firm pinkish leather and is employed for sole leathers. The solid extract contains 65% of tannin. Golden wattle, used for tanning in New Zealand, is the tree *A. pycantha.* Turwar bark, or Avarem, used in India for tanning cattle hides, is from the tree, *Cassia auricula,* and is similar to wattle.

**Catgut.** String made from the intestines of sheep, used for violin strings, and for tough, durable cords for rackets and other articles. After cleansing and soaking in an alkali solution, the intestines are split, drawn through holes in a plate, cured in sulphur or other material, and graded according to size. Sheep intestines are also used for making surgical sutures, but for this purpose they are not called catgut, but simply Gut. In the meat-packing industry the intestines of sheep and goats are referred to as Casings and are employed as the covering of sausage and other meat products. They are exported from Australia, New Zealand, Argentina, Chile, and some other countries in vast quantities, and are graded by diameter, freedom from holes, strength, color, and odor. Intestines of hogs and beef cattle are also used as sausage casings, but they are not as tender and edible as those from sheep.

**Cedar.** A general name that includes a great variety of woods. The true cedars comprise trees of the natural order of *Coniferae,* genus *Cedrus,* of which there are three species: Lebanon cedar,

*Cedrus libani;* Himalayan cedar, *C. deodora;* and Atlas cedar, *C. atlantica.* The differences are slight, and all of the species are sometimes classed as *C. libani.* The Himalayan cedar is also known as Deodar. All are mountain trees, and are native to southern Europe, Asia, and northern Africa. The true cedar is yellow in color, fragrant in odor, takes a beautiful polish, and is very durable. It is used in construction work, and timbers in temples in India more than 400 years old are still in perfect preservation. The wood weighs about 36 lb. per cu. ft. Numerous species of *Cedrela* occur in tropical America, Asia, and Africa, and are also commonly called cedar, but the wood has greater resemblance to mahogany. In the United States and Canada the name cedar is applied to woods of species of *Thuya, Juniperus,* and *Cupressus,* more properly classified as thuya, juniper, and cypress.

Spanish cedar, or Central American cedar, used in the United States as a substitute for mahogany in patternmaking, and for cigar boxes, furniture, carving, cabinetwork, and interior trim, is a soft wood from numerous species of *Cedrela,* called in Spanish America by the name of Cedro. It is of a light-red color sometimes beautifully figured with wavy grain, has an agreeable odor, is easily worked, seasons well, and takes a fine polish. The weight is 28 to 33 lb. per cu. ft. The trees grow to a large size, logs being available 40 in. square. The imports come chiefly from Central America and the West Indies, but the trees grow as far south as northern Argentina. Paraguayan cedar is the wood of the tree *C. brasiliensis,* of Paraguay, Brazil, and northern Argentina, employed locally for cabinetwork, car building, and interior building work. It is similar in appearance to Spanish cedar but is denser, harder, and redder in color. The wood known as Southern white cedar, and called juniper in the Carolinas, is from the tree *Chamaecyparis thyoides,* growing in the coastal belt from Maine to Florida. The heartwood is light brown tinged with pink, and the thin sapwood is lighter in color. The wood is light in weight, straight-grained, durable, and fragrant. The more plentiful White cedar of the West Coast, known also as Port Orford cedar, Oregon cedar, Ginger pine, and in England as Lawson cypress, is from the tree *Chamaecyparis lawsoniana* of California and Oregon, mostly from a narrow coastal strip in Oregon to an altitude of about 5,000 ft. Mature

trees reach a height of 160 ft. and a diameter of 6 ft. The wood is white with a yellow tinge and trace of red. It is rather hard, tough, with a fine straight grain, and is very durable. It has an agreeable aromatic odor, and is free from pitch. The wood is used for doors, sash, boats, matches, patterns, and where a light, strong, straight-grained wood is required.

**Cellulose.** The main constituent of the structure of plants, which, when extracted, is employed for making paper, plastics, and in many combinations. Chemically, cellulose is made up of long-chain molecules in which the complex unit $C_6H_{10}O_5$ is repeated as many as 2,000 times. Cellulose itself is a white amorphous powder insoluble in water, sodium hydroxide, or in alcohol, but dissolved by sulphuric acid. The highly refined insoluble cellulose with all the sugars, pectin, and other soluble matter removed is called Alpha cellulose. The simplest form of cellulose used industrially is Regenerated cellulose, in which the chemical composition of the finished product is similar to that of the original cellulose. It is made from wood or cotton pulp digested in a caustic solution to which carbon bisulphide or other chemical is added to digest the fibers. The viscous liquid is forced through a slit into an acid bath to form a thin sheet, which is then purified and bleached. Cellophane, of E. I. duPont de Nemours & Co., Inc., is a regenerated cellulose used in the form of thin sheets for wrapping. It is used transparent, or is dyed in colors or embossed. The thinnest sheets, 0.00088 in. in thickness, have 21,500 sq. in. per lb. The waterproofed material is coated with a thin film of cellulose nitrate lacquer. Barcote, of the Foote Mineral Co., is a nearly pure cellulose used in plastics or for carbonizing. It is a buff-colored, odorless powder or granular material with residual ash content of 1.6%. Some cellulose is obtained from potatoes as a by-product in the production of starch. It is pure white and is used in plastics.

The so-called Water-soluble cellulose used as a substitute for gum arabic and carob-bean flour as a stabilizer, thickener, or emulsifier, is Sodium cellulose glycollate in powder form. It is made by the action of monochloracetic acid on alkali cellulose. It is also used to increase the effectiveness of detergents. Collocel S, of the Dow Chemical Co., is this material. Collocel A is aluminum cellu-

lose glycollate, a water-insoluble brownish powder used for waterproofing paper.

Ethyl cellulose is a colorless, odorless ester of cellulose resulting from the reaction of ethyl chloride and cellulose. The specific gravity is 1.07 to 1.18. It is noninflammable, very flexible, stable to light, and forms durable alkali-resistant coatings. It is used as a thin wrapping material, for protective coatings, as a hardening agent in resins and waxes, and for molding plastics. Ethyl cellulose plastics are thermoplastic and are noted for their ease of molding, light weight, and good dielectric strength, 400 to 520 volts per mil. But they are softer and lower in strength than cellulose-acetate plastics. Lumarith EC, of the Celanese Plastics Corp., is ethyl cellulose in the form of sheets, films, foil, and molding powder. Celcon is a trade name applied by this company to its ethyl cellulose plastics.

Ethocel is ethyl cellulose of the Dow Chemical Co., and Stripcoat is a solution of ethyl cellulose used for dipping automotive and aircraft replacement parts or other metal products to form a thin, waterproof protective coating to prevent corrosion. The coating strips off easily when the part is to be used. The same material is marketed by a number of other companies for the same purpose under a variety of trade names. Methyl cellulose is a white, granular, flaky material, which is a strong emulsifying agent, and is used in soaps, floor waxes, shoe cleaners, in emulsions of starches, glues, waxes, and fats, and as a substitute for gum arabic in pharmaceuticals. It gives colorless, odorless solutions resistant to fermentation. It dissolves in cold water, but is stable to alkalies and dilute acids. In soaps it lowers the surface tension of the water and aids lathering. It is also used for tree-wound dressings, and as a moisture-conserving soil conditioner. Methocel is the trade name of the Dow Chemical Co. for this material. Colloresin, of the General Drug Co., is methyl cellulose used to replace natural gums in pharmaceuticals.

**Cellulose acetate.** An amber-colored, transparent material made by the reaction of cellulose with acetic acid or acetic anhydride in the presence of sulphuric acid. It is employed for lacquers and coatings, molding plastics, interlayers for shatterproof glass, rayon, and photographic film. Cellulose acetate may be the tri-

acetate, $C_6H_7O_2(OOCCH_3)_3$, but may be the tetracetate or the pentacetate, or mixtures. It is made in different degrees of acetylation with varying properties. Unlike nitrocellulose, it is not flammable, and it has better light and heat stability. It has a refractive index of 1.47 to 1.50, and a sheet ⅛ in. thick will transmit 90% of the light. The specific gravity is 1.27 to 1.37, hardness 8 to 15 Brinell, tensile strength 3,500 to 8,000 lb. per sq. in., compressive strength up to 20,000 lb. per sq. in., elongation 15 to 80%, dielectric strength 300 to 600 volts per mil, and softening point 122 to 205°F. It is thermoplastic, and is easily molded. The molded parts or sheets are tough, easily machined, and resistant to oils and to many chemicals. In coatings and lacquers the material is adhesive, tough, and resilient, and does not discolor easily. In fiber form for rayons it can be made in extremely fine filaments that are strong and flexible, noninflammable, mildewproof, and easily dyed. Standard cellulose acetate for molding is marketed in flake form. The high acetyl type of the Hercules Powder Co. contains 56 to 58.5% of combined acetic acid, and it makes plastics of high dimensional stability. Cellulose triacetate, with 60 to 61.5% of combined acetic acid, is more insoluble, has higher dielectric strength, and is more resistant to heat and light than other types. It is cast into sheets, and is also used for resistant coatings.

Lumarith is a cellulose acetate of the Celanese Plastics Corp. in the form of rods, sheets, tubes, and molding powder. Lumarith X is a high acetyl cellulose acetate for molding. The tensile strength is up to 8,000 lb. per sq. in., Brinell hardness up to 12.5, and dielectric strength up to 365 volts per mil. Vuelite, of the Monsanto Chemical Co., is transparent cellulose acetate for fluorescent light fixtures and for shatterproof glass. A heavily pigmented cellulose-acetate sheet is used in England for aircraft covering under the name of Rhodoid. Cellomold is a cellulose-acetate molding powder of F. A. Hughes & Co., Ltd. Tenite is a high-strength cellulose-acetate molding material of the Tennessee Eastman Corp. Protectoid is Lumarith in the form of noninflammable motion-picture film. Masuron, of John W. Masury & Son, Nixonite, of the Nixon Nitration Works, and Plastacele, of E. I. duPont de Nemours & Co., Inc., are cellulose-acetate materials. Acele, of the latter company, is a name for acetate yarns. Kodapak, of the Eastman Kodak Co.,

is a transparent cellulose-acetate sheet material for packaging. Celanese is the name of cellulose-acetate yarns and fabrics of the Celanese Corp. of America. Celairese, of this company, is a fluffy acetate fiber used for interlinings. Lanese is a fine fluffy acetate fiber used to blend with wool for blankets and rugs. Fortisan, of the same company, is a specially processed strong acetate fiber of extreme fineness, 0.0001 in. diameter, originally developed for parachutes but now also used for fine fabrics. Forticel, of this company, is a cellulose propionate plastic for injection molding. It has a flow point at 161°C., and has high impact resistance.

Cellulose-acetate lacquers are sold under many trade names. They are solutions of acetate in alcohols with plasticizers and pigments. Vimlite, of the Celanese Plastics Corp., is a window glazing made of cellulose acetate applied over wire mesh. As it transmits the ultraviolet rays of sunshine it is used for glazing greenhouses and farm buildings. It weathers well and has a bursting strength of 200 lb. per sq. in. Cellulose-acetate butyrate is made by the esterification of cellulose with acetic acid and butyric acid in the presence of a catalyst. It has the same appearance and approximately the same range of properties as cellulose acetate, but can be used with less plasticizers, has less water absorption, and is more stable to heat and light. It is particularly valued for coatings, insulating tapes, varnishes and lacquers, and electrical parts. Tenite II is this material. Hercose C, of the Hercules Powder Co., is cellulose-acetate butyrate used for cable coverings and airplane coatings. It is more soluble than cellulose acetate and more miscible with gums. It forms durable and flexible films.

**Cellulose nitrate plastics.** Materials made by treating cellulose with a mixture of nitric and sulphuric acids, washing free of acid, bleaching, stabilizing, and dehydrating. For sheets, rods, and tubes, it is mixed with plasticizers and pigments and rolled or drawn to the shape desired. The cellulose molecule will unite with from 1 to 6 molecules of nitric acid. The lower nitrates are very inflammable, but they do not explode like the higher nitrates, and they are the ones used for plastics, rayons, and lacquers. The names Cellulose nitrate and Pyroxylin are used for the compounds of lower nitration, and the term Nitrocellulose is used for the explosives. Col-

lodion is a name given to the original solution of cellulose nitrate in a mixture of 60% of ether and 40 alcohol for making fibers and film, and the name is still retained in pharmacy. The name Soluble cotton is used to designate batches of cellulose nitrate wet with alcohol for storing for the production of lacquers.

Cellulose nitrate was first used as a plastic in England in 1855 by Alexander Parkes under the name Parkesine. It consisted of nitrocellulose mixed with camphor and castor oil for hardening and making it nonexplosive. Later, in 1868, J. W. and J. S. Hyatt made an improved cellulose nitrate and camphor plastic under the name of Celluloid, which is now the trade name of the Celanese Plastics Corp. for cellulose nitrate plastics. Xylonite was the name used in England for the nitrocellulose hardened with camphor made by Daniel Spill in 1868. The name is still used by the British Xylonite Co. for cellulose nitrate plastics. Cellulose nitrate is the toughest of the thermoplastics. It has a specific gravity of 1.35 to 1.45, tensile strength of 6,000 to 7,500 lb. per sq. in., elongation 30 to 50%, compressive strength 20,000 to 30,000 lb. per sq. in., Brinell hardness 8 to 11, and dielectric strength 250 to 550 volts per mil. The softening point is 160°F., and it is easy to mold and easy to machine. It also is readily dyed to any color. It is not as light-stable as cellulose acetate, and is therefore no longer used for laminated glass. It is resistant to many chemicals, but has the disadvantage that it is inflammable. The molding is limited to pressing from flat shapes. It burns with a smoky flame, and the fumes are poisonous. Methyl or amyl alcohols are the usual solvents for the material, and various plasticizers are used, some of which aid in reducing the flammability. Camphor is the usual hardener and plasticizer, from 24 to 30% being the usual amount. Cellulose nitrate plastics in rod, sheet, and tube forms are marketed under trade names. Some of these are Pyralin and Viscoloid of E. I. duPont de Nemours & Co., Inc.; Nitron, of the Monsanto Chemical Co.; Nixonoid, of the Nixon Nitration Works; Amarith, of the Celanese Plastics Corp.; and Fiberloid, of the Fiberloid Corp. Cellulose nitrate lacquers, which are solutions with pigments and plasticizers, are quick drying on evaporation of the solvent, and they give good adhesive films that are tough, flexible, and resistant. They are sold under many trade names such as Duco, Zapon, and Arcozon.

**Cement.** A material, generally in powder form, that can be made into a paste usually by the addition of water and, when molded or poured, will set into a solid mass. Numerous organic compounds used for adhering, or fastening materials, are called cements, but these are classified as adhesives, and the term cement alone means a construction material. The best known and most widely used of the construction cements is Portland cement. It is a bluish-gray powder obtained by finely grinding the clinker made by heating strongly an intimate mixture of calcareous and argillaceous minerals. The chief raw material is a mixture of high-calcium limestone and clay or shale. The mixture should contain about 75% of calcium carbonate and the remainder largely aluminum silicate and free silica. Next in importance is the argillaceous limestone known as Cement rock, either alone or with high-calcium limestone. A mixture of blast-furnace slag and limestone is also used. The raw materials for portland cement are ground either wet or dry, and the clinker must be neither underburned nor overburned. The calcined cement contains from 25 to 60% of tricalcium silicate, from 7 to 44 dicalcium silicate, and about 10 tricalcium aluminate. Gypsum may be added to control the setting. The color of the cement is due chiefly to iron oxides. In the absence of impurities the color would be white, but neither the color nor the specific gravity is a test of quality. The specific gravity is at least 3.10. Good cement is always ground fine, with 98.5% passing a 200-mesh screen. Nonstaining cements are those free from perceptible amounts of iron oxide.

White cement is from pure calcite limestone, such as that found in eastern Pennsylvania. It is ground finer and used for a better class of work but the physical properties are similar to those of ordinary cement. The White cements of France and England are made from the chalky limestones, and have superior working qualities as they are usually ground finer. High-speed cement usually contains high percentages of alumina and lime and will harden rapidly, but is more costly than ordinary grades. Aluminate cement made from bauxite will reach a strength in 24 hr. equal to that of ordinary cement in 28 days, and is thus valuable for laying roads or bank walls. Aluminate cement contains about 40% of alumina, 40 lime, 15 iron oxide, and 5 silica and magnesia. Lumnite cement,

of the Atlas Lumnite Cement Co., is an aluminate cement. Intermediate lower cost cements, called Accelerated cements, that will set in about 3 days, are portland cement with a high percentage of lime. Portland cement is sold in 94-lb. cloth or paper bags of 1 cu. ft. capacity, 4 to the barrel.

Natural cement is made by calcining sandy limestone at a moderate red heat and grinding the porous clinker. This is the most ancient of the manufactured cements, and is still called Roman cement. It is low in cost and will set more quickly than portland cement, but is softer and weaker. When used for laying brick and stone it is called Masonry cement, but ordinary Mortar for laying brick is not this product but is slaked lime and sand. Cement mortar is a mixture of portland cement, sand, and water. It is much harder and more durable than lime mortars, but some lime may be added to make it spread more readily. It is also employed as a finish covering for walls of masonry, brick, or concrete. A mortar composed of 1 part of portland cement to 3 parts of sand will have a compressive strength after 1 day of 800 lb. per sq. in.; after 7 days, 2,750 lb. per sq. in.; and after 28 days, 3,100 lb. per sq. in. Oxychloride cement, or Sorel cement, is composed of Magnesium chloride, $MgCl_2$, and calcined magnesia. It is strong and hard, and, with various fillers it is used for floors and stucco. Magnesia cement, is Magnesium oxide, MgO, prepared by heating the chloride or carbonate to redness. When mixed with water it sets to a friable mass but of sufficient strength for covering steam pipes or furnaces. It is usually mixed with asbestos fibers to give strength and added heat resistance. The term 85% magnesia means 85% of magnesia cement and 15 asbestos fibers. The cement will withstand temperatures up to 600°F.

Keene's cement, also known as Flooring cement and Tiling plaster, is a Gypsum cement. It is made by burning gypsum at about 110°C. to plaster of paris, dipping the burned lumps in a solution of alum, drying, and then burning again at from 400 to 500°C. It is then ground to a fine powder, and should be white in color. Parian cement is similar, except that borax is used instead of alum. Martin's cement is made with potassium carbonate instead of alum. These cements are also called Hard-finish plaster, and they will set very hard and white. They are used for flooring and to imitate

tiling. An ancient natural cement is Pozzuolana cement. It is a volcanic material found near Pozzuoli, Italy, and in several other places in Europe. It is a volcanic lava modified by steam or gases so that it is powdery and has acquired hydraulic properties. The chief components are silica and alumina, and the color varies greatly, being white, yellow, brown, or black. It has been employed as a construction cement since ancient times. Trass is a similar material found in the Rhine district of Germany. Santorin is a light-gray volcanic ash with somewhat similar characteristics from the Greek island of Santorin. Artificial pozzuolana cements are made from highly siliceous minerals such as diatomite or pumicite, or the Slag cements made from granulated blast-furnace slag may be varieties of pozzuolana cement.

**Ceramic clays.** Clays used for making pottery, tiles, brick, and pipes, but more particularly the better grade of clays for pottery and molded articles not including the fireclays and fine porcelain clays. Clay is a general name for all earths that form a paste with water and harden when heated. The U.S. Department of Agriculture distinguishes clay as having small grains, less than 0.002 mm. in diameter, as distinct from Silt with grains from 0.002 to 0.05 mm. Most clays are composed chiefly of silica and alumina. Kaolins are the purest forms of clay. The clayey mineral in all clays is kaolinite, or minerals closely allied, as Anauxite, $Al_2O_3 \cdot 3SiO_2 \cdot 2H_2O$, and Montmorillonite, $Al_2O_3 \cdot 4SiO_2 \cdot 2H_2O$, the latter serving to increase the bond strength of ceramic clays. When the aluminum silicates are in colloidal form, the material is theoretically true clay, or Clayite. Some clays, however, derive much of their plasticity from colloids of organic material, and since all clays are of secondary origin from the weathering or decomposition of rocks, they may vary greatly in composition. Hardness of the clay depends upon the texture as well as on the cohesion of the particles. Plasticity involves the ability of the clay to be molded when wet, to retain its shape when dry, and to have the strength to withstand handling in the green or unfired condition. The degrees of plasticity are called fat, rich, rubbery, and waxy, or the clays may be termed very plastic, which is waxy, sticky plastic, medium plastic, and lean, which is nonplastic. Clays that require a large amount of

water for plasticity tend to warp when dried. Those that are not easily worked may be made plastic by alkaline starch solutions, ammonium alginate, organic plasticizers, or such materials as lignin. Clays with as much as 1% of iron burn red, and titanium increases this color. Yellow ochres contain iron as a free hydrate. Most clays contain quartz sand and sometimes powdered mica. Calcareous clays are known as Marls. Pyrites burn to holes in the brick bordered by a ring of magnetic oxide, and a good clay should be free of this mineral. Limestone grains in the clay burn to free lime which later slakes and splits the ceramic. Most of the common brick clays are complex mixed earths likely to have much undesirable matter that makes them unsuitable for good tile, pipe, or pottery. The Kingsley clay of Georgia, used for art ware, wall tile, dishes, and refractories, has only 0.4% of iron oxide, 0.15 $Na_2O$, 0.1 $K_2O$, and 0.05 CaO. It contains about 45% of silica, 40 alumina, and 1.15 titanium oxide.

In firing clays, the moisture is driven off when the temperature is raised from 100 to 150°C., and the chemically combined water is lost at 400 to 700°C. Incipient fusion ranges from 900 to 1200°C., at which point the fluxes begin to be viscous. Common brick is usually finished at this point. Above this temperature the pores are filled with vitreous semimolten material, and the ware will cool to a vitreous luster. Stoneware and paving brick are fired to this condition. At higher temperatures the clay body fuses. Clinker brick is fired to the fusion point. Bright and true colors are obtained when the wares are muffled during the firing to prevent oxidation of the impurities. Industrial stoneware is made from specially selected or blended clays to give desired properties, and these may be marketed under trade names. Ceratherm, of the United States Stoneware Co., is an acid-resistant and heat-shock-resistant ceramic produced from high-alumina clay. It is strong and nonporous and is used for pump and chemical equipment linings. The ceramic marketed under the name of Prestite by the Westinghouse Electric Corp. for insulators and molded electrical parts is blended of flint, feldspar, kaolin, and ball clay. It is nonporous and moistureproof without a glaze, has high dielectric strength, a tensile strength of 5,000 lb. per sq. in., and a compressive strength of 48,000 lb. per sq. in.

**Cerargyrite.** An ore of the metal silver, found in the upper zone of silver veins in Nevada, Colorado, Idaho, Peru, Chile, and Mexico. It is sometimes called Horn silver, owing to its hornlike appearance. It is a Silver chloride, AgCl, containing theoretically 75.3% of silver, with sometimes some mercury. The hardness is 2.3 and specific gravity 5.8. It is usually massive, resembling wax, with a pearl-gray color.

**Cerium metals.** A group of metallic elements that occur together and have been called Rare-earth metals, or Rare earths, because of the great difficulty of extracting them rather than because of their rarity. They include cerium, thorium, lanthanum, ytterbium, yttrium, praseodymium, and neodymium. Thorium is separated out by a relatively easy process, and the others remain grouped as the cerium metals, except as some are separated out in compounds for special uses. Cerium, symbol Ce, has an iron-gray color, is only slightly harder than lead, is malleable, has a specific gravity of 6.92, and melts at 623°C. The chief source of cerium is monazite sand. After extraction of the thorium oxide from the monazite the residual matter is reduced by converting the oxides to chlorides and then removing the metals by electrolysis. The product obtained is an alloy containing about 50% of cerium together with lanthanum, didymium, and the other rare metals. It is usually called Misch metal, the German name for mixed metal, and its original use was for making the Pyrophoric alloy, or Sparking metal, known as Auer metal. Auer metal, patented by Auer von Welsbach in 1903, is an alloy of 35% of iron and 65 misch metal, which makes sparks when struck with steel. It is used for gas and cigarette lighters. The French Kunheim metal contained 10% of magnesium and 1% aluminum instead of iron. Cerium standard alloy of the Cerium Metals Corp. is a type of misch metal containing 45 to 50% of cerium, 22 to 25 lanthanum, 15 to 17 neodymium, and the balance a mixture of yttrium, terbium, and other rare-earth metals with not more than 0.5% iron. It is used for making aluminum-cerium alloys. Cerium is also used for removing gases from radio tubes, and in electric-arc carbons to give a bluish-white light. In the form of cerium alloy, or misch metal, it is used as a scavenger in melting cast iron and steel.

It removes the sulphur and the oxides and completely degasifies steel. In stainless steel it is used as a precipitation hardening agent.

Ceria, or Ceric oxide, $CeO_2$, is a pale-yellow heavy powder of specific gravity 7.65, used in coloring ceramics and glass. Cerious oxide, $Ce_2O_3$, is a greenish powder of specific gravity 7.0, and refractive index 2.19. It absorbs ultraviolet light, and is an excellent opacifier for ceramics. It is also used in glasses for scientific lenses. Cerious nitrate, $Ce(NO_3)_3 \cdot 6H_2O$, is a red crystalline powder used in gas mantle manufacture. Cerium salts are used for coloring glass. Ceric titanate gives a golden-yellow color, and Ceric molybdate gives a blue color. Neodymium is used in some glasses to reduce glare. Praseodymium, together with neodymium, is used under the name of Didymium. The mixture gives glass a neutral gray color. Lanthanum, symbol La, is a white metal, malleable and ductile, with a specific gravity of 6.15 and a melting point of 810°C. Like the other rare-earth metals, it oxidizes easily in the air and is easily soluble in acids. It can be separated out by electrolysis, but has no separate uses as a metal. Lanthanum oxide, $La_2O_3$, is a white powder used in gas mantles and for absorbing gases in vacuum tubes. Ytterbium, symbol Yb, is obtained only in the form of its salts. Yttrium, symbol Yt, is obtained as a metal only with great difficulty. It is a dark-gray powder with a specific gravity of 3.8, melting at 1250°C. It decomposes water. These two metals were discovered first in the mineral Gadolinite with other earth metals, but this mineral is too rare for commercial production, or for separation of the metals Gadolinium, Terbium, and Europium which occur in it.

**Cesium.** Also spelled Caesium. A rare metal, symbol Cs, obtained from the mineral Pollucite, $2CsO \cdot 2Al_2O_3 \cdot 9SiO_2 \cdot H_2O$. The metal resembles rubidium and potassium, is silvery white and very soft. It oxidizes easily in the air and ignites at ordinary temperatures. It decomposes water with explosive violence. It can be kept only in a vacuum. The specific gravity is 1.903, melting point 28.5°C., and boiling point 670°C. It is used in low-voltage tubes to scavenge the last traces of air, but its chief use is in radio tubes. The cesium, in the form of Cesium chloride, CsCl, is used on the filament to increase sensitivity. It interacts with the tho-

rium of the filament to produce positive ions. In photoelectric cells cesium chloride is used for a photosensitive deposit on the cathode. All metals emit electrons when struck with ultraviolet light, but cesium releases electrons under the action of ordinary visible light, and its color sensitivity is higher than that of other alkali metals.

**Chalk.** A fine-grained limestone, or a soft, earthy form of Calcium carbonate, $CaCO_3$, composed of finely pulverized marine shells. The natural chalk comes largely from the southern coast of England and the north of France, but high-calcium marbles and limestones are the sources of most of the American chalk and precipitated calcium carbonate. Chalk is employed in putty, crayons, paints, rubber goods, linoleum, calcimine, and as a mild abrasive in polishes. Whiting and Paris white are names given to grades of chalk that have been ground and washed for use in paints, inks, and putty. French chalk is a high grade of massive talc cut to shape and used for marking. The color of chalk should be white, but it may be colored gray or yellowish by impurities. The commercial grades depend on the purity, color, and fineness of the grains. The specific gravity may be as low as 1.8. Finely ground calcium carbonate is marketed under trade names. Limeolith is precipitated calcium carbonate of the Kansas City Limeolith Co., used for paints, rubber, glass, and cosmetics. Suspenso, of the Diamond Alkali Co., is a very white, grit-free precipitated calcium carbonate for paints. Calcene, of the Columbia Chemical Div., Pittsburgh Plate Glass Co., is a precipitated calcium carbonate of fine particle size used as a pigment and to add strength and tear resistance to rubber. Kalvan, of R. T. Vanderbilt Co., Inc., is a similar material.

**Chamois.** A soft, pliable leather originally made from the skins of the chamois, *Antilopa rupicapra,* a small deer inhabiting the mountains of Europe but now nearly extinct. The leather was of a light-tan color, with a soft nap. All commercial chamois is now made from the skins of lamb, sheep, goat, or from the thin portion of split hides. The Federal Trade Commission limited the use of the term chamois to oil-dressed sheepskins mechanically suèded, but there are no technical precedents for such limitation.

The original Artificial chamois was made by tanning sheepskins with formaldehyde or alum, impregnating with oils, and subjecting to mechanical suèding, but chamois is also made by various special tannages with or without suèding. Those treated with fish oils have a distinctive feel. Chamois leather will withstand soaking in hot water and will not harden on drying. It is used for polishing glass and plated metals. Buckskin, a similar pliable leather, but heavier and harder, was originally soft-tanned, oil-treated deerskin, but is now more frequently made from goatskins.

**Charcoal.** An amorphous form of carbon, made by enclosing billets in a retort and exposing them to a red heat for 4 or 5 hr. It is also made by covering large heaps of wood with earth, and permitting them to burn slowly for about a month. Much charcoal is now produced as a by-product in the distillation of wood, a retort charge of 10 cords of wood yielding an average of 2,650 gal. of pyroligneous liquor, 11,000 lb. of gas, and 6 tons of charcoal. Wood charcoal is used as a fuel, for making black gunpowder, for carbonizing steel, and for making activated charcoal for filtering and absorbent purposes. Gunpowder charcoal is made from alder, willow, or hazel wood. Commercial wood charcoal is usually about 25% of the original weight of the wood, and is not pure carbon. The average composition is 95% of carbon and 3 ash. It is an excellent fuel, burning with a glow at low temperatures, and with a pale-blue flame at high temperatures. In the early days it was much used in blast furnaces for melting iron, and it produces a superior iron with less sulphur and phosphorus than when coke is used. Red charcoal is an impure charcoal made at a low temperature, and retaining much oxygen and hydrogen. Charklets is a name for briquettes of charcoal made with a binder and used as a fuel.

**Charcoal iron.** Originally, all iron was made with charcoal, but because of the relative scarcity of wood and the greater expense charcoal is now used in the blast furnace instead of coke to produce iron only for special purposes. It has less phosphorus and sulphur than ordinary pig iron. Cast iron made from charcoal iron has a dense structure and has a tendency to chill. It is used for such purposes as car wheels and magnet cores. Charcoal pig

iron is also used for making high-grade steel for boiler tubes. Charcoal iron is marketed in various grades from 3.25% of graphitic carbon and 0.37 combined carbon, to 3.5% combined carbon. Elverite, of the Fuller Lehigh Co., is a charcoal type of cast iron, which gives a hard chill leaving a soft, gray-iron core. Stora is the trade name of Swedish charcoal iron in small notched pigs, used for making malleable iron.

**Chaulmoogra oil.** A brownish semisolid oil from the seeds of the fruit of the tree *Taraktogenos kurzii* and other species of Siam, Assam, and the East Indies. It is used chiefly for skin diseases and for leprosy. A similar oil is also obtained from other genera of bushes and trees of the family *Flacourtiaceae,* and that obtained from some species of *Hydnocarpus* is superior to the true chaulmoogra oil. The tree *H. anthelminthica,* native to Siam, is cultivated in Hawaii. This oil consists mainly of chaulmoogric and hydnocarpic acids. Sapucainha oil, from the seeds of the tree *Carpotroche brasiliensis,* of the Amazon Valley, contains chaulmoogric, hydnocarpic, and gorlic acids, and is a superior oil. Gorliseed oil, from the seeds of the tree *Oncoba echinata* of tropical Africa, and cultivated in Costa Rica and Puerto Rico, contains about 80% of chaulmoogric acid and 10 gorlic acid. Dilo oil is from the kernels of the nuts of the tree *Calophyllum inophyllum* of the South Sea Islands. In Tahiti it is called Tamanu.

**Cheesecloth.** A thin, coarse-woven cotton fabric of plain weave, 40 to 32 count, and of coarse yarns. It was originally used for wrapping cheese, but is now employed for wrapping, lining, interlining, filtering, as a polishing cloth, and as a backing for lining and wrapping papers. The cloth is not sized, and may be either bleached or unbleached. It comes usually 36 in. in width. The grade known as Beef cloth, originally used for wrapping meats, is also the preferred grade for polishing enameled parts. It is made of No. 22 yarn or finer. For covering meats the packing plants now use a heavily napped knitted fabric known as Stockinett. It is made either as a flat fabric or in seamless tube form, and is also used for covering inking and oiling rolls in machinery. Lighter grades of cheesecloth, with very open weave, known as Gauze, are used for surgical dressings, and for backings

for paper and maps. Baling paper is made by coating cheesecloth with asphalt and pasting to one side of heavy kraft or Manila paper. Cable paper, for wrapping cables, is sometimes made in the same manner but with insulating varnish instead of asphalt.

**Chemical indicators.** Dyestuffs that have one color in acid solutions and a different color in basic or alkaline solutions. They are used to indicate the relative acidity of chemical solutions, as the different materials have different ranges of action on the acidity scale. The materials are mostly weak acids, but some are weak bases. Some are natural dyestuffs, but most are coal-tar derivatives. The best known is litmus, which is red below a pH of 4.5, and blue above a pH of 8.3. It is used to test strong acids or alkalies. Alkanet is another natural dyestuff indicator. Some of the coal-tar indicators are: Malachite green, which is yellow below a pH of 0.5 and green above 1.5; Phenolphthalein, which is colorless below a pH of 8.3 and magenta above 10.0; and Methyl red, which is red below 4.4 and yellow above 6.0. A Universal indicator is a mixture of a number of indicators that gives the whole range of color changes, thereby indicating the entire pH range. But such indicators must be compared with a standard to determine the pH value.

The change in color is caused by just a slight rearrangement of the atoms of the molecule. Some of the indicators, such as Thymol blue, exhibit two color changes at different acidity ranges because of the presence of more than one chromophore arrangement of atoms. These can thus be used to indicate two separate ranges on the pH scale. Test papers are strips of absorbent paper that have been saturated with an indicator and dried. They are used for testing for acidic or basic solutions, and not for accurate determination of acidity range or hydrogen-ion concentration such as is possible with direct use of the indicators. Common test papers are litmus, congo red, sulphide, and starch-iodide.

**Cherry.** The wood of several species of cherry trees native to Europe and the United States. It is brownish to light red in color, darkening on exposure, and has a close, even grain. The weight is about 40 lb. per cu. ft. It retains its shape well, and takes a fine polish. The annual cut of commercial cherry wood is small, but

it is valued for instrument cases, patterns, electrotype blocks, paneling, and cabinetwork. The American cherry is mostly from the tree *Prunus serotina,* known as the Black cherry, although some is from the tree *P. emarginata.* The black cherry wood formerly used for airplane propellers has a specific gravity of 0.53 when oven-dried, compressive strength perpendicular to the grain 1,170 lb. per sq. in., and shearing strength parallel to the grain 1,180 lb. per sq. in. This tree is found only thinly scattered through the eastern part of the United States. The wood is light to dark reddish with a beautiful luster and silky sheen, but has less figure than mahogany. English cherry is from the trees *P. cerasus* and *p. avium.*

**Chestnut.** The wood of the tree *Castanea dentata,* once growing plentifully along the Appalachian Range from New Hampshire to Georgia, but now very scarce. Several other species of *Castanea* native to Europe also furnish a similar wood. All of the trees grow to a large size, but the wood is inferior to oak in strength though similar in appearance. It is more brittle than oak, has a coarse, open grain often of spiral growth, and splits easily in nailing. The color is light brown or yellowish. It is used for posts, crossties, veneers, and some mill products. Chestnut wood contains from 6 to 20% of tannin, which is obtained by soaking the chipped wood in water and evaporating. Chestnut extract is valued for tanning leather, giving a light-colored strong leather. The seed nuts of all varieties of chestnut are used for food and are eaten fresh, boiled, or roasted. The Horse chestnut is a smaller tree, *Aesculus hippocastanum,* grown as a shade tree in Europe and the United States. The nut is round and larger than the chestnut. It is bitter in taste, but is rich in fats and starch and, when the saponin is removed, it produces an edible meal with an almondlike flavor used in confections in Europe.

**Chia-seed oil.** A clear amber-colored oil extracted from the seeds of the plant *Salvia hispanica* of Mexico, and used as a drying oil for paints and varnishes. It has a higher drying value than linseed oil. The seeds yield about 30% of oil, which contains 39% of linolenic acid, 45 linoleic, 5 palmitic, 2.7 stearic, with some arachidic, oleic, and myristic acids. The specific gravity is 0.936,

iodine value 192, and acid value 1.4. The seeds scatter easily from the pods and are difficult to collect.

**Chicle.** The coagulated latex obtained from incisions in the trunk of the evergreen tree *Achras zapota* and some other species of southern Mexico, Guatemala, and Honduras. The crude chicle is in reddish-brown pieces, and may have up to 40% impurities. The purified and neutralized gum is an amorphous white to pinkish powder insoluble in water, which forms a sticky mass when heated. The commercial purified gum is molded into blocks of 10 to 12 kilos for shipment. It contains about 40% of resin, 17 rubber, and about 17 of sugars and starches. Under the name of Txixtle the coagulated latex was mixed with asphalt and used as a chewing gum by the Aztec Indians, and this custom of chewing gum was widely adopted in the United States. More than 15 million pounds of chicle are produced annually and used chiefly as a base for chewing gum, sometimes mixed with jelutong.

**Chloride of lime.** A white powder, a Calcium chloride hypochlorite, of the composition $CaCl(OCl)$, having a strong chlorine odor. It decomposes easily in water, and is used as a source of chlorine for cleaning and bleaching. It is produced by passing chlorine gas through slaked lime. Chloride of lime, or Chlorinated lime, is also known as Bleaching powder, although commercial bleaching powder may also be a mixture of calcium chloride and calcium hypochlorite. Perchloron, of the Pennsylvania Salt Mfg. Co., is Calcium hypochlorite.

**Chlorinated hydrocarbons.** A large group of materials used as solvents for oils and fats, for metal degreasing, dry cleaning of textiles, as refrigerants, in insecticides, and in fire extinguishers. They are hydrocarbons in which hydrogen atoms were replaced by chlorine atoms. They range from the gaseous methyl chloride to the solid Hexachloro ethane, $CCl_3CCl_3$, with most of them liquid. The increase in the number of chlorine atoms increases the specific gravity, boiling point, and some other properties. They may be divided into four groups: the methane group, including methyl chloride, chloroform, and carbon tetrachloride; the ethylene group, including dichlorethylene; the ethane group, including ethyl chlo-

ride and dichlorethane; and the propane group. All of these are toxic, and the fumes are injurious when breathed or absorbed through the skin. Some decompose in light and heat to form more toxic compounds. Some are very inflammable, while others do not support combustion. In general, they are corrosive to metals, and in their use as refrigerants or in solvent baths the metal equipment must be of corrosion-resistant alloys.

Chloroform, or Trichloromethane, is a liquid of the composition $CHCl_3$, boiling point 61.2°C., and specific gravity 1.489, used industrially as a solvent for greases and resins, and in medicine as an anesthetic. It decomposes easily in the presence of light to form phosgene, and a small amount of ethyl alcohol is added to prevent decomposition. Ethyl chloride, also known as Monochlorethane, Kelene, and Chelene, is a gas of the composition $CH_3CH_2Cl$, used in making ethyl fluid for gasoline, as a local anesthetic in dentistry, as a catalyst in rubber and plastics processing, and as a refrigerant in household refrigerators. It is marketed compressed into cylinders as a colorless liquid. The specific gravity is 0.921, freezing point −140.8°C., and boiling point 12.5°C. The condensing pressure in refrigerators is 12.4 lb. at 6°F., and the pressure of vaporization is 10.1 lb. at 5°F. Its disadvantage as a refrigerant is that it is highly inflammable, and there is no simple test for leaks. Methyl chloride is a gas of the composition $CH_3Cl$, which is compressed into cylinders as a colorless liquid of boiling point −10.65°F., and freezing point −144°F. Methyl chloride is one of the simplest and cheapest chemicals for methylation. In water solution it is a good solvent. It is also used as a catalyst in rubber processing, as a restraining gas in high-heat thermometers, and as a refrigerant. For refrigeration, the condensing pressure used is 80.8 lb. at 86°F., and the pressure of vaporization is 6.2 lb. at 5°F.

**Chlorinated rubber.** An ivory-colored or white powder produced by the reaction of chlorine and rubber. It contains about 65% by weight of rubber, and is represented by the empirical formula $(C_{10}H_{13}Cl_7)_x$. Rubber was first chlorinated in 1846 to improve its aging qualities, but was not marketed until about 75 years later. The first commercial chlorinated rubber was the Duroprene of the United States Alkali Co. Chlorinated rubber is used

in acid-resistant and corrosion-resistant paints, in adhesives, and in plastics. The uncompounded film is brittle, and for paints the material is plasticized with gums and synthetics to produce a hard, tough, adhesive coating, resistant to oils, acids, and alkalies. The specific gravity of chlorinated rubber is 1.64, and bulking value 0.0735 gal. per lb. The tensile strength of the film is 4,500 lb. per sq. in. It is soluble in hydrocarbons, carbon tetrachloride, and in esters, but insoluble in water. The unplasticized material has a high dielectric strength, up to 2,300 volts per mil. Tornesit and Parlon are chlorinated rubbers of the Hercules Powder Co. Paratex, of the Truscon Laboratories, and Roxaprene, of the Roxalin Flexible Lacquer Co., Inc., are chlorinated-rubber coating materials. Pliofilm, of the Goodyear Tire & Rubber Co., is a rubber hydrochloride made by saturating the rubber molecule with hydrochloric acid. It is made into transparent sheet wrapping material which heat-seals at 105 to 130°C., or is used as a coating material for fabrics and paper. It gives a tough, flexible, water-resistant film. Pliolite, of this company, is a cyclized rubber made by highly chlorinating the rubber. It is used in insulating compounds, adhesives, protective paints, and as a waterproofing agent. It is soluble in hydrocarbons, but is resistant to acids and alkalies. Pliowax is this material compounded with paraffin or ceresin wax. Pliolite S-1 is this material made from synthetic rubber, and makes a highly resistant coating material. Tensolite, of the Tensolite Corp., used to make filaments for filter cloth and braided goods, is a chlorinated natural rubber. Dartex and Alloprene are German chlorinated rubbers. Cyclized rubber is normally made by heating rubber with sulphonyl chloride or with Chlorostannic acid, $H_2SnCl_6 \cdot 6H_2O$. It contains a minimum of 92% of rubber hydrocarbons, and the rubber molecule is more saturated than in natural rubber. The material is thermoplastic somewhat similar to gutta-percha or balata, and makes an excellent adhesive. Cyclized rubber has a specific gravity of 1.06, softening point 80 to 100°C., molding temperature 125 to 155°C., tensile strength 4,000 to 4,500 lb. per sq. in., flexural strength up to 9,000 lb. per sq. in., and very low water absorption. It is used in adhesives for bonding rubber to metals, as a stiffening agent for rubber in wire insulation, and for waterproofing paper.

**Chlorine.** An elementary material, symbol Cl, which at ordinary temperatures is a gas, $Cl_2$, but which is marketed in pressure cylinders as a liquid. Its name comes from its greenish-yellow color. It occurs in nature in great abundance in combinations, in such compounds as common salt. It has a powerful suffocating odor, and is strongly corrosive to organic tissues and to metals. During the First World War it was used as a poison gas under the name of Bertholite. An important use for liquid chlorine is for bleaching textiles and paper pulp, but it is also used for the manufacture of many chemicals. For bleaching, it is also widely employed in the form of compounds easily broken up. Chlorine dioxide, $ClO_2$, for example, is a reddish-yellow gas which is more than twice as effective as a bleach than chlorine, but it is unstable and must be made just before use from chlorine and sodium chlorite. Dry chlorine may be used for detinning steel, and the recovered product, Tin tetrachloride, is used for weighting silk. Chlorine may be made by the electrolysis of common salt. The specific gravity of the gas is 1.408, or 2.491 times heavier than air. The boiling point is −33.6°C., and the gas becomes liquid at atmospheric pressure at a temperature of −24.48°F. The liquid chlorine is shipped in steel cylinders of 10- to 150-lb. capacity. The vapor pressure ranges from 39.4 lb. at 0°C. to 602.4 lb. at 100°C. The gas is an irritant and not a cumulative poison, but breathing large amounts destroys the tissues.

**Chrome-molybdenum steel.** Any alloy steel containing chromium and molybdenum as the predominating alloying elements. Chromium gives hardness and toughness to the steel, while molybdenum improves the forging and machining properties and increases the strength. Chrome-molybdenum steels are noted for high strength and toughness. Only small amounts of alloying elements are used in the standard steels. A chrome-molybdenum steel used in the form of airplane tubing contains 0.80 to 1.10% of chromium, 0.15 to 0.25 molybdenum, 0.40 to 0.60 manganese, and 0.25 to 0.35 carbon. It has a tensile strength of 95,000 lb. per sq. in., min., with elongation of 10%, and is slightly air-hardening. It draws well, and tubes with a wall thickness of only 0.035 in. are made. Molybdenum adds red hardness to steel

to a greater degree than tungsten, and the amounts used in these steels is sufficient to make them slightly red-hard and air-hardening. S.A.E. steel 4140, which has the same composition as the airplane tubing but with 0.40% carbon, has a tensile strength up to 260,000 lb. per sq. in., elongation 8%, and Brinell hardness 490 when oil-quenched and drawn. The chrome-molybdenum steels marketed by the Crucible Steel Co. under the name of Almo steel for airplane, automotive, and ordnance work, have tensile strengths up to 167,000 lb. per sq. in., with elongation of 18%. A steel used for superheater tubes at 900 lb. pressure and 925°F., contains 5% of chromium and 0.50 molybdenum. Chrome-molybdenum steels, with high carbon, have great resistance to wear at high heat, and are used for die blocks for forging. Cromo steel, of the Michigan Steel Casting Co., is a cast steel with a tensile strength of 100,000 lb. per sq. in. and elongation 15 to 25%, used for large die blocks. Albor die steel, of Wm. Jessop & Sons, Inc., used for dies for stamping hard metals, contains 0.90% of chromium, 0.30 molybdenum, and 0.90 carbon. It is tough and deep hardening. Atlas No. 93, of the Allegheny Ludlum Steel Corp., is a shock-resistant steel with 0.65% chromium, 0.35 molybdenum, and 0.55 carbon. Chrome-molybdenum steels with carbon to 1% are used for castings for bucket lips, crusher parts, and other heavy-duty parts. They have tensile strengths up to 150,000 lb. per sq. in., with elongation of 12 to 14%.

**Chrome oxide green.** A pigment marketed in the forms of dry powder or ground in oil, used in paints and lacquers and for coloring rubber. It is a bright-green, crystalline powder of the composition $Cr_2O_3$, with specific gravity 5.20 and melting point 1990°C., insoluble in water. The dry powder has a $Cr_2O_3$ content of 97% min., and is 325 mesh. The paste contains 85% pigment and 15 linseed oil. Chrome oxide green is not as bright in color as Chrome green but is more permanent. Chrome green is a mixture of Prussian blue and chrome yellow.

**Chrome-vanadium steel.** A chromium alloy steel containing a small amount of vanadium which has the effect of intensifying the action of the chromium and the manganese in the steel. It also aids in the formation of carbides, hardening the alloy, and also

increasing the ductility by the deoxidizing effect. The amount of vanadium is usually 0.15 to 0.25%. These steels are valued where a combination of strength and ductility is desired. They resemble those with chromium alone, with the advantage of the homogenizing influence of the vanadium. A chrome-vanadium steel having 0.92% chromium, 0.20 vanadium, and 0.25 carbon has a tensile strength of 100,000 lb. per sq. in., and when heat-treated has a strength up to 150,000 lb. per sq. in. and elongation of 16%. Chrome-vanadium steels are used for such parts as crankshafts, propeller shafts, and locomotive frames. High-carbon chrome-vanadium steels are the mild-alloy tool steels of high strength, toughness, and fatigue resistance. The chromium content is usually about 0.80%, with 0.20 vanadium, and with carbon up to 1%. Arrow steel, of the Latrobe Electric Steel Co., contains 0.90 to 1% of chromium, 0.16 to 0.20 vanadium, 0.50 to 0.60 manganese, and 0.20 to 0.30 carbon. It is used for shafts, gears, and stressed parts. Crown steel, of the same company, has higher manganese and up to 0.50 carbon, both elements making it more deep-hardening. It is used for automotive springs, gears, crankpins, and tools. The tensile strength is 185,000 lb. per sq. in., and elongation 15%. Milwaloy, of the Milwaukee Steel Foundry Co., is a casting steel. Grade 7 contains 1.5 to 1.75% of chromium, 0.60 to 0.70 vanadium, and 0.30 to 0.50 carbon. It is used for high-strength parts. Many high-alloy steels also contain some vanadium, but where the vanadium is used as a cleansing and toughening element and not to give the chief characteristics to the steel these alloys are not classed as chrome-vanadium steel. H.Y.C.C. steel of the Crucible Steel Co., for example, is an oil-hardening steel of high wear resistance containing 12% of chromium and 2.25 carbon with 0.25 vanadium. It is a hard, deep-hardening steel for dies.

**Chromic acid.** A name given to the red, crystalline, strongly acid material of the composition $CrO_3$ known also as Chromium trioxide or as Chromium anhydride. It is in reality not the acid until dissolved in water forming a true chromic acid of the composition $H_2CrO_4$. It is marketed in the form of porous lumps. The specific gravity is 2.70, melting point 196°C. It is produced by treating sodium or potassium dichromate with sulphuric acid. The

dust is irritating, and the fumes of the solutions are injurious to the nose and throat as the acid is a powerful oxidizing agent. Chromic trioxide is used in chromium-plating baths, for etching copper, in electric batteries, and in tanning leather.

**Chromite.** An ore of the metal chromium, called Chrome ore when used as a refractory. It is found in the United States, chiefly in California and Oregon, but most of the world production is in South Africa, Rhodesia, Cuba, Turkey, Philippines, Cuba, Greece, and New Caledonia. The theoretical composition is $FeO \cdot Cr_2O_3$, with 68% chromic oxide, but pure Iron chromate is rare. Part of the iron may be replaced by magnesium, and part of the chromium by aluminum. The silica present in the ore, however, is not a part of the molecule. Chromite is commonly massive granular, and the commercial ores contain only from 35 to 60% of chromic oxide. The hardness is 5.5 and the specific gravity 4.6. The color is iron black to brownish black, with a metallic luster. The melting point is about 3900°F., but when mixed with binders as a refractory the fusion point is lowered. New Caledonia ore has 50% chromic oxide, Turkish ore averages 48 to 53%, Brazilian ore runs 46 to 48%, and Cuban ore averages only 35%. Most of the domestic ore in the United States is low grade.

Cuban ore is rich in Spinel, $MgO \cdot Al_2O_3$, and deficient in magnetite, and this type is adapted for refractory use even when the chromic oxide is low. The Indian ore from Baluchistan is also valued for refractory use, as are other hard lumpy ores high in $Al_2O_3$ and low in iron. For chemical use the ores should have more than 45% of chromic oxide, not more than 8% silica, and be low in sulphur. Metallurgical ore should have not less than 48% of chromic oxide, and the ratio of chromium to iron should not be less than 3 : 1. Chromite is used for the production of chromium, ferrochromium, in making Chromite bricks and refractory linings for furnaces, and for the production of chromium salts and chemicals. For bricks the ground chromite is mixed with lime and clay and burned. Chromite refractories are neutral and are resistant to slag attack. A chrome-ore high-temperature cement marketed by the General Refractories Co. under the name of Grefco has a fusion point of 3400°F.

**Chromium.** An elementary metal, symbol Cr, used in stainless steels, heat-resistant alloys, high-strength alloy steels, for wear-resistant electroplating, and in its compounds for pigments, chemicals, and refractories. The specific gravity is 6.92, melting point 2750°F., and boiling point 3992°F. The color is silvery white with a bluish tinge. It is an extremely hard metal, the electrodeposited plates having a hardness of 9 Moh. It is resistant to oxidation, is inert to nitric acid, but dissolves in hydrochloric acid and slowly in sulphuric acid. Chromium occurs in nature only in combination. Its chief ore is chromite, from which it is obtained by reduction and electrolysis. It is marketed for use principally in the form of master alloys with iron or copper. The term Chromium metal usually indicates a pure grade of chromium containing 97 to 98% of chromium and not more than 1 iron and 0.50 carbon. Chromium metal is used for making special alloys, particularly resistance metals, or for chemical use in which case it is marketed as a powder of 250 and 300 mesh. Chromium plating is widely used where extreme hardness or resistance to corrosion is required. When plated on a highly polished metal, it gives a smooth surface that has no capillary attraction to water or oil, and chromium-plated bearing surfaces can be run without oil. Chromium plating is sometimes given trade names such as Aranium of Manning, Bowman & Co. For decorative purposes chromium plates as thin as 0.0002 in. may be used; for wear resistance, plates up to 0.50 in. are used.

**Chromium cast iron.** Cast iron containing chromium as the chief alloying element. It is used where hardness and high strength are required. Chromium in cast iron is a carbide-forming element. The free carbides begin to form in the iron at about 0.60% chromium. Small amounts of chromium refine the graphite structure but, at about 1% chromium content, the cementite builds up rapidly. At about 3% chromium, the graphite disappears and the matrix consists of oriented cementite. At 5% chromium, there is much massive carbide in the structure. Chromium also prevents the decomposition of iron silicide, and unless modified with other alloying elements the iron may reach a hardness of 700 Brinell. Usually, nickel is used in combination with chromium to balance the chro-

mium by acting as a graphitizer and preventing the formation of hard carbide spots. The proportion of nickel to chromium is generally about 3 to 1. Ni-Hard, of the International Nickel Co., is a chromium-nickel white iron containing 4 to 6% of nickel and 1 to 1.25 chromium. It is tough, and when chilled has a surface hardness up to 700 Brinell. For greater wear resistance it may contain manganese up to 1.5%. Sometimes very high carbon is used in these irons for wear resistance. Flintmetal, of the Taylor-Wharton Iron & Steel Co., contains 4 to 4.5% of nickel, 1.25 to 1.75 chromium, and 3 to 3.5 carbon. It has a Brinell hardness of 600. Chromium cast irons are used for automotive body dies, rolls, and various wear-resistant castings, but most of them are high in nickel and are classified with the nickel-chromium irons.

**Chromium copper.** A name applied to master alloys of copper with chromium used in the foundry for introducing chromium into nonferrous alloys, or to Copper-chromium alloys, or Chrome copper, which are high-copper alloys containing a small amount of chromium with or without other alloying elements. When they also contain tin, silicon, or iron, they may be referred to as Chromium bronze. A chromium-copper master alloy marketed under the name of Electromet chromium copper by the Electro Metallurgical Sales Corp. contains 8 to 11% of chromium, 88 to 90 copper, and a maximum of 1 iron and 0.50 silicon. Chrome copper in wrought form has high impact strength, and the electrical conductivity is higher than when the copper is hardened with silicon. Chrome copper with 0.50% of chromium has a thermal conductivity about 85% that of high-conductivity copper, which is about twice that of aluminum alloy, or seven times that of cast iron. Such alloys are used for cylinder heads. A wrought chrome copper of the American Brass Co. contains 0.85% of chromium and 0.10 silicon, and has a tensile strength of 92,000 lb. per sq. in. with elongation of 3%. Chromium bronze, used for bearings, is a cast metal containing 1% of chromium, 1 iron, and from 2 to 10 tin. It has high strength and good wearing qualities.

**Chromium-nickel steel.** This name usually applies to a group of corrosion-resistant alloys, or Austenitic steels, containing about 18% of chromium and 8 nickel, as distinct from the high-strength,

nickel-chromium steels with only small amounts of chromium, and from the heat-resistant, nickel-chromium-iron alloys containing high percentages of chromium. The patents for the 18-8 steels are held by the Chemical Foundation, and the steels are usually marketed under trade names. Chromium-nickel steels are ductile and malleable. With low carbon they can be drawn and cupped, although they harden rapidly with cold work and must be annealed after each draw or the steel tends to crack. About three times the power is required to draw an 18-8 steel as is needed for an ordinary steel of the same carbon content. The steels are corrosion-resistant and also resistant to most acids. The strengths range from 75,000 to 140,000 lb. per sq. in., with elongations of 30 to 65%. The weight is 0.279 to 0.287 lb. per cu. in. When polished, they have a brilliant luster which does not dull on exposure, and they are referred to as stainless steels. Those with low carbon are more corrosion-resistant than those with higher carbon, and they are used for chemical and food equipment. Defistain, of the Rustless Iron Corp., is an 18-8 steel with low carbon. Enduro 18-8, of the Republic Steel Co., has 0.08 to 0.20% carbon. The tensile strength is 85,000 lb. per sq. in. and elongation 55%. Carpenter stainless No. 8, of the Carpenter Steel Co., is an 18-8 type of steel with 0.10 carbon and having 0.25% selenium to make it free-machining. Super stainless steel is a name given in England by Hadfield to the 18-8 steels to distinguish them from the standard 13% chromium stainless steels. The original Krupp austenitic, or KA steel, had 20% chromium and 7 nickel, which was later balanced at 18-8.

A Chromium-manganese steel containing 18% of chromium, 5 to 6 manganese, 4 to 5 nickel, and 0.12 carbon, gives high resistance to corrosion, is comparable to the 18-8 steels, but has better drawing and working characteristics. The 18-8 steels are subject to grain growth, but small amounts of nitrogen may be used to inhibit grain growth, and the nickel may be lowered in the nitrogen-bearing steels. Small amounts of molybdenum and copper may be included to increase the corrosion resistance and to improve the working qualities. Stainless U, of the Colonial Steel Co., is an 18-8 type of steel with the addition of 1.5% of molybdenum and 1.25 copper, and having 0.15 carbon. As rolled, it has a tensile strength of 100,-

000 lb. per sq. in. and elongation of 40%. Maxilvry steel, of Edgar Allen & Co., Ltd., is a chromium-nickel steel containing copper, intended for deep drawing. The tensile strength, annealed, is 40 tons per sq. in., elongation 68%, and hardness 149. Bethalon steel, of the Bethlehem Steel Co., is an 18-8 steel having a tensile strength of 90,000 lb. per sq. in., which, when fully heat-treated, has a tensile strength of 174,000 lb. per sq. in. and Brinell hardness of 352. Sta-Gloss, Hi-Gloss, and Duro gloss are stainless steels of the Jessop Steel Co. Allegheny metal, of the Allegheny Ludlum Steel Co., is 18-8 steel in various grades of carbon and varied with molybdenum or other elements. Allegheny 18-8-M contains 16 to 18% of chromium, 10 to 14 nickel, 0.10 carbon, and 2 to 3 molybdenum.

Most makers of the 18-8 wrought steels offer a wide range of grades some of which are stabilized with titanium or columbium to prevent intergranular corrosion. These wrought steels are available in the form of sheets, plates, tubes, and wire. Circle L22, of the Lebanon Steel Foundry, is a cast steel for pump, valve, and chemical equipment parts. It contains 19.5% of chromium, 9 nickel, 1.25 silicon, and 0.75 manganese, and is produced in an induction furnace with a maximum of 0.07% carbon. The low carbon permits welding without the formation of carbides on large structures that cannot be heat-treated. This steel has a tensile strength of 75,000 lb. per sq. in., elongation of 50%, and hardness 135 Brinell. With a small amount of selenium to improve machining, it is called Circle L22M, and with about 3% of molybdenum to increase chemical resistance and to prevent intergranular corrosion at high temperatures it is called Circle L22XM. This latter steel also has higher strength and hardness. Circle L23 is this type of steel with 0.20% carbon. Durco KA2S steel, of the Duriron Co., is an 18-8 cast steel with 0.07% carbon. Durco KA2SMo is a similar steel with 3% of molybdenum. When cast, it has a tensile strength up to 95,000 lb. per sq. in., elongation 40 to 45%, and hardness 140. Evansteel, of the Chicago Steel Foundry Co., is chromium-nickel cast steel in various grades which may contain vanadium or molybdenum, employed for wear-resistant and chemical-resistant parts.

**Chromium steel.** Any steel containing chromium as the predominating alloying element may be termed chromium steel, but the name alone usually means the hard, wear-resisting steels that derive the property chiefly from the chromium content. Chromium combines with the carbon of steel to form a chromium carbide, but when other carbide-forming elements are present double or complex carbides are formed. Chromium refines the structure, gives deep-hardening, increases the elastic limit, and gives a slight red hardness so that the steels retain their hardness at more elevated temperatures. Chromium steels have great resistance to wear. They also withstand quenching in oil or water without much deformation. Up to about 2% of chromium may be included in tool steels to add hardness, wear resistance, and nondeforming qualities. When the chromium is high, the carbon may be much higher than in ordinary steels without making the steel brittle. Steels with 12 to 17% of chromium and about 2.5% carbon have remarkable wear-resisting qualities and are used for cold-forming dies for hard metals, for broaches, and for rolls. However, chromium narrows the hardening range of steels unless balanced with nickel. They also work-harden rapidly unless modified with other elements. The high-chromium steels are corrosion-resistant and heat-resistant, but are not to be confused with the high-chromium stainless steels which are low in carbon. Chromium steels with about 1% of chromium are used for gears and shafts. Uma steel No. 1, of the Republic Steel Corp., has 0.55 to 0.75% of chromium, 0.35 to 0.65 manganese, and 0.15 carbon. It is a casehardening gear steel. Uma No. 5 has 0.85 to 1.10% of chromium, 0.70 to 0.90 manganese, and 0.50 carbon. It is deep-hardening, with a tensile strength up to 135,000 lb. per sq. in., and is used for transmission gears. This type of steel with higher carbon is deep-hardening and has high compression strength and is used for ball and roller bearings. Teton steel, of the Allegheny Ludlum Steel Co., has 1.25% of chromium and 1 carbon, and is employed for ball bearings, spindles, and for hard wear-resistant parts.

Chromium steels with 3 to 4.5% of chromium and 0.80 to 1 carbon are used for dies for hot pressing and forging. EB alloy, of the Allegheny Ludlum Steel Corp., has 3.75% of chromium, 0.55 vanadium, 0.70 molybdenum, and 0.65 carbon. Another hot-work

steel of this company is Potomac steel with 5% of chromium, 1.75 molybdenum, 1.25 tungsten, and 0.32 carbon. Uniloy chrome steel, of the Cyclops Steel Co., contains 4 to 6% of chromium, 0.1 to 0.25 carbon, up to 0.60 manganese, with either molybdenum, 0.40 to 0.60%, or tungsten 1 to 1.25%. A small amount of tungsten, or smaller amount of molybdenum, refines the grain, increases the elastic limit, and makes the steel more resistant to corrosion at elevated temperatures. The Chromium-tungsten steels are employed where resistance to hot chemicals or petroleum is required, but the steels with high tungsten are usually classed as tungsten steel regardless of the amount of chromium. A steel used for high-strength resistant castings is Circle L-10 of the Lebanon Steel Foundry. It contains 5.5% of chromium, 0.50 molybdenum, 0.65 manganese, 0.40 silicon, and 0.20 carbon. When heat-treated it has a tensile strength of 100,000 lb. per sq. in. and elongation of 20%. Nicroman is an all-purpose tool steel of Henry Disston & Sons, Inc., with 1% of chromium, 1.65 nickel, 0.35 copper, and 0.70 carbon.

A wear-resistant die steel, marketed by the Carpenter Steel Co. under the name of Hampden steel, contains 12.5% of chromium, 0.25 nickel, 0.25 manganese, and 2.1 carbon. It is deep-hardening, has high compressive strength, and is valued for forming rolls and spinning tools. A similar-purpose tool steel with air-hardening properties is Carpenter No. 610. It has 12% of chromium, 1.5 carbon, 0.80 molybdenum, 0.20 vanadium, and 0.30 manganese. Huron steel, of the Allegheny Ludlum Steel Corp., is a wear-resistant steel having 12.5% of chromium, 1 vanadium, and 2 carbon. It is used for dies. O-Hi-O, of the Vanadium Alloys Steel Co., is an air-hardening die steel having 12% of chromium, 1.55 carbon, 0.85 vanadium, 0.40 cobalt, and 0.80 manganese. Crocar, of this company, is a wear-resistant die steel with similar composition but with 2.2% carbon. Croloy, of Henry Disston & Sons, Inc., used for punches, dies, gages, and shear blades, has 12% of chromium, 1.5 carbon, 1 vanadium, and 0.80 molybdenum. Mix 812 steel of this company has 12% of chromium and 1.8 carbon. It is a fine-grained oil-hardening steel used for wearing surfaces and cutting edges, but it work-hardens and is difficult to machine. G.S.N. steel, of this company, is a high-chromium, high-carbon die steel.

**Cinchona.** The hard, thick, grayish bark of a number of species of evergreen trees of the genus *Cinchona,* native to the Andes from Mexico to Peru but now grown in many tropical countries chiefly as a source of quinine. The small tree *Remijia pedunculata* also contains 3% of quinine in the bark, and quinine occurs in small quantities in other plants and fruits, notably the grapefruit. Cinchona bark was originally used by the Quechua Indians of Peru in powdered form and was called Loxa bark. It derives its present name from the fact that in 1630 the Countess of Cinchon was cured of the fever by its use. In Europe it became known as Peruvian bark and Jesuits' bark. Quinine is one of the most important drugs as a specific for malaria and as a tonic. It is also used as a denaturant for alcohol as it has an extremely bitter taste. Metallic salts of quinine are used in plastics to give fluorescence and glow under ultraviolet light. Quinine is a colorless crystalline alkaloid of the composition $C_{20}H_{24}O_2N_2 \cdot 3H_2O$. It is difficultly soluble in water, and is marketed in the form of the more soluble Quinine sulphate, a white powder of the composition $(C_{20}H_{24}O_2N_2)H_2SO_4 \cdot 2H_2O$. Quinine bisulphate has the same composition but with 7 molecules of water. During the Second World War Quinine hydrochloride was preferred by the Navy. It contains 81.7% of quinine compared with 74% in the sulphate and is more soluble in water but has a more bitter taste. Synthetic quinine can be made, but is more expensive. The substitute called Atabrine, of I. G. Farbenindustrie, is Quinacrine hydrochloride. It is not a complete substitute, is toxic, and is a dye that colors the skin when taken internally.

The bark of the tree *Cinchona ledgeriana* yields above 7% of quinine but is not a robust tree and in cultivation is grafted on the tree *C. succirubra* which is hardy but yields only 2 to 3% of quinine. Ledgeriana trees on plantations in Mindanao and in Peru yield as high as 13% total alkaloids from the bark. Most of the world production is from the *C. officinalis* and *C. calisaya,* which are variations of *C. ledgeriana,* or yellow bark. The Red bark, *C. succirubra,* is grown in India. The trees are grown from seeds which are small, 75,000 to the ounce. The peak gathering of bark is 10 years after planting of the 2-year seedlings, and the trees are uprooted to obtain bark from both trunk and root. An 8-year-old tree yields 4 kilos of bark, and a 25-year tree yields 20 kilos but

of inferior quality. The bark is dried and ground to powder for the solvent extraction of the alkaloids. Besides quinine the bark contains about 30 other alkaloids chief of which are Cinchonidine, Quinidine, and Cinchonine. Totaquina is the drug containing all the alkaloids. It is cheaper than extracted quinine and is effective against malaria and is a better tonic. Quinidine has the same formula as quinine but is of right polarization instead of left. It is used for heart ailments. Cinchonine, $C_{19}H_{22}ON_2$, has right polarization and is thirteen times more soluble in water than quinine sulphate. Cinchonidine has the same formula, but is left polarization. Australian quinine, or Alstonia, is not true quinine. It is from Dita bark, the bark of the tree *Alstonia scholaris* of Australia, and is used as a febrifuge. It contains the water-soluble alkaloid Ditaine, $C_{22}H_{28}O_4N_2$, and the water-insoluble alkaloid Ditamine, $C_{16}H_{19}O_2N$. Fagarine, used as a substitute for quinidine for heart flutter, is extracted from the leaves of the tree *Fagara coco* of northern Argentina.

**Cinnabar.** The chief ore of the metal mercury. As a pigment it was originally called Minium, a name now applied to red lead. It is a Mercuric sulphide, HgS, which when pure contains 86.2% of mercury. The ores, however, are usually poor, the best ones containing only about 7% of mercury, and the average American ore having only 0.5%. The chief production is in Italy, Spain, Mexico, and the United States. Cinnabar has a massive granular structure with a hardness of 2 to 2.5, a specific gravity of about 8, and usually a dull earthy luster. It is brownish red in color, from which it derives the name Liver ore. Chinese cinnabar is ground as a fine scarlet pigment for inks. Cinnabar is not smelted, the extraction process being one of distillation, made possible by the low boiling point of the metal. Another ore of mercury found in Mexico is Livingstonite, $2Sb_2S_3 \cdot HgS$. It is a massive, red-streaked mineral of specific gravity 4.81 and hardness 2. Calomel, a minor ore in Spain, is a white to gray crystalline mineral of the composition $Hg_2Cl_2$ with a specific gravity of 6.5. It is also called Horn mercury. It is used in medicine as a purgative, but is poisonous if retained in the system. The ore found in Colorado and known as Coloradoite is a Mercuric telluride, HgTe. It has an iron-black

color and a specific gravity of 8. Tiemanite, found in California and Utah, is a Mercuric selenide, HgSe, having a lead-gray color and a specific gravity of 8.2. There are more than 20 minerals classed as Mercury ores.

**Cinnamon.** The thin, yellowish-brown highly aromatic bark of the tropical evergreen laurel tree *Cinnamomum zeylanicum,* of Ceylon, China, and the East Indies. It is used as a spice, as a flavor in confectionery, perfumery, and medicine. The bark is marketed in rolls or sticks packed in bales of 112 lb. Cassia is the bark from the *C. cassia* of South China. Saigon cinnamon is Chinese cassia cinnamon, and is not as thin or as smooth a bark, and it does not have as fine an aroma and flavor. Cassia buds are small dried flowers of the *C. cassia,* used ground as a spice, or for the production of oil. They resemble cloves in appearance, and have an agreeable spicy odor and sweet warm taste. Cinnamon oil, Cinnamon leaf oil, and Cassia oil are essential oils distilled, respectively, from the bark, leaf, and bud. They are used in flavoring, medicine, and perfumery. Cinnamon oil contains about 70% of Cinnamic aldehyde, 8 to 10% of eugenol, and also pinene and linalol. The specific gravity is 1.03, and the refractive index 1.565 to 1.582. The pale-yellow color darkens with age. The leaf oil is used as a substitute for clove oil. About 1.9% of oil is obtained from cassia buds, but it lacks the delicate fragrance of cinnamon oil. Nikkel oil, a bright-yellow liquid with an odor of lemon and cinnamon, is distilled from the leaves and twigs of the tree *C. laureirii* of Japan. It contains citral and cineol, and is used in perfumery.

**Cloves.** The dried flower buds of the evergreen tree *Caryophillus aromaticus,* grown chiefly in Zanzibar, but also in Madagascar, East Africa, and the East Indies. The buds yield 15 to 19% of a pungent yellowish essential oil, Clove oil, also called Caryophil oil. It contains 85% of Eugenol, and also the terpene Clovene, $C_{15}H_{24}$. Clove oil is used in medicine as an antiseptic in tooth pastes, in flavoring, and for the production of artificial vanilla. Eugenol is a viscous phenol-type liquid. It is also the basis for carnation-type perfumes. Clove buds are chiefly valued as a highly aromatic spice. The clove tree attains a height up to 40 ft., bearing in 7 or 8 years, and continuing to bear for a century, yielding 8 to 10 lb. of dried

cloves annually. Clove stems are also aromatic, but contain only 5 to 6% of oil of inferior value.

**Coal.** A general name for a black mineral formed of ancient vegetable matter, and employed as a fuel and for destructive distillation to obtain gas, coke, oils, and coal-tar chemicals. Coal is composed largely of carbon with smaller amounts of hydrogen, nitrogen, oxygen, and sulphur. It was formed in various geological ages and under varying conditions, and occurs in several distinct forms. Peat is the first stage, followed by lignite, bituminous coal, and anthracite, with various intermediate grades. The mineral is widely distributed in many parts of the world. The value of coal for combustion purposes is judged by its fixed carbon content, volatile matter, and lack of ash. It is also graded by the size and percentage of lumps. The percentage of volatile matter declines from peat to anthracite, and the fixed carbon increases. A good grade of coal for industrial power-plant use should contain 55 to 60% of fixed carbon and not exceed 8% of ash. The B.t.u. value should be 13,500 to 14,000 per lb. Finely ground, or Powdered coal, is used for burning in an air blast like oil, or may be mixed with oil. Coal in its natural state absorbs large amounts of water and also, because of impurities and irregular sizes, is not as efficient as a fuel as the Reconstructed coal made by crushing and briquetting lignite or coal and waterproofing with a coating of pitch.

**Coated fabrics.** The first coated fabric was a rubberized fabric produced in Scotland by Charles Macintosh in 1823 and known as Mackintosh cloth for Rainwear use. Since no method of vulcanization was then known, the cloth was made by coating two layers of fabric with rubber dissolved in naphtha and pressing them together, making a double fabric impervious to water. Rubberized fabrics are now made by coating cotton or silk with compounded rubber and passing between rollers under pressure. The final vulcanized coating is usually 0.002 to 0.003 in. thick, and the resultant fabric is flexible and waterproof. Synthetic rubbers are also used for coating fabrics, especially those that require resistance to oils or chemicals. The bulk of coated fabrics are now made by impregnating or coating with synthetic resin compositions. Nitrocellulose plasticized with oil-modified alkyd resins give flexible coatings

of great durability and water resistance. This type of coating was used for military fabrics to resist temperatures as low as −20°F. and as high as 240°F. They are also used for coating book covers. Pliosheen, of the Goodyear Tire & Rubber Co., is silk or rayon fabric treated with Chemigum type of synthetic rubber. It is waterproof, odorless, flame-resistant, and easily cleaned. Cavalite, of E. I. duPont de Nemours & Co., Inc., is silk coated with synthetic rubber. Terson voile, of the Athol Mfg. Co., is a sheer-weight rayon coated with vinylite resin. It is strong, crack-resistant, waterproof, and weighs 2 oz. per sq. yd. It is used for umbrellas, rainwear, industrial linings, and book covers. Geon latex, of the B. F. Goodrich Co., used for coating fabrics, is a water dispersion containing a solid content of 50% vinyl resin. Rhoplex, of Rohm & Haas, is a modified acrylic resin which forms a tough, elastic, odorless coating. Exylin is a trade name of McCoy, Jones & Co., Inc., for rainwear and bag fabrics coated with vinylite resin.

Leather fabrics, used as substitutes for upholstery leather for furniture and automobile-seat covers, are usually cotton fabrics coated with plastics and embossed with designs to imitate leather. The base cloth may be of various weights from light sheetings to heavy ducks and may be napped on the back. Leather fabrics are more durable, more easily cleaned, and lower in cost than split leathers. Fabricoid, of E. I. duPont de Nemours & Co., Inc., is an upholstery material marketed in various weights, colors, and designs. It is used for automobile covering, book covers, and waterproof articles. Tontine, of this company, is a plastic impregnated cloth used for window shades, and Pontan is a rubberized fabric made to imitate colored leathers. Coated fabrics are also made from yarns treated with synthetic resin, usually vinyl butyral, to give an extremely thin surface coating that is scarcely detectible but makes the fabric water-resistant, immune to insect attack, and easily cleaned.

Impregnated fabrics are fabrics that have been treated with fungicides or with flame-resistant chemicals, and may also be coated with a waterproofing resin. Stabilized fabrics, however, are not waterproofed or coated, but are fabrics of cotton, linen, or rayon that have been treated with a water solution of urea-formaldehyde resin to give them greater resiliency, resistance to creasing, and re-

sistance to shrinkage in washing. Shrinkproof fabrics are fabrics of cotton or wool that have been given an impregnation of about 2% of resin by dipping in a water solution of alkylated melamine-formaldehyde resin, then washing so that the resin remains only in the core of the fibers. The fabric retains its original softness, texture, and appearance, and is not waterproofed, but the fibers have increased stability and can shrink but slightly in washing. Resloom M-75 of the Monsanto Chemical Co. and Lanaset of the American Cyanamid Co. are liquid resins for shrinkproofing fabrics.

**Cobalt.** An elementary metal, symbol Co. Cobalt is a white metal resembling nickel but it has a blue tinge. Although allied to nickel, it has distinctive differences. It is not as corrosion-resistant as nickel, and its power of whitening copper alloys is inferior to that of nickel. It is diamagnetic like nickel, but has nearly three times the saturation value and twenty times the maximum permeability. Like tungsten, it has the property of adding red-hardness to cutting alloys. It also hardens alloys to a greater extent than nickel, especially in the presence of carbon. Cobalt has a specific gravity of 8.756, melting point 1480°C., and electrical resistivity of 9.8 microns, which is about the same as pure iron. The tensile strength of pure cast cobalt is 34,500 lb. per sq. in., but with 0.25% of carbon this is increased to 62,000 lb. per sq. in. Cobalt is not used in bronzes like nickel, but some cobalt may be used to neutralize the yellow of nickel to produce white alloys. It is also employed in cutting alloys and tool steels, in magnet steels, in high-permeability electrical alloys, as a catalyst, and its compounds are employed as pigments and for coloring ceramics.

Cobalt metal is marketed in rondelles, or cast slugs about 1 in. in diameter and ¾ in. thick, and in shot and anodes. Some cobalt powder is also marketed, and cobalt oxide is sold in kegs of 534 lb. The metal is obtained by smelting the ores in a blast furnace and then treating the arsenides in acids from which the cobalt hydroxide is precipitated. This is changed to the oxide by heating, and the oxides are reduced electrolytically. The chief ores are cobaltite and smaltite. Cobaltite, or Cobalt glance, found in Ontario, is a sulpharsenide of the metal, CoAsS, and occurs with Gersdorffite, NiAsS. Another sulphide is Linnaeite, $Co_3S_4$, containing theoreti-

cally 58% of cobalt, but usually containing nickel and iron. Smaltite is also an ore of cobalt as it contains theoretically 28.1% of cobalt. Erythrite is a hydrous cobalt arsenate which occurs near the surface of the smaltite deposits in French Morocco. Cobalt is also produced from the copper ores of the Belgian Congo and northern Rhodesia, and these ores form the chief source of the commercial cobalt.

**Cobalt oxide.** A steel-gray to blue-black powder employed as a base pigment for ceramic glazes on metal, as a colorant for glass, and as a chemical catalyst. It gives excellent adhesion to metals and is valued as an undercoat. It is also one of the most powerful colorants for glass, 1 part in 20,000 parts of a batch giving a distinct blue color. Cobalt oxide is produced from treatment of cobalt-nickel ores, and has the composition $Co_3O_4$, but the oxide commercially known as Black cobalt oxide may be a mixture with $Co_2O_3$, and is cobaltous-cobaltic oxide. It is marketed on the basis of 70 to 71% cobalt. The two classes are called RKO and SKO grades, with specific gravities ranging from 5.8 to 6.3. Gray cobalt oxide has the composition CoO, but this form and $Co_2O_3$ are unstable and change to $Co_3O_4$ on heating. It is marketed on the basis of 75% cobalt. The pigment known as Smalt, and as Royal blue and Saxon blue, is a deep-blue powder made by fusing cobalt oxide with silica and potassium carbonate. It contains 65 to 71% of silica, 16 to 21 potash, 6 to 7 cobalt oxide, and a little alumina. It is used for coloring glass and in vitreous enamels, but does not have good covering power as a paint pigment.

**Cobalt steels.** Cobalt is a much rarer and more expensive metal than nickel, but it has powerful influencing properties in steel and iron alloys, and is used in tool steels, cutting alloys, and magnet steels. Small amounts of cobalt are used in special tool steels to give hardness, but large amounts decrease the impact resistance. The cobalt steels retain hard carbides at high temperatures, and the high-speed steels containing cobalt are harder than the regular tungsten steels and can be operated at higher temperatures. The quality is developed to a greater extent when chromium is present in the steel. Considerable amounts of cobalt are thus employed in the super high-speed steels, but they are more difficult to forge

and require greater care in heat-treatment than the plain high-speed steels. Cobalt increases residual magnetism in steel and increases the coercive magnetic force. High percentages of cobalt are therefore sometimes used in magnet steels and in high-permeability electrical alloys.

**Cochineal.** A dyestuff of animal origin, which before the advent of coal-tar dyes was one of the most important coloring materials. Cochineal is the female of the *Coccus cacti,* an insect that feeds on various species of cactus of Mexico. The insects have no wings, and at the egg-laying season are brushed off the plants, killed by boiling, and dried. They are dark reddish brown in color. Cochineal contains 10 to 20% of pure coloring matter, carminic acid, mostly in the eggs, from which the Carmine red, $C_{11}H_{12}O_7$, is obtained by boiling with mineral acid. Carmine red produces brilliant lake colors of various hues with different metals. Commercial cochineal may be adulterated with starch, kaolin, red lead, or chrome lead. The brilliant red pigment known as Carmine lake is made by precipitating a mixture of cochineal and alum.

**Cocoa beans.** The seed beans from the large fruit pods of the cacao tree, *Theobroma cacao,* native to Mexico, and *T. leiocarpum,* native to Brazil. The tree was cultivated in Mexico from ancient times, and the beans were used by the Aztecs to produce a beverage called Chocolatl which contained the whole substance of the fermented and roasted bean flavored with vanilla. Cocoa beans are now produced in many countries, and the United States imports from about 40 countries, although 75% of the prewar imports were from the Gold Coast, Nigeria, and Brazil. The tree grows only in the tropics, cannot withstand temperatures below 60°F., but grows best in the highlands. It begins to bear in 4 or 5 years and continues to bear for as long as 50 years, having fruits and flowers throughout the year. The fruits are melonlike pods 6 to 9 in. long with a pulp and from 40 to 60 seed beans. The pulp and seeds are scooped out, fermented, and dried in the sun. During the curing the beans lose their bitter taste and become reddish brown in color. They are then washed, dried, and polished. Numerous varieties are cultivated. The flavor and aroma also vary with soil and climate, and differences in curing methods also produce differences in

the beans, so that types and grades are best known by the shipping ports and districts in which they are grown. Mico cocoa is wild cocoa of Central America. The beans are smaller than the cultivated ones and are noted for fine flavor. Cocoa beans are shipped dried but not roasted. They are roasted just before use to develop the flavor, to increase the fat content, and to decrease the tannin content. The hard shells are removed, and the roasted seeds are ground and pressed to produce Bitter chocolate. Sweet chocolate is made by adding sugar and flavoring, usually vanilla. Cocoa, for beverage purposes, is made by removing about 60% of the fatty oil from chocolate by hydraulic pressing and powdering the residue to which is usually added ground cocoa shells. The removed fatty oil is Cocoa butter, used for bakery products, cosmetics, and pharmaceuticals. A hundred pounds of cocoa beans yield 48 lb. of Chocolate powder, 32 lb. of cocoa butter, and 20 lb. of waste. Besides fat the chocolate contains much starch and protein and has high food value, but is not as stimulating as the cocoa since the alkaloid is largely contained in the waste and shells. These contain 1 to 1.5% of theobromine and are used for the synthetic production of caffein. The chocolate is used in the manufacture of confectionery, chocolate bars, bakery products, and flavoring sirups.

**Cocobola.** The wood of the hardwood tree *Dalbergia retusa,* of Central America, also known as Honduras rosewood. It is a beautiful wood, extremely hard, and very heavy with a weight of 75 to 85 lb. per cu. ft. It has orange and red bands with dark streaks and takes a fine polish. The thick sapwood is hewn off before shipment, and the heartwood logs are usually not more than 18 in. in diameter. The commercial wood comes from Panama and Costa Rica, and is used for canes, turnery, inlaying, scientific instrument cases, and knife handles. Cocos wood, also called Cocoawood and West Indian ebony, used chiefly for inlaying, is from the tree *Brya ebenus* of tropical America. The sapwood is light yellow, and the heartwood is brown streaked with yellow. The grain is dense and even, and the wood is hard.

**Coconut oil.** The oil obtained from the thick kernel or meat adhering to the inside of the shell of the large nuts of the palm tree *Cocos nucifera* growing along the coasts of tropical countries.

The tree requires salt air, and inland trees do not bear fruit unless supplied with salt. The name coco is the Carib word for palm. Copra is the dried meat of the coconut from which the oil is pressed. The dried copra contains 60 to 65% of oil. It is an excellent food oil, and is also valued for soaps because of its high lathering qualities due to the high percentages of lauric and myristic acids. It is also employed as a source of lauric acid for making lauryl alcohol, and of other acids for use as plasticizers and in pharmaceuticals. Coconut oil was once the chief illuminating oil in India, and the oil for burning was exported under the name of Cochin oil. This oil was cold-pressed and filtered and was water-clear. Coconut oil has a melting point of 27 to 32°C., specific gravity of 0.926, saponification value 251 to 263, and iodine value 8 to 9.6. It contains 45 to 48% of lauric acid, 17 to 20 myristic, 10 capric, 5 to 7 palmitic, up to 5 stearic, and some oleic, caprylic, and caproic acids.

In sun-drying coconut meat to make copra there is a loss of some of the oil, sugars and other carbohydrates, and some proteins. The oil from copra contains more free fatty acid than that from fresh dried coconut and is rancid, requiring neutralization, decolorization, and deodorization. The meal and cake are also dirty and rancid but are useful for animal feed or fertilizer. Dehydrated coconut meat gives a better yield of oil and is not rancid. The copra cake of India is called Poonac. The chief production of copra and coconut oil is in southern Asia, the East Indies, the Philippines, and in the South Sea Islands. About 5,000 coconuts are required to produce a metric ton of copra, and the average yield of crude oil is 63%. The stearine separated from crude coconut oil by the process of wintering is known as Coconut butter and is used in confectionery. It has a melting point of 27 to 32°C. Hydrogenated coconut oil is a soft solid with a melting point of 45°C. Desiccated coconut, produced by oven drying or dehydration of the fresh coconut meat, is used shredded as a food and also powdered in many bakery products as a food and stabilizer. It has high food value, containing not less than 60% of oil, 15 carbohydrates, 14 cellulose, 6 to 7 protein, and various mineral salts and considerable vitamin B. It is easily digested and has antitubercular value, but its characteristic coconut flavor is not universally liked.

**Coffee.** The seed berries, or beans, of the Arabian coffee tree, *Coffea arabica,* the Liberian coffee, *C. liberica,* and the Congo coffee, *C. robusta,* of which the first species furnishes most of the commercial product. The coffee bean contains the alkaloid caffeine used in medicine as a stimulant and in soft drinks, but most of the commercial coffee beans are used for the preparation of the beverage coffee, with small quantities for flavoring. The alkaloid is stimulating and is harmless in small amounts as it does not break down in the system and is easily soluble in water and thus carried off rapidly, but in large quantities at one time it is highly toxic. The normal effect is contraction of the muscles which relieves tiredness, but causing irritation as the muscles relax. The Arabian coffee plant is a small evergreen tree first introduced to Europe through Arabia. The first plants were brought to America in 1723, and the trees are now grown in most tropical countries. It requires a hot, moist climate, but develops best at higher altitudes. There are numerous varieties, and the coffee beans also vary in aroma and taste with differences in climate and cultivation. The Liberian and Congo species, grown on the west coast of Africa, are more hardy plants, but the coffee is different in aroma and is used only for blending. Mocha coffee and Java coffee are fragrant varieties of the Arabian coffee. The fruits are small fleshy berries containing two greenish seeds. They are dried in the sun, or are pulped by machine and cleaned in fermenting baths and oven-dried. After removal of the skin from the dried beans they are graded and shipped as green beans. The general grades are by shipping ports or regions with numbered grades or qualities. The flavor and aroma are developed by roasting. Brazil produces about half of all coffee. In blending, Brazilian coffee is the base for most blends, Medellin coffee from Colombia is used for rich flavor, Mexican Coatepec for winey flavor, San Salvador for full body, Costa Rican for fragrance, and Arabian mocha for distinctive flavor. Chicory, which is used extensively in Europe for blending with coffee, is the dried, roasted, and ground root of the perennial plant *Cichorium intybus,* native to Europe and growing wild in the United States. It is cultivated in the Central states. From 5 to 40% of chicory may be used in some blends of coffee. It gives a taste preferred by some.

**Coir.** A fiber by-product of the coconut industry. The fiber is retted from the outer husks, hammered with wooden mallets, and then combed and bleached. The coarse and long fibers are used for brushmaking, the finer and curly fibers are spun into coir yarn used for mats, cordage, and coarse cloths. In the West Indies it is mixed with sisal and jute to make coffee-bag cloth. In the Pacific islands it has been used with cement to make a hard-setting, lightweight board for siding. In India Coir fiberboard is made by bonding with shellac, pressing, and baking. The boards are hard and have a good finish. Coir is easily dyed. The Ceylon coir yarn is sold in two quality grades, Kogalla and Colombo, with subdivisions according to the thickness and texture. The yarn is properly called coir, and the harsh brush fiber is best known as Coconut fiber. Coir yarn averages 330 meters per kilogram. The Indian yarn is in 450-yd. lengths tied into bundles. A hundred nuts yield 17 or 18 lb. of fiber. Coconut shell, a by-product of the copra industry, is used for making activated charcoal and for Coconut shell flour used as a filler in molded plastics. It has a composition similar to walnut shell, being chiefly cellulose with about 30% of lignin, 17 pentosans, and 5 methoxyl.

**Coke.** The porous, gray, infusible residue left after the volatile matter is driven off of bituminous coal. The coal is heated to a temperature of 1200 to 1400°C., without allowing air to burn it, and the volatile matter expelled. The residue, which is mainly fixed carbon and ash, is a cellular mass of greater strength than the original coal. Its nature and structure make it a valuable fuel for blast furnaces, burning rapidly and supporting a heavy charge of metal without packing. Soft, or bituminous, coals are designated as coking or noncoking, according to their capacity for being converted into coke. Coal low in carbon and high in ash will produce a coke that is friable and not strong enough for furnace use, or the ash may have low-melting constituents that leave glassy slag in the coke. Coke is produced in the beehive and by-product ovens, or is a by-product of gas plants. One ton of coal will yield an average of 0.7 ton of coke, 11,500 cu. ft. of gas, 12 gal. of tar, 27 lb. of ammonium sulphate, 50 gal. of benzol, 0.9 gal. of toluol and naphtha, and 0.5 lb. of naphthalene. The fixed carbon of good coke

should be at least 86%, ash less than 12%, and sulphur not more than 1%. The porosity may vary from 40 to 60%, and the apparent specific gravity should not be less than 0.8. A Foundry coke should have an ignition point of about 1000°F., with sulphur below 0.7%, and the pieces, screened to above 2½ in., should be strong enough to carry the burden of ore and limestone. Semicoke and Smokeless fuel are coals carbonized at low temperatures and briquetted for household use. Coalite is an English name for fuel of this type, and Carbolux is a French household coke. Carbonite is a natural coke found in England and in Virginia, used as a fuel. It is a cokelike mineral formed by the baking action of igneous rocks on seams of bitumious coal. Petroleum coke is the final residue in the distillation of petroleum, and forms about 5% of the weight of the crude oil. The chipped coke has the sand and impurities removed, and is about 99% pure carbon. It is used for making arc carbons, and carbon-molded products.

**Cold-molded plastics.** Materials used for molding mechanical and electrical parts under simple pressure. No chemical transformation takes place as with the synthetic molding resins. They are usually mineral resins or bituminous materials such as gilsonite, with fillers, and with drying oils or driers, and the color is normally black. The fillers may be silica, talc, kaolin, or asbestos fibers, to add strength and heat resistance, and they may be as high as 80% of the total. The plastics may withstand temperatures up to as high as 600°F., although the melting point of the original bituminous binder may be little above 200°F. The plastics are insoluble in water, good electrical insulators, acid-resistant, heat-resistant, but usually much weaker in strength than synthetic molded plastics. Synthetic resins that cure with catalysts may be molded cold, but are not ordinarily classed with these. Plastics of the cold-molded type are Aico, of the American Insulator Co.; Ebrok, of the Richardson Co.; Okon, of the American Hard Rubber Co.; and Thermoplax, of Cutler-Hammer, Inc.

**Cold-rolled steel.** Low-carbon, open-hearth steel that has been worked into strips, sheets, or bars by cold rolling. The carbon content is usually from 0.08 to 0.12%, with manganese from 0.30 to 0.80%. After the regular hot rolling has been completed, the

steel is annealed and pickled, and then passed cold through finishing rolls which smooth and polish the surfaces and increase the hardness and tensile strength. Only a slight reduction is made by cold-rolling sheet steel. For the making of cold-rolled strip steel the slabs after hot rolling are sheared to length, then hot-rolled into strip which is wound on a coil. The coils are recoiled to loosen the scale, pickled, rolled in breakdown mills, and annealed. The cold rolling is then accomplished until the desired hardness is obtained. It is usually in four tempers, but sometimes in six, from No. 1, hard, to No. 6, dead soft. Dead-soft steel is for severe drawing and cupping work. It has a minimum tensile strength of 37,500 lb. per sq. in. and an elongation of 40%. Medium soft, or quarter soft, is for forming or light drawing. The minimum tensile strength is 42,500 lb. per sq. in., with elongation of 20%. Medium hard, or half hard, is for bending at sharp right angles across the grain. The tensile strength is 50,000 lb. per sq. in. Hard rolled is for flat work and easy punching. The tensile strength is 55,000 lb. per sq. in., and elongation 5%. Specifications for cold-rolled sheet steel for automobile bodies call for less than 0.14% of carbon, under 0.60 manganese, and under 0.045 each of sulphur and phosphorus. The average tensile strength of the normalized sheet is 50,000 lb. per sq. in. Thinsteel is the trade name of the Cold Metal Products Co. for cold-rolled strip steel in thin gages made to very close accuracy. It comes in various tempers from dead soft to full hard in gages down to 0.001 in. Stainstripe, of the Acme Steel Co., is cold-rolled steel with decorative designs rolled on. Cold-drawn steel is bar or rod steel that has been finished by cold drawing through dies. Cold drawing doubles the yield point of hot-rolled bars, and imparts a high finish. The tensile strength of commercial, low-carbon, cold-drawn steel is 70,000 lb. per sq. in., and elongation 15%. Rycase is the name of a low-carbon, high-manganese, cold-drawn steel of Joseph T. Ryerson & Son, Inc., used for spindles to be casehardened. The tensile strength is 75,000 lb. per sq. in.

**Columbite.** An ore of the metal columbium. Its composition varies and may be $FeO \cdot Cb_2O_5$ or $(FeMn)Cb_2O_6$, or it may also contain tungsten and other metals. It is produced chiefly in

Nigeria and marketed on the basis of the $Cb_2O_5$ content. But columbium occurs more usually in combination with tantalum. The combined mineral known as Colombo-tantalite, mined in South Dakota and in the Belgian Congo, is marketed on the basis of the total $Ta_2O_5 \cdot Cb_2O_5$ content, and as the tantalum increases and the specific gravity increases the mineral is called tantalite. Columbite concentrates containing about 60% columbium pentoxide, $Cb_2O_5$, are shipped in 100-kilo bags.

Columbium. An elementary metal, symbol Cb. It was called Niobium in Germany, with the symbol Nb. It occurs in the minerals columbite and tantalite and, as it closely resembles tantalum, is difficult to separate from it. Columbium has a fine yellowish-white color, a specific gravity of 8.57, a melting point of 2415°C., tensile strength of 48,000 to 59,000 lb. per sq. in., annealed, and up to 130,000 lb. per sq. in. in drawn wire. The electrical conductivity is one-eighth that of copper. It is ductile and malleable when pure, but slight amounts of impurities make the metal hard and unworkable. It can be machined readily with carbon tetrachloride as a cutting lubricant, but cold working makes it tough and springy. It is insoluble in most acids and not easily attacked by alkalies. The metal oxidizes in the air at about 200°C., but the adherent film of oxide prevents further oxidation. At high temperature it has the property of absorbing gases, which makes it useful as plate and grid metal in high-vacuum tubes, and its gas-absorbent properties are stronger than those of tantalum. The color of the metal is more attractive than that of tantalum, and it is used for watch cases and jewelry. It is also used in stainless steels in small amounts for inhibiting intergranular corrosion. In chromium steels it reduces air hardening, gives high impact strength, reduces creep, shortens the annealing time, and improves oxidation resistance. Columbium metal is marketed in sheet, wire, rod, and powder. It also comes as Columbium oxide, $Cb_2O_5$, a white powder that melts at 1520°C., and as Potassium columbate, $4K_2O \cdot 3Cb_2O_5 \cdot 16H_2O$. Ferrocolumbium, for adding columbium to steel, is marketed as an alloy containing 50 to 60% of columbium and 7 silicon. Columbium carbide, CbC, used for cutting tools in the same way as tantalum carbide, is an extremely hard crystalline

material with a melting point of about 3800°C. It is made by sintering powdered columbium and carbon in a hydrogen furnace.

**Composite metals.** Sheet or plate metal having a face of special resistant metal welded to a base plate of lower-cost metal. The term usually refers to steels, since the other composite metals are known as duplex metal or by other terms. The composite sheet metals are also called Armored metals. The term Composite tool steel usually refers to steel in bar form machined along the entire length and having an insert of alloy tool steel welded to the backing of mild steel. This type of steel is used for shear blades, die parts, and forming tools. Composite steel sheets are made by rolling together the two metals to obtain the bond of adhesion, or by resistance welding to obtain cohesion. The sheets and plates are employed for making tanks, boilers, and chemical processing equipment where it is desired to have an acid-resistant or heat-resistant facing with the more easy working and lower cost of the plain steel plate. The normal thickness of the armor metal is 20% of the total thickness of the plate. There is great saving in high-cost metals with this type of plate. A single-armor plate having an 18-8 stainless steel to a depth of 20% on one side saves 144 lb. of chromium and 64 lb. of nickel per 1,000 lb. of total plate. A double-armor plate, with both sides to a depth of 20%, saves 108 lb. of chromium and 48 lb. of nickel per 1,000 lb. of plate.

Pluramelt, of the Allegheny Ludlum Steel Corp., is composite steel with various types of stainless steels integrally bonded to a depth of 20% by a process of intermelting. Croloy, of the Babcock & Wilcox Co., is a bonded plate consisting of a thin sheet of stainless steel welded to a base plate of carbon-molybdenum steel, with a sheet of nickel welded between the two to prevent migration of the carbon. Ingaclad, of the Ingersoll Steel & Disc Co., consists of stainless steel bonded to carbon steel plate. Silver-Ply is a Stainless-clad steel of the Jessop Steel Co., made with a stainless coating either 10 or 20% of the thickness of the plate combined with the mild steel backing by hot rolling. SuVeneer steel, of the Superior Steel Corp., used for automobile bumpers, has a veneer of stainless steel bonded to spring steel. Bronze-clad steel, of Ampco

Metal, Inc., is sheet steel with high-tensile, corrosion-resistant bronze rolled on one or both sides. The cladding is from 0.031 in. up to 40% of the thickness of the sheet. It is used for tanks and chemical equipment.

Composition metal. Also called Composition brass, although it does not have the characteristics of a true brass. A general name for casting alloys that are in a mid-position between the brasses and the bronzes. The most widely used standard composition metal is Ounce metal, containing 85% of copper, 5 zinc, 5 tin, and 5 lead, which derived its name from the fact that originally 1 oz. each of the white metals was added to 1 lb. of copper. It makes a good average bearing metal and, as it gives a dense casting that will withstand liquid pressures, is also used for valves, pump and carburetor parts. It casts well and machines easily, and takes a good polish, so that it is widely employed for general mechanical castings. It has about the same coefficient of expansion as copper, and can thus be used for pipe fittings. A.S.T.M. alloy No. 2 is this metal. It contains 84 to 86% of copper, 4 to 6 zinc, 4 to 6 tin, and 4 to 6 lead, and may also contain up to 0.75% of nickel and small amounts of iron, either as intentional additions to increase strength or as impurities. The minimum tensile strength is 26,000 lb. per sq. in., yield point 12,000 lb. per sq. in., and elongation 15%. Well-cast alloys may have strengths as high as 32,000 lb. per sq. in., with elongation of 20% or higher, and Brinell hardness 50 to 59. The weight is 0.31 lb. per cu. in. This alloy is also called Red casting brass, Hydraulic bronze, and Steam brass.

In the high-copper red casting-brass series, for any given content of copper and zinc, the higher the ratio of tin to lead the stronger but less ductile the alloy. The higher the content of zinc, the more ductile the alloy. For cast pipe fittings the American Brass Co., advocates 80 to 86% of copper, 4 to 15 zinc, 2 to 6 lead, and 3 to 6 tin. This type of alloy is called Valve bronze, and when the copper content is higher it is called Valve copper. It should cast readily without cracks, checks, or porous spots. The M bronze of the U.S. Navy, for valves, contains 86 to 91% of copper, 6.25 to 7.25 tin, 1.5 to 5 zinc, 1 to 2 lead, and not over 0.25 iron. It has a tensile strength of 34,000 lb. per sq. in. and

elongation of 17%. It will withstand continuous temperatures up to 500°F., while the 85-5-5-5 bronze can be used for temperatures only to 400°F. A.S.T.M. alloy No. 1, designated as high-grade red casting brass for general castings, contains 85% of copper, 1.5 lead, 6.5 tin, and 4 zinc. It has a tensile strength of 36,000 lb. per sq. in., elongation 25%, and Brinell hardness 50 to 60.

Nickel is added to composition metals for hydraulic and steam castings to densify the alloy and make the lead more soluble in the copper. One company uses an alloy containing 84.5% of copper, 5 lead, 7 zinc, 2.5 tin, and 1 nickel for casting injectors and lubricator parts. The nickel is added to the melt in the form of nickel shot which contains 5 to 7% of silicon to deoxidize the metal and increase the hardness. For heavy high-pressure hydraulic castings as much as 5% silicon may be added to alloys containing nickel, giving strengths above 40,000 lb. per sq. in. The alloys for machinery bearings usually contain higher proportions of tin or lead, or both, and are classified as high-lead bronze, but Johnson bronze No. 44, for bearings, contains 88% copper, 4 tin, 4 lead, and 4 zinc. The Hardware bronze used for casting hardware and automobile fittings to be highly polished and plated is likely to be a true copper-zinc brass or a leaded brass with only a small amount of lead. Oreide bronze, a term still used in the hardware industry, was the metal employed for carriage and harness hardware. It contains 87% of copper and 13 zinc, and polishes to a golden color. The hardware bronze of the Chase Brass & Copper Co. contains 86% of copper, 12.85 zinc, and 1.75 lead. Aluminum, even in small amounts, is not considered a desirable element in the red casting brasses as it decreases the ductility and requires more care in casting.

**Concrete.** A construction material composed of portland cement, sand, and gravel or broken stone, in the proportions 1 volume of cement to 2 of sand and 4 of stone, but these proportions are varied according to the strength and other qualities required. When hardened into massive structures, it is practically artificial rock. The quality of concrete is usually judged by its compressive strength. A rich mixture for columns and highly stressed

structures is 1:1:3. A lean mixture used for some foundations is in the proportion of 1:3:6. After 28 days' setting, rich-mixture concrete should have a compressive strength of 2,800 lb. per sq. in., standard mixture 2,200 lb. per sq. in., and lean mixture 1,400 lb. per sq. in. The gradual increase in strength of concrete is due to the hydration of the tricalcium aluminates and silicates of the cement, and there should be a proper working time before the action begins. With a good grade of portland cement the initial set should not develop in less than an hour. The sand used in concrete was originally specified as roughly angular, but the rounded grains are now preferred. The stone is usually sharply broken. The weight of concrete varies with the type and amount of rock and sand employed. A limestone concrete will weigh about 150 lb. per cu. ft.; the same mixture in trap rock may weigh 155 lb. per cu. ft.

Concrete blocks may be made from cement, sand, and gravel, or with cement and sand alone. For insulating purposes they may be made with cement and asbestos fibers. Careystone, of the Philip Carey Co., is cement with asbestos pressed into blocks, into corrugated slabs for roofing and siding, or into sheathing and wallboard. Reinforced concrete is a combination of concrete with a steel internal structure generally composed of rods or metal mesh. The strength of the concrete is thus greatly increased, and it is used for buildings, bridges, telegraph poles, roads, and fences. Nonslip concrete, for steps, is made by applying aluminum oxide grains, sizes 3 to 60 mesh, to the concrete before it hardens.

Insulating concrete and lightweight concretes are made by special methods, or by the addition of spongy aggregates. Slag may be used for this purpose. Aerocrete is a porous lightweight concrete produced by adding aluminum-bronze powder to the cement. The reaction between the flakes of metal and the lime in the cement forms hydrogen and causes bubbles. This concrete is a heat and sound insulator but is not strong. Haydite is a patented lightweight aggregate made by burning shale in a rotary kiln, which produces a material of expanded cellular structure. Haydite concrete weighs below 100 lb. per cu. ft., but is not as strong as gravel concrete. Superock and Waylite are trade names for expanded aggregate made by treating molten slag with water or steam.

Microporite is a German aggregate made by steam-treating ground silica and lime. Calicel, of the Keasbey & Mattison Co., is a lightweight spongy aggregate made by fusing silicates of lime and alumina and cooling to produce a stone of cellular structure. Fluftrok, of the Fluftrok Corp., is a lightweight aggregate made by heating obsidian in a kiln. The rock expands to 16 times its original volume, forming a porous material. Mixed with about 10% of portland cement it is made into building blocks that are light and strong.

**Contact metals.** Metals used for contact points or surfaces for electrical apparatus. The qualities required are high electrical conductivity, corrosion resistance, and wear resistance. Because of its superior electrical conductivity and corrosion resistance, silver is preferred where great wear resistance is not needed. Fine silver, of 99.9% purity, is used widely as a contact facing, but where greater hardness is required coin silver of 10% copper content is used. A harder Silver-copper alloy of 38% copper is used for commutator segments of small direct-current motors. Nickel brass is harder, cheaper, has good resistance to corrosion and wear, and the electrical conductivity is sufficiently high for push buttons and telephone contacts. Where high resistance to arcing is required tungsten is employed, but the conductivity is low. However, for high-speed equipment it is more important to have a heat-resistant metal than to have high electrical conductivity. An ordinary low-melting contact metal will last only about 25,000 contacts, while an aircraft magneto is required to make 36,000 sparks per minute, and a telegraph relay may operate 6 million times a day. Silver-tungsten alloys, made by powder metallurgy, combine the conductivity of silver with the arc resistance of tungsten, and are used for contacts. Silver-tungsten alloys of the Gibson Electric Co. contain 20 to 90% silver with hardnesses of 80 to 100 Rockwell B and good conductivity. Silver-graphite alloys, with low percentages of graphite, are used for contacts that require rubbing or sliding lubrication and for brushes and collector rings. Aeralloy, of the H. A. Wilson Co., is a Platinum-ruthenium alloy with high ruthenium content, used for aircraft magneto contacts. It is very

hard and gives long wear life. Wilco No. 6 alloy, for automotive magneto contacts, is platinum hardened with ruthenium.

**Coolants.** Liquids employed for quenching steels in heat-treating, although this term is also used to designate the cutting oils used on machines to cool the work and improve the cutting. When water is used for the normal water-hardening steels, it may be modified with soda or other material to give a less drastic and more uniform cooling. A water bath containing 5% of sodium hydroxide gives uniform rapid cooling. Oils are used in cooling or quenching baths for many alloy steels, as they remove the heat from the steel more uniformly and not as suddenly as water. Quenching oils are usually compounded, although fish oils alone are sometimes employed. Fish oils, however, have offensive odors when heated. Vegetable oils alone are likely to oxidize and become gummy. Animal oils become rancid. Lard and palm oils give low cooling rates, while cottonseed, neatsfoot, and fish oils give more rapid cooling. Mineral oils compounded with fish, vegetable, or animal oils are sold under trade names and vary considerably in their content. Oil-quenching baths are usually kept at a temperature of not over 150°F. by providing cooling pipes. Tempering oils differ from quenching oils only in that they are compounded to withstand temperatures up to about 525°F.

**Copal.** A general name for fossil and other hard resins found in nearly all tropical countries and used in making varnishes and lacquers, adhesives, and coatings. Copals are distinguished by their solubility in chloral hydrate. All of the copals are also soluble in alcohol, linseed oil, and in turpentine. The hardest and most prized varieties come from Africa. Zanzibar copal, from the tree *Trachylobium verrucosum,* or from species no longer existent, is one of the hardest of the varnish resins, with a melting point of 240 to 360°C., compared with 180 to 200°C. for Congo copal from Guinea. Madagascar copal is from the tree *Hymenaca verrucosa,* and is darker than Zanzibar. Gum benguela is a semifossil resin from the tree *Gulbourtia copalfera* of West Africa. The melting point is 170°C. Many species of trees of the genus *Hymenaca* of tropical America furnish copals. The Brazilian copal known as Jutahycica resin is from the Jatahy tree which is plentiful in the

Amazon Valley. Jatabó and Trapucá resins are fossil copals from species of *Hymenaca* of the state of Bahia, Brazil. Congo gum, chiefly from the tree *Copaifera demensi,* is the most insoluble of the natural resins but, after thermal processing, it is soluble in a wide range of solvents. The specific gravity of copals is from 1.04 to 1.13. The colors vary from white through yellow, red, brown, to brownish black.

The commercial copals are classed in five groups: East African, West African, Manila, East Indian, and South American. The name copal is applied in the East Indies to the resin of the tree *Agathis alba,* closely related to the Kauri pine. The types include Manila copal, Loba, and Boea. In Malaya the tree has been classed as *Dammara orientalis* and the copal is known as White dammar. In the Philippines the tree is called Almacido, and the gum, Manila copal. There are seven grades of Manila copal, from No. 1 pale, scraped chunks, to the No. 7 dust. Hard copal is harder than dammar, and has a higher melting point, but the hardness of the resin depends greatly upon the seasoning time in the ground. The semihard and soft copals are produced directly from the trees by tapping. The melting point of a copal from *A. alba,* collected 1 day after tapping, averages 85°C., compared with 105°C. when collected 3 months after tapping. Fossil copals of high quality and hardness are also obtained by separation from the low-grade coals of Utah. The copal, known as Copalite, has an amberlike appearance of light yellow to red color, with a specific gravity of 1.02 to 1.06, melting point of 165°C., and hardness about the same as that of Congo gum. The coal yields about 5% of gum.

**Copper.** One of the most useful of the metals, and probably the one first used by man. It is found native and in a large number of ores, but it is much less plentiful than nickel and some other metals. Its apparent plentifulness is only because it is easy to separate from its ores and is often a by-product from silver and other mining. The chemical symbol is Cu. It is yellowish red in color, tough, ductile, and malleable, gives a brilliant luster when polished, has a disagreeable taste and a peculiar odor. It melts at 1083°C. and boils at 2310°C. The specific gravity is 8.91, and weight 0.321 lb. per cu. in. It is the best conductor of electricity

next to silver, with a conductivity 92% that of silver. The coefficient of expansion is 0.000017 per deg. C. The tensile strength of cast copper is from 17,000 to 20,000 lb. per sq. in. with elongation of 40 to 50%. Annealed wrought copper has a strength of 32,000 lb. per sq. in. with elongation of 56%, while cold-drawn copper has a tensile strength of 56,000 lb. per sq. in. with elongation of 6%. The Bus-bar copper used by the electrical companies has a tensile strength up to 40,000 lb. per sq. in. Copper does not have the ductility of brass for metalworking, but does not work-harden as rapidly as brass. Pure copper is difficult to cast as the molten metal absorbs oxygen, forming oxides. Copper is used for electrical conductors, for making brasses and bronzes, for sheathing, fittings, pipe, and for cast articles. Small amounts of copper are added to some steels to give corrosion resistance.

More than half of all copper is sold in Wirebars of about 200 lb. for rolling and drawing. About 25% of the copper used in the United States goes into electrical manufactures and about 15% into electrical wiring. The United States produces more than half of all copper. Chilean and Belgian Congo copper are next in importance, but Peru, Canada, and other countries are important producers. Secondary copper is a term used to designate copper recovered from smelting scrap and old copper alloys. The production of secondary copper is about 40% that of new copper. Copper is marketed in three general grades: electrolytic, lake, and casting. Electrolytic copper has a purity not less than 99.9%.

Commercial wrought copper in bars, wire, sheets, and rods is marketed as Electrolytic tough pitch, Oxygen-free copper, Phosphorized copper, and Arsenical copper. Electrolytic tough pitch, or High-conductivity copper, oxidized with phosphorus without residue and annealed, has an electrical resistance of 0.67879 microhm per in. cube at 20°C., which is taken as 100% conductivity. This copper has the disadvantage of becoming brittle when heated and of not giving a high finish. Much of the copper marketed for commercial use as copper contains slight amounts of silicon or other hardener, but even as little as 0.40% of arsenic or other impurity will reduce the electrical conductivity drastically. Oxygen-free copper has high conductivity, is not subject to brittleness, and will withstand more cold working. Phosphorized copper

contains residual phosphorus. It has high strength, higher hardness and resistance to corrosion, but has lower conductivity. Anaconda condenser tubes of arsenical copper contain 0.25% of arsenic. Lake copper, from the Lake Superior region, usually contains arsenic.

Hard-drawn wire or sheet arsenical copper has a tensile strength of 60,000 lb. per sq. in., while the annealed material has a strength of 32,000 lb. per sq. in. and elongation of 45%. Cast copper has only 80 to 90% the conductivity of wrought copper. A special grade of copper having high ductility, high conductivity, and fatigue resistance is made without melting by converting electrolytic cathode copper directly into rods and strips by rolling at elevated temperature in a reducing atmosphere. The Phelps Dodge Copper Products Corp. produces this copper under the name of PDCP copper. Electro-sheet copper is thin sheet copper produced by electrodeposition. It is marketed by the American Brass Co. in roll sheets of 1 to 7 oz. per sq. ft. (0.0013 to 0.0094 in.), and is used for roofing and dampproofing. Rocan copper is a sheet copper of Revere Copper & Brass, Inc., having high strength and resistance to corrosion fatigue. It contains 0.50% arsenic. It is used for roofing and leaders. Roofing copper is hot-rolled soft copper sheet in 14- to 32-oz. weights, but Cornice copper is cold-rolled to a hard temper. The 16-oz. is used for gutters and leaders. Braziers' copper is a term used to designate heavy sheets of copper weighing from 1.5 to 6 lb. per sq. ft., used for coppersmiths' work. Coppersmiths' copper is hot-rolled, soft-temper, heavy sheets up to ½ in. Copper foil is sheet copper less than 0.005 in. in thickness.

Cupaloy, of the Westinghouse Electric Corp., is nearly pure copper containing small amounts of silver and chromium, giving a strength equal to a 0.30 carbon steel and having 85% the conductivity of copper. It is used for welding electrodes and electrical parts. Switch copper, of the Revere Copper & Brass, Inc., is electrolytic copper in shaped bars to close tolerances and burnished finish used for switch blades and electrical parts. It has a minimum tensile strength of 36,000 lb. per sq. in., elongation 15% min., and Rockwell B hardness of 35 to 65. Copper powder is usually chemically reduced copper in noncrystalline form. It is used in a liquid vehicle for copper coating, or for sintering. Copper

powder of the Nichols Copper Co. is 98.3% pure, and all particles pass through a 350-mesh screen. Copper powder in flake form for paint and ink pigment is produced by the Phelps Dodge Corp. by electrolysis. The cathodes are coated with oxidized castor oil and the deposited copper is in crystalline flakes easily reduced to a fine grade of red bronze powder by stamp milling. Copper shot is copper in the form of round globules, used chiefly in jewelry manufacture in alloying gold and silver. Leaded copper is copper in commercial rods and shapes containing a small amount of lead to make it free-machining. Copper is also marketed in the form of master alloys such as Copper aluminum, which is an alloy of 50% of copper and 50 aluminum melting at 1070°F., used for making aluminum alloys.

**Copper acetate.** Also known as Crystals of Venus. A dark-green crystalline poisonous powder of the composition $Cu(CH_3COO)_2 \cdot H_2O$, of specific gravity 1.882 and melting point 115°C. It is soluble in water and in alcohol. It is used as a pigment in paints, lacquers, linoleum, inks, and for making artificial verdigris or patina on copper articles. It is also used as a catalyst in making phthalic anhydride plastics. When used for mildew proofing cotton cloth the copper precipitates out to form the Waxate, or copper soap coating. Verdigris is an old name for basic copper acetate as a blue-green pigment, but the name is now usually applied to the bluish-green corrosion crust on copper. The greenish-brown crust known as Patina, formed on bronze, is esteemed as a characteristic of antiquity. It is a basic sulphate of copper, usually with oxides of tin, copper, and lead. Another green copper paint pigment is Copper carbonate, also called Artificial malachite. It is a poisonous powder of the composition $CuCO_3 \cdot Cu(OH)_2$, made by adding sodium carbonate to a solution of copper sulphate. The specific gravity is 3.7. It is insoluble in water.

**Copper ores.** There are about 15 copper ores of commercial importance, and these are widely distributed in almost all parts of the world. More than 40 countries produce copper on a commercial scale. The average copper content of ores, however, is usually low, and copper would be an expensive metal if it were not for the valuable by-products, silver, gold, nickel, and other metals. About

80% of the ores in the United States contain only 1.17 to 1.57% of copper and are concentrated before smelting. The direct smelting ores average from 4.3 to 6.2% of copper. The most important ore of copper is Chalcopyrite, also known as Copper pyrites and Yellow copper ore. It occurs widely distributed, associated with other minerals, and may carry gold and silver. It is the chief copper ore in many parts of the United States, Canada, Chile, Africa, England, and Spain. Chalcopyrite is a sulphide of copper and iron, $CuFeS_2$, containing theoretically 34.5% of copper. It usually occurs massive, with a hardness of 3.5 and a specific gravity of 4.2. The color is brass yellow, with greenish-black streaks. To obtain the copper, the ore is first smelted with enough sulphur to combine with all of the copper, producing a matte which is a mixture of $Cu_2S$ and FeS together with impurities. Air is then blown through the molten matte in a reverberatory furnace, converting the iron sulphide to oxide and the sulphur to sulphur dioxide. The remaining copper is cast into pigs which are called Blister copper, owing to its blistered appearance. Blister copper contains 96 to 99% of copper, with various metals and arsenic and sulphur. It is not used commercially, but is refined in furnaces or electrolytically.

Chalcocite is another important ore. It is found in Montana, Arizona, Alaska, Peru, Mexico, and Bolivia. It is a Cuprous sulphide, $Cu_2S$, containing theoretically 79.8% of copper. It usually occurs massive, but crystals are also found. The hardness is 2.5 to 3, and the specific gravity 5.5. It has a shining lead-gray color. Tennantite, or Gray copper ore, found in Colorado, Wyoming, and Montana, has the composition $3Cu_2S \cdot As_2S_3$, with sometimes antimony. When much of the arsenic is replaced by antimony it is called Tetrahedrite. Azurite, also called Blue copper carbonate and Chessylite, is a mineral found with other copper ores. It is a basic carbonate of copper, $Cu(OH)_2 \cdot 2CuCO_3$, occurring in azure-blue crystals. Malachite, or Green copper ore, is an important carbonate ore $Cu(OH)_2 \cdot CuCO_3$, containing theoretically 57.4% of copper. It has a bright-green color, specific gravity of 3 to 4, and hardness of 3.5 to 4. Cuprite, or Red copper ore, is a cuprous oxide, $Cu_2O$, containing theoretically 88.8% of copper. It occurs usually massive, but sometimes in crystals. The specific

gravity is 6, and the hardness 3.5 to 4. The color may be various shades of red, with an adamantine luster in the clear crystalline form, or a dull earthy luster in the massive varieties. Cuprite is found in the copper deposits in Arizona, and is one of the ores in Chile, Peru, and Bolivia.

Bornite, also known as Horseflesh ore, Peacock ore, and Variegated ore, is an important ore of copper widely distributed and mined in Chile, Peru, Canada, and the United States. It occurs in massive form, having a bronze color that turns purple on exposure. The composition is $Cu_5FeS_4$, having theoretically 63.3% of copper. It has a metallic luster and a hardness of 3. Chrysocolla is a minor ore of copper occurring in the oxidized parts of copper veins of Arizona and New Mexico. It is a hydrous copper silicate of the composition $CuSiO_3 \cdot 2H_2O$. It occurs in compact masses with a specific gravity of 2 to 2.4 and a hardness of 2 to 4. The color is green to bluish. It was used as a green pigment by the ancient Greeks. Atacamite is an ore found in Bolivia, Arizona, and Australia. It is a copper chloride with copper hydroxide, $CuCl_2 \cdot 3Cu(OH)_2$, generally found in confused crystalline aggregates, fibrous or granular. The hardness is 3 to 3.5, specific gravity 3.75, and the color may be various shades of green.

**Copper oxide.** There are several oxides of copper, but industrially the term refers to Red copper oxide, or Cuprous oxide, $Cu_2O$, a reddish crystalline powder formed by the oxidation of copper at high temperatures. It also occurs naturally in cuprite ore. The specific gravity is 6.0 and melting point 1235°C. It is insoluble in water but soluble in acids and alkalies. It is used in coloring glass and ceramics red, in electroplating, and in alternating-current rectifiers. Rextox, of the Westinghouse Electric Corp., is copper upon which a layer of copper oxide has been formed. Electric current will flow easily from the oxide to the copper, but only with difficulty from the copper to the oxide. It is thus used for transforming alternating current into pulsating direct current. Black copper oxide, or Cupric oxide, CuO, is a brownish-black amorphous powder of specific gravity 6.4 and melting point 1065°C. It is used for coloring ceramics green or blue. In its natural ore form it is called Tenorite. Copper hydroxide, formed by the

action of an alkali on the oxides, is a poisonous blue powder of the composition $Cu(OH)_2$ and specific gravity 3.37. It is used as a pigment.

**Copper-silicon alloys.** Silicon up to 6.7% is soluble in copper, and forms hard, strong alloys very resistant to corrosion. Above 3% of silicon, the alloys are too hard for most uses. The plain copper-silicon alloys are used for springs. Manganese up to about 1% may be added to improve the working qualities, and the ratio of silicon to manganese is kept at 3 to 1. When hard-drawn these alloys can have tensile strengths up to 150,000 lb. per sq. in. Webert alloy, of the American Brass Co., contains small amounts of silicon and manganese, and is used for pressure die castings. The tensile strength is 85,000 lb. per sq. in. Arcoloy, of the American Radiator Co., is a casting alloy containing 97.25% of copper, 2.63 silicon, 0.12 iron, and 0.01 phosphorus. Cusiloy A, of the Scovill Mfg. Co., has 95.5% of copper, 3 silicon, 1 iron, and 0.5 tin. It is marketed in various forms, and the annealed wire has a tensile strength of 60,000 lb. per sq. in. and elongation of 50%. Herculoy 418, of Revere Copper & Brass, Inc., contains 96.5% of copper, 3 silicon, and 0.5 tin. The tensile strength of the annealed sheets is 60,000 lb. per sq. in. with elongation 50%, and of the cold-rolled sheet 85,000 lb. per sq. in., with elongation of 10%. The weight is 0.308 lb. per cu. in., melting point 1820°F., but the electrical conductivity is only 8.1% that of copper. It is resistant to many chemicals, and is used as a structural metal in the chemical industries.

Alloys of this type but with lower silicon contents are softer and more ductile and are suited to cold heading, spinning, and drawing. Herculoy 419 has 2% of silicon and 0.25 tin. Herculoy 421 has 1.5% of silicon and 0.25 manganese. This alloy in annealed sheet form has a tensile strength of 38,000 lb. per sq. in. and elongation of 35%, while the cold-rolled sheet has a tensile strength of 60,000 lb. per sq. in. and elongation of 10%. The copper-silicon alloys are marketed in sheets, rods, bars, shapes, tubes, forgings, and ingots for castings. Both the silicon-tin and the silicon-manganese types are single phase, and the castings are dense and fine grained, suitable for such uses as valves.

**Copper sponge.** A porous copper made by mixing copper powder with a volatile nonmetallic substance, pressing, and heating in a hydrogen atmosphere at 900 to 1000°C. to drive off the volatile matter and sinter the copper particles together. The copper sponge is then saturated with lead by immersion in molten lead in a vacuum. The chief use is for machine bearings.

**Copper steel.** Steel containing about 0.25% of copper and very low in carbon, employed for construction work where mild resistance to corrosion is needed and where the cost of the higher resistant chromium steels is not warranted. It is employed in sheet form for culverts, ducts, pipes, and for such manufacturing purposes as washing-machine boilers. The copper neutralizes the corroding influence of the sulphur in the steel, and also aids in the formation of a fine-grained oxide that retards further corrosion. Copper is not added to unalloyed high-carbon steels because it causes brittleness and hot-shortness. When the carbon content is very low, the metal is in reality a Copper iron. Molybdenum in small quantities may also be added to give additional corrosion resistance, and the percentage of carbon may be raised to 0.40% when about 0.05% of molybdenum is added. Toncan iron, of the Republic Steel Corp., has this composition, and has a tensile strength of 40,000 to 48,000 lb. per sq. in., elongation 32 to 40%, and weight 0.283 lb. per cu. in.

The copper-bearing iron specified for culverts by the A.S.T.M. contains not less than 0.20% of copper and not more than 0.10% of carbon, manganese, phosphorus, sulphur, and silicon as impurities. But up to 0.20% of phosphorus in very low-carbon copper iron increases the corrosion resistance and the strength. The German corrosion-resistant copper iron known as Resista has 0.10% phosphorus with not more than 0.10% carbon. The tensile strength is up to 85,000 lb. per sq. in. with elongation of 20%. Cor-Ten, of the U.S. Steel Corp., is a structural steel containing somewhat more phosphorus with 0.30% of copper, 0.5 chromium, 0.10 carbon, and 0.5 silicon. The tensile strength is 70,000 lb. per sq. in., elongation 22%, and the corrosion resistance is about five times that of plain carbon steel. Lyonore metal is an open-hearth steel of the Lyon Conklin Co. containing small amounts of

chromium and nickel. In the low-alloy steels from 0.5 to 1.5% of copper can be added as the copper graphitizes the free carbides, and these steels have excellent drawing characteristics and have a high fatigue limit. Yoloy, of the Youngstown Sheet & Tube Co., is a high-tensile, corrosion-resistant structural steel with 1% of copper, 2 nickel, and up to 0.20 carbon. The tensile strength is up to 90,000 lb. per sq. in., with elongation of 30%. Copperoid is a plain copper steel of this company. Other copper-bearing steels are Cop-R-Loy, of the Wheeling Steel Co.; Apolloy, of the Apollo Steel Co.; Gohi iron, of the Newport Rolling Mill Co.; Newaloy, of the Newton Steel Co.; Beth-Cu-Loy, of the Bethlehem Steel Co.; Copper-Clude, of Spang, Chalfant & Co., Inc.; and Weircoloy, of the Weirton Steel Co.

**Copper sulphate.** Also called Bluestone and Blue vitriol. An azure-blue crystalline lumpy material of the composition $CuSO_4 \cdot 5H_2O$ and specific gravity 2.286. It is soluble in water and insoluble in alcohol. When heated, it loses its water of crystallization and melts at 150°C. It is used for wet electric-battery solutions, for copper plating, in dyestuffs, germicides, in coppering steel, and in various chemical processes. In its natural form, called Chalcanthite, it is a rare mineral found in arid regions and deposited from the waters in copper mines. It is produced commercially as a by-product in copper refineries, or by the action of sulphuric acid on copper or copper oxide.

**Coral.** A shiny hard calcareous material valued for jewelry, buckles, beads, and novelties. It is a growth composed of the skeletons of the protozoa creatures *Corallium nobile* and other species. The structures are built up by these creatures into forms like leafless trees or shrubs, fans, mushrooms, or cups. White coral is common and not used commercially. The most valuable is the Red coral, a twiglike species that grows about 12 in. in height with thin stems. Pink coral and Black coral are also valued. Red and pink corals come from the Indian Ocean and off the coast of northeastern Africa. Black coral is from southeastern Asia. The red and black varieties are very hard and take a beautiful polish. The pink is softer, with a more delicate appearance, and is used for beads.

**Cordage.** A general term for the flexible string or line of twisted fibers used for wrapping, baling, power transmission, and hauling. Cordage fibers are any materials used for making ropes, cables, twine, and cord. In general, the cordage fibers are hard compared with those used for weaving into fabrics, but cotton and some other soft fibers are used for cord. Twine is cordage less than $\frac{3}{16}$ in. in diameter, and composed of two or more rovings twisted together. Rope is cordage made by twisting several yarns into strands, and then twisting the strands into a line. A cable is a strong rope, usually referring to the large sizes of special construction. Cord is an indefinite term for twine, but is, more specifically, the soft cotton twines used for wrapping. The term string is used for the weak cotton cords used for wrapping light packages. Seaming twines are made of flax fibers. Seine twine is a three-strand cotton twine with 2 to 56 plies per strand. Most of the Binder twine is made from sisal, but Indian twine is made from jute. Ramie fiber is used for marine twines. About 50% of American strong cordage is from Manila hemp, and about 30% from sisal. Manila hemp is very resistant to sea water. Sisal is used for the cheaper grades of rope, but it absorbs water easily. True hemp is considered a superior fiber for strong ropes. Untarred Hemp rope is used for elevator cables, and tarred hemp is employed for ship cables. Marine rope, used by the Navy, is almost entirely of Manila hemp. Most industrial rope is made in three strands and may be hard lay, medium lay, or soft lay.

Cordage fibers are also obtained from a wide variety of plants. Generally, after retting the fibers, the softer and finer fibers are separated out for use in weaving into fabrics and the harder and coarser fibers are marketed as cordage fibers. New Zealand hemp, or New Zealand flax, is a strong cordage fiber obtained from the leaves of the swamp lily, *Phormium tenax*, grown in New Zealand and in Argentina. The fibers are white, soft, and lustrous. One variety of the plant reaches a height of 16 ft. and the other variety 6 ft. Olona fiber, grown in Hawaii and used locally for fishing nets, is from the plant *Touchardia latifolia.* The tensile strength is much greater than that of hemp, and it has great durability. Gravatá is a Brazilian name for the very long and resistant fibers from the leaves of the pineapple plant, *Ananas sagenaria.* The leaves

of this species are up to 7 ft. in length. The fiber known as Widuri of the East Indies is bast fiber from the tree *Calotropis gigantea* which yields the madar kapok. It has great strength and is resistant to sea water. It is used for ropes and fish nets. Agel fiber is from the stems and leaves of the Gebang palm of the Celebes where the various grades are used for sail cloth, rope, fishing nets, and the coarser fibers are woven into Bangkok hats. The fibers from the leaf stalks are fine and white. Caraguatá is a strong, highly resistant fiber from the plant *Bromelia balansea* of Paraguay. It was employed by the Indians for making hammocks, and is now used for cordage and burlap fabrics.

Synthetic fibers are also used for cordage. Nylon rope is about twice as strong as Manila rope, is lighter, and because of its property of stretching rapidly but recovering slowly it makes a desirable rope for lifting and towing, giving a smooth, shock-absorbing pull. Nylon ropes are used for airplane glider pulling. Glass rope, woven from continuous filaments of glass fiber, is used for chemical and electrical applications where resistance to chemicals or electrical insulation is needed. It is strong, but is expensive and has low flexing strength. It comes in diameters from ¼ to ¾ in. Fiberglas cordage, of the Owens Corning Fiberglas Co., is marketed in diameters from 1/64 to ⅛ in. made of continuous filament or staple glass fibers. The ⅛-in. untreated continuous filament cord has a breaking strength of 258 lb.

**Core oils.** Liquid binders used for sand cores in foundry work. The binder should add strength to the core, and should burn out after the metal is poured, so that the sand core will collapse. Linseed oil is considered one of the best binders, but it is usually expensive and may be mixed with cheaper vegetable oils or with mineral oil. In some cases fish oil or rosin is also used. Molasses, dextrin, or sulphite liquor may be included in prepared core oils. The specifications of the American Foundrymen's Association call for 50% of raw linseed oil, 25 H grade rosin, and 25 water-white kerosene, with no fish oil. A good core oil should have a specific gravity of 0.9368 max., a flash point of 165 to 200°F., a Saybolt viscosity of 155 min., an iodine number of 154, and be of light color. However, any drying oil or semidrying oil can be used to

replace all or part of the linseed oil. Perilla and corn oils are used, and core oils of linseed and soybean oil mixtures have good strength. The liquor from sulphite pulp mills contains lignin and is used as a core binder. Glutrin, of the Robeson Process Co., is a core oil with sulphite liquor. Truline is a resinous binder in powder form marketed by the Hercules Powder Co. Uformite 580, of the Resinous Products & Chemical Co., is a Core binder especially for aluminum sand cores. It is a modified urea-formaldehyde resin which bakes in the core at 325 to 375°F., and will break down in the core at temperatures above 450°F.

Cork. The thick, spongy bark of a species of oak tree, *Quercus suber,* grown in Spain, Portugal, Italy, Algeria, Morocco, Tunisia, and to a limited extent in the United States. It is used for bottle stoppers, insulation, vibration pads, and floats for rafts and nets. About half of the cork used in the United States is for insulation corkboard, and 25% for crown bottle tops. The scrap cuttings are used for refrigerator insulation, packing for the transportation of fruits, and for the manufacture of linoleum and pressed products. When marketed as Granulated cork, this material usually comes in sizes of ½ in. and No. 8 mesh. Cork is also used natural or in the form of pressed compositions for gaskets, oil retainers, roll coverings, polishing wheels, and many other articles. The material has a cellular structure with more than 50% of the volume in air cells. The cell structure is peculiar, and each cell is in contact with 14 neighboring cells, and because of lack of capillarity it does not absorb moisture. When dried, cork is light, porous, easily compressed, and very elastic. It is one of the lightest of solid substances, the specific gravity being 0.15 to 0.20. It also has low thermal conductivity, and is valued as an insulator in buildings and refrigerators. Charring begins at 250°F., but it ignites only with difficulty in contact with flame. The cork tree grows to a height of about 30 ft. After it has attained the age of about 25 years it can be barked in the summer, and this barking is repeated every 8 or 10 years. The quality of the bark improves with the age of the tree, and, with proper barking, a tree will live for 150 years or more. The thickness of the bark

varies from ½ to 2 in. Cork bark is shipped in bales of 170 lb., and Cork waste in bales of 148 lb.

Brazilian cork is the bark of the tree *Angico rayado,* called Pao santo bark, and also from the trees *Piptadenia incuriale* and *P. colomurina.* The bark has a cellular structure and, when ground, has the appearance of a low grade of true cork, but is softer. It is suitable for insulation. The trees grow in northeastern Brazil, beginning to produce in 12 to 15 years, and reproducing in about 5 years. A substitute for cork for insulation packings and acoustical panels is marketed by the Palmetex Corp. under the name of Palmetex. It is the compressed pith from the internal fibers of the saw-tooth palm, *Cerano repens,* of the Eastern Gulf states. It has lower heat conductivity than cork, but without a binder it is more friable.

**Corkboard.** Construction board made by compressing granulated cork and subjecting it to heat so that the particles cement themselves together. It is employed for insulating walls and ceilings against heat and cold, and also as a sound insulator. Cork tile is corkboard in smaller, regularly shaped blocks for the same purposes. The natural gum in the cork is sufficient to bind the particles, but other binders may be used. Corkboard produced by the Armstrong Cork Co. is marketed in sheets in thicknesses from 1 to 6 in. The weight is from 6 to 10 lb. per cu. ft., depending upon the amount of compression and the binder. The heat conductivity is 0.304 B.t.u. per hr. per bd. ft. for 1°F. difference in temperature between the sides, or about one-third that of wood. Corkboard retains the properties of cork, being cellular, and without capillarity or tendency to absorb moisture. Novoid corkboard, of the Cork Import Corp., is made with both large and small granules tightly packed to leave only small air spaces. Corinco corkboard is produced by the Cork Insulation Co. Joinite, of L. Mundet & Son, Inc., is a corkboard for use under machinery to deaden vibration and noise. Corkoustic is a sound-absorbent cork board of the Armstrong Cork Co. for walls and ceilings. It has a sound-absorbing coefficient of 0.30 compared with 0.032 for brick walls. Linotile, of this company, is a resilient tile made of powdered cork, oxidized oils, and color pigments.

**Corn.** One of the most important food grains of the world for both human and animal consumption, but also used industrially for the production of starch, glucose, alcohols, alcoholic beverages, and corn oil. Corn was unknown to Europe before the discovery of America where it was one of the chief foods of the Indians from Canada to Patagonia. In Europe and in foreign trade it is known by its original name of Maize, and the Incan name of Choclo still persists in South America for the grains on the cob. In Great Britain corn means all hard grains including wheat, and the American term corn is an abbreviation of the name Indian corn. Corn is the seed grain of the tall leafy plant *Zea mays* of which there are innumerable varieties or subspecies. It grows in temperate climates and in the high elevations of the tropics where there is a warm growing season without cold nights, but high commercial yields are limited to areas where there is a combination of well-drained friable soil, plenty of moisture, few cloudy days, and no night temperatures below 66°F. during the growing season of four months. About half the world production is in the United States and Argentina, but large amounts are also grown in southern Europe and northern India. About the end of the nineteenth century corn constituted 15% of the energy value of the American diet, but it has now decreased to less than 4%. The grains are produced in rows on a cob enclosed by leafy bracts. They are high in starch and in other food elements, and form a valuable stock feed especially for hogs and poultry. Nearly 90% of the commercial corn in the United States is for animal feed. But corn is one of the cheapest and easiest sources of starch, and much of the Argentine corn is used for starch and glucose. The average yield of corn grains is about 24 bu. per acre, although yields as high as 50 bu. per acre are obtained.

Sweet corn is a type of Soft corn, *Zea saccharata,* cultivated for direct eating and for canning. There are about 70 varieties grown widely on farms, but not cultivated for industrial applications. Pop corn, *Zea everta,* has very hard, small, elongated oval grains which, when heated, explode into a white, fluffy, edible mass without further cooking. It was used by the Indians as a food for journeys, and is now grown for food and confections. The corn cultivated for stock feeding and for starch and glucose are varieties

of Flint corn, *Zea indurata,* and Dent corn, *Zea indentata.* Flint corn has long cylindrical ears with hard smooth grains of various colors. Dent corn has larger and longer ears which are tapering, with white or yellow grains. About 300 varieties of dent corn are grown in the corn belt of the United States, while the Argentine corn is largely flint varieties which yield high starch. The Waxy corn grown in Iowa produces a starch comparable with the root starches. In the wet milling of corn for the production of Cornstarch, the germ portion of the grain is separated as a by-product and used for the extraction of Corn oil, or Maize oil. The germ contains 50% of oil which is a bright-yellow liquid of specific gravity 0.920 to 0.925, iodine value 120. It contains 43% oleic, 39 linoleic, 7 palmitic, and 3 stearic acids. It is used as an edible oil as a substitute for olive oil and in margarine, and also in soaps, belt dressings, core oils, and for vulcanizing into factice. Corn sirup and glucose are produced directly from the starchy corns. Zein, of the Corn Products Refining Co., is a protein extracted from corn. It is dissolved in alcohol to form a lacquerlike solution which will dry to a hard, tough film. It is used as a substitute for shellac, and is more water-resistant than shellac.

Kafir corn is a variety of sorghum grass not related to true corn. The plant is a tall annual with a stalk similar to corn but with smaller leaves and long cylindrical beardless heads containing small round seed grains. It is widely grown in tropical Africa, and a number of subvarieties are grown on a limited scale in Kansas, Texas, and Oklahoma. The grain is similar in composition to corn but has a peculiar characteristic flavor. It is used as flour in bread mixtures, and in biscuit and waffle flour.

**Corrosion-resistant alloys.** Any metals that offer resistance to corrosion, such as the alloys of the noble metals, the stainless steels, and the nickel-copper alloys, may be termed corrosion-resistant alloys, but the name usually refers to the highly alloyed, chemical-resistant chromium or chromium-nickel ferrous alloys not otherwise specifically designated as stainless iron or steel. Many of these alloys are also heat-resistant, or resistant to scaling at high temperatures, and there is no real dividing line between the corrosion-

resistant and the heat-resistant alloys. The high-chromium iron alloys are resistant to nitric acid and to sulphur attack.

The Chromium-iron alloys and the Chromium-nickel alloys give corrosion-resistant and acid-resistant properties within certain limits as defined by the stainless irons and steels. Other elements extend the range of these limitations. Molybdenum gives added resistance to hot oils. Copper neutralizes the corrosive effects of any sulphur present, and combines with the phosphorus to give an added corrosion-resistant element. It also graphitizes any free carbides and absorbs any oxygen present to form fine-grained oxides. With molybdenum in the alloy the copper content can be considerable without making the alloy brittle. Silicon gives resistance to acids except to hydrofluoric acid. The nickel gives strength to the alloys and prevents corrosion cracking. These alloys are white in color and take a brilliant polish even when the iron content is high, and they are thus valued for food-processing equipment. Those with some cobalt are more silvery in color, and have increased resistance. The use of chromium, nickel, and cobalt in ferrous alloys for acid resistance antidates the invention of the stainless steels. An old alloy under the name of Borcher's metal had 30 to 36% of chromium, with nickel, cobalt, and sometimes molybdenum. Sideraphite was an iron alloy with a high content of nickel, and with copper and tungsten.

Most of the corrosion-resistant alloys are now marketed under trade names. Lebanon No. 34, of the Lebanon Steel Foundry, for resistance to sulphuric and hydrochloric acids, has 20% of chromium, 30 nickel, 3.25 molybdenum, 5 copper, 3.25 silicon. The tensile strength is 72,000 lb. per sq. in. and elongation 45%. One grade of Midvaloy, of the Midvale Co., contains 60% of nickel, 10 chromium, 2 tungsten, and 1.5 manganese. When cast, this alloy has a tensile strength of 65,000 lb. per sq. in. and elongation of 24%. Cooper alloy 531, of the Cooper Alloy Foundry Co., contains 10 to 14% of chromium, 27 to 30 nickel, 3 to 4 each of molybdenum and copper, 0.10 max. carbon, 0.5 to 0.8 each of silicon and manganese, and 0.4 to 0.6 antimony. The antimony forms an insoluble copper-antimony film that gives added resistance to hydrochloric acid. It is also highly resistant to nitric and sulphuric acids. Noncorrodite, of the Millbury Steel Foundry

Co., is a high-chromium steel for castings. The silicon irons, containing high percentages of silicon, also form a group of corrosion-resisting metals much used for cast parts for chemical equipment.

Vitallium, an alloy of 65% cobalt, 35 chromium, and 5 molybdenum, originally used for surgical straps because of its noncorroding quality and high resistance to body acids and fluids, was adopted during the war for turbosuperchargers for military planes because of its resistance to hot gases at continuous temperatures of about 1500°F. This metal has good precision casting qualities. Eatonite, of the Eaton Mfg. Co., used for valve facings to withstand the corrosive action of hot gases and antiknock fuels, is a similar material but with tungsten instead of molybdenum, and part of the cobalt replaced by nickel. An alloy used by the Germans to resist the hot gases of jet-propelled aircraft, under the name of Tinadure, contained 30% of nickel, 15 chromium, 1.8 titanium, and 0.10 carbon. Chrondure, for the same purpose, contained 12% of chromium, 18 manganese, 1 vanadium, 0.20 nickel, and 0.5 carbon. Berlaloy contained 17% of chromium, 15 nickel, 2 molybdenum, and 1.15 combined tantalum and cobalt.

**Corundum.** An extremely hard, crystalline mineral used as an abrasive. It is a natural aluminum oxide, $Al_2O_3$, found in India, Burma, the Near East, South Africa, and in the states of Georgia and the Carolinas, but almost all of the commercial production is in South Africa. The finest, clear, colored crystals are sorted out as gem stones, and the premium ore is the large crystal material left after the gem pickers have sorted for gem stones. This ore usually brings more than 50% higher price than the boulder chips. Small amounts are shipped in grain. The crude ore is washed, crushed, and graded. The hardness is about 8.8, and specific gravity about 4. It has a high refractive index, and is next to the diamond in the passage of X rays. When pure the stone is colorless, but it usually contains metallic oxides, and the colors are white, gray, pink, yellow, brown, red, and blue. There are four grades to which all corundum shipped from South Africa must conform. South African government Grade A is over 92% $Al_2O_3$; Grade B is 90 to 92%; Grade C is 85 to 90%; and Grade D is under 82%. In the United States the grain sizes for coarse

grinding are 8 to 36 mesh, but most of the natural corundum is used for optical glass grinding in sizes from 60 to 275 mesh. Artificial corundum, or aluminum oxide made in the electric furnace, is purer, more uniform, and harder, and is preferred in the mechanical industries. The word corundum is Hindu, and originally applied to gem stones. The Ruby is a red corundum colored with chromic oxide. The off-color reds in the rubies are also used for pivot-bearing jewels. The Sapphire is a blue corundum colored with titanic oxide. The deep cornflower blue is valued as a gem stone, and the pale stones are used for watch jewels. The Oriental topaz is a yellow corundum containing ferric oxide. The Indian sapphires of Mogok, Burma, Kashmir, and those of Ceylon, are famous as gems. The index of refraction of corundum is 1.77, and the dispersion factor is lower than that of the diamond so that these gems lack sparkle, but they are valued for their color and hardness.

**Cotton.** The white to yellowish fiber of the calyx, or blossom, of several species of plants of the genus *Gossypium* of the Mallow family. It is a tropical plant, and the finest and longest fibers are produced in hot climates, but the plant grows well in a belt across Southeastern United States and as far north as Virginia. It requires a growing season of about 200 days with an average summer temperature above 75°F. and a dry season during the time of ripening and picking. Cotton was used in India and China in most ancient times, was described in Greece as a vegetable wool of India, but was not used in Europe until the early Middle Ages. All of the Asiatic species are short-staple, and the long-staple cottons are from species cultivated by the American Indians. Cotton has a wide variety of uses for making fabrics, cordage, padding, and for producing cellulose for plastics, rayon, and explosives.

There are many species and varieties of the plant, yielding fibers of varying lengths, coarseness, whiteness, and silkiness. Cotton fiber contains 88 to 96% of cellulose, dry weight, together with protein, pectin, sugars, and 0.4 to 0.8% wax. Ordinary treatment does not remove the wax. When removed by ether extraction the fiber is stronger but is harsh and difficult to spin. The most noted classes are Sea Island, Egyptian, American upland, Brazilian, Arab-

ian, and Nanking. Sea Island cotton, *G. barbadense,* was native to the West Indies, and named when brought to the islands off the American coast. It is grown best in hot moist climates, and is the longest, finest, and silkiest of the fibers. Its length varies from 1¼ to 2½ in., but it is cream-colored. Egyptian cotton, grown in Egypt and the Sudan, came originally from Peruvian seed. Peruvian cotton, *G. acuminatum,* is long-staple, silky, has strength and firmness, but is brownish in color. The Tanguis cotton from Peru is valued for fine English fabrics. Egyptian cotton, or Maco, is next in quality to Sea Island. The long staple is from 1⅛ to 1⅜ in., and the extra-long staple is over 1⅜ in. It has a fine luster and great strength. It also has a remarkable twist, which makes a strong, fine yarn. It is used chiefly in yarns for the production of fine fabrics, thread, and for automobile-tire fabrics. American-Egyptian cotton is grown in Arizona. The fiber has an average length of 1⅝ in., and has the same uses as the Egyptian. Upland cotton, *G. hirsutum,* is the species originally grown by the Aztecs of Mexico. It is whiter than Egyptian or Sea Island cottons, and is the easiest and cheapest to grow. There are 1,200 named varieties of this plant. The short-staple upland has a fiber under 1⅛ in. in length, and can be spun only into coarse and medium yarns, but it is the most widely grown of cottons in the United States. Long-staple upland is from 1⅛ to 1⅜ in. in length. The common grades of cotton fiber in the United States vary in diameter from 0.0006 to 0.0009 in. Sea Island cotton fiber is as fine as 0.0002 in., compared with 0.001 in. for the coarse Indian cotton. The cotton of India, China, and the Near East is from *G. herbaceum,* and the fiber is short, ⅜ to ¾ in., but is very strong.

In normal times, in spite of a surplus of cotton in the United States, the Indian cotton is imported for use in blankets and in hard fabrics. The Chaco cotton grown in Argentina is from Louisiana seed, and probably 70% of total world cotton is now grown from American upland seed although it varies in characteristics due to differences in climate and soil. The world production of cotton in the year before the war was 28,800,000 bales of 478 lb. each, with 43% produced in the United States. Cotton yarn is put up in 840-yd. hanks, and the number, or count, of cotton yarn indicates

the number of hanks to the pound. The No. 10 cotton yarn, therefore, will have 10 hanks, or 8,400 yd., to the pound.

Absorbent cotton is cotton fiber that has been thoroughly cleaned and the natural wax removed with a solvent such as ether. It is very absorbent and will hold water. It is marketed in sterilized packages for medical use. Cotton batting is raw cotton carded into matted sheets, and put up usually in rolls to be used for padding purposes. Cotton waste, used in machine shops for wiping under the general name of Waste, is usually in mixed colors, but the best grades are usually all white, of clean soft yarns and threads without sizing. It is very oil-absorbent. Comber waste consists of the lengths of fiber up to 1 in., and is not sold with the waste from yarns, but is sent to mills producing cheap fabrics. Cotton fillers, used as reinforcing materials in molding plastics to replace wood flour or other fibers, are made by cutting cotton waste or fabric pieces into short lengths. Filfloc, of the Rayon Processing Co., is cotton flock for this purpose; Fabrifil is cotton fabric cut into small pieces; Cordfil is cotton cord cut into very short pieces. They give greater strength to the molded product than wood flour.

**Cotton fabrics.** Cotton cloth is made in many types of weave and many weights, from the light, semitransparent Voile, made of two-ply, hard-twisted yarn, and Batiste, a fine, plain-woven fabric, to the coarse and heavy canvas and duck. They may have printed designs, as in Calico which is highly sized, or have yarn-dye plain stripes, plaids, or checks, as in Gingham, or have woven figures, as in Madras. Percale is a printed fabric similar to calico but with a higher yarn count. Swiss is a plain-woven, fine, thin muslin, stiff and crisp. Dotted Swiss is a very thin, transparent, plain-woven cotton with colored swivel or lappet woven dots. It is sized stiff and crisp. Dimity is a plain-woven, sheer fabric with ribs in the form of corded checks or stripes. It comes in white or colors. Organdy is a plain-woven, thin, transparent crisp fabric stiffened with shellac or gum, usually in delicate color shades. All of these are plain woven. Poplin is a lateral-ribbed fabric, often mercerized. It is heavier than broadcloth. Rep has a rib produced by heavy warp yarns. Crash is a rough-texture fabric with effects produced by novelty yarns. Charmeuse in the cotton industry is a

soft, fine, satin-weave fabric of Egyptian cotton used industrially as a lining material. Chambray is a plain-woven, lightweight cotton similar to gingham but with no pattern and a dyed warp and white filling. It is used for linings, shirtings, and dresses. Cotton damask is a type of jacquard figured fabric having warp sateen figures in a filling sateen ground or vice versa. The surface threads of the figures lie at right angles to those in the ground so that the light is diffusely reflected, causing them to stand out in bold relief. It is usually of coarse or medium yarns, 15's to 30's, and bleached and finished to imitate linen. Cotton crepe is a cotton fabric having a pebbled surface. The pebble is produced with sulphonated oil, lauric acid ester oil, or other soluble oil which is washed off after the treatment. When the word crepe is used alone, it usually signifies silk crepe. Domet is a warp-stripe cotton fabric similar to flannel, used for apparel linings. Venetian is a highly mercerized, stout, closely woven fabric with the yarn in reverse twist. It is used as a lining for hats, pocketbooks, and luggage. Cottonade is a coarse, heavy, cotton fabric made to look like woolens and worsteds in weave and finish, and is used for men's suit linings. Eiderdown is a cotton fabric of knitted soft-spun yarns, heavily napped on one or both sides. It is used for shoe and glove linings. Tarlatan is a thin cotton fabric with a net weave, heavily sized. It is used for coat linings.

Twill is a fabric in which the threads form diagonal lines. Tackle twill, used for football uniforms, is also used in olive drab color for army parachute troop uniforms. It is a strong, snag-resistant fabric having a right-hand twill with a rayon warp and combed cotton filling. It is 8.5 oz. per sq. yd., 180-lb. warp, and 80-lb. filling. Cavalry twill is not a cotton cloth, but is of worsted or rayon twill woven with a diagonal raised cord. Foulard is a highly mercerized twill-woven cotton with a silky feel. It is plain or printed and is used for dresses or sportswear. Cotton duvetyn is a twill-woven, mercerized cotton fabric with a fine nap that gives it a soft velvety feel. It is much used for apparel linings and pocket linings. Brilliantine is a lightweight fabric with a cotton warp and a twilled worsted filling, yarn dyed. It is used for apparel linings.

**Cottonseed oil.** One of the most common of the vegetable oils, with about 5 billion pounds produced annually, of which 30% is produced in the United States. It is used primarily as a food oil in salad oils, margarine, cooking fats, and for sardine packing, but it also has a wide industrial use in lubricants, cutting oils, soaps, quenching oils, and in paint oils. The hydrogenated oil is widely used as a cooking grease. Its food value is lower than that of lard, but is often preferred because it is odorless and does not scorch. Cottonseed oil is expressed from the seed of the cotton plant, *Gossypium,* and is entirely a by-product of the cotton industry, its production depending upon the cotton crops. The yield of seed is 890 lb. per 478-lb. bale of cotton, and 100 lb. of seed yields 15.5 lb. of oil. When the seeds are crushed whole, the oil is dark in color and requires careful refining. The American practice is to hull the seeds before crushing. The oil is colorless, nearly odorless, and has a specific gravity of 0.915 to 0.921. Upland cotton seed contains about 24% of oil, which has 40% of linoleic, 30 oleic, and 20 palmitic acids. The residue is caked and sold as Cottonseed meal for cattle feed and fertilizer. About 1,000 lb. of cake and 580 lb. of hulls are obtained per short ton of seed. The American oil has an iodine value up to 110, and a saponification value of 192 to 200. Egyptian and Indian oils are inferior in color, and the Indian oil has a fishy odor and a fluorescence. Cottonseed stearin is the solid product obtained by chilling the oil and filtering out the solid portion. It has an iodine value between 85 and 100, and consists largely of palmitin. It is used for margarine, soap, and as a textile size. Winter-yellow cottonseed oil is the expressed oil after the stearin has been removed.

**Cottonwood.** The wood of the large trees *Populus monilifera, P. deltoides,* and other species of the United States and Canada. It is a soft wood of a yellowish-white color and a fine, open grain. It is sometimes called poplar, or Carolina poplar, and Whitewood. The weight is about 30 lb. per cu. ft. The wood is easy to work, but is not strong and warps easily. It is used for packing boxes, paneling, and general carpentry. The *P. deltoides,* or Eastern cottonwood, used in paneling, has a specific gravity when kiln-dried of 0.43, a compressive strength perpendicular to the grain of 650 lb.

per sq. in., and a shearing strength parallel to the grain of 660 lb. per sq. in. This wood comes from the lower Mississippi Valley. Black cottonwood is from the large tree *P. trichocarpa,* of the Pacific Coast. The wood is used for boxes, excelsior, and pulpwood. It has a light color, uniform texture, and fairly straight grain. Swamp cottonwood, *P. heterophylla,* also called River cottonwood, grows in the Mississippi and Ohio river valleys. Balsam poplar is from the tree *P. balsamifera,* of the Northeastern states. It is a soft weak wood used chiefly for containers and for making excelsior. The tree also goes under the Algonquin name of Tacamahac. The wood may be marketed as cottonwood even when mixed with aspen. It is an excellent paper-pulp material. The name cottonwood is also applied to the wood of the tree *Bombax malabaricum,* native to India, Burma, and Ceylon, which produces kapok. The wood is white in color, soft, and weighs about 28 lb. per cu. ft. It has the same general characteristics as cottonwood.

**Creosote.** Also called Dead oil and Pitch oil. A yellowish poisonous oily liquid obtained from the distillation of coal tar. It has the odor of carbolic acid, a specific gravity of 1.03 to 1.08, and a boiling point of 200 to 300°C. The crude Creosote oil is used as a wood preservative and as a harsh disinfectant. Creosote is also obtained in the distillation of pine wood tar, and is then a yellowish liquid with a smoky odor, a mixture of phenols and derivatives. Creosote oil contains the poisonous Acridine which may be separated out and used as an insecticide. The high distillates from pine-tar creosote oil may also be separated out and used for wood preserving. The higher distillates are used so that the impregnation in the wood will not be driven off by the sun. No-D-K, of the Tennessee Eastman Corp., is a wood-impregnating creosote of this class. The distillation of wood also produces charcoal, gas, and Methyl acetate, a sweet-smelling liquid of the composition $CH_3COO \cdot CH_3$, and boiling point 54°C., used as a solvent for lacquers. Cresol, also known as Cresylic acid and as Methyl phenol, obtained in the distillation of coal tar, is a mixture of the three isomers of cresol, $CH_3 \cdot C_6H_4 \cdot OH$, and Xylenol, $(CH_3)_2 \cdot C_6H_3 \cdot OH$. The crude material is a brownish-yellow liquid solidifying at 11°C. It is used in soap emulsion cutting oils as a disinfectant, and in medicine as a

strong antiseptic such as Lysol which is a 50% solution of cresols in liquid soap. But its important use is in the production of other chemicals. Ortho cresol is a colorless solid with a melting point of 30°C. and a boiling point of 191.5°C. It is soluble in alcohol, but only slightly soluble in water. It is used in the manufacture of cumarones, disinfectants, and fumigants, and as a plasticizer. Meta cresol is a colorless to yellow liquid freezing at 12°C. and boiling at 202.8°C. It is used in the manufacture of photographic developers, nitro cresols, disinfectant soaps, printing inks, paint and varnish removers, as a preservative in leathers, glues, and pastes, in the reclaiming of rubber, and in making synthetic resins, perfumes, and pharmaceuticals. Para cresol is a colorless solid melting at 36°C. and boiling at 202.5°C. It is the least soluble of the cresols. It is used in the manufacture of cresotinic acid dyes, disinfectants, and pharmaceuticals.

**Crinoline.** A stiff fabric of very open weave, made of coarse cotton yarns and heavily sized. The weave is plain. It was originally made of horsehair and linen, and hence its name. Crinoline is bleached, or is dyed in plain colors, and is used industrially as a supporting medium for parts made of waxes or composition, or where a stiff coarse fabric is needed.

**Crotonaldehyde.** A straw-colored, inflammable, mobile liquid of the composition $CH_3 \cdot CH{:}CH \cdot CHO$, with specific gravity 0.852 to 0.858, and boiling point 99 to 104°C. It is used as a solvent for resins, gums, and rubber, and in tanning leather. It is soluble in water, alcohol, benzol, and naphtha. Crotonaldehyde, also known as Crotonic aldehyde and Propylene aldehyde, has a pungent, suffocating odor and is a lachrymatory for tear gas. It is also used in city gas mains as a warning agent on the escape of poisonous fuel gas. One pound of crotonaldehyde per million cubic feet of air will awaken a sleeping person.

**Cryolite.** A mineral of the composition $Na_3AlF_6$, found in commercial quantities in Greenland, and used as a flux in the electric production of aluminum, in the making of special glasses and porcelain, as a binder for abrasive wheels, and in insecticides. It occurs in masses of a vitreous luster, colorless to white, with a hardness of

2.5. It fuses easily. Kryalith, of the Pennsylvania Salt Co., is cryolite of 98 to 99% purity, and Kryocide is a grade of 90% purity. The latter is the dust from the natural ore, and is used as an insecticide. Synthetic cryolite is made from sodium carbonate, bauxite, and fluorite.

**Cryptostegia rubber.** Rubber obtained from the leaves of two species of perennial vines native to Madagascar, *Cryptostegia grandiflora* and *C. madagascariensis*. The former was grown in India and the rubber was known as Palay rubber. It was brought to Mexico and Florida as an ornamental plant and now grows extensively in Mexico and the West Indies. The maximum rubber content is found in the leaves 3½ months old, at which time it is 2 to 3% of the dry weight of the leaf. There is also about 8% resin in the leaf which must be separated from the rubber as it makes it soft and tacky. The *C. madagascariensis* contains less rubber, but the leaves of hybrid plants grown from both species give increased yields of rubber. The hybrid does not come true to type from seed, and is propagated from cuttings. When extracted and separated from the resin, cryptostegia has the same uses as ordinary hevia rubber. Another plant that yields rubber from the leaves is the desert Milkweed, *Asclepias erosa, A. subulata,* and other species growing in the dry regions of Southwest United States. The short and slender leaves are produced only on the young stems and the gathering season is short. The dry leaves are ground, and the rubber is obtained by solvent extraction. The average rubber content is about 2%, but as much as 12% has been obtained from some species of wild plants. As with guayule and cryptostegia a considerable amount of resin is extracted with the rubber. Goldenrod rubber is extracted similarly from the leaves of the goldenrod, the dry leaves containing as much as 7% of rubber mixed with resin. The species which contains the most rubber is *Solidago leavenworthii.* It does not occur in the plant as a latex, but is in isolated globules in the cells, mostly in the leaf. The Milk bush, *Euphorbia tirucalli,* of Cuba and Jamaica, also produces rubber of good elasticity, but the crude latex from the bush causes skin blisters, and the extraction requires special treatment.

**Cumerone.** A colorless oily liquid of the composition $C_8H_6O$, employed in making synthetic resins. Cumerone occurs in the fraction of naphtha boiling between 165 and 175°C., and is isolated by acid treatment. The specific gravity is 1.096, and boiling point about 172°C. It has a characteristic odor, is insoluble in water, and is easily oxidized. Another product of a similar character is Indene, $C_9H_8$, a colorless liquid boiling at about 182°C. that can be oxidized and polymerized readily. The Indene resins are classed with the cumerone resins, but they are lighter in color and are used in varnishes. The simple polymer, or di-indene resin, is a crystalline solid melting at about 58°C. The polyindene resins are made by polymerizing indene with ultraviolet light and oxygen. The Cumerone resins, which are polymers of $C_6H_4 \cdot CHO:CH$, made by the action of sulphuric or phosphoric acids on cumerone, are very soluble in organic solvents, and are used in lacquers, waterproofing compounds, molding, and in adhesives. The specific gravity of the molded resins is 1.05 to 1.15. They have high dielectric strength. Paracumerone, called also Paraindene and Cumar gum, is a synthetic resin which is a copolymer of cumerone and indene. The grades vary from a soft gum to a hard brown solid, with melting points from 5 to 140°C. Varnishes made with it are resistant to alkalies. Nevindene, of the Neville Co., is a cumerone-indene resin of specific gravity 1.08 and melting point 10 to 160°C., used for compounding with rubber and synthetics. Nevilloid C-55 is a Cumerone-indene resin in water emulsion for coatings. It forms cohesive translucent films of slightly tacky nature. Blended with melamine resin it forms a clear and hard film. Cumar is the name of a cumerone-indene resin of the Barrett Co. Piccoumaron, of the Pennsylvania Industrial Chemical Corp., is a cumerone-indene resin in grades from liquids to brittle solids.

**Cupro-nickel.** Any alloy of copper and nickel, as nickel and copper form solid solutions in all proportions. Nickel and copper are found naturally alloyed in many copper mines, and as the two metals are difficult to separate the cupro-nickel alloys were among the first alloys used. They are ductile and malleable, are very corrosion-resistant, and have a maximum hardness at about 50% nickel. A 15% nickel alloy can be rolled from a thickness of 1½

in. to about 0.040 in. without intermediate annealing. Nickel whitens copper and gives the alloys a characteristic pinkish-white color sometimes called yellow, which can be whitened by the addition of small amounts of cobalt. At least 10% of nickel is needed to obtain a nickel-white color, and this amount gives high corrosion resistance. Cupro-nickel with 2.5% of nickel is used for the driving bands of shells, 15% nickel for bullet jackets and condenser tubes, and 25% for coinage. The higher nickel alloys are used for resistance wire, for corrosion-resistant equipment, and for parts where strength, toughness, and a white color without plating are required. For the latter use, however, the alloys usually contain other elements. When color is important, the alloys should not contain zinc because of the change in color by dezincification. Aluminum is also used as a whitener and hardener. An old formula for a silvery-white alloy for silverware, called Minargent, was for 100 parts of copper, 70 nickel, 6 antimony, and 2 aluminum. The standard cupro-nickels are 5, 15, 20, and 30% nickel. Supernickel is a name given by the American Brass Co. to the 70-30 alloy for condenser tubes. This alloy and the 80-20 alloy are also marketed by the Revere Copper & Brass, Inc., for condenser tubes. The 70-30 alloy has a tensile strength, annealed, of 49,000 lb. per sq. in. with elongation of 50%, and when hard-drawn the strength is 75,000 lb. per sq. in. with elongation of 5%. The weight is 0.323 lb. per cu. in. Benedict metal is a white alloy used for condenser tubes, hardware, and chemical machinery parts. It contains 85% of copper, 14.5 nickel, and 0.5 of other elements. The white alloy of the Scovill Mfg. Co. known as Adnic, used for valve diphragms and parts for chemical equipment, has 70% of copper, 29 nickel, and 1 tin. When hard-drawn it has a tensile strength of 113,000 lb. per sq. in. and elongation of 10%. The hot-rolled rod has a strength of 65,000 lb. per sq. in. and elongation of 45%. This is essentially the same alloy marketed by the Revere Copper & Brass, Inc., as Admiralty metal.

Small amounts of silicon added to cupro-nickel form a nickel silicide that gives a Hardenable copper, which is the ancient tool material of the Incas. But, since the nickel is usually low in these alloys, they are not classed with the cupro-nickels. An alloy of this type marketed by the American Brass Co. under the name of

Tempaloy contains 95% of copper, 4 nickel, and 1 silicon. It is hard and strong, and can be forged or cold-rolled. Annealing by heating throws the nickel silicide into solid solution and produces a soft and ductile metal, which can be hardened again by holding at a temperature of 450°C. for several hours. The tensile strength is from 50,000 to 150,000 lb. per sq. in. with hardness above 200 Brinell. Small amounts of manganese and iron may be added to cupro-nickel to harden and strengthen the alloy. Davis metal, of the Chapman Valve Mfg. Co., for valves and fittings, contains 67% of copper, 29 nickel, 2 iron, 1.5 manganese, and 0.5 carbon and silicon. The castings are hard and corrosion-resistant. Cufenium, a white alloy used as a base metal in tableware, contains 72% of copper, 22 nickel, and 6 iron. Some chromium may be added for further corrosion resistance. Everbrite, of the American Manganese Bronze Co., has 60% of copper, 30 nickel, 3 iron, 3 silicon, and 3 chromium. It is white in color, has a tensile strength, cast, of 75,000 lb. per sq. in., elongation of 14%, and Brinell hardness of 170. Cataract metals, of the Niagara Falls Smelting & Refining Corp., is the name of a series of cupro-nickel alloys containing small amounts of other elements. Copper-nickel alloy is the name used for the 75-25 and 50-50 cupro-nickel slabs, ingots, and shot used for adding nickel to brasses and bronzes. Federal specifications for copper-nickel alloy call for a minimum of 65% of copper and 25 nickel with other elements allowable.

The high-nickel cupro-nickel alloys are very corrosion-resistant at high temperatures, and are used for electrical resistance wire and strip where the temperature does not exceed 1100°F. Lucero, of the Driver-Harris Co., is a 70-30 alloy, and Copel is a 55-45 alloy for resistance wire. The 55-45 alloy has an electrical resistivity of 294 ohms per cu. mil ft., tensile strength, cold-drawn, of 140,000 lb. per sq. in. Because of its constant-temperature coefficient of resistance it was given the name of Constantan when used in low-temperature pyrometers. It has a high thermoelectric effect with either copper or iron, but cannot be used for high-temperature pyrometers as the melting point is 1290°C. Advance metal, of the Driver-Harris Co., and Cupron, of the Wilber B. Driver Co., are names for this alloy for pyrometer use.

**Curupay.** The wood of the tree *Piptadenia cebil,* native to Argentina, Paraguay, and Brazil. In northern Argentina and Paraguay it is also known under the Guarani name Cevil. The wood is very hard and heavy, weighing 74 lb. per cu. ft., has a reddish color, and a handsome, wavy grain. It is used as an ornamental hardwood, and is much employed locally for construction.

**Cutting alloys.** Nonferrous alloys used for cutting tools, as distinguished from alloy steels, although some may contain iron and be allied to the super high-speed steels. They may have a base of cobalt or nickel and they usually contain chromium and tungsten with enough carbon to form hard carbides. An early cutting alloy of this kind known as Cooperite contained 80% nickel with tungsten, molybdenum, and silicon. Stellite, of the Haynes Stellite Co., is made in two grades, 98M2 and Star J-metal for cutting tools. It contains high percentages of cobalt, chromium, and tungsten, about 2 of carbon, and small amounts of iron and molybdenum. The hard cutting properties are inherent in the alloy, and are not obtained by heat-treatment as in the steels. It retains its hardness at red heat. Stellite is silvery white in color, has a hardness of about 570 Brinell, and a tensile strength up to 130,000 lb. per sq. in. J-metal is a special high grade. Delloy No. 6, of the Penn Rivet Corp., contains 43% of cobalt, 33.4 chromium, 19.1 tungsten, and 2.7 carbon. It is marketed in standard tool bits. The tensile strength is 54,000 lb. per sq. in., compressive strength 325,000 lb. per sq. in., and hardness 61 to 64 Rockwell C. T and V alloy, of the Jessop Steel Co., has 45% of cobalt, 32 chromium, 19 tungsten, and 2.4 carbon. These cast alloys have greater wear resistance than high-speed steel. Speedaloy, of the Tungsten Alloy Mfg. Co., is a cobalt-chromium-tungsten cast alloy for cutting tough alloy steels. Rexalloy, of the Crucible Steel Co., is another cast cobalt-chromium-tungsten cutting alloy. Steels of this cast type can be made with a boron content up to 1.5%, which gives increased hardness. Borcoloy, of General Aircraft Equipment, Inc., is a cobalt alloy with boron to give added hardness and wear resistance. Kutkost, of the General Tool & Die Co., is a cutting alloy containing boron marketed in the form of cast tool tips. Crobalt, of the Michigan

Tool Co., is a cast alloy containing high cobalt and chromium, used for tools and wear-resistant parts.

**Cutting oils.** Oils used on cutting tools and on work being machined to aid in the cutting action. The chief object of the oil is to act as a lubricant between the tool and the work, decreasing the friction. These oils, therefore, are usually heavy oils or compounds distinguished from the thin solutions of soluble oils employed for flooding the work with the object of keeping it cool. However, the cutting oil also carries off much of the heat and enables the tool to stand up longer under the cutting action. There is no sharp dividing line between the cutting oils and the coolants which are designated in the mechanical industries as Soluble oils because they are generally used in this water solution. These soluble oils also have some lubricating action. Lard oil is a good cutting oil, but is seldom used alone because of its cost. It is mixed with mineral and vegetable oils, or with hydrogenated oils. The mineral-lard oils are used for machining copper alloys or for turning steel where a good surface finish is required. Lard oil mixed with kerosene is used for cutting aluminum and for monel metal. Ordinary mineral oils are used for light cutting operations and combine lubrication and cooling. For cutting brass, an emulsion of oil in soapy oil is often employed.

Sulphonated or Sulphurized oils are used for the tougher and harder brasses and bronzes as the sulphur adds film strength to the oil and also gives better penetration to the cutting edge. An oil of this nature is definitely also a soluble oil and is both a cutting oil and a coolant when it is in water solution. These soluble oils are made by treatment of an oil with sodium hydroxide or other alkali, either by direct mixture or by the addition of soaps to the oil. Oils thus treated emulsify readily because of the formation of sodium oleate and sodium palmitate, and they can be mixed with water in all proportions. The presence of sulphur is important for cutting action. Pine oil may be added to improve the odor. It also has a cleansing action. Cresol or other disinfectant is usually also added. Rosin or rosin oil may be added to improve cutting action.

Federal specifications for a compounded soluble oil permit a maximum of only 10% of water, with no separation of the water

in 24 hr. at 75°F. The coolant known as Soda water in machine shops contains little or no oil and is a solution of soap and soda ash in water. It has a corrosive action, and also tends to wash out lubricant from the machine bearings. For 18-8 stainless steel and for high-carbon or alloy steels the sulphur-base oils are used as cutting oils, but highly sulphonated oils are not employed on nonferrous alloys where there is reaction of the sulphur with the metals. Cleartex, Sultex, and Transultex are sulphurized oils of the Texas Co. in different grades for the cutting of hard steels. Carbon tetrachloride mixed with turpentine in the proportion of 3 to 1 is used for hard chromium steels. A typical oil for screw cutting is made with 75% of paraffin oil and 25 cottonseed oil. For cutting fine threads white lead mixed with a heavy oil may be used. Cutting compounds are marketed under many trade names. They may vary widely in composition, and may contain also antioxidants or inhibitors to prevent rancidity of the vegetable or animal oils used. The cutting lubricant marketed by the Acheson Colloids Corp. under the name of Aquadag is a solution of 22% of colloidal graphite in water.

**Cuttle bone.** Also called Cuttlefish bone. A calcareous powder made from the internal shell of a Mediterranean marine mollusk of the genus *Sepia,* used as a fine polishing material for jewelry and in tooth powders. Sepia is a dark-brown pigment made from the black secretion or inky fluid found in an internal ink sac of the *Sepia* mollusk. It is used in India inks of sepia or dark-brown color. The sepia fluid was formerly employed directly as a writing ink.

**Cylinder iron.** A general name for cast irons primarily designed for engine cylinders, pistons, and piston rings, but also used where a strong, hard, and wear-resistant iron is needed. Cylinder irons should be hard, close-grained, and be capable of casting readily without hard spots or holes. They should also have good heat conductivity, and copper may be added to increase the conductivity. A plain cylinder iron for internal-combustion engines contains 3 to 3.25% total carbon, 2 to 2.25 of silicon, 0.40 to 0.75 manganese, and 0.12 max. each of sulphur and phosphorus. But the cylinder irons now usually contain alloying elements. Nickel decreases the

tendency of the low-silicon irons to chill in the thin sections, and also increases the strength. Some chromium is added to increase the strength and hardness, and molybdenum may be included to refine the grain and increase the strength. A low-silicon locomotive cylinder iron for 200 lb. steam pressure has 1.25% of nickel, 1 silicon, 0.60 to 1 manganese, and 3 total carbon. An outboard-engine cylinder iron contains 2% of nickel and 0.50 chromium with a small amount of copper. A truck-engine iron containing 3% total carbon, 0.75 of combined carbon, 2 silicon, 1.7 nickel, and 0.7 chromium, has a tensile strength of 38,000 lb. per sq. in. and a Brinell hardness of 229. High-grade cylinder irons with close grain and hardness of 185 to 210 Brinell in the bore have a range of 3.1 to 3.4% total carbon, 0.50 to 0.70 of combined carbon, 1.8 to 2.4 silicon, 0.50 to 0.80 manganese, 0.25 to 1.5 nickel, 0.10 to 0.50 chromium, 0.10 to 0.70 molybdenum, 0.12 to 0.20 phosphorus, and 0.10 to 0.12 sulphur. They are made with about 20% of steel scrap. The tensile strength is 35,000 lb. per sq. in.

**Cypress.** A number of different woods are called cypress, but when the name is used alone it is likely to refer to the wood of the cypress tree, *Cupressus sempervirens,* and other species of the same genus of Europe and North America. This wood is light in weight, soft, light brown in color, and has a pleasant aromatic odor. It is very durable, and is used for furniture, chests, doors, and general construction. The wood usually referred to in the Eastern United States as cypress, and also as Marsh cypress, Red cypress, Bald cypress, Yellow cypress, Gulf cypress, and Southern cypress, is from the coniferous tree *Taxodium distichum,* and the Pond cypress is from *T. ascendens,* of the Southeastern states. Southern cypress grows along the coast from Delaware to Mexico, especially in Florida and the lower Mississippi Valley. The red cypress is along the coast and the yellow is inland, the coastal types being darker in color. The trees are sometimes very old, reaching a height of 120 ft. in 800 years. The wood is yellowish red or pink in color, and is moderately hard with an open grain. The weight is about 32 lb. per cu. ft. It is very durable, and is valued for shingles, tanks, boatbuilding, or for construction where resistance to weather exposure is needed. The wood called yellow cypress on the West Coast, also known as

Sitka cypress, Alaska cedar, and Yellow cedar, is from the tree *Chamecyparis nootkaensis,* or *Cupressus sitkaensis,* growing on the Pacific Coast from Alaska to Oregon. The trees reach 6 ft. in diameter and 120 ft. in height in 500 years. The heartwood is bright yellow and the sapwood slightly lighter. The wood has a fine, uniform, straight grain, is light in weight, moderately hard, easily worked and polished, shock-resistant, and durable. It is used for furniture, boatbuilding, and interior finish. The Monterey cypress, *C. macrocarpa* of California, is one of the chief trees planted on reforestation projects in New Zealand.

Dammar. Also written Damar. The resin from various species of trees of the genus *Shorea, Balanocarpus,* and *Hopea,* but the name is also applied to the resins of other trees, especially from the *Agathis alba,* the source of Manila copal. There is no dividing line between the dammars and the copals, and dammar may be considered as a recent or nonfossil copal, the Malay word damar meaning simply a gum. The best and hardest dammars are from deposits at the bases of the trees, which are then the seasoned or fossil resins like the copals. Dammar is obtained by tapping the trees and collecting the solidified gum after several months. It is used in varnishes, lacquers, adhesives, and coatings. The usual specific gravity is 1.04 to 1.12, and the melting point up to 120°C. The average grade of dammar does not have a melting point much higher than 100°C. Dammar is a spirit varnish resin, gives a flexible film, but is softer and less durable than the copals. It is noted for its complete solubility in turpentine. It is also soluble in alcohol, and the Batavia and Singapore dammars are soluble in chlorinated compounds and in hydrocrabons. Dammar is classified according to color and size, the best grades being colorless and in large lumps. The high-grade pale-colored dammars from Batavia and Sumatra, including the so-called Cat's-eye dammar, are from species of *Hopea.* Most of the White dammar equivalent to Manila copal comes from Madagascar. It is semihard to hard, and is used in paints where resistance to wear is required, as in road-marking paints, but is not as hard as Congo copal. In general, the true dammars are from the *Shorea* and *Balanocarpus,* and they are inferior in hardness to the fossilized resins approaching the copals.

The *Shorea* resins are usually dark in color. The Malayan black dammar, Dammar hitam, is from a species of *Balanocarpus.* The plentiful Dammar Penak is from the Malayan tree *Balanocarpus heimii,* which also yields the important wood known as Chengal used for furniture and boatbuilding. Black dammar is from the tree *Canarium strictum,* of India, and comes in black, brittle lumps, easily ground to powder. The reddish Dammar sengai is also from a species of *Canarium.* These are types of elemi.

**Dandelion rubber.** The gum latex extracted from the roots of the Russian dandelion, which, when separated from the contained resin, has practically the same characteristics as the rubber from the hevia tree. Dandelion rubber, from various species of dandelion plant, *Taraxacum,* chiefly the plants known as Kok sagyz, Tau sagyz, and Crim sagyz, native to Turkestan, is produced on a large scale in Russia. Because of the cost of production, the plant is grown only on a small scale in the United States and Canada. The roots, which extend 15 to 20 in. into the ground, contain up to 10% of rubber after the plant has passed the first year flowering period. The normal yield is about 6% of rubber with also considerable resin which must be separated before use of the rubber. The dry roots also contain a high percentage of Inulin, $(C_6H_{10}O_5)_6 \cdot H_2O$, which is easily convertible to sugar and to alcohol.

**Degras.** A brownish waxy fat of a faint disagreeable odor, obtained from the wool of sheep by washing, and used for leather dressing, as a rubber softener, in lubricating greases, in slushing oils, and for preparing lanolin. In crude form it is also called Wool grease. It contains Lanoceric acid, $C_{30}H_{60}O_4$, Lanopalmic acid, $C_{15}H_{30}O_3$, and about 25% of Lanosterol, a high alcohol related to cholesterol. Lanolin is the purified and hydrated fat, also known as Lanain, and in pharmacy as Lanum. In the cosmetics industry for use in toilet soaps, salves, and cosmetics it is termed Adeps lanae. The melting point is about 40°C. It is soluble in alcohol. Wool grease from the scouring of wool was originally called Yorkshire grease. Moellon degras is not wool grease, but is a by-product of chamois leathermaking. The sheepskins are impregnated with fish oil and, when the tanning is complete, the

skins are soaked in warm water and the excess oil pressed out to form the moellon degras.

**Denaturants.** Materials used chiefly for mixing with ethyl alcohol to be employed for industrial purposes to prevent the use of the alcohol as a beverage and to make it tax-free under the Tax Free Industrial Alcohol Act. The qualities desired in a denaturant are that its boiling point should be so close to that of the alcohol that it is difficult to remove by ordinary distillation, and that it should be ill tasting. Some of the denaturants are poisonous and cause death if the alcohol is taken internally. The usual denaturants are methyl alcohol, pyridine, benzene, kerosene, and pine oil. One or several of these may be employed, but denaturants must be approved by the Bureau of Internal Revenue. Completely denatured alcohol is a term used to designate alcohol containing poisonous denaturants, and these are employed only for antifreeze, fuels, and lacquers, but not in contact with the human body. Special denatured alcohol is alcohol containing denaturants authorized for special uses, such as pine oil for hair tonics. Many approved denaturants are marketed under trade names. Denol is the name of a mixture of primary and secondary aliphatic higher alcohols. Agadite is a compounded petroleum product. Hydronol is a hydrogenated organic product. Denaturants are also used in imported oils that are permitted entry at lowered tax rates for industrial use so that they cannot be diverted for edible use. Rapeseed oil, for example, is denatured with brucine.

**Derris.** The root of various species of vines of the bean family, *Derris uliginosa, D. elliptica,* and *D. trifoliata,* growing in the East Indies. It is imported as crude root, and marketed as a fine powder of 200 mesh for use as an insecticide diluted with dusting clay to a rotenone content of 1%, or as a spray in kerosene or other liquid. The root contains Rotenone, a colorless, odorless, crystalline solid poison of complex composition, $C_{22}H_{22}O_6$, and melting point 163°C. The great value of rotenone as an insecticide is that it is highly toxic to cold-blooded animals, including insects and worms, and nonpoisonous to warm-blooded animals. It is widely used as an agricultural insecticide as it is harmless to birds. It is about 30 times more toxic to cutting worms than lead arsenate. Rotenone

is also found in many other plants, and when separated has the same toxic power. Cubé is the root of the vine *Lonchocarpus utilis,* of Peru, containing rotenone and used for the same purposes as derris. Timbó, also known as Urucú and as Tingi and Conambi, is the root of the vine *L. urucu,* of Brazil, also containing rotenone and used in the same manner. Barbasco is a name applied to timbó and all other fish-killing plants of the Orinoco Valley. The Caribs used the root either in shredded or in extract form for catching and killing fish. A cubic foot of root will poison an acre of water without harming the fish as food. Other plants of the same family are Nicou, Nekoe, and Haiari of the Guianas, and rotenone sometimes goes under the name of Nicouline. The high yield of rotenone from East Indian derris, up to 12%, is due to careful selection and propagation in cultivation, the semiwild roots of South America sometimes containing only about 2%. The Brazilian Government standard for timbó is 4% rotenone content. From 1 to 4% of rotenone is also obtained from the long leathery shoots of the perennial weed *Tephrosia virginiana,* known as Devil's shoestring, growing in Texas.

**Detergents.** Materials which have a cleansing action like soap. Although soap itself is a detergent, the term usually applies to other chemicals, or Soapless soaps, which give this action. The detergents may be sulphonated fatty acids such as turkey red oil; the Monopole soaps, or highly sulphonated fatty acids of the general formula $(SO_2OH)_xR \cdot COONa$; the Gardinols, which are sulphonated fatty alcohols; and the natural saponins. Detergents are employed widely in textile washing, metal degreasing, paper-pulp processing, and in other industrial cleansing. They are also used in household cleansing powders, soapless shampoos, and tooth pastes. In the latter uses they are marketed under a variety of trade names. Irium, a name used in a dentrifice, is Sodium lauryl sulphate, $C_{12}H_{25} \cdot SO_4Na$, a white powder made from lauric acid by reducing to laural alcohol and sulphonating. It is employed under other names in household cleaners. Nytron, of the Solvay Process Co., is a sodium sulphate in which the hydrocarbon part is derived from petroleum. It is a buff-colored powder very soluble in water.

**Dextrin.** Also called Amylin. A group of compounds with the same empirical formula as starch $(C_6H_{10}O_5)_x$, but believed to have a smaller value of $x$. They have strong adhesive properties and are used as adhesive pastes, particularly for envelopes, gummed paper, and postage stamps, for blending with gum arabic, in pyrotechnic compositions, and in textile finishing. Dextrin is a white, amorphous powder, tasteless and odorless. It dissolves in an equal amount of water to form a sirupy liquid, and is thus distinguished from starch. It is made by moistening starch with a mixture of dilute nitric and hydrochloric acids, and then exposing to a temperature of 100 to 125°C. Dextrin varies in grade chiefly owing to differences in the type of starch from which it is made. British gum is a name given to dextrins that give high tack for paste use.

**Diamond.** A highly transparent and exceedingly hard crystalline stone of almost pure carbon. When pure, it is colorless, but it often shows tints of white, gray, blue, yellow, or green. It is the hardest known substance, and is placed as 10 on the Moh hardness scale. The diamond always occurs in crystals in the cubical system and has a specific gravity of 3.521 and a refractive index of 2.417. It has been valued since ancient times as a gem stone, but it is used extensively as an abrasive, for cutting tools, and for dies for drawing wire. These Industrial diamonds are diamonds that are too hard or too radial-grained for good jewel cutting. Jewel diamonds have the formation in regular layers, while industrial diamonds are grown in all directions. Technically these are called Feinig and naetig. Ballas diamonds, valued for industrial drilling, are formed with the crystallization starting from one central point. The stones thus formed do not crack in the tool as easily as those with layer formation. Stones for diamond dies are examined in polarized light to determine the presence of internal stresses. They are then drilled normal to the rhombic dodecahedron plane with cleavage planes parallel to the die-hole axis to obtain the greatest die-service life. The stones for industrial purposes are also the fragments and the so-called Bort which consists of the cull stones from the gem industry including stones of radiating crystallization that will not polish well. Bort also includes an amorphous variety of diamond in brown, gray, or black colors, known as Black diamonds, Car-

bonados, or Carbons, found in Brazil in association with gem diamonds. The carbons have no cleavage planes, are compact, and thus offer greater resistance to breaking forces. The carbons vary greatly in quality and hardness, some being actually harder than the rating of 10. Diamond dust is a powder obtained by crushing the fragments of bort, or from refuse from the cutting of gem diamonds. It is used as an abrasive for hard steels, for cutting other stones, and for making Diamond wheels for grinding. Diamond powder is marketed in 16 standard grades by size of particle, the largest being 550 microns, and the smallest being 325 mesh, or 20 to 60 microns. There are also 8 grades of Diamond flour from 2 to 60 microns.

The value of diamonds bases on the gem value and is determined by color, purity, size, and freedom from flaws. The weight is measured in carats. Diamond splinters as small as $\frac{1}{500}$ carat may be cut and faceted. The most valued gems are the blue white. A faint straw color detracts from the value, but deep shades of yellow, red, green, or blue are prized. Most of the diamonds come from South Africa, Brazil, and India. About 50,000 diamonds have been found in Arkansas since the first discovery in 1906. The average weight of the Arkansas diamonds is less than 1 carat, with the largest 40.22 carats. Some diamonds are found in the Appalachian region, the largest, from West Virginia, weighing 34.46 carats. Few of the American diamonds are of gem quality, but are of full hardness. The annual world production of diamonds is about 14 million carats, two-thirds of which are used for industrial purposes. The largest diamond found in Brazil, the President Vargas, was a flawless stone weighing 726.6 carats. It was cut into 23 stones. The famous Kohinoor diamond weighed originally 793 carats, and the Jonkers diamond from South Africa was a blue-white stone weighing 726 carats. The Cullinan diamond weighed 3,106 carats.

**Diatomaceous earth.** A class of compact, granular, or amorphous minerals composed of hydrated or Opaline silica, used as an abrasive, for filtering, in metal polishes and soaps, as a filler in paints and molding plastics, and for making insulating blocks and boards. In the portable drinking-water filters employed by the Army for tropical use the filtering medium was diatomaceous earth

as it removes dysentery cysts and blood flukes as well as cleaning the water. Diatomaceous earth is formed of fossil diatoms in great beds and is not earthy, and a preferred name is Diatomite. In ground form it is sometimes referred to as Fossil flour. Tripoli and kieselguhr are varieties of crystalline diatomite. The American production of the mineral is mainly in Oregon, California, Washington, Idaho, and Nevada. After mining, the material is crushed and calcined. When pure it is white; with impurities it may be gray, brown, or greenish. The powder is marketed by fineness and chemical purity. The density is usually 12 to 17 lb. per cu. ft. Its high resistance to heat, chemical inertness, dielectric strength, and good surface finish imparted makes it a desirable filler for plastics. For insulating purposes, bricks or blocks may be sawed from the solid or molded from the crushed material, or it may be used in powdered form. Diatomite block has a porosity of 90% of its volume and makes an excellent filter. Celite, of Johns-Manville, is a 325-mesh uncalcined, amorphous diatomaceous earth for portland-cement mixtures, paper finishes, and for use as a flatting agent in paints. Diatomaceous earth is used in cement for fine ornamental detail work and for waterproofing. Sil-O-Cel, of this company, is insulating brick cut from diatomite. It will withstand temperatures up to 1600°F. Sil-O-Cel C-22 is calcined diatomaceous earth in powder form. It will withstand temperatures up to 2000°F. Superex, of the same company, is calcined diatomite powder bonded with asbestos fibers to resist temperatures up to 1900°F. Dicalite, of the Philip Carey Co., is a fine diatomite powder weighing 8 to 8.5 lb. per cu. ft. loose, and 15 to 17 lb. tamped, used for heat-insulating cement or as an insulating filler for walls.

**Die-casting metal.** Any alloy employed for making parts by casting in metal molds, or dies, in pressure-casting machines as distinct from other permanent mold castings where no pressure is used. The pressures may be as high as 5,000 lb. per sq. in., resulting in a dense structure in the casting. The important groups of die-casting metals are aluminum base, zinc base, and copper base. Lead-base alloys are used, but mostly for casting ornaments and toys. Aluminum die-casting alloys are now largely silicon alloys with from 3 to 12% of silicon, with or without copper, and with

sometimes a small amount of magnesium. Some contain nickel for better color and higher strength and toughness. Additions of small amounts of tin improve machining and polishing qualities, but develop hot-shortness. An alloy with 95% aluminum and 5 silicon when die-cast has a tensile strength of 30,000 lb. per sq. in. and elongation of 7%. With 5% silicon and 4 copper the alloy has a strength of 40,000 lb. per sq. in., elongation of 3.5%, and Brinell hardness of 75. Alcoa 85, of the Aluminum Co. of America, is this alloy. Aluminum-base alloy of the Milwaukee Die Casting Co., known as Ruselite, contains 94% of aluminum, 4 copper, and 2 chromium and molybdenum. It has a whiter color and is very corrosion-resistant. The tensile strength is 30,000 lb. per sq. in. with elongation of 6%. An aluminum die-casting alloy of the Allied Die Casting Corp., known as Renyx, contains, in one grade, 91.5% of aluminum, 4 nickel, 4 copper, and 0.5 silicon. It has good color and is resistant to corrosion. Renyx AZN is a zinc-base alloy containing 92% of zinc, 4 aluminum, 3 copper, and 0.1 manganese. Alcoa 380 is an aluminum-base alloy with 8.5% of silicon and 3.5 copper. It has a tensile strength of 45,000 lb. per sq. in., and elongation of 2%.

The zinc-base alloys are not as strong as the aluminum-base alloys, but they require only a moderate casting temperature, are easily cast in pressure machines, are low in cost, and have good color that can be plated easily. They have a wide field of use, and the alloys are marketed in standard composition ingots under the name of zinc-base alloys or by trade names such as Zamak of the New Jersey Zinc Co. They usually contain about 4% of aluminum, up to about 3% of copper, with slight additions of magnesium or other elements. The magnesium-base alloys are valued where light weight is essential. Alloy AM230, of the Aluminum Co. of America, is a magnesium alloy with 9 to 11% of aluminum, 0.5 to 1 silicon, and 0.10 manganese. This alloy weighs 0.066 lb. per cu. in., and has a tensile strength of 31,000 lb. per sq. in. A typical copper-base alloy contains 64% of copper and 36 zinc, and is a yellow brass. The tensile strength is 40,000 lb. per sq. in.

**Die steels.** Any tool steels used for dies. Originally, the term meant high-grade carbon steel with about 0.90 to 1% of carbon

that could be hardened to retain a keen cutting edge and not shrink or warp greatly in the hardening. Unalloyed tool steels are still widely used for many types of dies. They have the advantage of low cost and ease of machining. The modern tool steels of this kind are made to a high degree of uniformity, and the manganese and silicon contents are well adjusted to give depth of hardening and uniformity of grain structure. Typical of this type of steel is H-9 Extra steel, or Cold-heading die steel, of the Carpenter Steel Co. It contains 0.90% of carbon, 0.40 manganese, and 0.40 silicon, and can be used for such severe service tools as coining dies, cold-heading dies, and knurls. Low-alloy steels with carefully adjusted alloy content are also widely used for dies for general purposes and are more easily machined and treated than the higher alloyed steels. A typical steel of this kind is Artdie steel of the Columbia Tool Steel Co. It contains 0.95% of carbon, 0.30 chromium, 0.02 vanadium, 0.25 manganese, and 0.25 silicon. It is deep hardening, and is used for production dies in the jewelry industry. However, when the term die steel is now used alone it is most likely to refer to the preheat-treated die blocks of high-alloy steels for making forging, plastic-molding, and die-casting dies without subsequent hardening. Other die steels are more likely to be designated by the names for the specific types such as nondeforming steel, hot-die steel, wear-resistant steel, or vanadium steel. Die-block steels of this type, with high resistance to wear, having high chromium and high carbon, are also used for molds or dies for pressing porcelain insulators and other ceramics. Airdi 225, of the Crucible Steel Co. of America, is an air-hardening die block steel with 12% of chromium, 2.25 carbon, 1 molybdenum, and 0.25 vanadium. Airdie 110 is the same steel with only 1.1% carbon. It is easier to machine but is not as wear-resistant. Cromoco die steel, of the Firth Sterling Steel Co., has 12% of chromium, 1 cobalt, 1 molybdenum, and 1.6 carbon. It is used for forming dies, swages, ring gages, and shear blades. It is air-hardening, and has high strength and hardness. Where it is not desired to employ a high-alloy steel, the simple chrome-vanadium steels with about 1% of chromium, 0.15 vanadium, and 0.50 to 1 carbon are widely used for dies that require a high degree of hardness, toughness, and

resistance to fatigue. Albany steel, of the Allegheny Ludlum Steel Corp., is a steel of this type. These are the S.A.E. steels 6150 to 6195.

**Disinfectants.** Materials used for killing germs, bacteria, or spore, and thus eliminating causes of disease or bad odors in factories, warehouses, or in oils and compounds. In medicine the term Antiseptic is employed in a similar sense. Some disinfectants are also used as preservatives for leather and other materials, especially chlorine and chlorine compounds. Phenol is one of the best-known disinfectants, and the germ-killing power of other chemicals is usually based on a comparison with it. Practically all bacteria are killed in a few minutes by a 3% solution of phenol in water, but phenol has the disadvantage of being irritating to the skin. Industrial disinfectants are usually sold as concentrates to be diluted to the equivalent of a 3 to 5% solution of phenol. Too large a proportion of disinfectants in oils, solutions, or in the air may be injurious to workers, and the advice of health officials is ordinarily obtained before general use. Cresote oil and cresylic acid are employed in emulsions in disinfecting sprays and dips. Formaldehyde has high germicidal power, and is used for hides and leather. Antiseptic atmospheres may be produced by spraying chloramine T, iodine, or argyrol. Chloramine T is a white crystalline powder of the composition $CH_3C_6H_4SO_2NClNa \cdot 3H_2O$, soluble in water and in organic solvents. Besides its use as an antiseptic and germicide it is also employed as an oxidizing and chlorinating agent. Thymol is used as a disinfectant in ointments, mouth washes, soaps, and solutions. Condensation products of thymol with other materials are also used. Thymoform, $C_{21}H_{28}O_2$, made by condensing thymo with formaldehyde, is a yellow powder used as an antiseptic dusting powder. Thymidol is an antiseptic made by condensing thymol with menthol. Hexylresorcinol, $CH_3(CH_2)_5C_6H_3(OH)_2$, is a more powerful antiseptic than phenol and is not injurious to the skin or tissues. Pinosylvine is a natural antiseptic extracted from the heartwood of the pine tree, where it protects the tree against decay and insects. It is related chemically to resorcinol, and its germ-killing power is 30 times that of phenol.

**Divi-divi.** The dried seed pods of the tree *Caesalpinia coriaria,* native to tropical America, employed in tanning leather. Most of the divi-divi is produced in Colombia, Dominican Republic, and Venezuela. It is used chiefly in blends with other tannins to increase acidity, to give a light color to the leather, and to plump and soften the leather. The pods are about 3 in. long, and contain up to 45% of pyrogallol tannin. They require to be kept from fermentation, which develops a red coloring matter. The best pods are the thickest and lightest in color, and they are used to replace gambier, valonia, and myrobalans. The commercial extract contains 25% of tannin. Algarobilla, from the pods of the *C. brevifolia,* of Chile, is a similar tanning agent. Cascalote is from the pods of the tree *C. cacolaco* of Mexico, and is the standard tanning material of Mexico. White tan, or Tari, is from the pods of the *C. digyna* of the Far East. Tara, or Bogotá divi-divi, also called Cevalina, is from the pods of the tree *C. tinctoria* of Colombia. The pods contain 32% of tannin. It makes a soft leather and is used to replace sumac.

**Dogwood.** A heavy hardwood noted for its ability to stay smooth under long-continued rubbing. Its outstanding use is for shuttles for weaving. The texture is fine and uniform. Other uses of the wood are for small pulleys, golf-club heads, mallet heads, jewelers' blocks, skate rollers, and bobbins. There are 17 known varieties of the plant in the United States, only four of which grow to tree size. The White dogwood is *Cornus florida;* the Pacific dogwood is *C. nuttallii;* Roughleaf dogwood is *C. asperfolia;* and Blue dogwood is *C. alternifolia.* Dogwood grows sparsely throughout the Eastern states. The wood is marketed in bolts or short logs. Turkish dogwood was formerly imported for rollers and shuttles.

**Dolomite.** A type of limestone employed in cementmaking, as a flux in melting iron, as a lining for basic steel furnaces, for the production of magnesium metal, for filtering, and as a construction stone. It is a carbonate of calcium and magnesium of the composition $CaCO_3MgCO_3$, together with impurities, occurring widely distributed in coarse, granular masses or in fine-grained compact form known as Pearl spar. The specific gravity is 2.8 to 2.9 and hardness 3.5 to 4. It is naturally white, but may be colored by im-

purities to cream, gray, pink, green, or black. For furnace linings it is calcined, but for fluxing it is simply crushed. The raw dolomite, marketed by Basic Refractories, Inc., for open-hearth steel making is washed crushed stone in ⅝-in. size. When calcined at a temperature of 2700 to 3100°F., dolomite breaks down to MgO and CaO. Calcined dolomite used in Germany as a water filter material under the name of Magno masse is in grain sizes 0.5 to 5.0 mm. Dolomite for the production of magnesia, some of which is cut as building marble, contains 10 to 20% of magnesia, 27 to 33 lime, 1 to 12 alumina, 40 to 46 carbonic acid, 1 to 5 silica, and 0 to 3 iron oxide. For the production of magnesium metal, calcined dolomite and ferrosilicon are brought to a high temperature in a vacuum and the magnesium driven off as a vapor.

**Douglas fir.** The wood of the tree *Pseudotsuga taxifolia,* of the Northwestern United States and British Columbia. It is sometimes called Oregon pine, Douglas pine, Douglas spruce, Red fir, Fir, Yellow fir, and Puget Sound pine. The wood of young trees with wide growth rings is reddish brown, and is the type called red fir. The wood of older trees of slower growth with narrow rings is usually yellowish brown and is called yellow fir. Both woods may come from the same tree. The narrow-ringed wood is generally the stronger and heavier. Douglas fir averages below longleaf pine in weight, strength, and toughness, but above loblolly pine in strength and toughness, though below it in weight. The grain is even and close, with resinous pores less pronounced than in pitch pine. It is a soft wood, and is fairly durable. The weight is 34 lb. per cu. ft. The compressive strength perpendicular to the grain is 1,300 lb. per sq. in.; the shearing strength parallel to the grain is 810 lb. per sq. in. Douglas fir is used for general construction work, woodenware, crossties, and where large timbers are required. The trees grow to great heights, the average being 80 to 100 ft. The stand is estimated at more than 450 billion board feet, or about one-fourth of all timber in the United States.

**Drawing paper.** A heavy paper, usually white or buff color, employed for making drawings. For mechanical drawings the buff color is preferred as it is easier on the eyes and not so readily soiled. Drawing papers are smooth or rough, the first being hot-

pressed. Good grades of drawing paper should permit considerable erasure without destroying the appearance. Buff detail paper for pencil use is made slightly rough or grained. High-grade paper for ink work is extra hard-sized and coated. Drawing paper is marketed in rolls of widths from 30 to 72 in., and in standard sheets varying from cap, 17 by 13 in., to antiquarian, 52 by 31 in. Tracing paper is usually a good grade of hard transparent tissue paper in sheets and rolls, in white or buff colors.

**Driers.** Materials used for increasing the rapidity of the drying of paints and varnishes. The chief function of driers is to absorb oxygen from the air and transfer it to the oil, thus accelerating its drying to a flexible film. They are in reality catalyzers. Driers may be oxides of lead, cobalt, or manganese, such as pyrolusite and cobalt linoleate. Metallic salts of organic acids, such as aluminum resinate and aluminum palmitate, also have this property. Manganese acetate, $(CH_3COO)_2Mn \cdot 4H_2O$, is a common paint drier. It is a pinkish crystalline powder soluble in water and in alcohol. Sugar of lead, used as a drier, is Lead acetate, $Pb(C_2H_3O_2)_2 \cdot 3H_2O$, a white crystalline material. Lead oleate, $Pb(C_{18}H_{33}O_2)_2$, is a drier made by the action of a lead salt on oleic acid. It is also used for thickening lubricants. Lead linoleate, $Pb(C_{18}H_{31}O_2)_2$, is a drier made by adding litharge to linseed oil and heating. Lead and manganese compounds together act more effectively as driers than either alone. Lead resinate adds toughness of film as well as drying power. Cobalt driers are twice as rapid in drying power as manganese driers, but too rapid drying often makes a wrinkled film which is desirable for some finishes but not for others. Excessive use of driers will destroy the toughness of the film and cause the paint to crack. Solutions of driers are called liquid driers, and it is in this form that the driers are most used. Certain oils, such as tung oil, have inherent drying properties and are classed as drying oils but not as driers. Driers may be sold under trade names. Zinar, of Newport Industries, Inc., for cellulose lacquers and rubber cements, is a Zinc resinate with 5.6% metallic zinc content and melting point of 160°C.

**Drill.** A stout, twilled cotton fabric used for linings and where a strong fabric lighter than duck is required such as for laminated

plastics. It differs from duck also in that it has a warp-flush weave that brings more warp than filling to the face of the cloth. It comes unbleached, bleached, or piece-dyed, or may be yarn-dyed. It is made in various weights, and is designated in ounces per yard the same as duck. Tan-colored drill is called Khaki. A somewhat similar fabric to drill is Denim, which is a heavy, twill-woven, warp-flush cotton fabric but usually lighter in weight than drill. The warp is yarn-dyed, usually either light blue or dark brown, but also in other colors. The filling is made with one black and one white yarn. Denim is designated by the weight in ounces per yard. It is much used for workmen's overalls and jumpers, and the light weights for this purpose and for sportswear are called Jean. Denim is also used for upholstery, and industrially where a tough fabric is needed. Art denim, in plain colors or woven with small figures, is used for upholstery.

**Drill rod.** Tool-steel round rod made to a close degree of accuracy, generally not over or under 0.0005 in. the diameter size, and usually polished. It is employed for making drills, taps, reamers, punches, or for dowel pins, shafts, and rollers. Some mills also furnish square rods to the same accuracy under the name of drill rod. Common drill rod is of open-hearth high-carbon steel hardened by quenching in water or in oil. The usual commercial sizes are from 1½ in. in diameter down to No. 80, which is 0.0135 in. in diameter. The usual lengths are 1 and 3 ft. The sizes are by the standard of drill gages, with about 200 different diameters. The carbon content is usually from 0.90 to 1.05%, with 0.25 to 0.50 manganese, 0.10 to 0.50 silicon, and a maximum of 0.04 phosphorus or sulphur. It also comes in high carbon with from 1.50 to 1.65% of carbon and 0.15 to 0.35 manganese. Drill rod can also be obtained regularly in high-speed steels, and in special alloy steels for dowel pins. Needle wire is round tool-steel wire used for making needles, awls, and latch pins. It comes in coils, in diameters varying by gage sizes from 0.010 to 0.105 in. Needle tubing for hypodermic needles is stainless-steel tubing 0.035 in. in diameter or smaller. It requires about 100 cold-drawing operations and annealings to reduce it to this size. Stud steel is an English name for round bar steel made to close limits and hardened and

descaled, used for heavy pins and studs. Pin bar is small-diameter rod of casehardening steel used for dowel pins. Drill steel, for mine and quarry drills, comes in standard rounds, octagons, squares, and cruciform bars, solid or hollow, usually in carbon steel.

Drug plants. Known in the trade as Crude drugs and Botanicals. The roots, leaves, stalks, flowers, or bark of many plants are used for medicines or for the production of medicinal products. Many of these are acute poisons having specific physiological effects on nerves, blood, heart action, or organs of the body. Knowledge of the specific effect of each, with control of the amount to produce a needed effect to correct organic disturbances, constitutes the theory of the use of these. The manufacture and sale of drugs in all civilized countries are controlled by various laws and by recognized and listed standards known as formulary and pharmacopoeia. The term drug has come to have an awesome significance, but many drugs occur in the most common foodstuffs, and it is theoretically possible by a perfect balance of foods and by the taking of the right foods at the right time to obtain balanced physiological effects and perfect health. Conversely, the excessive consumption of some foodstuff causes toxic conditions because of the contained drugs. Many of the most valuable drug plants contain Alkaloids which have complex arrangements of carbon, hydrogen, oxygen, and nitrogen. Most of the alkaloids are violent poisons even in small quantities, and, with few exceptions such as quinine, are not employed as medicines except under the direction of trained physicians or pharmacists. The actual specific effect of the drug, and the amount to produce sufficient effect without injury, must be understood before use of a drug. Pain-killing drugs, for example, do not kill pain but diminish the conductivity of the nerve fibers and thus prevents the brain from recording the pain.

Drug plants are almost unlimited in number. Belladonna, used to relieve pain, to check perspiration, and as a dilatant, consists of the leaves, roots, flowers, and small stems of the perennial herb *Atropa belladonna* cultivated chiefly in Yugoslavia and Italy, but also grown in the United States. The plant is called Banewort and Deadly nightshade. The leaves are dried in the shade to retain the

green color. They contain two alkaloids Atropine and Hyoscyamine. Henbane is the dried leaves and flowering tops of the ill-smelling herb *Hyoscyamus niger,* a plant of the nightshade family containing several alkaloids. It is used as a sedative. The plant is grown in southern Europe and Egypt and to some extent in the United States. It is harvested in full bloom and dried in the shade.

Stramonium is the dried leaves, flowers, small stems, and seeds of the Thorn apple or Jimson weed, *Datura stramonium,* an annual of the nightshade family which grows as a common weed in the United States. It is shipped from Ecuador under the name of Chamico. It produces the alkaloids, atropine and hyoscyamine, and is used as a nerve sedative, hypnotic, and antispasmotic. Under cultivation, the yield is 1,000 to 1,500 lb. of dry leaf or 500 to 2,000 lb. of seed per acre. In general, the yield of drug plants in cultivation is high, so that only small acreages are needed. Aconite is the dried root of the Monkshood, a herbaceous perennial plant, *Aconitum nepellus.* It is grown in Europe and the United States. The root contains the colorless, crystalline, extremely poisonous alkaloid Aconitine, $C_{34}H_{47}O_{11}N$. It is used as a cardiac sedative, diaphoretic, and to relieve pain and fever. Digitalis, an important heart stimulant, consists of the leaves of the perennial Foxglove plant, *Digitalis purpurae,* native to Europe but also grown in New England and the Pacific Northwest. The leaves contain the bitter glucoside Digitoxin, $C_{34}H_{54}O_{11}$. The Glucosides contain no nitrogen as do the alkaloids. They are the ethers of single sugars. Ipecac is the rhizome of the shrub *Cephaelis ipecacuanha,* of tropical South America, chiefly Brazil. It contains Emetine, $C_{30}H_{40}O_5N_2$, and other alkaloids, and is used as an emetic, tonic, and expectorant. Gentian, also known as Bitter root, is the dried root of the perennial herb *Gentiana lutea* of central Europe. It contains glucosides, and is used in tonics, and also in cattle feeds.

Ginseng is the dried root of the plant *Panex ginseng* of China, and *P. quinquefolium* of North America. It is used as a stimulant and stomachic. Doggrass root, known in medicine as Triticum, is the powdered dried rhizome of Scotch grass, *Agropyron repens,* which abounds in the meadows of the Northern United States. It has a slight aromatic odor and sweet taste and is used as a diuretic. Lobelia is the dried leaves and tops of the small

annual plant *Lobelia inflata,* known in the Northeastern states as Indian tobacco. It contains the alkaloid Lobinine, and is used as an emetic and antispasmotic. Erigeron is the herb and seeds of the Fleabane herb, *Erigeron canadensis,* which grows wild in the North Central and Western states. The herb yields 0.35 to 0.65% of Erigeron oil used as an astringent and tonic. Hamamelis is the dried leaves of the witch hazel shrub, *Hamamelis virginiana,* of the Eastern United States. It is used as a tonic and sedative, and the water extract of the leaves and twigs with 15% of alcohol is known as Witch hazel. It is used as an external astringent. It is fragrant, and contains a tannic acid from the bark of the twigs. Ephedrine, or Ephedra, is an alkaloid extracted from the dried twigs of the Mahuang, *Ephedra sinica,* and other species of mountain shrubs of China and India. It is also grown in South Dakota. It is used as an adrenalin substitute to raise blood pressure, and also in throat medicines and nasal sprays. Hoarhound is an extract from the leaves and flowering tops of the small perennial herb *Marrubium vulgare* of North America, Europe, and Asia. It is used in preparations for colds, and also as a flavor in confections.

Cascara is the bark of the small Buckthorn tree, *Rhamnus purshiana,* of the Northwestern states and Canada. It was also called Chittem bark. It was used by the Indians and given the name Cascara sagrada by the Spaniards. The word cascara simply means bark; the word sagrada is not translated sacred but is a term applied to medicinal botanicals. Cascara is used as a laxative and tonic. The European buckthorn, *R. frangula,* also yields cascara. Aloe, used in purgative medicines, is the dried resinous juice from the leaves of the bush *Aloe vulgaris* of the West Indies and *A. perryi* of West Africa. The cut leaves are placed in troughs where the juice exudes. It is then evaporated to a viscous black mass which hardens. Both aloe and cascara contain the glucoside Emodin, occurring also in senna and in Rhubarb. The latter, the stalks of which are much used as a food, is known in medicine as Rheum and is employed as a laxative and stomach tonic. Aletris root is a botanical drug from the Stargrass, *Aletris farinosa,* growing in the Eastern United States. It is also known as Colic root, and is used as a tonic and uterine stimulant. Senega, used as an emetic and stimulant, is the dried root of the Snakeroot or Milk-

wort, *Polygala senega,* a small perennial herb grown in the Eastern United States. Calumba root is the yellow root of the woody climbing plant *Coscinium fonestratum* of Ceylon. It is used as a cure for tetanus. The wood, which has a bright-yellow color, is used locally as a dye. Tanacetum is the dried leaves and tops of the Silverweed, *Tanacetum vulgaris* of Michigan and Indiana, used as a vermifuge. The green herb yields about 0.2% of Tansy oil, or Tanacetum oil, which contains a terpene Tanacetene, and borneol. It is used as an anthelmintic.

Ergot, used to stop hemorrhage, is the dried sclerotium of the fungus *Claviceps purpurea,* which develops on rye and some grasses. The purple structure that replaces the diseased rye grain contains the alkaloid Clavine, $C_{11}H_{22}O_4N_2$. Ergot oil, used in medicinal soaps, is obtained by extraction from the dry ergot. It was the original source of Ergosterol, an inert alcohol which, when irradiated, yields vitamin D. Ergot is produced chiefly in Spain. Araroba, or Goa powder, is a brownish, bitter, water-soluble powder scraped out of the split logs of the tree *Andira araroba* of Brazil. The Carib Indians used the powder for skin diseases, and it is now employed for eczema and skin affections. It contains Chrysarobin, a complex mixture of reduction products of a complex acid contained in the wood. Labdanum is an oleoresin obtained in dark-brown or greenish lumps from the branches of the Rock rose, *Cistus ladaniferus,* and other species of the Mediterranean countries. It yields a volatile oil with a powerful sweet characteristic odor which is used as a stimulant and expectorant and also as a basis for lavender and violet perfumes. It was originally obtained in Greece by combing from the fleece of sheep that browsed against the bushes. Buchu is the dried leaves of the South African herb *Barosma betulina* used as an anticatarrhal.

**Drying oils.** Vegetable oils which are easily oxidized by exposure to the air and thus suitable for producing a film in paints and varnishes. The drying of an oleoresinous varnish takes place in two stages. First, the reducer or solvent evaporates, leaving a continuous film composed of gums and drying oil. The drying oil is then oxidized by exposure, leaving a tough, hard skin. This oxidation is hastened by driers, but the drying oil itself is responsible

for the film. The drying power of oils is measured by their Iodine value, as their power of absorbing oxygen from the air is directly proportional to their power of absorbing iodine. Linseed oil is the most common of the drying oils, though tung oil and oiticica oil are faster in drying action. Linseed oil alone will take about seven days to dry, but can be quickened to a few hours by the addition of driers. Linseed oil and other oils may be altered chemically to increase the drying power.

Conjugated oils are oils that have been altered to give conjugated double bonds in place of isolated double bonds in the molecules of the fatty acids. Conjulinol, of the Woburn Degreasing Co., is a drying oil of this class made from linseed oil. The iodine value is 154, and the drying time is greatly reduced. Normally, soybean oil is not classed as a drying oil although it may be blended with drying oils for paint use. But by chemical alteration it can be given good drying power. Conjusoy is a drying oil made by conjugation of soybean oil. The iodine value is 128, and the drying time is about half that of the original oil. Castor oil, which has poor drying properties, is dehydrated to form an excellent drying oil. Other methods are used to alter oils to increase the drying power, notably polymerization of the linoleic and some other acids in the oils, or oils may be fractionated and reblended to increase the percentage of acids that produce drying qualities. Heat-treating or cooking of some oils also increases the drying power. Kel-X-L oil, of Spencer-Kellogg & Sons, is a modified linseed oil with an iodine value up to 170, used as a substitute for tung oil in quick-drying varnishes. Kellin, of the same company, is a quick-drying blended oil with a linseed-oil base, while Kellsoy is a similar oil with a soybean-oil base. Dorscolene, of Dorward & Sons Co., is a drying oil made from fractionated and blended fish oils. The German substitute drying oil known as Resinol was a liquid obtained by the distillation of the heavy fractions of the benzolated oils derived from scrubbing coke oven gas.

Although the great volume of drying oils is produced from linseed, soybean, tung, oiticica, castor, and fish oils, many other oils have drying properties and are used in varying quantities. N'gart oil is from the seed nuts of a climbing plant of Africa, and is equal in drying power to linseed oil. Lallemantia oil, obtained

from the seeds of the *Lallemantia iberica*, of southeastern Europe and Asia, is a drying oil resembling linseed oil in physical properties. Isano oil, obtained from the kernel of the nut of the *Ongokea klaineana* of tropical Africa, is a pale-yellow viscous oil that has little drying power, but when heat-treated sets up an exothermic action to produce a good varnish oil. Anda-assu oil, used in Brazil for paints, is from the seeds of the plant *Joannesia princeps*. The seeds yield 22% of a clear yellow oil with an iodine value of 142 which is bodied by heating. Manketti oil is a varnish oil with about two-thirds the drying power of linseed oil. It is a light-yellow viscous oil from the seed nuts of the tree *Ricinodendron rautanenii*, of southwest Africa and the *R. africanum*, of the French Congo.

**Duck.** A strong, heavy cotton fabric employed for sails, awnings, tents, heavy bags, shoe uppers, machine coverings, and where a heavy and durable fabric is needed. It is woven plain, but with two threads together in the warp. It is made in various weights, and is designated by the weight in ounces per running yard 22 in. wide. It is marketed unbleached, bleached, or dyed in colors, and there are about 30 specific types with name designations usually for particular uses such as Sail cloth. When woven with a colored stripe, it is called Awning duck. Russian duck is a fine variety of Linen duck. Large quantities of cotton duck are used for making laminated plastics and for plastic-coated fabrics, and it is then simply designated by the weight. Belt duck, for impregnated conveyer and transmission belts, is made in loosely woven soft ducks and in hard-woven, fine-yarn hard fabric. The weights run from 28 to 36 oz. Hose duck, for rubber hose, is a soft-woven fabric of plied yarns not finer than No. 8, made in weights from 10 to 24 oz. The grade of duck known as Elevator duck for conveyer belts is a hard-woven 36-oz. fabric. Plied-yarn duck is used for Army tents instead of flat duck as it does not tear easily and does not require sizing before weaving. Canvas is duck of more open weave. The term is used loosely in the United States to designate heavy duck used for tarpaulins, bags, sails, and tents. But more properly it is a heavy duck of square mesh weave more permeable than ordinary duck, such as the can-

vas used for paintings and for embroidery work. The word duck is from the Flemish doeck meaning cloth, originally a heavy linen fabric. The word canvas is from the Latin *cannabis,* originally a coarse, heavy hempen cloth for tents.

**Duplex metal.** Sheet or plate metal composed of sheets of two different metals rolled together. It was developed as an industrial product only recently, particularly to give corrosion resistance or appearance without the expense of a solid plate, but the process is an old one in the jewelry industry. The early French duplex metal called Doublé consisted of copper or brass with a thin facing of noble metal for acid resistance, or of silver or gold for appearance. The Gold shell, used for cheap jewelry, is a duplex metal with gold rolled on a rich-low brass. This material was called Abyssian gold, Talmi gold, and other names. Efkabimetal was a German doublé consisting of copper clad with a noble metal. Feran, a German duplex metal, was made by passing strips of aluminum and iron through rolls at a temperature of 350°C. and then cold-rolling to sheet. Alclad, of the Aluminum Co. of America, is an aluminum-clad aluminum alloy, with the exposed pure aluminum giving added corrosion resistance, and the aluminum-copper base metal giving strength. The base metal is Alcoa 17-S, and the pure aluminum coating is usually 0.0035 in. in thickness. It is used for aircraft sheathing. The German Lautal with pure aluminum rolled on is called Allautal. Zinnal is a German aluminum sheet with tin cladding on both sides, while Cupal is a copper-clad aluminum sheet. Chromaloid, of the American Nickeloid Co., consists of a zinc base with sheet chromium bonded on one face. The chromium face is highly polished, and the sheets are used for corrosion-resistant table tops and stamped parts. Nickeloid, of the same company, is sheet zinc with polished nickel bonded to the face.

Brass-clad steel, used for making bullet jackets and shell cases, consists of a 90-10 brass on one side of a mild steel sheet, with the brass equal to 20% of the weight of the sheet. The duplex metal called Bronze on steel, of the Johnson Bronze Co., used for bearings, is made by powdering the borings from castings of 80% of copper, 10 tin, and 10 lead, and bonding this homogeneous powder

to strip steel in a hydrogen furnace so that no oxides are formed. The strip is then rolled and subsequently formed into bearings and bushings. The thin bronze coating saves tin and copper, and the bearing is more resistant to pounding than a cast bronze. Calorized metals are steel or iron surface-treated with aluminum by a process that makes a surface impregnation of aluminum to resist hot gases and molten white metals. Insuluminum, of the General Electric Co., is calorized steel for lead pots and chemical equipment. It will withstand temperatures to 1650°F. Clad steels are available regularly in large sheets and plates, and are used extensively for tank cars, chemical tanks, and architectural work. They are made with coatings of nickel, stainless steels, or monel metal, the metals being rolled together at white heat under heavy pressure. The cladding metal on one surface is usually equal to 10% of the weight of the plate. The Nickel-clad flange steel, of the Lukens Steel Co., has a tensile strength of 55,000 lb. per sq. in. Niclad, of the Flannery Mfg. Co., has the nickel or nickel alloy deposited on the steel or iron by a continuous welding process.

**Dyestuffs.** Materials employed for giving color to textiles, paper, leather, wood, or other products. They may be either natural or artificial. Many chemicals will stain and color other materials, but a product is not considered as a dye unless it will impart a distinct color of some permanence to textiles. The natural dyestuffs may be mineral, animal, or vegetable, but the artificial dyes are derived mainly from coal-tar bases. Tyrian purple, from various Mediterranean snails, was in ancient times the most noted of the animal dyestuffs. Cochineal and kermes are other animal dyes. One of the earliest metallic or mineral dyestuffs was called Iron buff. It was made by allowing pieces of iron to stand in a solution of vinegar to corrode. After dipping fabrics in this solution they were rinsed in a solution of wood ashes. Mineral dyes now include ochre, chrome yellow, and Prussian blue. Vegetable dyes may be water solutions of woods, barks, leaves, fruits, or flowers. The buff and brown textile colors of early New England were made by boiling fresh green butternuts in water, while a dark-red dye was made by boiling the common red beet in water. Vegetable dyes now include Brazil wood, barwood, sappan wood,

fustic, logwood, madder, henna, saffron, annatto, indigo, and alkanet. The Camphire of the ancients mentioned in the Bible and Koran was a reddish-orange dyestuff made by grinding to a paste the red, sweet-scented spikes of the small cypress tree, *Lawsonia inermis,* of Egypt and the Near East. It was used by the Eastern and Roman women to stain the fingernails, and is now used under the name of Henna for dyeing leather and as a hair dye. It gives various shades from yellowish to red or brown. Argol, a brilliant red used extensively until replaced by synthetic dyes, is from the Orchilla, a lichen found in the Canaries and Near East. It was used to produce the brilliant colors of the medieval Florentine cloth. Chinese green, Buckthorn bark, or Lokao, is the powdered bark of the buckthorns, *Rhamorus globosa* and *R. utilis,* of China and Russia. It is used in dyeing silk and cotton. Weld, from the plant *Reseda luteola* of Europe, produces a very bright-yellow color with an alum mordant. With indigo it produces green. Woad is the dried fermented leaves of the plant *Isatis tinctoria* of Europe. It gives a blue color, but is now little cultivated.

The synthetic dyes are mostly coal-tar or aniline colors. They are more intense, brighter, faster, and generally cheaper than natural dyestuffs. There are thousands of these dyes, classified by a color index rather than by their chemical composition. The dyes are complex chemicals, but they usually contain characteristic groups of atoms so that the color or change in color can be predicted. The chemical names refer to the forms of atom groupings, such as the Azo dyes. Some of the dyes will color animal fibers well and not vegetable fibers, or vice versa, while some will color all fibers. Some can be dyed direct, while others require a mordant. Some are permanent, or fast, while others are water-soluble and will fade when the fabric is washed, or some may not be light-fast and will fade when exposed to light. Dyes are acid when they operate best in an acid bath, and basic when operative in an alkaline bath. Some of the so-called Vat dyes are insoluble and are applied in the soluble colorless form and afterwards reduced or oxidized to color. The Sulphur dyes are made by treating the organic compounds with sodium sulphide. They are fast to wash-

ing and to light, but the range of color is more limited. They are used only on vegetable fibers as the bath is strongly alkaline.

**Ebony.** A hard, black wood valued for parts subject to great wear, and for ornamental inlaying. It is the wood of various species of trees of the ebony family, *Ebenaceae,* although the name is also applied to some woods of the genus *Dalbergia,* family *Leguminosae.* Black ebony, from the tree *Diospyros dendo* of West Africa, and Ebony, from the tree *D. melanoxylos,* of India, are the true ebonies. Black ebony has a black heartwood with brownish-white sapwood. It is next to lignum vitae in hardness, has a fine, open grain, and weighs 78 lb. per cu. ft. It is used for inlaying, piano keys, and turnery. The ebony of India is also extremely hard, with a fine and even grain. The heartwood is black with brownish streaks. Marblewood, or Andaman marblewood, is an ebony from the tree *D. kurzii* of India and the Andaman Islands. The wood is black with yellowish stripes. It has a close, firm texture, is hard, takes a fine polish, and weighs 65 lb. per cu. ft. Marble ebony is another species from Madagascar. The ebony from Japan, called Kaki, is from the tree *D. kaki.* It has a black color streaked with gray, yellow, and brown. The grain is close and even, and the wood is very hard, but the weight is less than that of African ebony. Ebony wood is shipped in short billets, and is graded according to the color and the source, as Niger, Macassar, Cameroon. Green ebony is a name sometimes given to the cocoswood of the West Indies. Artificial ebony, formerly composed of asphaltic compounds, is now usually molded plastics.

**Elemi.** A soft, sticky, opaque resin with a pleasant odor, obtained from the Pili tree, *Canarium luzonicum,* of the Philippines, and employed for giving body and elasticity to lacquers and in lithographic inks. It is also substituted for dammar, as it is generally cheaper. Other substitute elemi resins are obtained from various trees of the family *Burseraceae* of tropical Africa and America. The pili trees are hacked or stripped, and the resin collects on the bark, a tree yielding about 5 lb. per year. West Indian elemi is from the tree *Dacryodes hexandra* of the West Indies. Nauli gum is elemi from the tree *C. commune* of the Solomons. Elemi oil, obtained by distilling elemi, is a colorless

liquid of specific gravity 0.87 to 0.91, used in perfumes and in medicine. It has an aniselike odor. In pharmacy, elemi is used in plasters and ointments.

**Elkskin.** The commercial name for a soft, pliable, and durable leather made from kips or from overgrown calf by a special tanning process and impregnation with oils. It is used chiefly for children's shoe uppers and for pocketbooks. A heavier elkskin, or Elk leather, for sport shoes and boots, is made from cow hides by the same treatment. Elkskin, like chamois, dries out to its original softness after wetting. Smoked elk is elk leather dyed cream-colored to imitate the original leather of elks, which was smoked over a wood fire.

**Elm.** The wood of several species of the elm tree, of the Eastern United States and Canada, and northern Europe. The common elm of Europe, *Ulmes campestris,* is a rather hard wood with a coarse, open cross grain, having dark-brown heartwood and white sapwood. American elm, known as White elm, has a finer grain, and a weight of about 40 lb. per cu. ft. It is whitish brown in color, hard, and tough. It is the best known commercially of the six species grown in the United States. The American elm is not a forest tree, but is grown as a shade and ornamental tree. It does not grow in the mountains. The trees frequently reach a diameter of 6 ft. and a height of 100 ft. The tough, durable wood is valued for ax handles, cooperage, and for parts requiring a combination of strength, bending qualities, and ability to withstand rough usage. Rock elm, or Hickory elm, *U. thomasii,* is also native to the United States and Canada. It has a very fine, close grain and is slightly heavier. It is sometimes called Cork elm. Slippery elm is a smaller forest tree, *U. fulva,* of Northeastern United States. Considerable lumber comes from this tree under the name of Red elm. The inner bark of the tree is mucilaginous with a sweet taste and characteristic odor. It was used by the Indians as a chewing gum and as a poultice for skin affections. The dried and powdered bark is now used in medicine for skin affections and for the throat. It contains Ulmic acid, or Geic acid, $C_{20}H_{14}O_6$.

**Emery.** A fine-grained, impure variety of the mineral corundum, mixed with other minerals, chiefly magnetite. It occurs as a dark-brown granular massive material, with a specific gravity of 3.7 to 4.3 and a hardness of about 8. It usually contains only 55 to 75% of $Al_2O_3$. It is used as an abrasive either ground into powder or in blocks and wheels. The grains are graded in sizes from 220 mesh, the finest, to 20 mesh, the coarsest. Emery paper and cloth are usually graded from 24 to 120 mesh, and the grains are glued to one side of 9- by 11-in. sheets. Flour of emery is the finest powder, usually dust from the crushing. Emery cake as made for buffing and polishing is now not likely to be made of emery, but a graded combination of aluminum oxide and iron oxide, with a higher percentage of the hard aluminum oxide for buffing, and higher iron oxide for polishing. It is furnished in various grades of fineness, with grains of 120 to 200 mesh, or flour sizes, F, FF, and FFF. Emery takes its name from Cape Emery, on the Island of Naxos. Small amounts are produced in New York and Massachusetts.

**Emulsifying agents.** Materials used to aid in the mixing of liquids that are not soluble in one another, or to stabilize the suspension of nonliquid materials in a liquid in which the nonliquid is not soluble. The suspension of droplets of one liquid in another liquid in which the first liquid is not soluble is called an Emulsion. The emulsion of oil and water, used in machine shops as a cutting lubricant and work coolant, may be made with soap as the emulsifying agent. The emulsifying agent causes the droplets to be formed and protects droplets of the dispersed medium from uniting and thus separating out, but most emulsions will separate on long standing. The oil itself may be treated so that it is self-emulsifying. Sulphonated oils will thus form emulsions with water without any other agent. Saponin, bentonite, and the root starches are commonly used emulsifying agents. For the suspension of drug materials in pharmaceutical mixtures gum arabic, tragacanth, albumin, or algin may be used. Tapioca, sweet-potato starch, egg albumin, and proteins are common emulsifying agents for food preparations. Bentonite is used in adhesive and lacquer emulsions. Propylene laurate is a light, high-boiling liquid that is

self-emulsifying in water and is employed in pharmaceuticals and foods to stabilize the mixtures. Various long-chain chemicals are also used in making cutting compound emulsions as they also give antirust characteristics.

Enamel. A protective coating which upon hardening has an enameled or glossy face. Pottery enamels, Ceramic enamels, or Vitreous enamels, are composed chiefly of quartz, feldspar, clay, soda, and borax, with saltpeter or borax as fluxes. The quartz supplies the silica, and such enamels are fusible glasses. In acid-resisting enamels alkali earths may be used instead of borates. To make enamels opaque, opacifiers are used. They may be tin oxide for white enamel, cobalt oxide for blue, or platinum oxide for gray. Enamel-making materials are prepared in the form of a powder which is called Frit. The frit-making temperature is about 2400°F., but the enamel application temperatures are from 1400 to 1600°F. Enamels applied to metal are fired at red heat, and each succeeding coat must have a lower melting point than the one before it so as not to destroy the preceding coat. They must also have about the same coefficient of expansion as the metal to prevent cracking. The mineral oxide enamels fused to metals as coating were formerly called Porcelain enamel, but they are not porcelain and are now termed Vitreous enamels in the industry. They are carefully selected and blended oxides to produce thin and resistant coatings that will not chip easily. They are used to coat cooking utensils, signs, chemical equipment and machine parts, and corrugated iron and steel for siding and roofing. Vitric steel, of the Republic Stamping & Enameling Co., is vitreous enameled corrugated steel for building construction. White glass enamel is a low-melting enamel used on brass clock dials and scales.

Normally, a blue cobalt undercoat is used to give good adherence of white or colored enamels to steel, but special Enameling steels are available that require no ground coat. Ti-Namel, of the Inland Steel Co., is a sheet steel containing titanium to which a single white coat can be applied. Specially blended enamels are now also used which do not require the cobalt ground coat. Mirac, of the Pemco Corp., is a white enamel which gives good adhesion direct to steel when fired at 1500°F. Cloisonné enamel is an ancient

decorative enamel produced by soldering thin strips of gold on the gold base metal to form cells into which the colored enamel is pressed and fused into place. It is still produced by the old hand methods, but is imitated in synthetic plastics for such articles as clocks and radios. Enameloid-cloisonné is a name for such use by the Gemloid Corp. Glass-coated steel is made by covering high-silicon steel sheets with calcined magnesia and heating in an oxygen-free atmosphere. The magnesia reacts with the silicon in the steel and forms a tough glasslike enamel on the sheet.

The word enamel in the paint industry refers to glossy varnishes with pigments or to paints of oxide or sulphate pigments mixed with varnish to give a glossy face. In general, they do not have the heavy body of a paint and require undercoats. Japan is a name applied to black baking enamels. The same finish in other colors would not be called japan, as the original oriental lacquer was always black. Japan consists of a pigment, a gum, a drying oil, and a reducer, the same as any oil enamel. It is always baked, which drives off the solvent and fuses the gum into a uniform vitreous layer. Japans give a tough durable finish to small machine parts, but require expensive between-coat rubbing, and are now replaced by synthetic baking finishes. The modified phenol-melamine and alkyd-melamine synthetic resins produce tough and resistant enamel coatings. Quick-drying enamels are the cellulose lacquers with pigments. Fibrous enamel, used for painting roofs, is an asphalt solution in which asbestos fibers have been incorporated. When of heavy consistency and used for calking metal roofs, this material is called Roof putty.

**Erbium.** An exceedingly rare metal, symbol Er, which occurs in the rare mineral Gadolinite, or Ytterbite, $4BeO \cdot FeO \cdot Y_2O_3 \cdot 2SiO_2$, also the source of holmium, rhenium, and gadolinium. The mineral is found in Greenland and Sweden. Erbium has been obtained only in minute quantities as a dark-gray powder. It forms the rose-red Erbium oxide, or Erbia, $Er_2O_3$, and other highly colored reddish salts. At high temperatures erbia glows with a greenish light.

**Essential oils.** Aromatic oils found in uncombined form in various parts of plants, and employed for flavors, perfumes, dis-

infectants, medicines, stabilizers, for masking undesirable odors, and as raw materials for the manufacture of other products. They are usually the esters upon which the odoriferous properties of the plants depend, and are called essential oils because of their ease of solubility in alcohol to form essences. They are also called Volatile oils, although this term is sometimes also applied to the light and volatile distillates from petroleum. The essential oils are of four general classes: the Pinenes or Terpenes of coniferous plants, containing carbon and hydrogen of the empirical formula $C_{10}H_{16}$, such as oil of turpentine; Oxygenated oils containing carbon, hydrogen, and oxygen, such as oil of cassia; Nitrogenated oils containing carbon, hydrogen, oxygen, and nitrogen, such as oil of bitter almonds; Sulphurated oils containing carbon, hydrogen, and sulphur, such as oil of mustard. Although fixed vegetable oils are obtained by expression, the essential oils are obtained by distilling the buds, flowers, leaves, twigs, or other parts of the plant. Rose oil is found only in the flowers. Orange and lemon oils are from both the flowers and the fruits, but are of different compositions. Sweet birch and cinnamon oils are from the bark. Valerian and calamus are only in the roots, while sandalwood and cedar oils are only in the wood. Sometimes the essential oil is not in the plant, but is developed when the plant is macerated with water. Balsams are solid or semisolid resinous oils, and are mixtures of resins with cinnamic or benzoic acids, or both, with sometimes another volatile oil. They are obtained from a variety of trees, and are used in antiseptics, perfumes, flavors, and in medicine.

Esters. Combinations of alcohols with organic acids, which form several important groups of commercial materials. The esters occur naturally in vegetable and animal oils and fats as combinations of acids with the alcohol glycerin. The natural fats are usually mixtures of esters of many acids, coconut oil having no less than fourteen. Stearic, oleic, palmitic, and linoleic acid esters are the common bases for most vegetable and animal fats, and the esters of the other acids such as linolenic, capric, and arachidic give the peculiar characteristics of the particular fat, although the physical characteristics and melting points may be governed by the basic esters. Esters occur also in waxes, the vege-

table waxes being usually found on the outside of leaves and fruits to protect them from loss of water. The waxes differ from the fats in that they are combinations of mono acids with monohydric, or simple, alcohols, rather than with glycerin. They are harder than fats and have higher melting points. Esters of still lower molecular weights are also widely distributed in the essential, or alcohol-soluble, oils of plants where they give the characteristic odors and tastes. All of the esters have the characteristic formulas ArCOOR or RCOOR, where R represents an Alkyl, and Ar an Aryl group, that is, where R is a univalent straight-chain hydrocarbon having the formula $C_nH_{2n+1}$, and Ar is a univalent benzene ring $C_6H_5$—. In the esters of low molecular weight which make the odors and flavors, the combination of different alcohols with the same acid yields oils of different flavor. Thus, the ester methyl acetate, $CH_3COOCH_3$, is peppermint oil; amyl acetate, $CH_3COOC_5H_{11}$, is banana oil; and isoamyl acetate, $CH_3COO(CH_2)_3(CH_3)_2$, is pear oil. Esters are used as solvents, flavors, perfumes, waxes, oils, fats, fatty acids, pharmaceuticals, and in the manufacture of soaps and many chemicals.

**Etching materials.** Chemicals, usually acids, employed for cutting into, or etching, the surface of metals, glass, or other material. The usual method is to coat the surface with a wax, asphalt, or other substance not acted upon by the acid, cut the design through with a sharp instrument, and then allow the acid to corrode or dissolve the exposed parts. For etching steel, a 25% solution of sulphuric acid in water is used, or a ferric chloride solution may be used. For etching stainless steels a solution of ferric chloride and hydrochloric acid in water in the proportion of 5 :1 :6 may be used. For high-speed steels, brass, or nickel, a mixture of nitric and hydrochloric acids in water solution is used, or nickel may be etched with a 45% solution of sulphuric acid. Copper may be etched with a solution of chromic acid. Brass and nickel silver may be etched with an acid solution of ferric chloride and potassium chlorate. For red brasses, deep etching is done with concentrated nitric acid mixed with 10% of hydrochloric acid, the latter being added to keep the tin oxide in solution and thus retain a surface exposed to the action of the acid. For etching aluminum a 9% solution of copper chlo-

ride in 1% acetic acid, or a 20% solution of ferric chloride may be used, followed by a wash with strong nitric acid. Sodium hydroxide, ammonium hydroxide, or any alkaline solutions are also used for etching aluminum. Zinc is preferably etched with weak nitric acid, but requires a frequent renewal of the acid. Strong acid is not used because of the heat generated, which destroys the wax coating. A 5% solution of nitric acid will remove 0.002 in. of zinc per minute, compared with the removal of only 0.0005 in. per min. in most metal-etching processes. Glass is etched with hydrofluoric acid or with White acid. White acid is a mixture of hydrofluoric acid and Ammonium bifluoride, a white crystalline material of the composition $(NH_4)FHF$.

**Ether.** The common name for Ethyl ether, or Diethyl ether, a highly volatile, colorless liquid of the composition $(C_2H_5)_2O$ made from ethyl alcohol. It is used as a solvent for fats, greases, resins, and nitrocellulose, and in medicine as an anesthetic. The specific gravity is 0.720, boiling point 34.2°C., and freezing point −116°C. Its vapor is heavier than air and is explosive. Butyl ether, $(C_4H_9)_2O$, has a much higher boiling point, 140°C., is more stable, and is used as a solvent for gums and resins. Methyl ether, or Dimethyl ether, also known as Wood ether, is a colorless gas of the composition $(CH_3)_2O$, with a pleasant aromatic odor. The boiling point is −24.5°C. The specific gravity is 1.562 or, as a liquid compressed in cylinders, 0.724. It is soluble in organic solvents. It is used for fuel, as a welding gas, as a refrigerant, and for vapor-pressure thermometers. Hexyl ether, $C_6H_{13}OC_6H_{13}$, has a high boiling point, 226.2°C., very low water solubility, and a specific gravity of 0.7942. It is stable and not volatile, with a flash point of 170°F. It is used in foam breakers, and in chemical manufacture where anhydrous properties are desired.

**Ethyl alcohol.** Also called Methylcarbinol, and Ethanol when made synthetically. It is the common beverage alcohol, which when denatured for nonbeverage purposes is called Industrial alcohol. It is a colorless liquid with a pleasant odor but burning taste. The composition is $CH_3CH_2OH$, specific gravity 0.79, boiling point 78.5°C., and freezing point −117.3°C. It mixes with water

in all proportions and takes up moisture from the air. It burns with a bluish flame and high temperature, yielding carbonic acid and water. The ignition temperature is 965°F. It is one of the best solvents, and dissolves many organic materials such as gums, resins, and essential oils, making solutions called Essences. It is classed as a poison when pure, but is employed as a beverage in many forms. In small quantities it is an exhilarant and narcotic. Ethyl alcohol is produced easily by the fermentation of sugars, molasses, grains, and starch. It is also made cheaply by hydrating ethylene produced by the cracking of petroleum hydrocarbons. In Europe it is also made from the waste liquor of pulp mills by fermentation of the wood sugar. In all countries large amounts of Beverage alcohol are made from starches, grains, and fruits, retaining the original flavor of the raw material and marketed directly as wines, whiskies, and brandies. Ethyl alcohol is used as a solvent in varnishes, explosives, extracts, perfumes, pharmaceuticals, as a fuel, as a preserving agent, as an antifreeze, and in low-temperature thermometers. Up to 15% of alcohol can be used in gasoline motor fuels without change in the carburation. The German motor fuel Monopolin was a mixture of absolute alcohol and benzine.

Alcohol is sold by the proof gallon, a 100 proof containing 50% alcohol by volume and having a specific gravity of 0.7939. The term Alcohol, alone, refers to 188 to 192 proof. High-purity, Grain alcohol, or Pure ethyl alcohol, are terms for 190 proof. Absolute alcohol, or Anhydrous alcohol, is 200 proof, free of water. Methylated spirits is a term first used in England to designate the excise-free mixture of 90% ethyl alcohol and 10% wood alcohol for industrial use. Denatured ethyl alcohol, made unsuitable for beverage purposes, may be marketed under trade names such as Synasol of the Carbide & Carbon Chemicals Corp. Solox, of the U.S. Industrial Chemicals, Inc., consists of 100 parts of 190-proof alcohol, 5 of ethyl acetate, and 1 of gasoline, used for lacquers, fuel, and as a solvent. A substitute for ethyl alcohol for solvent purposes and as a rubbing alcohol is Isopropyl alcohol, or Isopropanol, a colorless liquid of the composition $(CH_3)_2CHOH$, and boiling point 82°C. It is also used as a stabilizer in soluble oils, and in drying baths for electroplating.

**Ethylene.** Also called Ethene. A colorless, inflammable gas, $CH_2:CH_2$, which is produced in the cracking of petroleum and many other organic materials. It was first produced in Holland by dehydrating ethyl alcohol by treating it with sulphuric acid. It was originally employed for enriching illuminating gas to give it a more luminous flame, and was called Olefiant gas because it formed an oil, ethylene dichloride, called Dutch liquid, when treated with chlorine. Its nature as a chemical radical was early discovered, and it was believed by the French chemist Wurtz to be the connecting link between organic and inorganic compounds. Ethylene is now used to produce plastics, ethylene glycol, and a great number of other chemicals. Under the name of Calorene it is marketed in pressure cylinders to replace acetylene for flame-cutting torches. When burned with oxygen, it gives a flame lower in temperature than acetylene, but the gas is more stable in storage. It is produced by dehydrating ethyl alcohol with sulphuric acid, or breaking down alcohol by the catalytic action of heated aluminum oxide or bauxite. It is also produced by the cracking of petroleum. Ethylene is the starting point for a number of chemicals used in making plastics, acrylic acid, styrene, and the vinyl compounds. But ethylene is also polymerized directly with high temperature and pressure to form the water-white translucent solid Polyethylene plastics. These are thermoplastic, have high dielectric strength, light weight, low water absorption, good chemical resistance, high flexibility and good strength, and ease of extruding. They are thus valued for electrical-wire insulation, for coating textiles and paper, and for injection-molded parts. Polyethylene was used in Germany for high-frequency insulation under the name of Lupolen. Polythene, of E. I. duPont de Nemours & Co., Inc., is a polyethylene plastic. The specific gravity is 0.92 to 0.95, tensile strength 1,600 to 2,000 lb. per sq. in. with elongation of 300 to 500%, softening point 220 to 240°F., dielectric strength 1,000 volts per mil. It is resistant to acids, alkalies, and oxygenated solvents, but is soluble in chlorinated hydrocarbons and hot aromatic solvents. The plastic is marketed in the form of molding powder, rod, sheet, tube, and thin foil. The powdered material can be flame-sprayed with an oxypropane flame for coating metals. Friction tape made with polyethylene has higher heat resistance and greater dielectric strength than the older tapes

made with rubber compounds. The synthetic resin Teflon, of E. I. duPont de Nemours & Co., Inc., is Tetrafluoro ethylene. As a plastic it is noted for high dielectric strength, 1,500 volts per mil, high heat resistance, 550°F., and high chemical resistance. It is waxy in nature which gives it self-lubricating properties for such uses as pressure-valve seats in chemical equipment. In thin sheets it is used as an electrical insulator. It has a gray color.

**Ethylene glycol.** Also known as Glycol and Ethylene alcohol. A colorless, sirupy liquid, $CH_2OHCH_2OH$, with a sweetish taste, very soluble in water. It has a low freezing point, −25°C., and is much used as an antifreeze in automobiles. A 25% solution has a freezing point of −5°F., without appreciably lowering the boiling point of the water. It has the advantage over alcohol that it does not boil away easily, and permits the operation of engines at much higher temperatures than with water alone, thus giving greater fuel efficiency. It is also used as a substitute for glycerin, and as a solvent for nitrocellulose. Diethylene glycol, $C_4H_{10}O_3$, is a water-white liquid boiling at 244°C., used as an antifreeze, as a solvent, and for softening cotton and wool fibers in the textile industry. A 50% solution of diethylene glycol freezes at −28°C. Cellosolve, $C_2H_5OCH_2CH_2OH$, of the Carbide & Carbon Chemicals Corp., is the monoethyl ether of ethylene glycol. It is a colorless liquid boiling at 135.1°C., and is a powerful solvent used in varnish removers, cleaning solutions, and as a solvent for paints, varnishes, plastics, and dyes. Carbitol, of the same company, is an ether of diethylene glycol of the composition $CH_3CH_2OCH_2CH_2OCH_2CH_2OH$, used as a solvent for oils, dyes, resins, and gums. The boiling point is 201.9 and freezing point −76°C. Methyl carbitol, with one less $CH_2$ group, is also a high-boiling solvent for gums and resins, and Carbitol acetate is used as a high-boiling solvent for cellulose acetate. Glycol diformate, $HCOOCH_2CH_2OOCH$, used as a solvent for cellulose acetate and nitrocellulose, is a colorless liquid soluble in water, alcohol, and ether. It hydrolyzes slowly, liberating formic acid.

**Ethyl silicate.** A colorless liquid of the composition $(C_2H_5)_4SiO_4$, used for making heat-resistant paints, for acidproof cement, for molded objects, and for preserving stone. The specific gravity

is 0.920 to 0.950, and boiling range 90 to 210°C. It contains 25% of available silica, though the Tetra ethyl orthosilicate has 27.9% of available silica. Water hydrolyzes ethyl silicate to alcohol and Silicic acid, $H_4SiO_2$, which dehydrates to an adhesive amorphous silica. For molding, the ester is mixed with silica powder, and for such products as bearings wood flour may be incorporated to absorb and retain the lubricating oil. Ethyl silicate solutions are employed for the surface hardening of sand molds and graphite molds for special casting. Silicic acid ester paints are used to harden and preserve stone, cement, or plaster, and for coating insulating brick. They are resistant to heat and to chemical fumes. Synthetic resin lacquers containing ethyl silicate have high adhesion to glass.

**Excelsior.** A name for the continuous, curly, fine wood shavings employed as a packing material to prevent breakage of fragile articles in shipping, or as a stuffing material. It is light and elastic. It was originally called Wood fiber or Wood wool. The raw material used in its manufacture is mainly aspen and basswood, or it may be made as a by-product of other wood manufactures. Poplar and cottonwood are also employed. A cord of wood yields about 1,500 lb. of excelsior.

**Expanded metal.** Sheet metal that has been slit and expanded to form a mesh, which is used for reinforced concrete work or plaster wall construction. It is made either with a plain diamond-shaped mesh, or with rectangular meshes. One type is made by slitting the sheet and stretching the slits into the diamond shape. The other variety is made by pushing out and expanding the metal in the meshes so that the flat surface of the cut strand is nearly at right angles to the surface of the sheet. Expanded metal is made from low-carbon steel, iron, or special metals, in sheets from 8 to 12 ft. in length and 3 to 6 ft. in width, in several thicknesses. It is also marketed as Metal lath, usually 96 in. long, and 14 to 18 in. wide. The expanded metal has greater rigidity than the original metal sheet, and also permits a welding of the concrete or plaster through the holes. Rigidized steel is thin sheet steel that is not perforated, but has the designs rolled into the sheet so that the rigidity of the sheet is increased two to four times. Thus, extremely thin sheets of stainless steel can be used for novelties, small mechanical products,

and for paneling. The Rigid-Tex steel of the Rigid-Tex Corp. is made in many intricate ornamental designs, and comes also in vitreous enameled sheets for paneling. Perforated metals are sheet metals with the perforations actually blanked out of the metal. They are marketed in sheets in carbon steel, stainless steel, or monel metal, with a great variety of standard perforation designs. Those with round, square, diamond, and rectangular designs are used for screens and for construction. Agaloy, of the Agaloy Tubing Co., is perforated metal made into tube form.

**Expansive metal.** An alloy which expands on cooling from the liquid state. The expansive property of certain metals is an important characteristic in the production of accurate castings having full details of the mold such as type castings. The alloys are also used for proof-casting of forging dies, for sealing joints, for making duplicates of master patterns, for holding die parts and punches in place, and for filling defects in metal parts or castings. Antimony and bismuth are the metals most used to give expansion to the alloys. Lewis metal, one of the original expansive alloys, had one part of tin and one of bismuth, and melted at 138°C. Matrix alloy, and Cerromatrix, of the Cerro de Pasco Copper Corp., contain 48% of bismuth, 28.5 lead, 14.5 tin, and 9 antimony. The melting point is 248°F., tensile strength 13,000 lb. per sq. in., and Brinell hardness 19. Cerrobase, of this company, is another alloy balanced to give the exact impression of the mold without shrinkage or expansion in cooling. It is harder than lead, and melts at 255°F.

**Explosive.** A material which, upon application of a blow, or by rise in temperature, is converted in a small space of time into other compounds more stable and occupying much more space. Commercial explosives are solids or liquids that can be instantaneously converted by friction, heat, shock, or spark, into a large volume of gas, thereby developing a sudden rise in pressure which is utilized for blasting or propelling purposes. Gunpowder is the oldest form of commercial or military explosive, but this has been replaced for military purposes by more powerfully acting chemicals. Smokeless powder was a term used to designate nitrocellulose powders as distinguished from the smoky black gunpowder. Blasting powders are required to be relatively slow acting to have a heaving

or rending effect. Military explosives used as propellants must not give instantaneous detonation, which would burst the gun, but are arranged to burn slowly at first and the explosion does not reach a maximum until the projectile reaches the muzzle. The more rapid-acting High explosives are generally used for bombs, torpedoes, Boosters, and Detonators. The detonators are the extremely sensitive explosives, such as lead azide, set off by a slight blow but too sensitive to be used in quantity as a charge. The booster explosives are extremely rapid but not as sensitive as the detonators. They are exploded by the detonators and in turn set off the main charge of explosive. Some explosives such as nitroglycerin can be exploded by themselves, while others require oxygen carriers or carbon carriers mixed with them. Other requirements of explosives are that they should not react with the metal container, be stable at ordinary temperatures, and should not decompose easily in storage or on exposure to the air.

Shaped charges of high explosive give a penetrating effect, known as the Monroe effect, used in armor-piercing charges. A solid mass of explosive spends itself as a flat blast, but with a conical hole in the charge, having the open end facing the charge, a terrific piercing effect is generated by the converging detonation waves coming from the sides of the cone, and drives a jet of hot gases through the steel armor. Permissible explosives are explosives that have been passed by the Bureau of Mines as safe for blasting in gaseous or dusty mines. Most of the permissibles are of ammonium nitrate or gelatin base. Lox, used in mines and quarries, is an explosive consisting of a paper cartridge filled with carbon black or wood pulp soaked in liquid air. It cannot be tamped as it is very sensitive. It is fired by electric detonators. Cardox, an explosive used in coal mining, consists of liquid carbon dioxide in a steel cylinder with aluminum powder. The powder is fired by an electric spark, heating and gasifying the carbon dioxide. Picric acid, or Trinitrophenol, $C_6H_2(OH)(NO_2)_3$, a lemon-yellow crystalline solid melting at 248°F., is a powerful explosive used in shells, and because of its persistent color also used as a dyestuff. It is called Melanite by the French, Lyddite by the English, and Schimose by the Japanese. It is made by treating phenol with sulphuric and nitric acids, or can be produced by treating acaroid resin with nitric acid. It reacts with

metals to form dangerous explosive salts, so that the shells must be lacquered. Cressylite, used for shells, is a mixture of picric acid and trinitrocresol. It has a lower melting point.

Explosive D, or Dunnite, made by the neutralization of picric acid with ammonium carbonate, is Ammonium picrate, $C_6H_2(NO_2)_3ONH_4$. It forms orange-red needles that explode when heated to 300°C., but is not sensitive to shock or friction. It is used as a bursting charge in armor-piercing shells. Trinitrotoluene, or Trinitrotoluol, $C_6H_2(CH_3)(NO_2)_3$, also commonly known as TNT, is the principal constituent of many explosives. It resembles brown sugar in appearance, melts at 80°C., and the fumes are poisonous even when absorbed through the skin. It is not as powerful as picric acid, but is very stable, not hygroscopic, and does not form unstable compounds with metals. It is exploded easily with mercury fulminate, and is used for shrapnel, hand grenades, mines, and depth bombs. TNT is made by the nitration of toluol with nitric and sulphuric acids. The intermediate product, Dinitrotoluol, is employed with hexanitrodiphenylamine for torpedoes. Hexanitrodiphenylamine, $(NO_2)_3C_6H_2 \cdot NH \cdot C_6H_2(NO_2)_3$, is a powder that explodes with great violence. It is highly poisonous, and causes painful blisters and inflammation. The commercial explosive Sodatol is made by mixing TNT with nitrate of soda.

Pentolite, used in rockets and as a booster and filler in shells, is made by nitrating an alcohol produced by treating a mixture of formaldehyde and acetaldehyde with lime. It is 20% more powerful than TNT. It melts below the boiling point of water and can be poured into shells. Tri-nitro-aniline, $(NO_2)_3C_6H_2NH_2$, commonly known as TNA, is derived from aniline by nitration, and is one of the strongest of the high explosives. It is a yellowish-green crystalline powder melting at 215°C. It stains the skin yellow but is not poisonous. It is more sensitive to shock than TNT and is more costly. Trinitro anisol, used in Japanese Baka planes, has the composition $C_6H_2OCH_3(NO_2)_3$. It is about equal to TNT in power, and has the advantage that it does not attack metals.

Tetryl, or Pyronite, $(NO_2)_3C_6H_2N(NO_2)CH_3$, is a nitro derivative of benzene. It is a yellow crystalline powder melting at 130°C., and exploding when heated to 186°C. It is more sensitive to shock than TNA, and has a higher rate of detonation than TNT.

It is too sensitive to be used as a shell filler, and is employed as a booster and in commercial explosives to replace mercury fulminate for detonators. The extremely high explosive RDX is Cyclo trimethylene trinitramine. It is used in bombs, torpedoes, mines, and rockets, but is very sensitive to shock and is mixed with waxes or plasticizers to reduce sensitivity. The blast effectiveness of TNT is increased 50% when 60% of RDX is mixed with it. When aluminum powder is added to high explosives, the brisance or blast effect is increased greatly. A powerful explosive used during the war contained 40% RDX, 40% TNT, and 20% aluminum powder.

**Fat liquors.** Oil and grease emulsions used in tanneries for treating tanned leather to lubricate the fibers, increase the flexibility, and improve the finish. There are two general types of fat liquor emulsions: acid and alkaline. The acid group includes sulphonated oils and some soluble oil combinations. Alkaline types are emulsions of oils with soaps or alkalies. Leather may also be treated first with an alkaline liquor and then with an acid, or borax or soda ash may be added to sulphonated oils to produce alkaline liquors. For suède and white leathers, egg-yolk emulsions may be used. The oils employed in emulsions may be sperm, cod, or castor oil, and those that are neutral have a neatsfoot oil base. The soaps are usually special for the tannery trade. Prepared fat liquors are also marketed under trade names. The Tanners' greases, used for sponging or milling onto the leather, are also usually trade-named mixtures of waxes, sulphonated oils, and soaps.

**Fats.** Natural combinations of glycerin with fatty acids, some fats having as many as 10 or more different fatty acids in the combination. They are derived from animal or vegetable sources, the latter source being chiefly the seeds or nuts of plants. Fats in a pure state would be odorless, tasteless, and colorless, but the natural fats always contain other substances that give characteristic odors and tastes. Fats are used directly in foods and also in the making of various foodstuffs. They are also used in making soaps, candles, lubricants, and in the compounding of resins and coatings. They are also distilled or chemically split to obtain the fatty acids for many uses. The world consumption of fats is tabulated at 26 million metric tons, but actual consumption is much higher because

of unrecorded consumption in meats, nuts, and other products. Fats are most important for food, containing more than twice the fuel value of other foods. They are also important carriers of glycerin necessary to the human system. Metabolism, or absorption of fats into the system, is not a simple process, and is varied with the presence of other food materials. The fats with melting points above 45°C. are not readily absorbed into the system. The heavy fats are called tallow. Lack of certain fats, or fatty acids, causes skin diseases, scaly skin, and other affections. Some fatty acids are poisonous alone, but in the glyceride form in the fats they may not be poisonous but beneficial. Fats can be made synthetically from petroleum or coal. During the war the Germans produced fatty acids by oxidation of paraffin recovered from the hydrogenation of brown coal and lignite. Edible fats were then produced by esterifying the $C_9$ to $C_{16}$ fractions of the acids. But the world resources of natural fats are potentially unlimited, especially from tropical nuts, forming a cheap source of fatty acids in readily available form.

**Fatty acids.** A series of organic acids deriving the name from the fact that the higher members of the series, the most common ones, occur naturally in animal fats. All of these acids contain the carboxyl group —COOH. The acids are used for making soaps, candles, coating compounds, as plasticizers, and for the production of plastics and many chemicals. The hydrogen atom of the group can be replaced by metals or alkyl radicals with the formation of salts or esters, and other derivatives such as the halides, anhydrides, peroxides, and amides can also be made. Some of the fatty acids can be polymerized to form plastics. Various derivatives of the acids are used as flavors, perfumes, driers, pharmaceuticals, and antiseptics. Certain fatty acids, such as oleic and stearic, are common to most fats and oils regardless of their source, while others, such as arachidic and erucic, are characteristic only of specific fats and oils. The names of the fatty acids often suggest their natural sources. Butyric acid, $CH_3CH_2CH_2 \cdot COOH$, is the characteristic acid of butter. Some acids, such as linoleic, are found in greater amount in cold-climate products, while some other acids are found in most abundance in hot-climate products. Lauric acid, or Dode-

canoic acid, occurs in high percentage in the oil of the coconut and other kernels of tropical palm nuts. It is a saturated acid much lower in carbon and hydrogen than linoleic acid, and is a semisolid melting at 44°C. Fatty acids are called saturated when they contain all the hydrogen with which they can combine, and they have the type formula $C_nH_{2n+1}COOH$. They have high melting points. Unsaturated fatty acids, such as oleic and linoleic, are liquid at room temperature, and are less stable than saturated acids.

**Feathers.** The light fluffy outgrowth or plumage of birds. The industrially important feathers are those from the duck, goose, chicken, and ostrich. Radiantly colored feathers from many other types of birds are used for ornamental and art purposes. An important featherwork art exists in Mexico as a development of the Aztec featherwork. Down is the soft feathers of young birds or the soft undergrowth of adult birds, used as a stuffing material. Eider down, from the eider duck, is highly valued for stuffing. About 100 million pounds of chicken feathers annually come from the commercial preparation of chickens in the United States. Some of these are used in the textile and plastics industries. The midrib and quill are made into protein plastic, and the fluffy barbs are used as stuffing, or are mixed with wool or cotton for weaving into light warm fabrics. Ostrich feathers, from the domesticated ostriches of Argentina, South Africa, and Australia, are used for ornamental purposes, hats, and dusting brushes. The ostrich has 24 feathers on each wing, some as long as 25 in., and the grade depends upon the color and the length. Male ostrich feathers are black. The female feathers are a soft gray, with white feathers in the wings and tail. The life of the ostrich is 50 to 75 years, and the feathers begin to be clipped at the age of 10 months. Ostrich eggs, which weigh 4 lb. and are laid every other day, are a valuable food by-product.

**Feldspar.** A general name for a group of abundant minerals used for vitreous enamels, pottery, tile, glass, in fertilizers, in fluxes, for roofing granules, and as an abrasive in soaps and cleaning compounds. Ground feldspar is also used for extinguishing magnesium fires as it melts and gives a smothering action. There are many varieties of feldspar, but those of greatest commercial importance

are the Potash feldspars, Orthoclase or Microline, $K_2O:Al_2O_3 \cdot 6SiO_2$, the Soda feldspar, Albite, $Na_2O:Al_2O_3 \cdot 6SiO_2$, and the Calcium feldspar, Anorthite, $CaO:Al_2O_3 \cdot 2SiO_2$. Orthoclase and microline have the same composition but different crystal structures. Orthoclase is called Sunstone. The colors of feldspar are from mineral oxides and impurities and are white, gray, yellow, pink, brown, and green. Albite is generally white, while microline is more often green. All of the chemical components of feldspar are glass-making materials, and in making glass about 150 lb. are used to each 1,000 lb. of sand. But the mineral in its natural occurrence varies widely in composition even in the same mine, and thus must be controlled chemically to obtain uniform results in glass and ceramic enamels. It occurs in pegmatic dikes associated with quartz, mica, tourmaline, garnet, and spodumene. The mineral is ground to a uniform size, from 80 to 140 mesh, and shipped in bags. Crude unground feldspar is also marketed in bulk. The melting point varies from 1185 to 1490°C., but the preferred range is 1250 to 1350°C. The hardness is 6 to 6.5, and the index of refraction is 1,518 to 1.588, the lowest being orthoclase and the highest anorthite. The specific gravity is 2.44 to 2.62 for orthoclase and microline, and 2.6 to 2.8 for anorthite. Tennessee and North Carolina feldspar has about 70% of $SiO_2$ and 17 of $Al_2O_3$, with 9 to 11 of $K_2O$, and 2 to 3 of $Na_2O$. New England feldspar is lower in silica and higher in potash. Potash spar from New York and New Jersey has about 12% of $K_2O$, and is suited for glass and pottery. Soda spar, with about 7% of $Na_2O$, is preferred for ceramic enamels. Cornwall stone, from England, is a kaolinized feldspar with about 2% of CaO. A similar stone from North Carolina is called Carolina stone. Aplite is a ceramic fluxing stone found in Virginia and used chiefly to supplement feldspar to provide more alumina. It is a white massive material of feldspars and other minerals, containing 60% of silica, 24 alumina, 6 calcia, 6 sodium oxide, and 3 potassium oxide. Another feldspar material is Alaskite, a feldspar and quartz mixture from North Carolina. Ground feldspar for enamels is sometimes called Glass spar. Dental spar is specially selected potash feldspar used in making artificial teeth. Amazon stone, or Amazonite, is a beautiful green microline found in Russia, Italy, Madagascar, and Colorado, used as a gem stone.

**Felt.** A fabric of wool, fur, or hair made by matting the fibers together under pressure when thoroughly soaked or steam-heated. The matting may also be accomplished by blowing the wet fibers under a powerful air blast and then pressing. The animal fibers mat together, owing to minute scales on their surface. Cotton and other vegetable fibers do not have the property of felting, but a percentage of vegetable or synthetic fibers may be incorporated to vary the characteristics of the felt. So great is the felting property of wool that only 20% is needed in mixtures. Most commercial felts are mixtures. New and reworked wool and noils are mixed with cotton, rayon waste, ramie, jute, casein fiber, and other fibers. Cotton decreases the density and prevents voids in the felt. Kapok gives lower thermal and sound conductance. Felt is made of staple fibers of about 1½ in. length, and noils of ¾ to 1 in. Longer fibers tend to mat. Shorter fibers lack depth of penetration to give necessary strength. Since most of the wool used is secondary or waste, all grades are employed, from the fines to the coarse carpet wools. Felt is the most ancient of all fabrics. It is now used for insulation, sound and vibration absorption, for padding and lining in instrument cases, hats, roofing, and where a soft resilient fabric is needed. Although the best hat felts are made with nutria or beaver fur, vast quantities of rabbit furs or mixed furs and wool are used. Hair felt is made of cattle hair, and is used largely for insulating cold-water pipes and for refrigerators. It comes in thicknesses from ¼ to 2 in., the ¼ in. weighing 4 oz. per sq. ft. Cattle- and goat-hair felts are also used for glass polishing. Baize is an old name for a thin woolen felt used for desk and table tops, box linings, and for bases of instruments. Its name is derived from the fact that it was originally bay, or brown, colored, but the industrial baize is now usually green. The same name is now also used to designate a plain-woven, loose, woolen fabric with a short, close nap, in plain colors for the same purposes. Feltex, of the Philip Carey Co., is an asphalt-saturated felt for roofing, and Mica-kote is a heavy felt coated with asphalt and finished with mica flakes, used for roofing. Unisorb, of the Felters Co., Inc., is a heavy felt in blocks and sheets for isolation pads under machinery to absorb vibration. Slaters' felt is a tarred sheathing felt used in building construction, usually in 25- and 30-lb. rolls. Fire felt, of Johns-Manville, is made of asbestos

fibers felted into sheets, blocks, or shapes, for boiler and furnace insulation. Slatekote, of the same company, is a heavy felt saturated with asphalt and coated with colored crushed slate, used for roofing.

**Ferric oxide.** The Red iron oxide, $Fe_2O_3$, found in abundance as the ore hematite, or made by calcining the sulphate. It has a dark-red color and comes in powder or lumps. The specific gravity is 5.20, and melting point about 1550°C. It is used as a paint pigment under such names as Indian red, Persian red, Persian Gulf oxide. In cosmetics and in polishing compounds it is called rouge. The Persian red oxide from the Island of Hormuz contains from 60 to 90% of $Fe_2O_3$, and is marketed on a 75% basis. The brown ferric oxide is made from ferrous sulphate and sodium carbonate and is not a pure oxide. The names Metallic red and Metallic brown are applied to pigments from Pennsylvania ores containing a high percentage of red iron oxide. Venetian red is a name for red iron oxide pigments mixed with various fillers. The Tuscan red pigments are red iron oxide blended with up to 75% of lakes, but may also be barium sulphate with lakes. Ferric oxide pigments make low-priced paints, and are much used as base coats for structural steel work. The oxides come chiefly from Alabama, Tennessee, Pennsylvania, Persia, and Spain. Black ferric oxide is a reddish-black amorphous powder, $FeO \cdot Fe_2O_3$, made by burning iron in an excess of oxygen. It is used as a paint pigment, for polishing compounds, and for decarbonizing steel. Magnetic black is a name for finely ground magnetic oxide used as a pigment. Hammer scale is the iron oxide $Fe_2O_4$, formed in the hot rolling or forging of steel, and is used for decarbonizing steel by packing the steel articles in the scale and raising to a high temperature. It is very hard, 5.5 to 6.5 Moh, and is also used as an abrasive.

**Ferrochromium.** A high-chromium iron master alloy used for adding chromium to irons and steel. It is also called Ferrochrome. It is made from chromite ore by smelting with lime, silica, or fluorspar in an electric furnace. High-carbon ferrochrome, of the Electro Metallurgical Co., contains 66 to 70% of chromium in grades of 4.5, 5, 6, and 7% of carbon. It is used for making tool

steels, ball-bearing steels, and other alloy steels. It melts at about 1250°C. It is marketed as crushed alloy in sizes up to 2 in., and as lump alloy in lumps up to about 75 lb. Low-carbon ferrochrome contains 67 to 72% of chromium, in grades of 0.06, 0.10, 0.15, 0.20, 0.50, 1, and 2% of carbon. It is used for making stainless steels and acid-resistant steels. Low-carbon ferrochrome is also preferred for alloy steel mixtures where much scrap is used because it keeps down the carbon and inhibits the formation of hard chromium carbides. The various grades of ferrochromium are also marketed as High-nitrogen ferrochrome, with about 0.75% of nitrogen for use in making high-chromium cast steels which would normally have a coarse crystalline structure. The nitrogen refines the grain and increases the strength. Foundry-grade ferrochrome, for making cast irons, contains 62 to 66% of chromium and 5 carbon.

**Ferromanganese.** A master alloy of manganese and iron used for deoxidizing steels, and for adding manganese to iron and steel alloys and bronzes. Manganese is the common deoxidizer and cleanser of steel, forming oxides and sulphides that are carried off in the slag. Ferromanganese is made from the ores in either the blast furnace or the electric furnace. Standard ferromanganese has 78 to 80% of manganese. British ferromanganese contains about 7% of carbon, but the content in the American alloy is usually 5 to 6.5%. Low-carbon ferromanganese is also marketed containing 0.10 to 1% of carbon. Low-phosphorus ferromanganese contains less than 0.10% of phosphorus. The alloys are marketed in lumps to be added to the furnace. Spiegeleisen is a form of low-manganese ferromanganese with from 15 to 30% of manganese and from 4.5 to 5.5 of carbon. The German name, meaning mirror iron, is derived from the fact that the crystals of the fractured face shine like mirrors. Spiegeleisen has the advantage that it can be made from low-grade manganese ores, but the quantity needed to obtain the required proportion of manganese in the steel is so great that it must be premelted before adding to the steel. It is used for making irons and steels by the bessemer process. Grade A spiegeleisen, of the Electro Metallurgical Co., has 19 to 21% of manganese, and 1 silicon; Grade B has 26 to 28% of manganese and 1 silicon. The melting point is from 1950 to 2265°F.

**Ferrophosphorus.** An iron containing a high percentage of phosphorus, used for adding phosphorus to steels. Small amounts of phosphorus are used in open-hearth screw steels to make them free-cutting, and phosphorus is also employed in tin-plate steels to prevent sticking together of the plates in annealing. Ferrophosphorus is made by melting phosphate rock together with the ore in making the pig iron. The phosphorus content is about 18% and is chemically combined with the iron. Another grade, made in the electric furnace and containing 23 to 25% of phosphorus, is used for adding phosphorus to bronzes. A master alloy for adding selenium to steels to give free-machining qualities to steel, particularly the stainless steels, is Ferroselenium. A typical ferroselenium, of the American Smelting & Refining Co., contains about 52% of selenium and 0.90 carbon.

**Ferrosilicon.** A high-silicon master alloy used for making silicon steels, and for adding silicon to transformer irons and steels. It is made in the electric furnace by fusing quartz or silica with iron turnings and carbon. It is marketed in various grades with from 15 to 90% of silicon. The silicon forms a chemical combination with the iron, but the alloys having more than about 30% of silicon are fragile and unstable. The silicon also causes the carbon to be excluded in graphite flakes. The alloys of high silicon content are called Silicon metal. One producer markets two grades, 15 and 45% silicon, while another has 15, 50, 75, 85, and 90% grades. The alloy is marketed in lumps or crushed form. Silicon is more often added to steels in combination alloys with deoxidizers or other alloying elements. Ferrosilicon aluminum, containing about 45% of silicon and 12 to 15% aluminum, is a more effective deoxidizer for steel than aluminum alone. It is also used for adding silicon to aluminum casting alloys. Silvaz, of the Electro Metallurgical Co., is a ferrosilicon aluminum containing also vanadium and zirconium. The alloy serves as a deoxidizer and fluxes the slag inclusions, and also controls the grain size of the steel. Simanal, of the Ohio Ferro Alloys Corp., is a Deoxidizing alloy containing 20% each of silicon, aluminum, and manganese. Alsifer, of the Vanadium Corp. of America, contains 40% of silicon, 20 aluminum, and 40 iron. The aluminum and silicon are in the form of an aluminum silicate which

forms a slag that is eliminated during the teeming of the steel. Alsimin is a Swiss ferrosilicon aluminum with 50% aluminum. Silicon aluminum is a master alloy for adding silicon to aluminum alloys, and it does not contain iron. A 50-50 silicon aluminum, of Alloys & Products, Inc., has a melting point of 1920°F., but is soluble in aluminum at 1275°F. It comes in pyramid waffle form for breaking into small lumps.

**Ferrotitanium.** A master alloy of titanium with iron used as a purifying agent for irons and steel owing to the great affinity of titanium for oxygen and nitrogen at temperatures above 800°C. The value of the alloy is as a cleanser, and little or no titanium remains in the steel unless the percentage is gaged to leave a residue. The Ferro-carbon-titanium is made from ilmenite in the electric furnace, and the carbon-free alloy is made by reduction of the ore with aluminum. Alloys containing more than 18% of titanium are used only in steel because of their high melting point. Federal specification grades are Grade A with 25 to 30% of titanium, 3 silicon, 6 aluminum, and 0.25 carbon, and Grade B with 15 to 18% of titanium, 3 silicon, 1.5 aluminum, and 7.5 carbon. Ferrotitanium comes in lumps, crushed, or screened. Tam alloy No. 78, of the Titanium Alloy Mfg. Co., contains 15 to 18% of titanium, 7 to 8 carbon, with low silicon and aluminum. It is used in cast iron and steels. Tam alloy No. 35 has 18 to 21% of titanium, and only 3.5 to 4.5 carbon. Its melting point is 2750°F. Ferrotitaniums with 18 to 22% of titanium are used for making fine-grained forging steels. Carbotam, of this company, contains 16 to 17% of titanium, 2.5 to 3 silicon, 6.5 to 7.5 carbon, 1.5 to 2 boron, and less than 1 carbon. It is used for cast steels to contain boron for high hardness. Manganese titanium is used as a deoxidizer for high-grade steels and for nonferrous alloys. A common grade contains 38% of manganese, 29 titanium, 8 aluminum, 3 silicon, 22 iron, and no carbon. Nickel titanium is used for hard nonferrous alloys. The low-iron grade contains 15% of titanium, 5 aluminum, 4 silicon, 1 iron, and 75 nickel.

**Ferrous sulphate.** Also called Iron sulphate and Green vitriol. It is a green crystalline material of the composition $FeSO_4 \cdot 7H_2O$. It occurs naturally as the mineral Melanterite. It is produced by

the action of dilute acid on iron and is a by-product of the galvanizing and tinning industries, recovered from the pickling baths. The specific gravity is 1.898, melting point 64°C., and it is soluble in water. On exposure to the air it becomes yellowish because of the formation of basic iron sulphate, and on heating to 140°C. becomes a white powder, $FeSO_4 \cdot H_2O$, which also occurs as the mineral Szomolnokite. Ferrous sulphate, under the name of Copperas, is an important salt in the ink industry to give color permanence to the inks. It is also employed in water purification, as a disinfectant, in polishing rouge, as a mordant in dyeing wool, and in the production of pigments. Prussian blue, or Chinese blue, is Ferric ferrocyanide, $Fe_4[Fe(CN)_6]_3$, a blue amorphous powder used as a pigment. It is made by combining iron chloride and potassium ferrocyanide. Celestial blue is the light-blue pigment made by extending Prussian blue with barytes. Ferric sulphate is a grayish amorphous powder of the composition $Fe_2(SO_4)_3 \cdot 9H_2O$, or $Fe_2(SO_4)_3$. The specific gravity of the hydrous is 2.1, and of the anhydrous 3.097. It is very soluble in water, and is used as a pigment, as a mordant in dyeing, for etching aluminum and steel, and as a disinfectant. Ferrisul, of the Monsanto Chemical Co., is anhydrous ferric sulphate used for speeding the action of metal pickling baths and for descaling boilers. In etching steel, the action of anhydrous ferric sulphate is 30 times more rapid than sulphuric acid.

**Fertilizers.** Materials used to add to the soil to supply plant food either directly or by chemical reaction with the soil. The preparation of fertilizers is now one of the major industries, and the commercial fertilizers include nitrates, phosphates, potash salts, calcium salts, and mixtures. They may also include the materials which regulate the acidity of the soil for better plant production, such as lime, and the materials which act as soil conditioners, as methyl cellulose. The value of fertile soils was understood in most ancient times, and natural fertilizers were used, including the use of sulphur for the vineyards of the Romans. But fertilizers were not understood or used in western Europe, and the lands were strikingly depleted before the introduction of their use from the Indians of America. The Algonquins employed fish as fertilizer, and the Incas of Peru and Bolivia used vast quantities of guano. Guano

(Quichua word Huano, guttural h), is the excrement of fish-eating sea birds deposited in great amounts on the dry rocky islands of the Peruvian Coast. It contains 12 to 16% of nitrogen. It was formerly imported into the United States, but is now replaced by nitrates. Much barnyard manure is employed as fertilizer, but does not enter the commercial mixed fertilizers except the dried and ground sheep manures. Much local fertilization is also done by the planting and plowing under of legumes that bring nitrogen from the air and also serve as soil conditioners. Chilean nitrate, phosphate rock, and potash are the chief natural minerals used as fertilizers. Nitrogen is needed in most soils, and phosphorus is a necessary ingredient in soils. Large quantities of muriate of potash are used in fertilizers to supply $K_2O$, while vast quantities of hydrated lime are employed to supply MgO and to reduce acidity of some soils. Potassium, calcium, and sodium are also supplied in combination forms especially with ammonia to yield nitrogen. Ammonium sulphate yields both nitrogen and sulphur. Calcium cyanamid is employed as a fertilizer to yield nitrogen and calcium. Crude urea is now also used as a fertilizer, and has the nitrogen in the same form as in the natural guanos and manures. Uramon, of E. I. du-Pont de Nemours & Co., Inc., is a urea fertilizer in the form of a dark-brown powder easily soluble in water and yielding 42% of nitrogen, equivalent to 51% ammonia. It also contains calcium and phosphorus. Superphosphates, made by acid treatment of phosphate rock, are used in large quantities in fertilizer mixtures. Fish meal, castor pomace, cottonseed meal, soybean meal, copra cake, and other residues from oil pressing are used as commercial fertilizers. Tankage from the meat-packing plants is also an important fertilizer material. Whale guano, from South Georgia and Newfoundland, is a mixture of whale-meat meal and bone meal. Ground bone meal is used in fertilizers to give phosphorus, calcium, and other mineral salts to the soil. Some plants require boron, and borax is applied as a fertilizer to some soils. Many vegetable products obtain their coloring and some characteristic properties from small quantities of copper, manganese, rubidium, iodine, and other elements that do not occur in all soils. The fertilizer industry thus depends upon scientific research into soils and botanical growth.

**Fiberboard.** Heavy sheet material of fibers matted and pressed or rolled to form a strong board, used for making trunks and boxes and also for partitions in building construction. The fibers may be of wood or cellulose, jute, flax, straw, or hemp. Board made of asbestos fibers is not classed as fiberboard. Originally, fiberboard contained no bonding material other than the natural bonds in the materials, but there is now no sharp dividing line between the boards made by different processes and with various resin binders. Fibrofelt, of the Union Fiber Co., Inc., is a pressed flexible fiberboard of matted flax- and rye-straw fibers made in thicknesses from $\frac{5}{16}$ to 1 in. Masonite, of the Masonite Corp., is produced from by-product wood chips reduced to the cellulose fibers by high steam pressure. The long fibers and the lignin adhesive of the wood are retained, and no chemicals are used in pressing the pulp into boards. Masonite quarter board, for paneling, is made in boards $\frac{1}{4}$ in. thick. Presdwood is a grainless grade made by compressing under hydraulic pressure, and is dense and strong. These types belong to the class known as Hardboard, in the processing of which the carbohydrates and soluble constituents of the original wood are dissolved out and the relative proportion of lignin increased, resulting in a grainless, hard, stiff, and water-resistant board free from shrinkage. The density of most hardboards is greater than 1.0, and the modulus of rupture is from 5,000 to 15,000 lb. per sq. in. The lignin acts as a binder for the fibers, but some hardboards are made harder and more resistant by adding a percentage of an insoluble resin. The process is not limited to the making of boards. Wood molding powder is made by the same method of treating wood fibers with steam pressure and hydrolyzing the hemicellulose, leaving the lignin free as a binder. Hardwood, of the Elmendorf Corp., is a hard board made from hardwood waste compressed into sheets under heat and hydraulic pressure. The surface is hard with a high polish. These hard boards are used for many construction parts, but the lighter and less dense fiberboards are preferred for insulation and some construction uses. Kimflex board, of the Kimberly-Clark Mills, is a lightweight, pliable fiberboard used for shoe counters. It is made from balsawood pulp using rubber latex as a binder. Electrite, of the West Virginia Paper & Pulp Co., is a wood fiberboard of high strength and high dielectric strength for electrical panels. Temlok,

of the Armstrong Cork Products Co., is a fiberboard made from pine wood fibers impregnated with resin and compressed into building boards and tiles. Temwood, of the same company, is a lightweight board of wood fibers hydraulically pressed into grainless boards in hard and semihard grades. Temboard is a decorative wood fiberboard used for interior paneling. Disfico board, of the Diamond State Fibre Co., for making trunks and boxes, is made of pressed jute and hemp fibers. It comes in sheets in plain colors. Thermax, of the Northwest Magnesite Co., is an insulating board made of shredded wood fibers with a fire-resistant cement. Heatherwood is a British hardboard made by pulping heather and pressing into boards with a synthetic binder.

**Filter sand.** A natural sand employed for filtration, especially of water. Much of the specially prepared filter sand comes from New Jersey, Illinois, and Minnesota, and is from ocean beaches, lake deposits, and sand banks. The specifications for filter sand require that it must be of fairly uniform size, free from clay and organic matter, and chemically pure, containing not more than 2% of combined carbonates. The grain sizes are specified in millimeters, the most common being from 0.35 to 0.65 mm. Very fine sand clogs the filter. Greensand, produced from extensive beds in New Jersey, is used as a water softener. It is a type of marl classed as Zeolite, and consists largely of Glauconite containing about 75% of silica, with iron oxide, potash, and alumina. In addition to filtering, the greensand softener extracts the calcium and magnesium from the water. It is regenerated for further use by passing common salt brine through it.

**Fireclay.** Clays that will withstand high temperatures without melting or cracking, used for lining furnaces, flues, and for making firebricks and lining tiles. Common fireclays are usually silicate of alumina. Theoretically these clays contain 45.87% of alumina and 54.13 of silica, but in general they contain considerable iron oxide, lime, and other impurities. The nearer to the theoretical proportions, the better is the clay as a refractory. Clays with an excess of silica are also found. The German Klingenberg clay used for crucibles has about 60% of silica. The term Refractory clay embraces nearly all clays having a melting point above 1600°C. But

the clays alone are likely to shrink and crack, and they may be mixed with other clays, sand, or graphite. Firebricks are made in various shapes and sizes and are usually white or buff in color. Common firebricks from natural clays will melt at from 2800 to 3100°F. Some other materials used in making firebricks are chromite, bauxite, diatomaceous earth, and magnesite, or the artificial materials silicon carbide and aluminum oxide, but bricks made of these are designated by the name of the material or by trade names. Chromite bricks will withstand temperatures up to 3700°F., and Magnesia bricks up to 3900°F., while silicon carbide bricks without a clay binder will withstand heats to 4000°F. Firecrete, of Johns-Manville, is a lightweight refractory consisting of calcined high-alumina clay used for furnace doors and floors. It will withstand temperatures to 2400°F. in continuous operation. Insuline, of the Quigley Co., is a calcined fireclay in small cellular particles. In insulating brick it is called Insulbrix, and as a lightweight concrete it is known as Insulcrete.

**Flax.** A fiber obtained from the flax, or linseed, plant, *Linum usitatissimum,* used for making the fabrics known as linens, and for thread, twine, and cordage. Flax consists of the bast fibers, or those in the layer underneath the outer bark, which are of fine texture. The plants are pulled up by the roots, retted, or partly decayed, scraped, and the fibers combed out and bleached in the sun. For the best European flax the preparation is entirely by hand. The important centers of flax preparation are in Russia, central Europe, Italy, Ireland, France, and Egypt. Some flax is also grown in the United States. The plants that are grown for the oil seed, linseed, yield a poor fiber and are not employed to produce flax. Flax fiber is valued because of its strength and durability. It is finer than cotton, very soft, and the fibers are usually about 20 in. long.

**Flint.** An opaque variety of chalcedony or nearly pure amorphous quartz which shows no visible structure. It is deposited from colloidal solution and is an intimate mixture of quartz and opal. It contains 96 to 99% of silica, and may be colored to dull colors by impurities. Thin plates are translucent. When heated, it becomes white. Flint is finely crystalline. It breaks or chips with a convex, undulating surface. The hardness is 7, and specific gravity

is 2.6. It was the prehistoric utility material for tools, and was later used with steel to give sparks on percussion. Gun flints are still made from a type of flint mined at Brandon, England, for special uses. Lydian stone, or Touchstone, was a cherty flint used for testing gold. Flint is now chiefly used as an abrasive, and in pottery and glass manufacture. Flint paper for abrasive use contains crushed flint in grades from 20 to 240 mesh usually coated on one side of 70- or 80-lb. paper. Flint is also used in the form of grinding pebbles. Potters' flint, used for mixing in ceramics to reduce the firing and drying shrinkage and to prevent deformation, is ground flint of about 140 mesh made from white French pebbles.

**Fluorspar.** Also called Fluorite. A crystalline or massive granular mineral of the composition $CaF_2$, used as a flux in the making of steel, for making hydrofluoric acid, in opalescent glass, in ceramic enamels, for making artificial cryolite, and as a binder for vitreous abrasive wheels. The specific gravity is 3.18, hardness 4, and the colors light green, yellow, rose, or brown. When ground, the color is white. The melting point is 1650°F. Germany is normally the largest producer of fluorspar. In the United States it is mined in Illinois, Kentucky, Nevada, and New Mexico. It is a better flux than limestone, making a fluid slag, and freeing the iron of sulphur and phosphorus. From 5 to 8 lb. is used per ton of steel. The usual grades for fluxing are smaller than ½ in. and contain 85% min. $CaF_2$, with 5% max. $SiO_2$. High-grade fluorspar for ceramic frit has 95 to 98% $CaF_2$, 3% max. $SiO_2$, 0.12% max. $Fe_2O_3$, and is known as No. 1 ground. Acid spar is a grade used in making hydrofluoric acid. It contains over 98% $CaF_2$ and 1% max. $SiO_2$, and is produced by flotation. Optical fluorspar is the highest grade but is not common. Pure Calcium fluoride, $Ca_2F_6$, is a colorless crystalline powder used for etching glass and in enamels. Calcium fluorite has silicon in the molecule, $CaSiF_6 \cdot 2H_2O$, and is a crystalline powder used for enamels.

**Flux.** A substance added to a refractory material to aid in its fusion, such as lime for melting iron. A secondary action of a flux, which may also be a primary reason for its use, is as a reducing agent to deoxidize or decompose impurities and remove them as slags or gases. In soldering, a flux may serve to remove oxides from the

surface to be soldered. Materials such as charcoal or impure boron carbide used to cover baths of molten metals may also be considered as fluxes. Fluxes for melting iron are lime, limestone, dolomite, or fluorspar. For brass, bronze, or soft white metals, resins may be used, and the covering flux may be charcoal, salt, or borax. Cryolite is a flux for aluminum and for glass. Fluxing alloys for brasses and bronzes are phosphor tin, phosphor copper, or silicon copper. They deoxidize the metals at the same time that alloying elements are added. For tinning steel, palm oil is used as a flux. For ordinary soldering, zinc chloride is a common flux. Tallow, rosin, or olive oil may also be used for soldering. Acetamide is used for soldering painted metals. For silver solders, borax is a common flux. For soldering stainless steel, the borax is mixed with boric acid, or pastes are made with zinc chloride and borax. Borax may also be used as a welding flux. White flux is a mixture of sodium nitrate and nitrite, and is a strong oxidizer used for welding. Welding fluxes for high-temperature welding usually contain manganese for deoxidation and a mineral flux such as fluorspar or cryolite. They are often coated on the welding rod. Manganox, of the Foote Mineral Co., is a prepared hausmanite with a manganese metal content of 64%, used for coating welding rods. It is more stable than the ferromanganese often used. Murex, of the Metal Thermit Corp., is a welding rod coated with a mineral flux and covered with asbestos. The flux and the asbestos form a slag that falls off the weld. Lapix, of E. F. Houghton & Co., is a mixture of carbon and clay used to cover the top of molten steel after pouring in ingot molds. It is exothermic and helps to maintain a longer liquid period so that the deoxidized materials rise to the top.

**Fluxing stone.** A common term for the limestone or dolomite used in the melting of iron. About 900 lb. of limestone are employed for every long ton of pig iron produced in the blast furnace. If iron ore were reduced without a basic flux, the silica and alumina would unite with the iron oxides to form double silicates of iron and alumina, and there would be a heavy loss of iron. With the addition of limestone, the silica and alumina, having strong affinity for the lime and magnesia, form compounds that contain very little iron. These compounds form a liquid slag which floats on the sur-

face of the molten iron and can be removed readily. The flux also removes sulphur and phosphorus from the iron. Some iron ores contain sufficient lime carbonate to be almost self-fluxing. Lime is more effective as a flux than limestone, but is more expensive. The action of the blast furnace is first to convert the limestone to lime. Upon being heated to 1525°F. limestone breaks down to lime, which then begins fusion with silica to form the slag at about 2600°F. Limestones for use as flux must be fairly pure, or additional undesirable compounds will be formed.

**Foil.** Very thin sheet metal used chiefly for wrapping and insulating but also for electrical applications. The word comes from the Latin *folium,* meaning leaf, and gold foil is called gold leaf. Tin foil is higher in cost than some other foils, but is much used for wrapping food products because it is not poisonous. Ordinary tin foil is made in thicknesses from 0.006 mm. (0.00024 in.) to 0.200 mm. (0.00787 in.), the former having 16,037 sq. in. per lb., and the latter 432 sq. in. per lb. Tin foil for radio condensers has 14,500 sq. in. per lb. An English modified tin foil, which has greater strength and is nontoxic in contact with foods, contains 8.5% of zinc, 0.15 nickel, and the balance tin. It can be rolled to thinner sheets. Lead foil, used for wrapping tobacco and other nonedible products, is rolled to the same thicknesses as tin foil, but because of its higher specific gravity has less coverage. The thinnest has 10,358 sq. in. per lb., and the thickest 279 sq. in. per lb. Lead foil has a dull luster, but it may be modified with some tin and other elements to give it a brighter color. Aluminum foil has a high luster, though not as high as pure tin foil. It is also produced with a satin finish made by pack-rolling. Aluminum foil comes in 34 thicknesses, from 0.006 mm., having 43,300 sq. in. per lb., to 0.200 mm., having 1,169 sq. in. per lb. It can be made as thin as 60,000 sq. in. per lb. It is obtainable in bright colors produced by dyeing or lacquering, and in printed or embossed designs. As it reflects heat waves, it is used also as an insulator in sheet form applied to building boards or in crumpled form in walls. The name Alfol was applied to crumpled aluminum foil for this purpose by the British National Physical Laboratory. Aluminum foil is an excellent radio reflector, and if strips are cut one-half the radar wave

length they throw back a powerful echo. Thin foil is cut into strips in various lengths up to several inches to be thrown from airplanes and scattered in the wind. A bundle of 6,000 strips weighs 6 oz. Gold leaf is not normally classed as foil, but is used for architectural coverings and for hot-embossed printing on leather. It is made by hammering in books, and can be made as thin as 0.0000033 in., a gram of gold covering 5,184 sq. in.

**Formaldehyde.** Also called Methylene oxide. A colorless, poisonous gas of the composition HCHO, boiling at −21°C. It is very soluble in water, and is marketed as a 40% solution by volume, 37% by weight, under the name of Formalin. The commercial formalin is a clear colorless liquid with a specific gravity of 1.075 to 1.081. When shipped by tank cars it contains 11 to 12% of methanol, or 6 to 7% when shipped in drums, as a stabilizer to prevent precipitation of polymerized formaldehyde. The material is obtained by oxidation from methyl alcohol. It is used in making synthetic resins, as a reducing agent in the silvering of mirrors, and as a disinfectant. Trioxane, of E. I. duPont de Nemours & Co., Inc., is an anhydrous formaldehyde, and is a white crystalline powder with a melting point of about 64°C. Glyoxal, of the Carbide & Carbon Chemicals Corp., is Dialdehyde, CHO·CHO, marketed as a water solution as a substitute for formaldehyde for resin manufacture and as a hardening and preserving agent. It is faster in action and has less volatility and odor than formaldehyde. Paraformaldehyde, $(CH_2O)_3$, also called Paraform, is a white amorphous powder used instead of formaldehyde where a water solution is not desirable. It is used as a catalyst and hardener for the resorcinol and some other synthetic resins, and as an antiseptic. Formol is a trade name for a solution of formaldehyde in methanol and water, used as an antiseptic.

**Formic acid.** Also called Methanoic acid and Hydrogen carboxylic acid. Formic acid is the simplest of the organic acids, with the composition HCOOH, and was originally distilled from red ants, receiving its name from the Latin name for ants. It is a pungent colorless liquid of specific gravity 1.22, boiling point 101°C., and freezing point 8.4°C., soluble in water and in alcohols. It is an easily oxidized reducing agent, and small amounts will blister

the skin and give the stinging sensation of ant or bee bites. Formic acid is produced by reacting sodium formate and sulphuric acid. It is used as a coagulant for rubber, as a disinfecting and deliming agent for hides, as a textile mordant, food preservative, in electroplating, as a germicide, and as a fermentation assistant in brewing.

**Fuel briquettes.** Various-shaped briquettes made by compressing powdered coal, usually with an asphalt or starch binder, but sometimes as Smokeless fuel without a binder. They are sometimes also made waterproof by coating with pitch or coal tar. They have the great advantage over raw coal that they do not take up large amounts of water like coal and thus have uniformity of firing. Fuel briquettes are made from anthracite screenings usually mixed with bituminous screenings as the bituminous coals require no binders. The usual forms of the briquettes are pillow-shaped, cubic, cylindrical, ovoid, and rectangular, and the usual size is not over 5 oz. The term Packaged fuel is used for cube-shaped briquettes wrapped in paper packages, used for hand firing in domestic furnaces. Koal Pak, of the Johnson Coal Cubing Co., consists of coal cubes wrapped eight to a package. The Coal briquettes of the Blaw-Knox Co. are made with anthracite dust and a small amount of Pocahontas-type bituminous coal with an asphalt binder. The cakes are 3 by 3 by 3 in. wrapped in kraft paper.

**Fuel oil.** Distillates of petroleum or shale oil used in diesel engines and in oil-burning furnaces. True fuel oils are the heavier hydrocarbons in kerosene, but the light or distillate oils are used largely for heating, and the heavy or residual oils for industrial fuels. In some cases only the light oils, naphtha and gasoline, are distilled from petroleum and the residue is used for fuel oil, but this is wasteful of the lighter oils. Fuel oil of low specific gravity requires preheating to obtain complete atomization. At 10°Bé. the minimum temperature to atomize fuel oil is 300°F., but at 40°Bé. a temperature of only 40°F. is required. Fuel oils used in oil burners are 28 to 32°Bé., and have a B.t.u. content of 142,000 per gal., completely atomizing at 90°F. Gas oil, which receives its name from its use to enrich fuel gas and increase the luminance of the flame, is also used as a fuel in oil engines. It is the fraction of petroleum distilling off after kerosene, or above about 300°C. It is

brownish in color and has a specific gravity of about 0.850. Ignition temperatures of crude oils vary from 715 to 800°F. in air at atmospheric pressure. Bunker C oil, for diesel engines, is a viscous, black fuel oil of specific gravity 1.052 to 0.9659 with a flash point above 150°F. The National Bureau of Standards lists six grades of fuel oils with flash points from 100 to 200°F.

**Fuller's earth.** A soft, opaque clay with a greasy feel used as a filtering medium in clarifying and bleaching fats, greases, and mineral and vegetable oils. It absorbs the basic colors in the organic compounds. It is also used as a pigment extender and a substitute for talcum powder. It was formerly much used in the textile industry as a fuller for woolen fabrics, cleansing them by absorbing oil and grease. It is a hydrated compound of silica and alumina. It may contain 75% of silica, 10 to 19 alumina, 1 to 4 lime, 2 to 4 magnesia, and sometimes ferric oxide. The usual color is greenish white to greenish brown. The rose-colored fuller's earth from Florida is a variety of Montmorillonite, $(MgCa)O \cdot Al_2O_3 \cdot 4SiO_2$. The Florida fuller's earth marketed by the Floridin Co. under the name of Floridin is a grayish-white material graded by sizes from B, which is 16 to 30 mesh, to XXX, which will pass 90% through a 200-mesh screen. Florex is this material processed by extrusion to increase the absorption capacity. A typical analysis gives 58.1% of silica, 15.43 alumina, 4.95 iron oxide, 2.44 magnesia, with small amounts of CaO, $Na_2O$, and $K_2O$. The specific gravity is 2.3. Florigel is the hydrated material which forms viscous suspensions in water, and is used to replace bentonite, as a filler for soaps, and for clarifying liquids. Diluex is finely powdered Florida fuller's earth used as a diluent or carrier for insecticides. Activated clay, or Bleaching clay, for bleaching oils, may be acid-treated fuller's earth, or it may be bauxite or kaolin. Florite, of the Floridin Co., is activated bauxite. It is a red, granular, porous material of 20 to 60 mesh, used for decolorizing and clarifying oils and waxes.

**Fulminates.** Materials used in percussion caps and detonators because of their ready explosiveness with a slight blow. They may be called Cap powder in cartridge caps and Detonators when used for detonating or exploding artillery shells. Mercury fulminate, $Hg(CNO)_2$, a gray or brown sandy powder, is the basis for many

detonating compositions. It is made by the action of nitric acid on mercury and alcohol, and is ten times more sensitive than picric acid. It may be mixed with potassium chlorite and antimony sulphide for percussion caps. Lead azide, $PbN_6$, is sometimes substituted for mercury fulminate. It is much more sensitive, and in large crystals is subject to spontaneous explosion. It is precipitated to suppress crystal formation and to form a free-flowing powder less sensitive to handling. Lead styphnate, used as a detonator, is made by the sulphonation and nitration of resorcinol to form Styphnic acid, or Trinitroresorcinol, $(NO_2)_3C_6H(OH)_2$. This powder is treated with magnesia and with a lead nitrate solution to form the lead styphnate powder. Azoimide, or Iminazoic acid, $HN \cdot N_2$, is an extremely explosive colorless gas liquefying at 37°C. which can be used in the form of its salts. Silver azoimide, $AgN \cdot N_2$, is highly explosive, and Barium azoimide, $BaN_6$, explodes with a green flash.

**Fumigant.** A liquid, powder, or gas used in fumigating warehouses or ships to kill insects, worms, and burrowing animals. For general use a fumigant should not be injurious to grains or stored foodstuffs. Fumigants are distinct from Repellents which are used for driving out insects and do not kill. However some repellents may contain naphthalene, rotenone, or other materials having toxic properties, and are insecticides rather than fumigants. Methyl bromide, or Bromomethane, $CH_3Br$, a gas with a liquefying point at 4.6°C., is an effective fumigant not injurious to grains. Dowfume BR10, of the Dow Chemical Co., is methyl bromide with chlorinated hydrocarbons, used in pressure cylinders for fumigating warehouses. Methyl bromide is also used for fumigating clothing warehouses and does not shrink or wrinkle woolen fabrics. Carboxide, of the Carbide & Carbon Chemicals Corp., is a mixture of carbon dioxide and ethylene oxide used as a fumigant. It does not injure grains or foodstuffs.

**Furfural.** Also known as Furfuraldehyde, Furol, and Pyromucic aldehyde. A yellowish liquid with an aromatic odor, having a composition $C_4H_3O \cdot CHO$, specific gravity 1.161, boiling point 161.7°C., and flash point 132°F. It is soluble in water and in alcohol but not in petroleum hydrocarbons. On exposure it darkens

and gradually decomposes. Furfural occurs in different forms in various plant life and is obtained from cornstalks, corncobs, straw, oat husks, and peanut shells by treating with mineral acids and distilling. In Iowa large quantities of Corncobs are processed to produce furfural and a by-product Cob meal which is used in feeds and fillers. Furfural is used for making synthetic plastics, as a plasticizer in other synthetic resins, as a preservative, in weed killers, and as a selective solvent especially for removing aromatic and sulphur compounds from lubricating oils. It is also used for the making of butadiene and other chemicals.

Various derivatives of furfural are also used, and the furfural derivatives, known collectively as Furans, have a widening field of use since they are readily obtainable from wastes and easily grown raw materials. Furfuryl alcohol, $C_4H_3O \cdot CH_2OH$, a yellow liquid with a brinelike odor, boiling at 176°C., and flash point at 167°F., is used as a solvent for nitrocellulose and for dyes. Furan, or Tetrol, $C_4H_4O$, used for plastics manufacture, is a colorless liquid boiling at 32°C. Methyl furan, or Sylvan, $C_4H_3O \cdot CH_3$, is a colorless liquid boiling at 62°C. Furfural acetone, $C_4H_3O \cdot CH:CHCOCH_3$, is a reddish-brown liquid boiling at 229°C. Furfural, when treated with aniline at 150°C., forms an insoluble black Furfural-aniline resin used in resistant protective coatings and enamels. Furfural-acetone resin, or Furfuracetone, is a transparent elastic resin made by the reaction of furfural and acetone in the presence of an alkali. Furfural also polymerizes with phenol to form Furfural-phenol resins that are self-curing. They have high heat, chemical, and electrical resistance, and have excellent adhesion to metals and other materials, making them adaptable for chemical and electrical coatings. The resins have high gloss, but a very dark color. The Tygon resins of the U.S. Stoneware Co. are furfural resins used for brush application as protective coatings for such purposes as chemical tank linings. They cure by self-polymerization, will withstand temperatures to 350°F., and are resistant to acids, alkalies, alcohols, and hydrocarbons.

**Fusible alloys.** Alloys having melting points below the boiling point of water, 100°C. They are used as binding plugs in automatic sprinkler systems, for low-temperature boiler plugs, for

soldering pewter and other soft metals, for tube bending, and for casting patterns and many ornamental articles and toys. They consist generally of mixtures of lead, tin, cadmium, and bismuth. The general rule is that an alloy of two metals has a melting point lower than that of either metal alone. By adding still other low-fusing metals to the alloy a metal can be obtained with almost any desired low melting point. The original Newton's alloy contained 50% of bismuth, 31.25 lead, and 18.75 tin. Newton's metal, used as a solder for pewter, contained 50% of bismuth, 25 cadmium, and 25 tin. It melts at 203°F., and will dissolve in boiling water. Lipowitz alloy, another early metal, contained 3 parts of cadmium, 4 tin, 15 bismuth, and 8 lead. It melts at 158°F., is very ductile, and takes a fine polish. It was employed for casting fine ornaments. A small amount of indium increases the brilliance and lowers the melting point. Wood's alloy, or Wood's fusible metal, was patented in 1860 and was the first metal used for automatic sprinkler plugs. It contained 7 to 8 parts of bismuth, 4 lead, 2 tin, and 1 to 2 parts of cadmium. It melts at 160°F., and this point was adopted as the operating temperature of sprinkler plugs in the United States; in England it is 155°F. An early alloy for tube bending contained 50% of bismuth, 26.7 lead, 13.3 tin, and 10 cadmium. It melts at 158°F., and can be easily removed from the tube after bending by dipping in boiling water.

Cerrobend, or Bendalloy, of the Cerro de Pasco Copper Co., is a fusible alloy for tube bending which melts at 160°F. Cerrosafe, or Safalloy, is a fusible metal used for toy-casting sets as the molten metal will not burn wood or cause fires. Alloys with very low melting points are sometimes used for this reason for pattern and toy casting. A fusible alloy with a melting point at 60°C. contains 26.5% of lead, 13.5 tin, 50 bismuth, and 10 cadmium. These alloys expand on cooling and make accurate impressions of the molds. Boiler-plug alloys have been made under a wide variety of trade names with melting points usually ranging from 212 to 342°F. D'Arcet's alloy, melting at 200°F., contained 50% of bismuth, 25 tin, and 25 lead. Lichtenberg's alloy, melting at 198°F., contained 50% of bismuth, 30 lead, and 20 tin. Guthrie's alloy had 47.4% of bismuth, 19.4 lead, 20 tin, and 13.2 cadmium. Rose's alloy contained 35% of lead, 35 bismuth, and 30 tin. Homberg's

alloy, melting at 251°F., contained 3 parts of lead, 3 tin, and 3 bismuth. Malotte's metal, melting at 203°F., had 46% bismuth, 20 lead, and 34 tin. The variation of these different alloys was largely because of the relative cost of the different alloying metals at various times. Fusible metals have also been used in strip form to test the temperature of metals, especially steels for heat-treating. The Temperite alloys of the Cornish Wire Co. were made for this purpose with definite melting points between 300 and 625°F. in steps of 25 deg.

**Fustic.** Known also as Cuba wood. The wood of the tree *Chlorophora tinctoria* of tropical America, used for cabinetmaking and as a dyewood. It has a yellow color, is very hard, and has a fine, open grain. The weight is about 41 lb. per cu. ft. The liquid extract of the wood produces the yellow dyestuff Morin, $C_{15}H_{11}O_7$, and the red dye Morindone, $C_{15}H_{11}O_5$. Fustic extracts are mordant dyes and give colors from yellow to olive with various mordants. Morin is used also as an indicator to detect aluminum, with which it develops a green fluorescence. Young fustic, or Hungarian yellow wood, is a yellow dyewood from the *Rhus cotinus*. Osage orange, called Bois d'arc, is the bright orange wood of the bush *Maclura pomifera* growing in the swamplands of Texas and Oklahoma. It has a high tannin content and is used in the textile and leather industries for orange-yellow and gold colors and to blend with greens. As a tanning agent it is blended with quebracho and chestnut extracts.

**Gallium.** An elementary metal, symbol Ga. It is soft and easily cut, and is soluble in acids. Its melting point is 30.1°C., softening when held in the hand. It has a wide liquid range, boiling at 1350°C., and is valued for thermometers for temperatures between 500 and 1000°C. It can also be substituted for mercury in vapor lamps. It is also used in dental alloys in place of mercury, and as a backing for mirrors. Gallium-tin alloy, containing 88% of gallium and 12 tin, is employed where a liquid metal is needed at temperatures below 15°C. Gallium forms many salts and, like aluminum, will form an alum. Below its melting point gallium is a fairly hard, grayish-white metal. The metal is found in small amounts associated with zinc ores and is recovered from zinc smelter-flue

dust. In Germany it is produced as a by-product of copper smelting. It is also a minor constituent in the mineral sphalerite to the extent of 0.01 to 0.1%, and it also occurs in almost all aluminum ores in a ratio of 50 to 100 grams of gallium per ton of aluminum. Gallium was originally called Austrium.

**Galls.** Tanning materials obtained from the Nutgalls, or Gall nuts, from the oaks of Europe and the Near East and from the sumac of China and Japan. Nutgalls are plant excrescences caused by the punctures of insects. They contain 50 to 70% of tannins, and are the richest in tannin of all the leather-tanning materials. The tannin is also valued for inkmaking and in medicine for treating burns. Green galls, or Aleppo galls, are obtained from the twigs of the Aleppo oak, *Quercus infectoria,* a shrub of the Near East. Those of blue color are the best quality, with green second, and the white of inferior grade. Chinese galls, from species of *Rhus,* are in the form of irregular roundish nuts which enclose the insect. They show no vegetable structure but have a dense resinous fracture and are very high in tannin. Gall, or Beef gall, is an entirely unrelated material. It is a bitter fluid from the livers of cattle, used in making soaps for washing dyed fabrics, and for fixing dyes in fabrics, and in water-color paints.

**Galvanized iron.** Iron or steel sheets coated with zinc and used for roofing, sheathing, culverts, and for making such articles as pails and tanks that require to be rust-resistant without painting. The most common sheets are of low-carbon steel, but the copper-bearing iron and steels are also used to give added corrosion resistance. The common dipped sheets are annealed, pickled, cold-rolled to increase the polish, and then dipped in molten zinc. They have a characteristic spangle which in thick coats is likely to peel and flake off under distortion. Sheets are graded by perfection of coating, gage, and size, as primes, seconds, and gray-coated. Primes are the perfect sheets. Galvanized sheets are either plain or corrugated. They usually come in lengths of 6, 7, and 8 ft., and widths of 24, 26, 28, 32, 34, and 36 in. The thickness is by gage sizes, usually from No. 14 to No. 30. The No. 14 sheet carries a 2-oz. zinc coating. Zinc alloy steel, of the Inland Steel Co., is zinc-coated steel sheet with the coating fused in and alloyed with the steel so that there is

no spangle. The sheet can be spun or drawn without cracking the coating. Gal-Van-Alloy is the trade name of this company for the galvanized sheet. Zinc-coated steel is now made extensively by continuous electroplating. Weirzin, of the Weirton Steel Co., is electroplated sheet steel. Galvanized wire is steel wire coated with zinc for rust resistance either by dipping in molten zinc or by continuous electroplating, and is marketed plain, twisted, or barbed. Barbed wire has double-pointed wire barbs held in the twisted wire. Bethanized steel, of the Bethlehem Steel Co., is wire electrogalvanized and then passed through a die which polishes and hardens the coating.

**Gambier.** Also spelled Gambir. A tanning and dyeing material extracted from the leaves and twigs of the shrubs *Uncaria gambir, U. Dacyoneuro,* and other species of India, Malaysia, and the East Indies. It is similar to catechu, and is also called White cutch, Yellow cutch, Cube cutch, and Tara japonica. The cubes of extract are brittle, have a dull-gray color, and a bitter astringent taste. The material contains Catechin, $C_{15}H_{14}O_6$, a yellow astringent dye also found in catechu and kino resin. Catechin is soluble in hot water and in alkaline solutions and is neutral with no acid properties. Gambier also contain Catechutannic acid, a reddish tannin. The liquid extract contains 25% of tannin, and the cube gambier has 30 to 40%. Gambier is used in tanning leather and in dyeing to give yellow to brown colors. It produces the Cutch brown on cotton fabrics. It has excellent fastness as a dye and is used in shading logwood and fustic, or as a mordant for fixing basic dyes. In tanning it gives a soft porous leather, has less astringency than other tannins, and is employed for tanning coat leathers and for blending with other tannins. Gambier is also used in boiler compounds and in pharmaceuticals. Plantation gambier, or Singapore cube, is refined clear gambier in small square cubes, while ordinary gambier may have dark patches or a black color with a fetid odor. Gambier bulat is round gambier, and Gambier papu is in long black sticks, both used locally for chewing.

**Garnet.** A large group of hard minerals used chiefly for abrasive paper and cloth, but also for bearing pivots in watches, and the finer

specimens for gem stones. Garnets are trisilicates of alumina, magnesia, calcia, ferrous oxide, manganese oxide, or chromic oxide. The general formula is $3R''O \cdot R'''_2O_3 \cdot 3SiO_2$, in which R'' is Ca, Mg, Fe'', or Mn'', and R''' is Al, Cr''', or Fe'''. There are thus twelve basic types of garnets, but sodium and titanium may also occur in the crystals, replacing part of the silicon, and there are also color varieties due to impurities.

The hardness is from 6 of grossularite to 7.5 of almandite and rhodolite, and the specific gravity is 3.4 to 4.3, with a melting point about 1300°C. The color is most often red, but it may be brown, yellow, green, or black. Spanish garnet is pale pink. High-iron garnets have the lowest melting points and fuse to a dark glass, while the high-chromium garnets have high melting points. Garnets occur in a wide variety of rocks in many parts of the world. Almandite, $3FeO \cdot Al_2O_3 \cdot 3SiO_2$, forms crystals of a fine deep-red color with a hardness of about 7.5, which fuses to a glassy mass at 1315°C. It is the most common garnet and is produced chiefly in New York state. It is crushed and graded for coating abrasive paper and cloth. The choice crystals are used as gem stones. Cape ruby, from South Africa, is a red almandite. Pyrope has the composition $3MgO \cdot Al_2O_3 \cdot 3SiO_2$. It has a deep-red color to nearly black, and hardness of 6.5 to 7.5. The nearly transparent or translucent crystals are selected for gem stones. Rhodolite, a pale-rose to purple variety of garnet, is a mixture of pyrope and almandite. These two garnets are found in the Eastern States.

Andradite has the composition $3CaO \cdot Fe_2O_3 \cdot 3SiO_2$, and the colors are yellow, green, or brown to black, with a hardness of 6.5. The orange-yellow variety is called Hessenite; the yellow-green is Tapazolite; the green is Demantoid; and the black variety is called Melanite. The Uralian emeralds are choice green crystals of demantoid from the Ural Mountains. Uvarovite has the composition $3CaO \cdot Cr_2O_3 \cdot 3SiO_2$, and is emerald green. Grossularite, $3CaO \cdot Al_2O_3 \cdot 3SiO_3$, may be white, yellow, or pale green. Succinite is an amber variety; Romanzovite is brown; and Wiluite is pale green. Spessartite, $3MnO \cdot Al_2O_3 \cdot 3SiO_2$, is brown to red, the yellowish-brown variety being Rothoffite. The sodium garnet is Lagoriolite, and a variety of calcium spessartite is called Essonite.

**Gasoline.** Known in England as Petrol. A colorless liquid hydrocarbon obtained in the fractional distillation of petroleum. It is used chiefly as a motor fuel, but also as a solvent. Ordinary gasoline consists of the hydrocarbons between $C_6H_{14}$ and $C_{10}H_{22}$, which distill off between the temperatures 69 and 174°C., usually having the light limit at Heptane, $C_7H_{16}$, or Octane, $C_8H_{18}$. The octane number is the standard of measure of detonation in the engine. Motor fuel, or the general name gasoline, before the wide use of high-octane gasolines obtained by catalytic cracking, meant any hydrocarbon mixture that could be used as a fuel in an internal-combustion engine by spark ignition without being sucked in as a liquid and without being so volatile as to cause imperfect combustion and carbon deposition. These included also mixtures of gasoline with alcohol or benzol.

The Federal specifications for motor fuel called for a hydrocarbon of which 90% would evaporate at 180°C., 50% at 125°C., and 10% at 65°C., with a maximum of 0.10% sulphur. The Gasanol used in the Philippines contained only 20% of gasoline, with 5 kerosene and 75 ethyl alcohol, while the German Dynalkol contained 70% gasoline with alcohol and benzol. But the gasolines containing as much as 15% ethyl alcohol require special carburetion. The common commercial gasolines in the United States had an upper limit at 225°C., and an average specific gravity of 0.75, with the Aromatic-free gasolines having a specific gravity of 0.718. Aviation gasoline had a boiling range below 150°C., but aviation gasolines are now the high-octane cracked and treated gasolines. Straight-run distillation yields gasoline of octane numbers from about 40 to 60, and the yield is 20 to 30% of the crude petroleum. In the heat-cracking process the heavy hydrocarbons of the petroleum are fragmentated and converted into lighter hydrocarbons of gasoline range. The octane number of the gasoline then ranges from 55 to 70, and the yield is higher. With catalytic cracking the octane number can be brought up to 100 or higher, and the yield proportionately increased. Cracked gasolines are rich in the Olefins, $C_nH_{2n}$, or ethylene series, which have antiknock properties but which polymerize and form resins with high heat. They are stabilized with antioxidants.

Synthetic gasoline was first produced in Germany by the Bergius

process of hydrogenation of powdered lignite at high temperatures and pressures to produce gasoline, an intermediate oil, and a heavy oil. But gasolines are also produced from the high-volatile bituminous coals. The low-grade fuel bituminous coals contain a high proportion of Anthraxylon, or Vitrain, which is that part of bituminous coal consisting of undisintegrated parts of trees and plants. This structure of coal has less carbon and can be liquefied more easily to produce gasoline and oils. A low-grade bituminous, such as Vigo No. 4 vein, with 65% of anthraxolin, gives a liquefaction to gasoline and oils of more than 96%, while a Pennsylvania medium-volatile fuel coal gives only 79% liquefaction and requires a greater consumption of hydrogen. Gasoline gel, used in incendiary bombs, is gasoline made into a thick gel with a chemical thickener. It adheres to the surface where it strikes and will produce a temperature of 3000°F. for 10 min. The thickener used under the name of Napalm was sodium palmitate. The motor fuel known as Triptane is Trimethyl butane. In automotive engines it is free from knock so that higher compressions may be employed. In blends with 100-octane gasoline it increases the power output about 25% in aviation engines.

**Gear bronze.** Any bronze used for casting gears and worm wheels, but the term usually means a tin bronze of good strength deoxidized with phosphorus and containing some lead to make it easy to machine and lowering the coefficient of friction. A typical gear bronze contains 88.5% of copper, 11 tin, 0.25 lead, and 0.25 phosphorus. It has a tensile strength up to 40,000 lb. per sq. in., elongation of 10%, and Brinell hardness from 70 to 80, or up to 90 when chill-cast. The weight is 0.306 lb. per cu. in. This is S.A.E. bronze No. 65. • A Hard gear bronze, or Hard bearing bronze, of the U.S. Navy, contains 84 to 86% of copper, 13 to 15 tin, up to 1.5 zinc, up to 0.75 nickel, and up to 0.5 phosphorus. A bronze for worm wheels contains about 87.5% of copper, 11 tin, 1.5 nickel, and 0.15 phosphorus. The tensile strength is 51,000 lb. per sq. in., and hardness 100 Brinell.

**Gelatin.** A colorless to yellowish water-soluble tasteless colloidal hemicellulose obtained from bones or from skins and used as a dispersing agent, sizing medium, coating for photographic films, and

as a stabilizer for foodstuffs and pharmaceutical preparations. It is also flavored and used as a food jelly. The protein Collagen is the gelatin-bearing substance in bone and skins. The bone is dissolved in hydrochloric acid to separate out the calcium phosphate and washed to remove the acid. The organic residue is called Osseine and is the product used to produce gelatin and glue. About 25% of the weight of the bone is osseine, and the gelatin yield is about 65% of the osseine. One short ton of green bones, after being degreased and dried, yields about 300 lb. of gelatin. When skins are used, they are steeped in a weak acid solution to swell the tissues so that the collagen may be washed out. The gelatin is extracted with hot water, filtered, evaporated, dried, and ground or flaked. Gelatin differs from glue only in the purity. Photographic gelatin is made from calfskins. Vegetable gelatin is the algin from seaweed.

German silver. A general name for copper-nickel-zinc white alloys used as a base metal for plated silverware, for springs and contacts in electrical equipment, and for corrosion-resistant parts. Federal Trade Commission rulings prohibit the use of the term in marketing products, but the term is used in manufacturing, and the term nickel brass or a variety of trade names used in marketing. The alloys are graded according to the nickel content. Extra white metal, the highest grade, contains 50% of copper, 30 nickel, and 20 zinc. The lower grade, called fifths, for plated goods, has a yellowish color. It contains 57% of copper, 7 nickel, and 36 zinc. All of the early German silvers contained iron, up to 2%, which increased the strength, hardness, and whiteness, but iron is not desirable in the alloys used for electrical work. Some of the early English alloys also contained up to 2% of tin, but tin makes the alloys brittle.

Germanium. A rare elementary metal, symbol Ge. It is a grayish-white crystalline metal of great hardness, being 6.25 Moh. The specific gravity is 5.35, and melting point 958°C. It is resistant to acids and alkalies. It gives greater hardness and strength to aluminum and magnesium alloys, and as little as 0.35% in tin will double the hardness. It is not used commercially in alloys,

however, because of its rarity and great cost. It is used chiefly in the form of its salts to increase the refraction of glass and in medicine in the treatment of anemia. The metal is trivalent and will form chain compounds like carbon and silicon. Germanium is obtained as a by-product from flue dust of the zinc industry, or it can be obtained by reduction of its oxide from the ores. The chief ore of the metal is Germanite which is a copper ore found in southwest Africa. Germanite contains no less than 20 elements. Together with about 45% of copper and 30 sulphur, it contains 6 to 9% of germanium and 1 gallium, with various amounts of iron, zinc, lead, arsenic, silica, titanium, tungsten, molybdenum, nickel, cobalt, manganese, cadmium, and carbon. The rare lead-silver ore, Ultrabasite, found in central Europe, also contains germanium. Many other metal ores, such as lepidolite, sphalerite, and spodumene, contain small amounts of germanium, so that it has an indirect use, especially in ceramics. As much as 1.6% of Germanium oxide, GeO, occurs in some English coals.

**Gilsonite.** A natural asphalt found in Colorado and Utah, used for roofing, paving, in rubber compounds, and in waterproof paints. It is a lustrous, black, almost odorless, brittle solid, having a specific gravity of 1.10. The melting points of the commercial screened material are 275, 305, and 330°F. It is one of the purest asphalts and has high molecular weight. It is soluble in alcohol, turpentine, and mineral spirits. Gilsonite was named after Samuel Gilson who discovered it about 1875. The selects come from the center of the veins, are very pure, have high solubility in naphtha, and have fusing points from 270 to 310°F. But most commercial gilsonite is now melted and regraded. Elaterite and Wurtzilite are similar asphalts found in Utah, used chiefly for acid-resisting paints. Grahamite, or Glance pitch, is another pure asphalt found in large deposits in Oklahoma, and in Mexico, Trinidad, and Argentina. It is used in insulation and molding materials and in paints. Manjak is a variety of grahamite from Cuba, Barbados, and Trinidad, used for insulation, japans, and varnishes. It is the blackest of the asphalts, has a higher melting point than gilsonite, but is usually not as pure. Millimar, of R. T. Vanderbilt Co., Inc., is processed gilsonite in 20-mesh powder used for rubber compounding.

**Ginger.** The most important spice obtained from roots, and one of the first Oriental spices known in Europe. It is the prepared root of the perennial herb *Zingiber officinale,* grown in India, China, the East Indies, and Jamaica. The roots are pale yellow and contain starch, an essential oil, and a pungent oleoresin, Gingerin. The first crop is the best; the product from the regrowth is called Rhatoon ginger and is inferior. Ginger is employed as a spice and condiment, in flavoring beverages and confections, and in medicine as a digestive stimulant and carminative. It has a cooling effect on the body. Preserved ginger is made by peeling off the thick scaly skin of the boiled roots and boiling in a sugar solution. Dried ginger is prepared by drying the peeled roots in the sun. When the roots have been boiled in lime water before peeling, Black ginger is produced. White ginger is made by bleaching the roots.

Other plants of the ginger family are also used as spices and flavors. Angelica is from the perennial herb *Angelica archangelica,* of Syria and Europe. All parts of the plant are aromatic. Angelica oil, distilled from the fruit, is used in perfumes, flavors for vermouth and bitters, and in medicine. Candied angelica consists of the stems steeped in sirup. It is bright green in color, has an aromatic taste, and is used for decorating confections. Galangal is from the roots of the perennial herb *Languas officinarum,* of China. It has an aromatic odor and pungent taste similar to a mixture of ginger and pepper. It is used chiefly as a flavor, but also in medicine. Tumeric, highly popular in India and Malaya as an ingredient of curries, is from the rhizomes of the perennial plant *Curcuma longa,* of South China and the East Indies. When used as a dye it is called India saffron. The roots are cleaned and dried in the sun. It is very aromatic, with a pungent bitter taste. Curry powders are not tumeric alone, but mixtures of tumeric with pepper, cumin, fenugreek, and other spices. Tumeric is used to flavor and color foodstuffs, and as a dyeing agent for textiles and leather and in wood stains. The natural dye is reddish brown, and gives a yellow color to textiles and foods. It is also used as a chemical indicator, changing color with acidity or alkalinity. Zedoary consists of the dried roots of the perennial plant *Curcuma zedoaria,* grown in India. Zedoary oil is a viscid liquid of reddish color

with an odor resembling ginger and camphor. It is used in flavoring, in medicine, and in perfumery.

**Glass.** An amorphous solid made by fusing silica with a basic oxide. Its characteristic properties are its transparency, its hardness and rigidity at ordinary temperatures, its capacity for plastic working at elevated temperatures, and its resistance to weathering and to most chemicals except hydrofluoric acid. The so-called organic glasses of transparent plastics, and the soft, soluble glasses with beryllium salts replacing the silica, are thus not glass in the established sense of the term, regardless of their transparency. Glass was made in ancient times by fusing sand and an alkali. The Egyptians were famous glassmakers, and were able to blend in various mineral oxides for color and other effects, but glass was not used extensively for windows until modern times. A simple Soda-lime glass may be represented by the formula $Na_2O \cdot CaO \cdot 6SiO_2$, which is nearly the type formula of the garnets except for the silicate crystallization, but glass is not a simple chemical compound. The structure is described as an open chain of silicon atoms, with the atoms of the oxides occupying the spaces in the loose structure. It does not crystallize like silica alone, and many garnets when melted will cool to an amorphous glass.

In its simplest form glass is made by melting together silica and soda ash. Bottle glass is a simple soda-lime-silica glass, the greenish color being due to iron impurities. The lime acts as a flux, and the calcium silicate produced gives the glass a chemical stability which quartz or fused silica do not have. The brilliance and sparkle in glass for bottles for food and drug containers are obtained by adding a small amount of barium. Glass is made in special furnaces by melting selected batches of raw materials to which may be added broken scrap glass called Cullet. The hardness, transparency, and brilliance of the glass vary with the composition. Metallic oxides may be used to color glass or to give special properties. Feldspar is employed as a source of alumina and to prevent disassociation of the soda ash and silica. Soda ash prevents fogging. Crown glass for windows is a hard, white soda-lime glass high in silica, a typical composition being 72% $SiO_2$, 13% CaO, and 15% $Na_2O$. It derives its name from the circular crowning method of making the

sheets, but it is highly transparent and will take a brilliant polish. The so-called Hard glass, or Bohemian glass, for brilliant glassware, is a potash-lime glass with a high silica content, the potash glasses in general not being as hard as the soda glasses, and having lower melting points. The artistry is largely responsible for the quality of Bohemian glass.

Quartz glass, or pure fused quartz, is entirely transparent to ultraviolet rays, but it is not a glass in the strict sense of the term, and fused quartz must have a special long heat-treatment to prevent crystallization. Flint glass for windows is a highly transparent soda-lime-quartz glass. Lustraglas, of the American Window Glass Co., is a highly transparent flat-drawn quartz glass. Window glass is any highly transparent glass for windows. Thermopane, of the Libbey-Owens-Ford Glass Co., is a heat- and sound-insulating window glass made with two panes of glass separated by a metal bonded to the edges of the glass, leaving an insulating layer of dehydrated air between the two glass sheets. The highly refractive flint glasses used in the Rhinestones for cheap jewelry and for the Paste diamonds, which derive their name from their softness as compared with the diamond, contain lead. They have an index of refraction of 1.67, but lack the double refraction and regular molecular arrangement of true gem crystals. Lead is also used in the Crystal glass used for cut glassware, and the brilliance from the lead is higher in the potash glasses than in the soda. English crystal, which is a potash glass, contains as high as 33% of lead oxide. It has high clarity and brilliancy, but is soft. Leaded glasses are also heavy, a crystal glass having a specific gravity of 6.33 compared with 2.25 for a borate glass. The boric oxide glasses, or Borax glasses, are transparent to ultraviolet rays. The so-called Invisible glass is a borax glass surface treated with a thin film of sodium fluoride. It transmits 99.6% of all visible light rays, thus casting back only slight reflection and giving the impression of invisibility. Ordinary soda and potash glasses will not transmit ultraviolet light. Glass containing 2 to 4% of ceric oxide absorbs the ultraviolet rays and is used for X-ray shields. Fluorescent glass for mercury-vapor discharge tubes contains ceric oxide. The Kromex glass of the MacBeth-Evans Glass Co., used for gaso-

line dispensing pumps, is a glass made to stop the passage of ultraviolet rays.

Metal salts are used in glass for coloring as well as controlling the characteristics. Manganese oxide is added to most glass to neutralize iron oxide, but an excess colors the glass violet to black. Jena blue glass gets its color and fluorescence from a mixture of cobalt oxide and ceric oxide. Ruby glass, or a rich red color, is produced with selenium and cadmium sulphides, or with copper oxide. It is also produced with Purple of cassius, or Gold-tin purple a brown powder which is a mixture of the yellow Gold chloride $AuCl_3$ and the dark-brown Tin oxide SnO. Amber glass is made with controlled mixtures of sulphur and iron oxide that give tints varying from pale yellow to ruby amber. Amber glass is much used for medicine bottles to prevent entry of harmful light rays. The Actinic glass of the Pennsylvania Wire Glass Co., used for skylights and factory windows, has a yellow tint that softens and diffuses the light and impedes passage of heat rays. Neophane glass is glass containing neodymium oxide which reduces glare and is used in yellow sunglasses, or small amounts may be used in windshield glass. Opalescent glass, or Opal glass, used for light shades, table tops, and cosmetic jars, has structures that cause light falling on them to be scattered, and they thus are white or translucent. They owe their properties to tiny inclusions with different indexes of refraction, such as fluorides, sulphides, or oxides of metals. Alabaster glass has inclusions of larger dimensions in lower numbers per unit than opal glass, and it shows no colors, whereas opalescent glass appears white by reflected light but shows color images through thin sections. Opal glass may contain lepidolite, which mineral contains various metals.

Monax glass, of the MacBeth-Evans Glass Co., is a white diffusing glass for lamp shades and architectural glass. Glass blocks for translucent units in factory walls are made from types of opalescent glass. Insulex, of the Owens-Illinois Glass Co., is a translucent glass brick of this kind. Polarized glass, for polarizing lenses, is made by the American Optical Co. by adding minute crystals of tourmaline or peridote to the molten glass, and stretching the glass while still plastic to bring the axes of the crystals into parallel alignment. Florentine glass does not refer to a mixture but to an

ornamental glass made by casting on an embossed bed, or by rolling with a roll upon which the designs are cut. Powdered glass, used as a filler in plastics, paints, composition tiles, and roofings, is made by grinding broken scrap glass.

**Glass cloth.** A name given to cotton fabric made of smooth, hard-twisted yarns which do not lint, and used for wiping glass. It may be of the type known as Sponge cloth, which is a twill fabric of nub yarn or honeycomb effect, or it may be of Terry cloth, which has a heavy loop pile on one or both sides. Another Wiping cloth for glass and instruments where a lint-free characteristic is important is made with a cotton warp and a high-tenacity rayon filling. It is strong, soft, and absorbent.

**Glass fiber.** The fine flexible fibers made from glass, used for heat and sound insulation, fireproof textiles, acid-resistant fabrics, retainer mats for storage batteries, panel boards, filters, and electrical insulating tape, cloth, and rope. It is distinct from mineral wool in that it is a glass made to definite formulation with a uniformity not found in mineral wool. Molten glass strings out easily into threadlike strands and this Spun glass was early used for ornamental purposes, but the first long fibers of fairly uniform diameter were made in England by spinning ordinary molten glass on revolving drums. The original fiber was about 0.001 in. in diameter. It was called Glass silk and Glass wool, and the loose blankets for insulating purposes were called Navy wool. The term navy wool is still used for the sewn insulating blankets of fine fibers faced on both sides with flameproofed muslin. These are made to Navy specifications for temperatures of 600 to 1000°F., and used for duct and pipe insulation and for soundproofing. It is also available in loose bats. Glass fibers are now made by letting the molten glass drop through tiny orifices and blowing with air or steam to attenuate the fibers. The usual composition is that of a soda-lime glass, but it may be varied for different purposes. The glasses low in alkali have high electrical resistance, while those of higher alkali are more acid resistant. They have very high tensile strengths, up to about 400,000 lb. per sq. in., but the breaking strength of yarns is expressed in pounds for any given yarn.

The commercial glass fibers marketed under the name of Fiberglas by the Owens-Corning Fiberglas Co. are made in seven standard diameters from 0.0002 to 0.008 in. The textile fibers from 0.0002 to 0.0004 in. are very flexible and silky and can be spun and woven on regular textile machines. Fiberglas cloth and Fiberglas tape are made in satin, broken twill, and plain weaves, the satin weave cloth 0.007 in. thick weighing 7 oz. per sq. yd. The Lagging cloth for high-temperature pipe insulation is a heavy Fiberglas cloth of 20 oz. per sq. yd. Glass insulating sheet, of the Irvington Varnish & Insulator Co., consists of tightly woven Fiberglas fabric impregnated with a clear or black insulating varnish. The finished cloth varies in thickness from 0.005 to 0.012 in., the glass fabric of the thinnest being 0.003 in. The 0.005-in. sheet has a tensile strength of 110 lb. per in. of width, equal to 22,000 lb. per sq. in., and a dielectric strength of 1,200 volts per mil. Glass insulating tape, of the Industrial Tape Corp., is Fiberglas fabric in tape form coated with a pressure-sensitive adhesive.

Glass cloth of plain weave of either continuous fiber or staple fiber is much used for laminated plastics. The cloth comes in thicknesses from 0.002 to 0.023 in. in weights from 1.43 to 14.7 oz. per sq. yd. Fiberglas yarns are marketed in various sizes and twists, in continuous or staple fiber, and with glass compositions for chemical or electrical applications. Glass sewing thread has a high twist. The minimum breaking strength of the 0.014 in. thread is 12 lb., and that of the 0.020 in. thread is 24 lb. Glass mat is composed of 0.0005-in. fibers felted or intertwined in random orientation to make a thin, porous material. It is used for making panel boards, impregnated sheets, and for air filters. Glasfloss, of the Glasfloss Corp., is prepared glass mat in thicknesses 0.10 to 0.125 in. Conolon, of the National Research & Mfg. Co., and Conolite, of the Consolidated Vultee Aircraft Corp., are lightweight construction boards made by impregnating glass fabric with 20% of a thermosetting resin and curing with heat and a light pressure of 10 lb. per sq. in. The tensile strength of the board is 120,000 lb. per sq. in., specific gravity 1.15, and hardness 98 Rockwell M. It is used for aircraft paneling and light structures. Corresite, of S. Blickman, Inc., is glass fabric with synthetic resin molded in the form of pipes and fittings for chemical use. Glass

filter cloth is made in twill or satin weaves in thicknesses from 0.030 to 0.070 in., and is used for chemical filtering. Fiberglas PF is glass fiber preformed into pipe, sheet, and other insulation coverings bonded with a thermosetting resin. It will withstand temperatures to 600°F. Fiberglas block is also bonded with a small amount of resin and will withstand temperatures to 600°F.

**Glass sand.** Sands employed in glassmaking. They are all screened, and usually washed to remove fine grains and organic matter. The grain standards of the American Ceramic Society specify that all should pass through a No. 20 screen, between 40 and 60% should remain on a No. 40 screen, between 30 and 40% should remain on a No. 60 screen, between 10 and 20% on a No. 100 screen, and not more than 5% should pass through a No. 100 screen. Sand for first-quality optical glass should contain 99.8% of $SiO_2$, a maximum of 0.1 of $Al_2O_3$ and 0.02 of $Fe_2O_3$. Third-quality flint glass may contain only 95% of $SiO_2$ and as high as 4% of $Al_2O_3$. Only in the eighth- and ninth-quality amber glasses is the content of $Fe_2O_3$ permitted to reach 1%. Potters' sand is usually a good grade of glass sand of uniform grain employed for packing to keep the ware apart.

**Glucose.** A sirupy liquid of the composition $CH_2OH(CHOH)_4CHO$, which is a monosaccharide, or single sugar, occurring naturally in fruits and in animal blood, or made by the hydrolysis of starch. It is made readily from cornstarch by heating the starch with dilute hydrochloric acid, which is essentially the same process as occurs in the human body. Most of the commercial glucose is made from cornstarch. It is used in confectionery and other foodstuffs, in tobacco and inks to prevent drying, in tanning, as a reducing agent, and for blending with cane sugar and sirups to prevent crystallization on cooling and because it is usually cheaper than sugar. The name glucose is usually avoided by the manufacturers of edible products, because of prejudices against its substitution for sugar, but in reality it is a simple form of sugar easily digested. It is used in medicine as a blood nutrient and to strengthen heart action, and may be harmful only in great excess. When free from starch, it is called Dextrose. It is also marketed as Corn sirup, but corn sirup is not usually pure glucose, contain-

ing some dextrine and maltose. The Maltose, or Malt sugar, in the combination has the empirical formula $C_{12}H_{22}O_{11}$. When hydrolyzed in digestion, it breaks down easily to glucose. When purified it is transparent and free of malt flavor. It is not as sweet as the sucrose of cane sugar, but is used in confectionery and as an extender of cane sugar. Glucose derived from grapes is called Grape sugar. The glucose in fruits is called Fruit sugar, Levulose, or Fructose. This is dextroglucose, and when separated out is in colorless needles which melt at 104°C. It is used in pharmacy. Corn sugar is also a solid white powder, being glucose with one molecule of water of crystallization. Glucose is only 70% as sweet as cane sugar and has a slightly different flavor.

**Glue.** A cementing material usually made from impure gelatin from the clippings of animal hides, sinews, horn and hoof pith, or from the skins and heads of fish, or from bones. The term Animal glue is limited to Hide glue, Extracted bone glue, and Green bone glue. Fish glue is not usually classed with animal glue, nor is casein glue. The vegetable glues are also misnomers, being classed with the mucilages. Synthetic resin glues are more properly classed with adhesive cements. Animal glues are hot-work glues, applied hot, and bind on cooling. Good grades of glue are semitransparent, free from spots and cloudiness, and are not brittle at ordinary temperatures. Bone glue is usually light amber in color; the strong hide and sinew glues are light brown. The stiffening quality of glue depends upon the evaporation of water, and it will not bind in cold weather. Glues made from blood, known as Albumen glues, and from casein are much used for fastening plywood. However, they do not have the strength of the best grades of animal glue, and are not resistant to mold or fungi. Marine glue is a glue insoluble in water, made from solutions of rubber or resins, or both. The strong and water-resistant plywoods are now made with synthetic resin adhesives.

Animal glue has been made since ancient times, and is now employed for cementing wood, paper, and paperboard. It will not withstand dampness, but white lead or other material may sometimes be added to make it partly waterproof. The so-called Casein glues are water-resistant. Soybean glue is made from soybean cake

and is used for plywood. It is marketed dry. It has greater adhesive power than other vegetable glues, or pastes, and is more water-resistant than other vegetable pastes. Hide glue is used in the manufacture of furniture, abrasive papers and cloth, matches, and print rollers. The bone glues are used either alone or blended in the manufacture of boxes, cartons, and trunks. Green bone glue is used chiefly for gummed paper and tape for cartons. In making bone glue the bones are crushed, the grease extracted by solvents, and the mineral salts removed by dilute hydrochloric acid. The bones are then cooked to extract the glue. Glues are graded according to the quality of the raw material, the method of extraction, and the blend.

There are 16 grades of hide glue and 15 grades of bone glue. Those with high viscosity are usually the best. Most glue is sold in ground form, but also as flake or pearl. Glues for such uses as holding abrasive grains to paper must have flexibility as well as strength, obtained by adding glycerin. Hoof and horn-pith glue is the same as bone glue, and is inferior to hide glue. Fish glue is made from the jelly separated from fish oil, or from solutions of the skins. The best Fish glue is made from Russian isinglass. Fish glues do not form gelatin well and are usually made into Liquid glues for photo mounting, gummed paper, household use, and for use in paints and sizes. The liquid glues are also made by treating other glues with a weak acid. Pungent odors indicate defective glue. The glues made from decomposed materials are weak. Preservatives such as sulphur dioxide or chlorinated phenol may be used. In use, glues should not be boiled. The melting point is usually about 140°F.

**Glycerin.** Also called Glycerol. A trihydroxy alcohol of the composition $C_3H_5(OH)_3$, forming an important constituent of oils and fats from which it is set free during saponification. Glycerin is a colorless, sirupy liquid with a sweet, burning taste. It is soluble in water and in alcohol. About 85% of the American production is as a by-product in the manufacture of soap, but it is also a by-product in the fractionation of fats, or as a by-product in the fermentation of sugar or molasses for alcohol. It is also made synthetically from propylene. The German glycerin

substitute Glycerogen contains 40% of glycerin, 40 propylene glycol, and 20 hexyl alcohols, and was made by the catalytic hydrogenation of hexose from wood. Coconut oil yields about 14% of glycerin, palm oil 11%, tallow 10%, soybean oil 10%, and fish oils 9%. Glycerin has a boiling point of 220°C., freezing point 17°C., and the double-distilled product has a specific gravity of 1.260. It is marketed crude or distilled. In water solutions the freezing point is lowered, reaching −60°F., the lowest point, at 37% of water. It is thus valuable as an antifreeze liquid. Glycerin is used in making plastics, as a plasticizer in resins, to control flexibility in adhesives and coatings, and in making nitroglycerin and dynamite. It does not evaporate easily and has a strong affinity for water, and is thus used in products that require to be kept from drying such as foodstuffs, cosmetics, tobacco, and stamping inks. As it is nontoxic, it is used as a solvent for pharmaceuticals. It is also used as an antiseptic in surgical dressings, as an emollient in throat medicines, and as a counterirritant in cosmetics.

**Gold.** An elementary metal, symbol Au, known since the most ancient times as one of the precious metals. It is so chemically inactive that it is found mostly in the native state. It is found widely distributed in all parts of the world. It is employed chiefly for coinage, ornaments, jewelry, and for gilding. Gold is extracted by crushing the ores and catching the metal with quicksilver. About 25% of the gold produced in the United States is placer gold and about 5% is a by-product of the copper industry. Ore with only 50 cents worth of gold per ton can be profitably worked by modern methods. The average gold recovered from ore in Western United States is 0.2 oz. per ton of ore, and in Alaska 0.044 oz. per ton. Native gold is usually alloyed with silver, placer gold being the purest. The natural alloy of gold and silver was known as Electrum, and under the Egyptian name of Asem was thought to be an elementary metal until produced as an alloy by the Romans. Gold is yellow in color, soft, and is the most malleable of all the metals. It can be beaten into extremely thin sheets. A gram of gold can be worked into leaf covering 6 sq. ft., and only 0.0000033 in. thick, or into a wire 1.5 miles in length. Cast gold has a tensile strength of 20,000 lb. per sq. in. The

specific gravity is 19.32, and the melting point 1943°F. It is not attacked by nitric, hydrochloric, or sulphuric acids, but is dissolved by aqua regia, or by a solution of azoimide.

Because of its softness, gold is almost always alloyed with other metals, usually copper, silver, or nickel, and graded on a basis of degrees of fineness in 1,000 parts, or on the basis of carat gold value, pure gold being 24 carats. Green gold, used in making jewelry, is an alloy of gold, silver, and copper, graded from 14 to 18 carat. The 18-carat green gold contains 18 parts of gold and 6 silver, with no copper. The 15-carat grade contains 15 parts of gold, 8 silver, and 1 copper. The 14-carat grade contains 14 parts of gold, 8¼ silver, and 1¾ copper. Coinage gold in the United States is 90% gold and 10 copper. In England it is 91.66% gold and 8.33 copper, and this alloy is called Standard gold. In Australia 8.33% silver is used instead of the copper, and the Gold-silver alloy is called Australian gold. Dental gold is a term for a wide range of wrought and cast alloys with usually from 65 to 90% of gold, 5 to 12 silver, and frequently platinum and sometimes palladium. A very small amount of iridium may also be used for hardening. Colors vary from white to yellow, and such alloys are also used for jewelry and for acid-resistant plates. Gold is easily electroplated on other metals and is thus much used for jewelry, ornaments, and for chemical resistance, but the gold is so soft that the thin plates wear off easily. Hard gold plate is a Gold-indium plate. The process of the Indium Corp. of America is to plate the gold and indium successively and then alloy by diffusion at 330°F. Precipitation hardening takes place, giving a hard, wear-resistant coating.

The consumption of gold for industrial purposes in the United States is about 3,000,000 oz. annually. South Africa is the most important producer of gold. Other important producers are Canada, the United States, and Western Australia, but gold is produced in 90 other countries. The ore of gold known as Calaverite, found in Colorado, California, and West Australia, is a Gold telluride, $AuTe_2$, containing theoretically 44% gold, found with the gold-silver telluride Sylvanite $(AuAg)Te_2$. It is a silvery-white granular mineral of specific gravity 9.35, and hardness 2.5, easily fusible.

**Granite.** A coarse-grained, igneous rock having an even texture, and consisting largely of quartz and feldspar with often small amounts of mica and other materials. There are many varieties. Granite is very hard, compact, and takes a fine polish, showing the beauty of the crystals. It is the most important building stone, and is also used as an ornamental stone. An important use is also for large rolls in pulp and paper mills. Granite surface plates, for machine-shop layout work, are made in sizes up to 30 by 72 in. and 10 in. thick, ground and highly polished to close accuracy. It is extremely durable, and since it does not absorb moisture like limestone or sandstone, it does not weather or crack like these stones. The colors are usually reddish, greenish, or gray. Rainbow granite may have a black or dark-green background with pink, yellowish, and reddish mottling, or it may have a pink or lavender background with dark mottling. The weight is 170 lb. per cu. ft., the specific gravity 2.72, and the crushing strength is from 23,000 to 32,000 lb. per sq. in. The most notable granite quarries are in northern New England. Mount Airy granite from North Carolina is light gray in color and is a Biotite containing feldspar, quartz, and mica. It is somewhat lighter in weight and of lower crushing strength than Maine granite. Balfour pink granite of North Carolina contains 72% silica, 14.1 alumina, 2 soda, 6 potash, 1.2 iron oxide, 0.12 titanium oxide, 0.20 manganese oxide, and 0.36 lime. The granite known as Pegmatite, of which there are vast quantities, contains beryllium in the form of beryl as a minor constituent.

**Grapeseed oil.** An oil obtained by pressing or extraction from grape seeds which are a by-product from the wine industry. The seeds contain 10 to 15% of oil, highly valued in Europe as an edible oil and for soaps. The cold-pressed oil is almost colorless, sweetish, and is similar to olive oil. The hot-pressed oil is dark green and is not sweet. The refined oil has a delicate green color and a nutlike taste. Grapeseed oil contains about 32% of oleic acid, 52 linoleic acid, and palmitic, stearic, and arachidic acids. In the United States it is used for paints and soaps.

**Graphite.** Also called Plumbago. It was formerly known as Black lead, and when first used for pencils was called Flanders'

stone. A natural variety of elemental carbon having a grayish-black color and a metallic tinge. It occurs in two forms: foliated and amorphous. Foliated graphite is used principally for crucibles and lubricants, and amorphous for lead pencils, foundry facings, electric brush carbons, stove polish, and paint pigments. It is infusible, but oxidizes at 600 to 700°C. It is a good conductor of heat and electricity, is resistant to acids and alkalies, and is readily molded. The specific gravity is 2 to 2.5. The hardness is 1 to 2, sometimes less than 1, and it has a decidedly greasy feel. It is a good lubricant, especially when mixed with grease, but the natural graphite contains silica and other abrasive materials so that the artificial graphite is preferred for lubricants. Graphite powder made in the electric furnace is superior to natural graphite because of its purity. It is marketed in grades by purity, electrical resistance, and fineness. It is used for molded products such as arc-light carbons, chemical equipment parts, and carbon brushes, and also for graphited bearings, paints and ink pigment, mold wash, covering molten steel to reduce piping, crucibles, and in rubber compounding. Artificial graphite is produced at very high temperatures, about 3000°C., and it will withstand this temperature indefinitely in inert atmospheres, although it combines with oxygen in the air above 600°C.

Graphite is found in large deposits in Mexico, India, Ceylon, and in the United States in Alabama and New York. Of the imported, the amorphous comes from Mexico and the crystalline from Ceylon and Madagascar. A proportion of Ceylon crystalline lump graphite is used in mixes for crucibles. Natural graphite occurs in veins in rock and always contains some impurities. Some varieties containing as little as 35% of graphitic carbon are used for paints. No. 1 Flake graphite should contain 90% of graphitic carbon. Mexican Amorphous graphite carries 80%. Crystalline graphite and Flake graphite are really synonymous terms to describe material of high graphite content, as distinguished from amorphous. Molding graphite is natural amorphous impure graphite ground to extreme fineness, used in foundry work. This type of graphite is also used for lead pencils. The amorphous graphite is mixed with clay and fired, the amount of clay determining the hardness of the pencil. Indelible lead for pencils may be graphite with a dye.

Combination lead is a term for ground graphite used for foundry facings. Graphite carbon raiser is a term given to graphite powder of 90% or more purity used for adding to molten steel to raise the carbon content. The grades are according to particle size with the finest having 98% through a 20-mesh screen. Scrap carbon electrodes are also used for this purpose. Molded graphite brushes for motors and generators may have the graphite mixed with metal powders, and the electric-carrying capacity varies with the metal powder. The extremely fine particles of artificial colloidal graphite will remain in suspension indefinitely, and are marketed in distilled water, mineral oil, castor oil, glycerin, or resin varnish, under trade names. Prodag is a solution in water marketed by the Acheson Colloids Corp. for foundry facings. Grafita and Grafene, of the United States Graphite Co., are grease and oil solutions for lubricating purposes.

**Graphited metals.** Graphite and metal or metallic oxide mixtures sometimes erroneously referred to as alloys, used chiefly as bearing metals. There are two general classes, those called bronze and those of the white metal or babbitt type. In general, the materials are produced by diffusing or sintering the powdered materials that have been compressed in molds. Graphited bronze, of the Johnson Bronze Co., contains 40 to 45% graphite; the remainder is metal. A grade of this material is called Ledaloyl. Genelite is a spongy bronze made by heating the powdered oxides of copper, lead, and tin with an excess of graphite, shaping in steel molds under high pressure, and sintering in a furnace. The porosity due to the graphite permits the product to absorb about 20% by volume of oil. The tensile strength is 8,000 lb. per sq. in., and the compressive strength 50,000 lb. per sq. in. Genelite is a product of the General Electric Co., used for bearings and sealing rings. Oilite, marketed by the Amplex Division, Chrysler Corp., is an 88-10-2 type of bronze made by briquetting the finely powdered metals and graphite under high pressure, heat-treating, finishing to size, and impregnating with the lubricant. The oil content averages 3.5% by volume. It is used as a self-lubricating bearing metal for speeds up to 30,000 r.p.m., and pressures of 6,000 lb. per sq. in. Graphalloy, of the Graphite Metallizing Corp., is made with either

bronze or babbitt metals, and the molten metal is forced into the graphite powder under high pressure. It is marketed in the form of bushings, rods, and tubes. Durex bronze, of the Moraine Products Div., General Motors Corp., is a diffused material made by sintering the partly reduced oxides of bronze metals with graphite under pressure. The resulting Graphite bronze will take up 29% of its volume of lubricant by capillarity. Gramix, of the United States Graphite Co., is a similar material. Graphex is the name of a series of bronze and babbitt graphited bearing metals of the Never-oil Bearing Co. The bronze metals have compressive strengths of about 30,000 lb. per sq. in., and the white metals 16,000 lb. per sq. in. In the Boroto metal, produced by E. Siegrist, London, the graphite is in colloidal form, and the metal can be remelted without destroying its qualities. All of the graphited metals can be machined with sharp tools.

**Gravel.** A natural material composed of small, usually smooth, rounded stones or pebbles. It is distinguished from sand by the size of the grain, which is usually above ¼ in., but gravel may contain large stones up to 3 in. in diameter, and some sand. It will also contain pieces of shale, sandstone, and other rock materials. Gravel is used in making concrete for construction, and as a loose paving material. Commercial gravel is washed to remove the clay and organic matter, and screened. Pea gravel is screened gravel between ¼ and ½ in. in diameter. It is used for surfacing with asphalt, or for roofing. Gravel is sold by the cubic yard or by the ton, and is shipped by weight. Bank-run gravel, with both large and small material, weighs about 3,000 lb. per cu. yd.

**Greenheart.** The wood of the tree *Ocotea rodioei* of British Guiana, especially valued for shipbuilding, dock timbers, planking, and lock gates because of its resistance to fungi and termites. It also goes under the name of Demerara greenheart, and under its native name of Bibiru. The tree grows to a height of 120 ft., with diameter of 2 to 3 ft., clear of branches for 50 to 70 ft. The wood is very strong and hard with good wearing qualities. The average weight is 62 lb. per cu. ft. with 12% moisture. The specific gravity, oven-dried, is 0.80. The heartwood is light olive to nearly black, and the sapwood pale yellow to greenish. A wood sometimes

marketed as greenheart is Itauba, from the tree *Silvia itauba* of the lower Amazon Valley. The color is a dingy yellow. It is used in naval construction. Surinam greenheart is the wood Bethabara, from the tree *Tecoma Leucoxylon* of Dutch and French Guianas. It is distinguished from greenheart by the yellow deposits in the pores, and is not as resistant as greenheart. Manbarklak, the wood of the tree *Eschweilera corrugata*, of Surinam, is reddish brown in color, weighs 76 lb. per cu. ft., is equal to greenheart for marine construction, but is scarcer. Angelique, the wood of the tree *Dicorynia paraensis* of the Guianas and lower Amazon, is very resistant to fungi and insect attack, and is used as a substitute for greenheart in marine construction. It is hard but not as heavy as greenheart, weighing 50 lb. per cu. ft. It has an olive-brown color with reddish patches. African greenheart is Dahoma, the wood of the large tree *Piptadenia africana* of the west coast of Africa. It is yellowish brown in color, weighs 50 lb. per cu. ft., but is not as resistant to marine borers as greenheart. The wood of a species of tonka bean tree of Panama, known as Almendro, *Coumarouna panamensis*, is very resistant to marine borers and is used as a substitute for greenheart. It is yellowish brown in color and is very heavy. The almondlike seeds of the tree are used as a food.

**Grinding pebbles.** Hard and tough rounded small stones, usually of flint, employed in cylindrical mills for grinding ores, minerals, and cement. Pebbles from Greenland, marketed usually through Denmark and known as Danish pebbles, are of great hardness and toughness. Newfoundland also supplies these pebbles. Quantities of Flint pebbles also come from Denmark for use in tube mills. They are smooth, round pebbles formed by the washing of the sea on the chalk cliffs, and come from the islands off the Danish coast. Danish pebbles are graded in seven sizes, according to French standards from No. 0 which is 30 to 40 mm. (1½ to 1¾ in.) to size E which is 100 to 130 mm. (4 to 5 in.). Small pebbles, ½ in. in diameter, are used for polishing iron castings by tumbling. American grinding pebbles are chiefly from Minnesota, Ohio, Nevada, and from the beaches of California. Quartzite pebbles are produced in Nova Scotia and Saskatchewan. Quartz pebbles from Alabama are 99% silica and low in iron, but they do

not wear as well as true flint pebbles. Granite, rhyolite, and andesite pebbles are also used for grinding. The Granite pebbles produced in North Carolina for feldspar and other mineral processing are broken into cubes and wet-milled to remove the edges and corners. They are graded in sizes from 1½ to 5 in. Porcelain grinding balls are made of high-grade resistant porcelain, and are marketed in stock sizes for use in tumbling barrels for grinding and polishing. They have the advantage over flint pebbles of greater uniformity.

**Grindstones.** Sandstones employed for grinding purposes. Grindstones are generally employed for the sharpening of edged tools, and do not compete with the hard emery, aluminum oxide, and silicon carbide abrasive wheels which are run at high speeds for rapid cutting. Grindstones are quarried from the sandstone deposits and made into wheels usually ranging from 1 to about 6 ft. in diameter, and up to 16 in. in thickness. They are always operated at low speeds because of their inability to withstand high centrifugal stresses. The grades vary from coarse to fine. Good grindstones have sharp grains, without an excess of cementing material that will cause the stone to glaze in grinding. The texture must also be uniform so that the wheel will wear evenly. The hard silica grains are naturally cemented together by limonite, clay, calcite, quartz, or mixtures. Too much clay causes crumbling, while too much calcite results in disintegration in the atmosphere. An excess of silica results in a stone that is too hard.

**Guanidine nitrate.** A white granular powder of the composition $(H_2N \cdot CNH \cdot NH_2) \cdot HNO_3$ employed in the manufacture of explosives and pharmaceuticals, for coating blueprint paper to speed up development time, and in photographic fixing baths. It melts at 206 to 212°C. and is strongly acid. Guanidine carbonate is a white nonhygroscopic granular powder of the composition $(H_2N \cdot CNH \cdot NH_2)_2 \cdot H_2CO_3$. It decomposes at 198°C. It is soluble in water, and has an alkaline reaction. Guanidine carbonate is used in the manufacture of pharmaceuticals, as an emulsifier in soaps, and in photographic developing solutions. Other derivatives of guanidine, such as Diphenyl guanidine, are used as plasticizers and accelerators for rubber.

**Guava.** The fruit of the tree *Psidium guajava* of the myrtle family to which the clove, allspice, and eucalyptus belong. Because of its content of acids, sugars, pectin, and vitamins, it is valued in the food industries for blending in jellies and preserves. The pulp is also used in ice-cream manufacture. Vast quantities of guava are used for hard jellies in Latin America. The fruit has more than ten times the vitamin C content of the orange and retains it better. It also contains vitamins A and $B_1$ and 11.6% of carbohydrates. The tree is native to America from Mexico to Peru and is also grown extensively in Brazil and the West Indies. It was one of the original Aztecan and Incan fruits, and is still known under the Carib name of Guayaba in Brazil and Argentina. There are about 150 varieties, and the large seedy fruit has a fragrant aroma and distinctive sweet flavor.

**Guayule.** A perennial plant, *Parthenium argentatum,* of the *Compositae* family, grown extensively in the semiarid regions of northern Mexico and southern California as a source of rubber. The plants are hardy woody shrubs that mature into the highest rubber content in 7 years. They contain in the dry state up to 22% of guayule rubber, in all parts except the leaves. The plant is uprooted in 3 to 5 years and is crushed and pulverized in mills, and the rubber extracted by flotation. The guayule rubber contains from 20 to 25% of resin so that it is suitable only for blending or for cements unless deresinated. Natural crude guayule is softer than hevea rubber, owing to the content of natural resins which act as plasticizers. In the low-sulphur compounds it remains permanently tacky, and is thus valued for use as a coating adhesive for the permanently tacky binding tape known as Scotch tape. When deresinated by extraction of the resin with acetone or other solvent, the rubber is suitable for all the uses of hevea rubber. The by-product Guayule resin is used in plastics. From 400 to 1,000 lb. of rubber are produced per acre under cultivation.

**Gum.** The wood of the tree *Liquidambar styraciflua,* of the United States and Mexico. It is also called Red gum and Sweet gum. In England it is known as California red gum although the gum wood of California is from a eucalyptus tree. In Europe, also, the term Satin walnut is used for the heartwood and Hazel pine for

the sapwood. Gum has a reddish-brown color, is soft with a fine, close grain, and weighs about 40 lb. per cu. ft. It is used for furniture, veneer, inside trim, cooperage, and the making of pulp for book paper. The timber is cut mostly in the Southern states, especially in Louisiana, Mississippi, and Arkansas. The trees have a height 80 to 100 ft. and average 1½ to 3 ft. in diameter with a straight clear trunk. Red gum is from the heartwood of mature trees and is reddish brown, Sap gum comes from the outer portion of logs or from young trees and is white tinged with pink. Nearly 25% of all the hardwood used in the United States is red gum. It has an interlocking grain which gives a fine appearance in veneers, but has a tendency to warp.

Gum is graded according to standards of the National Hardwood Lumber Association from firsts through selects to No. 3B common. Local names for red gum are Southern gum, Sycamore gum, Bilsted, and Star-leafed gum. Cotton gum, or Tupelo, of Louisiana, is from the tree *Nyssa aquatica.* It is also known as Water tupelo, Tupelo gum, Swamp gum, Sour gum. Black gum, or Black tupelo, also of the Southern states, is *N. sylvatica.* Swamp tupelo, also called Water gum and Swamp black gum, is from the tree *N. biflora.* Ogeche tupelo is from the tree *N. ogecha,* and is not common. It is also called Gopher plum, Wild limetree, and Sour tupelo. Black tupelo grows from New Hampshire to central Texas, but water tupelo is found chiefly along the coasts and river valleys of the South. The shipments of woods are usually mixed. Tupelo woods from the various species of *Nyssa* are fine-textured but with large pores. The heartwood is brownish gray and the sapwood is grayish white. They are tough and difficult to split, having an interlocking grain, and find wide use for such articles as mallets, toilet seats, furniture, and bottle cases.

**Gum arabic.** Also called Acacia gum. The gum exudation of the small tree *Acacia arabica,* and various other species of acacia trees of Africa. The chief area of cultivation is in the Egyptian Sudan. Kordofan gum, or Hashab gum, is a variety from the Red Sea area and forms the chief export of the Sudan. It is obtained by tapping the wild tree *Acacia verek,* and is of high quality. Sennaar gum is gum arabic exported from Arabian ports on the Red

Sea. Gum senegal, from the *A. senegal,* comes from the dry regions of French West Africa. Gum talha, Talco gum, or Talh gum, is a brittle and low grade of gum arabic from the North African acacia, *A. stenocarpa.* Gum arabic is used for adhesives, for thickening inks, as a binding and filling material for textiles, as a suspending medium in medicines, and for thickening rubber latex. It was the most ancient of adhesives. The trees are wounded and the sap allowed to run out, forming in yellowish, transparent lumps. It is soluble in water but insoluble in alcohol. It is also marketed as a white powder of 120 mesh. For drug use the crude gum is selected, blended, and ground to powder of uniform characteristics. Various nontoxic emulsifiers are used as substitutes for gum arabic in pharmaceuticals and cosmetics, and also in food products to improve smoothness. Bemul, of the Beacon Co., used as a substitute, is a glyceryl monostearate. It is a white solid in bead form melting at 58°C., soluble in hot water and in alcohol, and edible. The Satinwood of the Near East, valued since ancient times for its great durability, is the wood of the gum arabic tree. It is light in weight, hard, close-grained, and has an orange-brown color that darkens with age.

Gumwood. The wood of several species of Eucalyptus trees native to Australia and Tasmania, but now grown in many parts of the world. The wood is used in construction and for inferior furniture. There is a large production of eucalyptus lumber in Peru for railroad and mining timbers. The wood known as gum in Southern United States is from the tupelo and species of *Liquidambar.* The Blue gum is *Eucalyptus globulus,* which attains a height of 300 ft. and is grown on the West Coast of the United States. The wood has a pale straw color and is hard and tough. It has a twisted grain, shrinks and warps easily, but is very durable. The weight is about 50 lb. per cu. ft., being heavier than southern gum. Salmon gum, from *E. salmonophloria,* has a salmon-red color, is dense and hard, and has a fine, open grain. It is superior and has a great variety of uses. The weight is about 60 lb. per cu ft. Red gum, from *E. calophylla,* has a yellowish-red color, is strong, tough, and weighs about 45 lb. per cu. ft. The grain is fine, but has gum veins intersecting. Other species of gumwood are marketed under the

names of York gum, Jarrah, Blackbutt, Tuart, Karri, and Australian red mahogany.

Eucalyptus trees are believed in some countries to aid in eradicating malaria, and eucalyptus wood is burned by some to cure colds from the smoke. Eucalyptus oil, obtained from the dried leaves of the *E. globulus*, is used in pharmaceutical preparations for nose and throat treatment. It is the source of Cineole also called Eucalyptole. From 3 to 4% of oil is obtained from the leaves. It is a pungent yellowish oil. This type of Eucalyptus oil contains Phellandrine used in Australia as an antiknock agent in gasoline. Eucalyptus dives oil, from the leaves of the Australian tree *E. dives*, contains 92 to 94% of Piperitone, and is used in the manufacture of menthol. The yield is about 50% of Laevo menthol with a melting point of 33 to 35°C. It lacks the odor of U.S.P. menthol of which only 15% can be produced from this oil. More than 300 species of eucalyptus trees are known, and each produces a different oil.

**Gunmetal.** The common name for a casting bronze containing on an average 88% of copper, 10 tin, and 2 zinc. It casts and machines well, and is suitable for making steam and hydraulic castings, valves, and gears. It has a tensile strength of 32,000 to 45,000 lb. per sq. in., an elongation of 15 to 30%, with reduction of area of 12 to 25%. The specific gravity is 8.7, weight 0.315 lb. per cu. in., Brinell hardness 65 to 74. This alloy is the same as the G bronze of the U.S. Navy. In England it is called Admiralty gunmetal, and is specified as B.E.S. No. 383 for sand castings. Gunmetal ingot, marketed by H. Kramer & Co., may have the zinc replaced by 2% of lead. Such an alloy is easier to machine but has less strength. Modified gunmetal contains lead in addition to the zinc. It is used for gears and for bearings. A typical modified gunmetal by William H. Barr, Inc., contains 86% of copper, 9.5 tin, 2.5 lead, and 2 zinc. It has a tensile strength up to 40,000 lb. per sq. in., elongation 15 to 25%, Brinell hardness 63 to 72, and weight 0.31 lb. per sq. in. Federal specifications for Leaded gunmetal call for up to 1% of lead and 1 nickel.

**Gunpowder.** Also known as Black powder. An explosive extensively used for blasting purposes and for fireworks. It was introduced into Europe prier to 1250, and was the only propellant

used in guns until 1870. It is now superseded for military uses by high explosives. Black powder also has the disadvantage of deteriorating in the air or moisture. Gunpowder is a mechanical mixture of potassium nitrate, charcoal, and sulphur, in the proportions of 75, 15, and 10. More saltpeter increases the rate of burning; additional charcoal decreases the rate. A slow-burning powder for fireworks rockets may have only 54% of saltpeter and 32 charcoal. Commercial black powder comes in grains of graded sizes and is glazed with graphite. The grain sizes are known as pebble powder, large-grain, fine-grain, sporting powder, mining powder, Spanish spherical powder, and cocoa powder. The potential energy of gunpowder is estimated at 500 ft.-tons per lb., but the actual gun efficiency is less than 10% of this. A temperature of about 2100°C. is produced by the explosion. Gunpowder is the slowest acting of all the explosives, and has a heaving, not a shattering effect. Hence, it is effective for blasting and breaking up stone. Blasting powder is divided by duPont into two grades: A and B. The A powder contains saltpeter; the B powder contains nitrate of soda. The other ingredients are the usual sulphur and charcoal. B powder is not so strong or water-resistant as A powder, but is cheaper and is extensively used. Pellet powder is blasting powder made up in cylindrical cartridges for easier use in mining. White gunpowder is a powder in which the saltpeter is replaced by potassium chlorate. It is very sensitive and explodes with violence. It is used only for percussion caps and for fireworks.

**Gurjun balsam.** Also known as Wood oil, and sometimes called East Indian copaiba. An oleoresin obtained from various species of the *Dipterocarpus* tree, about 50 varieties of which grow in India, Burma, Ceylon, and the Malay Peninsula. It is a clear liquid with a greenish fluorescence. The specific gravity is 0.955 to 0.965. It is soluble in benzene. Gurjun balsam is used in lacquers and varnishes that are capable of resisting elevated temperatures. The Burmese trees form two groups yielding products known as Kanyin and In. Kanyin oils are brown in color, while the In oils are whitish and heavier. Gurjun balsam may consist of either or both of these products. Commercial Gurjun oil is obtained by steam distillation of the balsam, and has a specific gravity of 0.900 to 0.930. It is

soluble in alcohol. Copaiba balsam is a resin obtained from the Copaifera tree, a species of *Dipterocarpus*, of South America. Maracaibo copaiba and Para copaiba are the principal varieties. They are dark yellow or brown in color, and are soluble in alcohol. The resin is used as a plasticizer, in varnishes, tracing paper, and in pharmacy. The specific gravity in 0.940 to 0.990.

**Gutta percha.** A gum obtained by boiling the sap of species of trees of the order *Sapotaceae*, chiefly *Palaquium gutta* and *P. oblongifolia*, native to Borneo, New Guinea, and Malaya. It is grayish white, very pliable, but not elastic like rubber. It is harder and a better insulator than rubber. Gutta percha, like rubber, will vulcanize with sulphur and form a hard material. It is used for mixing with rubber, but its chief use is in the covering of electric cables. It has a greater pliability than rubber for the given hardness required in cable insulation. This property with its greater resistance to water makes it valuable for golf balls and dental fillings. It molds easily at 180°F. It is also employed like balata for impregnating driving belts, and for washers and valve seats, and in adhesives. Gutta percha is often imported as mixtures with inferior guttas from other trees. Gutta soh, for example, is a mixture from Singapore often colored red artificially. Gutta siak is a low-grade gutta from Sumatra. It has a reddish color, and is slightly elastic. Gutta sundik is from the tree *Payena leerii* of Malaya and the East Indies. It is white in color, and is mixed with gutta percha. Another gutta used to adulterate gutta-percha is Gutta hangkang, from the *Palaquium leiocarpum* of Borneo. It is slightly reddish. Gutta jangkar is a low-grade red gutta from Sarawak. Gutta susu of the East Indies is a gray-colored material slightly elastic.

**Gypsum.** A widely distributed mineral which is a hydrated Calcium sulphate, $CaSO_4 \cdot 2H_2O$, used for making building plaster, wallboard, tiles, as an absorbent for chemicals, as a paint pigment and extender, and for coating papers. In Germany it was used for producing sulphuric acid. Compact massive types of the mineral are used as building stones. The color is naturally white, but may be colored by impurities to gray, brown, or red. The specific gravity is 2.28 to 2.33, and the hardness 1.5 to 2. It dehydrates when heated to about 190°C., forming the hemihydrate $2CaSO_4 \cdot H_2O$,

which is the basic of most gypsum plasters. It is called Calcined gypsum, or when used for making ornaments or casts is called Plaster of paris. When mixed with water, it again forms the hydrated sulphate that will solidify and set firmly owing to interlocking crystallization. Theoretically, 18% of water is needed for mixing, but actually more is necessary. Insufficient water causes cracking.

Calcium sulphate without any water of crystallization is used for paper filler under the name of Pearl filler. It is not as white as the hydrated calcium sulphate, which, when used for fine writing papers, is called Crown filler. The paint pigment known as Satin spar is calcium sulphate finely ground and having a satiny luster. It is distinct from the pigment called Satin white, which is made by the precipitation of aluminum sulphate with lime and contains calcium sulphate, aluminum hydroxide, and some lime. Terra alba is an old name for ground gypsum as a paint filler. The anhydrous calcium sulphate in powder and granular forms will absorb 12 to 14% of its weight of water, and is used as a drying agent for gases and chemicals. It can then be regenerated for reuse by heating. Drierite, of the W. A. Hammond Drierite Co., is this material. Much calcined gypsum, or plaster of paris, is used as Gypsum plaster for wall finish. For such use it may be mixed in lime water or glue water, and with sand. Because of its solubility in water it cannot be used for outside work. Neat plaster, for walls, is the plaster without sand. When the term Plaster alone is used, it generally refers to gypsum plasters, but the Calcium plaster made from spent fuller's earth has greater workability and better water resistance than gypsum plaster.

Plaster board, or Gypsum wallboard, consists of sheets or slabs of gypsum mixed with up to 15% of fibers, employed as a fire-resistant material for walls, ceilings, or partitions. Standard specifications for gypsum boards call for thicknesses of ¼, 5/16, ⅜, and ½ in., with usual surface dimensions of 24 by 32 in. The weight of gypsum board ¼ in. thick is 1.2 lb. per sq. ft. Macoustic, of the National Gypsum Co., is a lightweight gypsum acoustical plaster. Grain board is a fireproof gypsum board with an imitation woodgrain surface used for walls. The hard-finish plasters for Flooring plaster may contain alum or other materials. Scott's cement is a

plaster made by grinding lime with calcined gypsum. It sets rapidly. Mack's cement is a hard cement made of dehydrated gypsum to which is added a small percentage of calcined sodium sulphate and potassium sulphate. It sets quickly and has good adhesion. It is used for walls and ceilings, and for floors when mixed with sand. Patterns and molds of plaster of paris have their strength raised and are made water-resistant by impregnating the dried and hardened plaster with a synthetic resin, particularly the furane resins which cure at low temperatures without pressure. The ordinary casting plaster of 100 parts solids and 60 parts water, called Hydrocal, is slightly acid, and must be treated with an acid-catalyzing resin, while the low-expansion plaster of 100 parts solids and 45 water, called Hydrostone, is alkaline and is treated with alkaline-catalyzed resin. Impregnation of plaster-of-paris castings with resin raises the compressive strength from 2,000 up to 9,000 lb. per sq. in., and the flexural strength from 700 to 3,500 lb. per sq. in.

A crystalline variety of gypsum, known as Selenite, occurs in transparent crystals and usually splits in thin laminations. A fine-grained, marblelike variety, called Alabaster, is employed in ornamental building work, and for lamps, vases, and novelties. Much alabaster is produced in Colorado. Travertine, which resembles alabaster but is grained like wood, is a water-deposited calcium carbonate. The Italian travertine is notable as a decorative building stone, but is also found in Georgia, Montana, and California.

**Hafnium.** An elementary metal, symbol Hf. It is present in the earth in about the same amount as copper, but has as yet no commercial application. The atomic weight is 178.6. All zirconium minerals contain several per cent of hafnium, but it is so similar chemically and so difficult to separate the two metals that all zirconium chemicals and alloys may contain some of it.

**Hair.** The fibrous covering of the skins of various animals, used for making coarse fabrics and for stuffing purposes. It is distinguished from wool in having no epidermal scales. It cannot be spun readily, although certain hairs, such as camel hair, are noted for great softness and can be made into fine fabrics. Horsehair is from the manes and tails, and is used as a brush fiber and for mak-

ing haircloth. It is largely imported from China and Argentina, cleaned and sorted. The imported hair from live animals is more resilient than domestic hair from dead animals. Brush hair is usually cut 3 to 5½ in. long, but tail hair for making Curled hair for weaving comes in lengths up to 30 in. Cattle hair is taken from slaughtered animals in packing plants. The body hair is used as a binder in plaster and cements, for hair felt, and for stuffing. The tail hair is used for upholstery, filter cloth, and stuffing. The Ear hair is used for brushes.

Artificial horsehair, or Monofil, is a single-filament cellulose-acetate fiber. It is used for braids, laces, hair nets, rugs, and pile fabrics. Crinex is a German artificial horsehair made of cuproammonium filament and used as a brush fiber. Rabbit hair does not felt, but is used in mixtures in felt hats. Angora rabbit hair, from France and England, is a soft woollike hair which dyes easily and is mixed in some woolens to give a soft feel. When the rabbit hairs are used for hats, they are called Rabbit fur. Haircloth is a stiff, wiry fabric with a cotton or linen warp and a filling of horsehair. It is elastic and firm, and is used as a stiffening and interlining material. The colors are black, gray, and white. The fabric is difficult to weave and disintegrates easily, as the hairs cannot be made into a single strand and must be woven separately. Press cloth, used for filtering oils, is made from human hair, which has high tensile strength, resiliency, and resistance to heat. The hair comes from China, usually 6 in. long. Camel hair is sometimes substituted for this use, or synthetic resin filaments are used.

**Heat insulators.** Materials employed for retarding the passage of heat. All substances offer some resistance to the passage of heat, but the term refers to materials having high resistance to heat rays, or low conductivity. Heat insulators may be such materials as felt, fiberboard, cork, or mineral wool, used for insulating partitions in buildings, and their efficiency may partly depend upon dead-air spaces or cellular construction. High-heat insulators, for insulating boilers or furnaces, may be highly refractory substances such as chromite, magnesia, fireclay, or asbestos. Hot pipe lines are usually insulated with 85% magnesia block and asbestos cement. Cold lines usually have a hair-felt covering finished with asbestos cement

or asphalted felt. Metals that are good conductors of heat will act as heat insulators to reflect back the radiant heat waves, which are normally about 95% of the total heat loss. These are called Reflective insulators. Crumpled aluminum foil is used in this way as a wall insulator.

Ferro-Therm, of the American Flange & Mfg. Co., Inc., is a steel sheet, 0.006 in. thick, coated with a white-metal alloy, used for house and refrigerator insulation. Ludlite board, of the Allegheny Ludlum Steel Co., is a panel having thin stainless steel backed with a fireproof composition of cement, magnesite, and asbestos fibers. Insulite is a wood-fiber insulating board made by the Insulite Co. Asbestos sheathing, felt pads, and special fiberboards are often marketed under trade names. Roofinsul is a lightweight insulation board composed of wood fibers compressed into board form, marketed by Johns-Manville for roof decks. Ceilinite, of the same company, is an asbestos felt reinforced on one side with asbestos cloth, made in thicknesses from $\frac{3}{32}$ to $\frac{1}{4}$ in. and used for interlining in steel cars and for fireproofing electrical switch boxes. Isotela is a French insulation for cold storage walls consisting of pads of matted coir. Dry-Zero, of the Dry-Zero Co., consists of carded kapok batts encased in fiberboard for use in refrigerated cabinets. Balsam wool, of the Wood Conversion Co., is an insulating material consisting of wood fibers chemically treated and cemented together into fleecy wool form.

A lightweight cellular glass for use as an insulator in cold-storage chambers to replace cork, magnesia, or diatomite, is Foamglas of the Pittsburgh-Corning Corp. It is a glass expanded or cellulated by the evolution of gas while in a molten condition. It is a mass of tiny sealed air chambers, about 3,000 per cu. in., and has low heat conductivity, 45 B.t.u. per hr. per sq. ft. per deg. F. per in. The strength and rigidity are greater than that of cork, and it will withstand temperatures up to 1000°F. The crushing strength of the blocks is 150 lb. per sq. in. Alumino-Hi-Temp, of the Philip Carey Co., is alumina reinforced with asbestos fibers, made in the form of blocks and bricks. Fibrox is a patented soft fibrous material used as a heat-insulating filler. It is a Silicon oxycarbide, SiCO, prepared by diffusing carbon monoxide and carbon dioxide through molten silicon. The fibers are light and fluffy.

**Heat-resistant alloys.** Nickel-chromium-iron alloys containing usually from 5 to 80% of nickel, 13 to 25 chromium, and the balance iron, which will not scale when exposed to high temperatures. Some of the alloys may contain only nickel and chromium, but more frequently all three metals are used, and some of the alloys may also contain aluminum, silicon, or other elements. They are used for heat-treating boxes, furnace parts, and machine parts exposed to high heats. The alloys will also resist oxidation and the action of many acids, and are used for chemical equipment. Cromax, of the Driver-Harris Co., contains 35% of nickel, 15 chromium, and the balance iron. It has a tensile strength of 60,000 lb. per sq. in. It is used for temperatures up to 1900°F. Veriloy, of the same company, is a grade of nickel-chromium alloy for medium temperatures. Nichrome, of this company, is the trade name of a group of alloys for various uses. The standard grade for castings contains 67% of nickel, 16 chromium, 12 iron, and 1 manganese. It has a tensile strength of 64,000 lb. per sq. in. at 20°C. and of 30,000 lb. per sq. in. at 800°C., and will resist oxidation up to 1800°F. for long periods. Such an alloy is tough but will machine readily. Q-Alloy, of the General Alloys Co., is the name of a large group of nickel-chromium-iron heat-resistant and chemical-resistant alloys of various grades. X-ite, of this company, contains 37 to 39% of nickel and 17 to 19 chromium, and is used for carburizing boxes. Duraloy A, of the Duraloy Co., is a chromium-iron alloy with 27 to 30% of chromium, used for hot-oil resistant castings. Calite, of the Calorizing Co., is the name of a series of high-chromium and high-nickel alloys.

Amsco alloy is a series of nickel-chromium and nickel-chromium-iron alloys of the American Manganese Steel Co. Mackenite metal is a similar series of the Duncan Mackenzie Sons Co. Cyclops No. 17, of the Cyclops Steel Co., contains 20% of nickel, 8 chromium, 0.75 manganese, 1.5 silicon, and 0.45 carbon. At a temperature of 1200°F. it has a tensile strength of 75,000 lb. per sq. in. For high load-carrying ability at high temperatures as much as 30% of chromium is used. Lebanon No. 48 contains 30% of chromium, 30 nickel, 0.40 carbon, and the balance iron. Allegheny 55, of the Allegheny Steel Co., has 23 to 30% of chromium, 1 manganese,

and 0.25 carbon. Castings have a tensile strength of 80,000 lb. per sq. in. Nichroloy, of the Hiram Walker & Sons Co., contains 23% of nickel, 20 chromium, 1 manganese, 1 vanadium, and 0.50 aluminum. It will withstand continuous temperatures up to 2000°F. Zorite, of the Michigan Products Corp., contains 35% nickel, 15 chromium, 1.75 manganese, and 0.50 carbon. The alloys with manganese have low coefficients of expansion.

Firearmor is the name of the Michigan Products Corp. for heat-resistant alloys. A typical grade contains 60% of nickel, 20 chromium, 1.75 manganese, and 0.50 carbon. Fahralloy, of the Southern Manganese Steel Co., is the name of chromium-nickel-iron alloys in various grades to withstand temperatures up to 2200°F. Fahrite, of the Ohio Steel Foundry Co., and Hybnickel, of the Pusey & Jones Corp., are heat-resistant alloys in various grades. A heat-resisting alloy containing silicon is Pyrasteel, of the Chicago Steel Foundry Co. It has 25% of nickel, 14 chromium, and 2.5 to 3 silicon, and will withstand temperatures up to 2000°F. Acipco steel, of the American Cast Iron Pipe Co., is a series of high-alloy heat-resistant steels cast centrifugally into 16-ft. tubes of standard sizes for chemical plants, K42B alloy, of the Westinghouse Electric Corp., is a chromium-nickel-cobalt alloy with high strength and creep resistance at high temperatures. At red heat, 1350°F., it is stronger than ordinary carbon steel at normal room temperature.

Chromium-silicon steels of higher chromium and silicon contents are in the class of heat-resistant alloys, and are used for valves for internal-combustion engines. Delhi A, produced by the Associated Alloy Steel Co., Inc., contains 17 to 19% of chromium, 0.75 silicon, and 0.1 carbon. Delhi hard contains higher carbon, up to 1.1%. Silcrome RA, of the Allegheny Ludlum Steel Co., has 16% chromium, 1 silicon, 1 copper, and 0.12 carbon. It is corrosion-resistant, ductile, and has a tensile strength up to 110,000 lb. per sq. in., and elongation of 25%. Elcomet, of the La Bour Co., Inc., is a chromium-nickel-silicon-iron alloy for valves. Delhi rustless iron, of the Allegheny Ludlum Steel Co., contains 18% of chromium, 1.5 silicon, and 0.08 carbon. It will withstand temperatures to 1600°F. without scaling, and has a tensile strength up to 110,000 lb. per sq. in. Tungsten and aluminum iron heat-resisting alloys are also used

for engine valves. Clebrium was an old alloy containing 13% of chromium, 3.5 molybdenum, 2 nickel, 1.5 silicon, and 0.75 manganese.

**Heat-resistant glass.** Glass that will withstand high temperatures, or rapid changes of temperature, without shattering. It is usually a borosilicate glass which is heat-treated and leached in an acid bath, leaving a porous high-silica material that can be fired to a solid mass, 96% pure silica. The best heat-resistant glasses can be used at temperatures up to 1000°C., and can be plunged into cold water from a red heat without injury. Such glasses are used for chemical equipment and for cooking utensils. Pyrex, of the Corning Glass Co., used for cooking utensils, will withstand temperatures up to 1100°F., and is also shock resistant. The specific gravity is 2.25, hardness 120 Scleroscope, and refractive index 1.4754. It has a light transmission higher than that of plate glass. Vicor No. 792, of the same company, is a 96% silica glass of white translucent color which can be made into large and complicated shapes, will withstand temperatures up to 1800°F., and has high thermal shock resistance. It is resistant to mild alkalies and to all acids except hydrofluoric. Vicor glass is used to replace nickel-chromium alloys for parts for electrical and chemical equipment. Duran glass, a German product, is used for hot chemical tubes and pipes. In general, the heat-resistant glasses contain $B_2O_3$ and a small amount of alumina, with the smallest possible amount of alkali.

**Heavy alloy.** A name applied to Tungsten-nickel alloy produced by pressing and sintering the metallic powders. It is used for screens for X-ray tubes and radioactivity units, for contact surfaces for circuit breakers, and for balances for high-speed machinery. The original composition was 90% tungsten and 10 nickel, but a proportion of copper is used to give a lower sintering temperature and to give better binding as the copper wets the tungsten. Too large a proportion of copper makes the product porous. An alloy of 90% of tungsten, 7.5 nickel, and 2.5 copper has a tensile strength of 90,000 lb. per sq. in., elongation of 4%, Brinell hardness of 250 to 290, and a specific gravity of 16.3 to 17. It is resistant to corrosion, and can be machined.

**Helium.** A colorless, odorless, elementary gas of extreme lightness, symbol He. The specific gravity is 0.1368, and liquefying point −269°C. The lifting power is only 92% that of hydrogen, but it is preferred for balloons because of its noninflammable character. It is also chemically inert. It is used for lighter-than-air aircraft and for weather-station balloons for radiosonde observations. It is employed in radio tubes and electric lamps because of its high heat conductivity which is six times that of air. For use in advertising signs it gives a pinkish-violet light when an electric current is passed through it. It is also used to inflate the large tires of cargo planes, saving about 150 lb. in weight of plane compared to air inflation. Commercial helium of 98% purity is used for gas-shielding electric welding on magnesium alloys to prevent oxidation. In medicine it is used in the treatment of asthma and respiratory diseases. Helium can be obtained from atmospheric nitrogen, but comes chiefly from natural gas, the gas of Texas yielding 0.94%. It also occurs in the mineral Cleveite where it was first discovered in 1895. Helium is always associated with radioactive materials, and the alpha rays are helium nuclei. It has a valency of zero and forms no known compounds, but the atomic nucleus of helium is supposed to be a constituent of all other elements.

**Hemlock.** The wood of the coniferous tree *Tsuga mertensiana,* of Northeastern United States. This species is also called Mountain hemlock, and is now scarce. Eastern hemlock, *Tsuga canadensis,* was formerly a tree common from eastern Canada to northern Alabama. In the southern area it is called Spruce pine, and in the northern area Hemlock spruce. The wood is coarse with an uneven texture, splintering easily. The trees are up to 80 ft. in height and up to 3 ft. in diameter. It is used for paper pulp, boxes and crates, and for inferior lumber. Western hemlock, *T. heterophylla,* is a wood produced in abundance from Alaska to northern California. It is known also as West Coast hemlock, Hemlock spruce, Prince Albert fir, Gray fir, Alaskan pine, and Western hemlock fir. Trees 100 years old are about 20 in. in diameter and 140 ft. high. The stand of the tree is estimated at more than 140 billion bd. ft. in the United States, of which 85 billion is in Washington and Oregon. The wood is light in color, with a pinkish tinge, light in weight,

moderately soft, and straight-grained. It is nonresinous and is free from resin ducts, but black knots are frequent. The select grades of the lumber are free from knots and suitable for natural and paint finishes. The wood is used for general construction, boxes, woodenware, and pulpwood. The lumber often comes mixed with Douglas fir. It is easy to work but does not plane smooth like pine. It has frequent dark streaks from heart rot, common in old trees. Hemlock-bark extract is obtained from the bark of the eastern hemlock, and is an important tanning material. Western hemlock bark is not in general use for tanning, but the bark contains 22% of tannin.

Hemp. A fiber from the stalk of the plant *Cannabis sativa,* valued chiefly for cordage, sacking, packings, and as a fiber for plastic filler. In normal times it is grown principally in southern Russia, central Europe, the Mediterranean countries and in Asia, but during the war was extensively cultivated in the United States. The fiber, which is obtained by retting, is longer than that of the flax plant, up to 75 in., but is coarser and not suitable for fine fabrics, although the finest and whitest fibers are sorted out in Europe and used in linen fabrics. It is also more difficult to separate the fiber and to bleach. It is stronger, more glossy, and more durable than cotton, and has been used for toweling and coarse fabrics to replace the heavy linen fabrics. Hemp rope was once the chief marine cordage, but it has been replaced largely by rope of abaca which is lighter and more water-resistant. Hemp contains a toxic alkaloid, and in India the stalks are chewed for the narcotic effect. The dried flowering tops, known in medicine as Cannabis, are called Marijuana when smoked in cigarettes. The material is shipped from Arabia under the name of Hashish, and from India as Ganja. Cannabis is used in medicine as a depressive antidote, but in excess the drug causes hallucinations. Hempseed oil, used in paints and varnishes, is made by pressing the seeds of the hemp plant. It has a specific gravity of 0.926, iodine value of 148.

Herring oil. A fish oil obtained by extraction from several species of fish of the herring family, *Clupeidae.* The Sardine is the smaller fish of this family. The Norwegian herring, *Clupea harengus,* or Sea herring, is the sardine of Maine, eastern Canada,

and the North Sea. In California and western Canada the sardine is a much larger fish, the Pilchard, *Sardinia coerulea.* The pilchard, or California sardine, constitutes about 25% by weight of the entire fish catch of the United States and Alaska. In France, Spain, and Portugal the European pilchard, *C. pilchardus,* and the *C. sardinus,* are used. The oil from the latter has a high iodine value. In Norway, the Sprat, *C. sprattus,* is also used. The Japanese herring is the *C. pallasi.* Herring oil, or Sardine oil, is employed as a quenching oil in heat-treating, either alone or mixed with other oils, in soaps, printing inks, lubricants, and for finishing leather. It is also fractionated to use in blends for paint oils. The oil contains a high percentage of palmitic acid and also linoleic and oleic acids. The specific gravity is 0.920 to 0.933, iodine value 130 to 180, and saponification value 179 to 194. Herring oil is made clear and odorless by hydrogenation. Most of the sardine oil is a by-product made from the refuse of the canning industry.

**Hexamine.** A white, crystalline powder used chiefly for the manufacture of synthetic resins in place of formalin and its sodium-hydroxide catalyst. It is formed by the action of formaldehyde and ammonia. It is hexa-methylene-tetramine, having the formula $(CH_2)_6N_4$, melting at 263°C., and is very stable when dry. It is readily soluble in water and in alcohol. It is also known as Formin, Crystogen, Aminoform, and Cystamine. In pharmacy it is called Methenamine. In the presence of an acid it yields formaldehyde and is used in medicine as an internal antiseptic. It is also used as an accelerator for rubber. Condensite, a molding resin of the Continental-Diamond Fibre Co., is a reaction product of phenol and hexamine.

**Hickory.** The wood of the Shagbark hickory tree, *Hicoria ovata,* and other species of the walnut order. It is prized as a wood for ax, pick, and other tool handles, and also for wheel spokes, carriage shafts, and golf clubs. The color of the thick sapwood is white, and the heartwood is reddish brown. It has a fine, even, and straight grain, and is tough and elastic, having 30% greater strength than white oak and twice the shock resistance, although not as durable. The weight is 45 to 52 lb. per cu. ft. The chief producing states are Arkansas, Louisiana, Mississippi, Tennessee,

and Kentucky, but the trees grow from New Hampshire to Texas. A mature shagbark tree 200 to 300 years old averages 100 ft. high and over 2 ft. in diameter. For handle manufacture the white wood and the red wood are considered equal in physical properties, and both possess the smooth feel required for handles. The average specific gravity when kiln-dried is 0.79, compressive strength perpendicular to the grain 3,100 lb. per sq. in., and shearing strength parallel to the grain 1,440 lb. per sq. in. There are more than 30 species of hickory, including the pecan trees. Besides the *H. ovata* three other species are important for the commercial wood: the Shellbark hickory, *H. laciniosa,* also called Kingnut; the Pignut hickory, *H. glabra,* also called Black hickory and Bitternut; and the Mackernut hickory, *H. alba,* also called Ballnut, Hognut, and White hickory. The kernels of the nuts of all species are edible, although some are bitter and astringent. The pecan hickories include the Pecan, *H. pecan,* the Water hickory, *H. aquatica,* and Nutmeg hickory, *H. myristicaeformis.*

**Hides.** A commercial name generally signifying the skins of full-grown beef cattle. Kip skins and Calfskins are the names given to the hides of the younger animals. Calfskins, from animals that have not eaten grass, produce a softer leather than Cattle hides. Hides of other animals besides the beef cattle, *Bos taurus,* are usually designated with the name of the animal, as Horsehide. The hides of smaller animals are designated as Skins, either tanned or untanned, as Pigskin. Quantities of wild pigskins, known as Capivara skins, are imported from Colombia. Cattle hides are shipped in immense quantities from India, Argentina, Uruguay, and other pastoral countries, for making into leather. They are shipped either dried or salted, and are distinguished by numerous grades, depending upon the class of animal, weight, method of skinning, and the preparation. Packing-house hides, well skinned, and packed in brine, are the best. The poorest grade is the country hides, taken off by inept knives and dried in the sun. The texture of the steer hides is more uniform than cow or bull hides, and the area is greater, permitting more economic cutting. Buffalo hides are from the domesticated Water buffalo of southern Asia and the Philippines. They are heavy, with a coarse grain, and are used to make a

heavy, rough leather for buffing wheels and heavy boots, and also for Rawhide mallets and gears. Rawhide is a treated but untanned form of leather. About 45% of the cattle hides used in the United States go into sole leather, 43% into shoe uppers, and 4% into belting and luggage.

**High brass.** Sometimes called Common brass, and formerly known as Market brass. The most common of all the commercial wrought brasses. The usual mill standard is 65% of copper and 35 zinc, and grades containing from 66 to 70% of copper are referred to as Deep-drawing brass. High brass is marketed in sheets, rolls, and strips, and is used largely for drawing, forming, and spinning. In the hard tempers it is used for parts made by blanking, forming, and bending. It is a cold-working material and is not suitable for hot working. The 65-35 brass marketed by the American Brass Co. under the name of Yellow brass has a tensile strength of 45,000 lb. per sq. in. and elongation of 60% when soft, and a strength of 76,000 lb. per sq. in. and elongation of 5% when hard-rolled. The weight is 0.306 lb. per cu. in., melting point 930°C., and coefficient of expansion 0.0000106. Bar stock of high brass, for turned parts, called High-brass bar, invariably contains some lead, up to about 3%, as the unleaded brass is tough and the turned chips do not break easily.

The alloy listed in Federal specifications as Commercial brass for wrought shapes actually covers the brasses from muntz metal to high brass, and is leaded. It contains 60 to 65% of copper, with lead permissible up to 3.75%. The government specifications for commercial brass for castings are equally broad. Butt brass, for hinges, has 64% of copper, 35 zinc, and 1 lead. The term Etching brass refers to the temper rather than to the composition. It is a high brass sheet in quarter-hard or half-hard temper used for name plates and dials. Bobierre's metal is an old name for 63-37 high brass. This alloy is called in England Basis brass, and is B.E.S. No. 265. Bristol brass and Prince's metal are old names for high brass. Spring brass is usually a high brass with 66 to 72% of copper rolled 8 numbers hard. The tensile strength, hard-rolled, is about 68,000 lb. per sq. in., and elongation 11%; spring wire may be 100,000 lb. per sq. in. S.A.E. specifications require that a spring wire be

capable of bending 180 deg. around a wire of its own diameter without cracking. Spring bronze is usually a high brass with a small amount of tin to add hardness. Pin metal, for common pins, has 62% of copper and 38 zinc, and is not annealed from the working.

**High-lead bronze.** Bronze alloys containing high percentages of lead to give a soft matrix metal for bearing use, as distinct from bronzes containing small amounts of lead to make them free machining. The first high-lead bronze was invented in England in 1870 under the name of Dick's bronze, and was used on British railways. In 1892 C. B. Dudley in the United States produced ExB metal containing 77% of copper, 15 lead, and 8 tin. It is still used as a car bearing metal and called Car brass. A common type of Leaded bronze used for bearings is the 80-10-10 mixture, and this alloy is also known as Ordnance bronze. It has a Brinell hardness of 58, a tensile strength of 30,000 lb. per sq. in., and when deoxidized with phosphorus has a dense structure. Lead does not alloy well with copper unless a catalyzer is present, the copper absorbing only about 3.5% of lead. It also tends to sweat out at a temperature of 327°C. High-lead bronze is now invariably deoxidized with phosphorus, or contains small amounts of nickel, arsenic, or some other element to aid in holding up the lead.

The alloys containing tin are true bronzes, and are not as difficult to cast as the copper-lead alloys. Some lead bronzes also contain antimony, which gives them a good crystalline structure useful for bearings. They are easy to cast. Retz alloy and Reith alloy contained about 75% of copper, 10 each of tin and lead, and 5 antimony. Cyprus bronze contained 65% of copper, 30 lead, and 5 tin. Allen red metal is a copper-lead alloy with 50% of lead and a small amount of sulphur to hold the lead in solution. Allen's metal was an early alloy containing 40% of lead, 55 copper, and 5 tin. Part of the lead was put in in the form of galena ore or lead sulphide. Johnson bronze No. 25, used for high-speed bearings, contains 75% of copper, 19 lead, 5 tin, and 1 nickel. High-lead bronzes are resistant to acids and, when used for casting chemical machine parts, are called Anti-acid bronze. The name Lead bronze

is used in England for an alloy of 75% of copper, 1 to 2 tin, and the balance lead.

A typical leaded bronze is alloy No. 6, of William H. Barr, Inc. It contains an average of 78% of copper, 8 tin, and 14 lead. The tensile strength is 28,000 to 32,000 lb. per sq. in., compressive strength up to 100,000 lb. per sq. in., and Brinell hardness 54 to 70. The weight is 0.335 lb. per cu. in. Johnson Alloy No. 29, of the Johnson Bronze Co., for electric-motor bearings, is the same as S.A.E. 67, and contains 78% of copper, 15 lead, and 7 tin. Lubrico, of the Buckeye Brass Mfg. Co., contains 75% of copper, 20 lead, and 5 tin. Sabeco metal, of the Fredericksen Co., has 21% of lead and 9 tin. Sumet bronze, of the Sumet Corp., is the trade name of a group of bearing bronzes in grades from the softest with 28% of lead and Brinell hardness of 30 to 33, to the hardest with 17.5% of lead and hardness of 58 to 62 Brinell. Arctic bronze, of the National Bearing Metals Corp., is the name of leaded bearing bronzes chill-cast in metal molds to give fine grain structure. Bearium, of the Bearium Metals Corp., refers to a group of high-lead bronzes containing 17.5 to 28% of lead and about 10 of tin. The softest grade, with a hardness of 35 Brinell, has a compressive limit of 7,800 lb. per sq. in. Durbar bronze, of the Buffalo Die Casting Corp., has 24% of lead and 4 tin. Durbar hard bronze has 10% of tin and 20 lead. Monarch metal, of the Monarch Alloy Co., is a high-lead bearing bronze in various compositions. It is melted in sealed crucibles and water-cooled in pouring, resulting in a fine dispersion of the lead. Tri-Alloy, of the Ford Motor Co., is a high-lead alloy for crankshaft bearings for heavy loads and high speeds. It contains 35 to 40% of lead, 4.5 to 5% silver, and the balance copper. The alloy is cast on strip steel and formed into bearings. Copper-lead alloys are now made also by sintering together copper powder and copperplated lead powder. They can thus be made in any proportion of lead.

**High-speed steel.** A general name for high-alloy steels which retain their hardness at very high temperatures and are used for metal-cutting tools. They are now divided into three general classes. The tungsten steels form the oldest class and are an outgrowth of the older mushet steels. The Mushet steel, or Air-harden-

ing steel, was invented in England in 1868. It contained 5 to 8% tungsten, 2.5% manganese, 1.5 silicon, and very high carbon. From 1893 to 1898 F. W. Taylor experimented with cutting tools made with a substitution of chromium for the high manganese and with less carbon, and the Taylor-White steel marketed in 1900 contained 8% of tungsten, 1.8 chromium, 1.15 carbon, 0.18 manganese, and 0.25 silicon. In 1900 the Bethlehem Steel Co. brought out the tungsten-chromium-vanadium steel now known as the 18-4-1.

The tungsten steels are divided into two general grades according to tungsten content, with 18 and 14% of tungsten, respectively. The Super high-speed steels, or Cobalt steels, are high in tungsten but contain considerable quantities of cobalt. They have added red-hardness but are inclined to be brittle. The third class of Molybdenum high-speed steels are an outgrowth of an early attempt by the U.S. Ordnance Dept. to substitute molybdenum for the imported metal tungsten. The first molybdenum steel was the Mo. S. H., or Self-hardening steel, of the Sanderson Steel Co., marketed in 1898. The first Watertown Arsenal steel contained about 9.5% of molybdenum, 4 chromium, 1.25 to 2 tungsten, 0.90 to 1.5 vanadium, 0.80 carbon, 0.20 to 0.40 manganese, and 0.25 to 0.50 silicon. Molybdenum has a more pronounced effect than tungsten in a ratio of 2 to 1, but it makes the steel more brittle and also makes it subject to decarburization. The standard tungsten steels are therefore sometimes modified with very small amounts of molybdenum. ML steel, of the Allegheny Ludlum Steel Co., has 18% of tungsten, 4 chromium, 1.85 vanadium, and 0.50 molybdenum. It gives a keener edge than the standard 18% tungsten steel.

The standard for tungsten high-speed steels is the 18-4-1 containing 18% of tungsten, 4 chromium, and 1 vanadium. This steel gives a balance of red-hardness, toughness, and cutting edge; in England preference is for the 14-4-2, which gives higher hardness and resistance to wear. Tungsten adds red-hardness to steel; chromium gives deep hardening and increases toughness; and vanadium gives hardness and improves the ability to keep an edge. Cobalt gives added red-hardness, but the steels are more difficult to forge and are more brittle. The property of red-hardness is described as the ability of the steel to retain the hard carbides up to a tempera-

ture of about 1750°F. The cobalt alloys that have this property but contain little or no iron are not classed as high-speed steel.

High-speed steels are marketed in rods, bars, flats, and tool shapes. They are sold under many trade names, such as Supremus and Jessco, of the Jessop Steel Co.; Clarite, of the Columbia Tool Steel Co.; Rex, Champion, and Peerless, of the Crucible Steel Co.; Colonial, of the Colonial Steel Co.; Blue Chip, of the Firth-Sterling Steel Co.; Panther, of the Allegheny Ludlum Steel Co.; and Kutkwik, of Henry Disston & Sons, Inc. Electrite uranium is a special brand of Electrite steel of the Latrobe Electric Steel Co. containing some uranium, which is a more powerful deoxidizer and hardener than vanadium. Star-Zenith, of the Carpenter Steel Co., is an 18-4-1 steel with elements in slight excess of standards.

Motung steel, patented by the Cleveland Twist Drill Co., contains 7.5 to 8.5% of molybdenum, 1.25 to 2 tungsten, 3.5 to 4.5 chromium, 0.90 to 1.5 vanadium, 0.65 to 0.85 carbon, 0.20 to 0.40 manganese, and 0.25 to 0.50 silicon. It weighs less than the 18-4-1 steel. The name Mo-Tung is used by the Universal-Cyclops Steel Corp. for this steel. The lower carbon contents are tough, while those with higher carbon have great hardness. It forges and hardens at lower temperatures than 18-4-1 but must be carefully controlled in heat treating to prevent decarburization. Other trade names for the steel when manufactured by other companies are Mogul, Tatmo, Mo-Cut, Vul-Mo, Mohican, LMW, Rex T-Mo, HM steel, and Di-mol. Van Lom steel, of the Vanadium-Alloys Steel Co., has 8.25 to 10% of molybdenum, 3.75 to 4.75 chromium, 2 to 4.25 vanadium, and 0.75 to 1.2 carbon. Bethlehem 66 steel, of the Bethlehem Steel Co., is a low-tungsten steel that will heat-treat without decarburization. It contains 5 to 5.75% of tungsten, 4.5 to 5.5 molybdenum, 3.75 to 4.25 chromium, 1.4 to 1.75 vanadium, and 0.80 carbon.

Twin Mo steel is a 6-6-2 tungsten-molybdenum steel of H. Boker & Co., Inc. Speed star steel of the Carpenter Steel Co. contains 5.5% of tungsten, 4.25 molybdenum, 4 chromium, 1.5 vanadium, and 0.80 carbon. If hardened in a reducing atmosphere, it will produce a fine-grained steel with a surface hardness of Rockwell 65. It is a general-use high-speed steel. Circle C steel, of the Firth-Sterling Steel Co., contains 9% of cobalt, 18.5 tungsten, 1.75

vanadium, 1 molybdenum, and 0.77 carbon. Gray Cut Cobalt steel, of the Vanadium-Alloys Steel Co., has 20.5% of tungsten, 4.25 chromium, 1.3 vanadium, 12.25 cobalt, 0.60 molybdenum, and 0.80 carbon. Red Cut Cobalt, of this company, and Co-Co steel, of the Colonial Steel Co., are 18-4-1 steels with the addition of 4.5% of cobalt and a small amount of molybdenum. Imperial major, of A. Milne & Co., has 12 to 13% of cobalt and 22 tungsten. It has high wear resistance when cutting at red heats. Maxite, of the Columbia Tool Steel Co., is an 18-4-1 type modified with 4% cobalt. D-6Co steel of Henry Disston & Sons, Inc., contains 19% of tungsten, 6 cobalt, 2 vanadium, 4 chromium, and 0.80 carbon. It cuts hard steels at high speed, but is difficult to forge and requires care in heat-treatment to prevent decarburization. Rex AA steel, of the Crucible Steel Co., is an 18-4-1 steel, while Rex AAA is this steel with 5% of cobalt and 0.50 molybdenum. Rex 95 contains 14% of tungsten, 4 chromium, 2 vanadium, and 0.50 molybdenum.

Some of the molybdenum high-speed steels developed to conserve tungsten also contain cobalt. S.T.M. steel, of the Simonds Saw & Steel Co., contains 5.75 to 9.5% of molybdenum, 1 to 1.5 tungsten, 3 to 8 cobalt, 3.5 to 3.75 chromium, 0.75 to 2 vanadium, and 0.80 to 1 carbon. CN-6 steel of this company contains 6% each of tungsten and molybdenum, 4 chromium, 1 vanadium, 0.50 copper, and 0.80 carbon. It is tough and fatigue resistant and is used for saws, planer knives, and chisels. A steel containing no tungsten is Rex VM of the Crucible Steel Co. It contains 8% of molybdenum, 4 chromium, 2 vanadium, and 0.85 carbon. It is used for drills, taps, hack saws, and milling cutters. Amotun steel, of the Atlantic Steel Co., used for threading dies, taps, and countersinks, contains 0.85% of carbon, 4 chromium, 6 cobalt, 1.75 vanadium, 1.5 tungsten, and 8 molybdenum. DBL steel, of the Allegheny Ludlum Steel Corp., contains 0.80% of carbon, 5.25 tungsten, 4 chromium, 4 molybdenum, and 1.5 vanadium. Milvan steel, of A. Milne & Co., has 19% of tungsten, 4 chromium, and 2 vanadium.

**Holly.** The wood of the tree *Ilex aquifolium,* and several other species of *Ilex,* or holly tree, native to Europe, and the tree *I. opaca,* of Southeastern United States. It is valued as a wood for inlaying

because of its white color, its fine, close grain, and its ease of staining to imitate ebony. It is hard, and the weight is 47 lb. per cu. ft.

**Horn.** The excrescent growth, or horns, from the heads of certain animals, notably beef cattle. Horn is used for making handles and various articles. The quality depends largely upon the size and age of the animal from which it comes, the No. 1 grade being the large steer horns, and the No. 2 those below 40 lb. per hundred. Horns occur on the head in pairs and are hollow, growing on a core of pithy bone. The horns are split by saws, soaked to make them flexible, and then flattened under pressure. Horn meal, made from the bone refuse, is sold largely as fertilizer. Horn pith, extracted by boiling the horns, is used for glue and for gelatin.

**Hot-die steels.** A general name for alloy steels that will resist shock and retain their hardness when operating in forging machines at high temperature. When used in hot-heading machines, they are also called Hot-work steels. Two types of these steels are commonly employed: one being a chromium steel with 3 to 4% of chromium, or in another grade with about 8 to 10%; and the other type being a tungsten steel with 8 to 10% of tungsten. The molybdenum high-speed steels are also used for hot-die work, or the standard tool steels may be modified with molybdenum. The chromium steels are oil-hardening and develop a high hardness. They are deep hardening but will withstand shock. The tungsten steels have higher impact value, and are superior for severe service at high heats such as for hot punching or for brass extrusion, but they are more expensive. The chromium steels are used for dies for compressive action, as for header machines. The higher tungsten steels give full red-hardness, but they are not hard enough for cutting dies. Nickel and vanadium may also be added to hot-die steels, giving increased hardness and toughness. The self-hardening high-tungsten steels containing high manganese and carbon are not classed as hot-work steels.

Mohawk steel, of the Allegheny Ludlum Steel Co., is a hot-die steel both tungsten and chromium. It has 14% of tungsten, 3.5 chromium, 0.70 vanadium, and 0.50 carbon. Atlas steel, of this company, contains 9 to 11% of tungsten, 3.5 chromium, 0.45 vanadium, and 0.35 carbon. Crescent steel, of the Crucible Steel Co.,

has 3.75% of chromium and 0.95 carbon. Peerless A, of this company, has 9% of tungsten, 3.25 chromium, and 0.25 vanadium, and is used for die-casting dies, extrusion dies, and gripper dies. C.Y.W. steel, of the Firth-Sterling Steel Co., has 3.5% of chromium, 0.50 manganese, and 1 carbon. It is used for dies and tools for heavy pressures. D.Y.O. steel, of the Carpenter Steel Co., has 14.5% of tungsten, 4 chromium, and 0.50 vanadium. Excelo, of this company, has 2.5% of tungsten, 1.5 chromium, 0.35 vanadium, and 0.55 carbon. It is used for hot shears. T-K steel, of this company, used for tools that require high red-hardness and resistance to abrasion such as swaging dies, contains 9% of tungsten, 3.5 chromium, 0.40 vanadium, 0.30 silicon, 0.30 manganese, and 0.35 carbon. Vasco Marvel steel, of the Vanadium Alloys Steel Co., has 9.25% of tungsten, 3.5 chromium, and 0.45 vanadium. Vasco Extrude Die is a combination of the two types. It has 15.5% of tungsten, 3 molybdenum, 4 chromium, and 2 nickel.

The hot-die steel, or die block steel, produced by the Heppenstall Co. under the name of Hardtem, is a nickel-chromium steel with molybdenum and vanadium. Another die block steel of the same company is C55 steel. It is an oil-hardening steel containing 0.50% of carbon, 0.75 chromium, 1.25 nickel, and 0.30 silicon. Hot-work 8 steel, of the Bethlehem Steel Co., contains 8.5% of molybdenum and 1.5 vanadium. It is tough, shock-resistant, abrasion-resistant, and resists heat checking. E.H.W. steel is a tungsten hot-work steel of the Latrobe Electric Steel Co. Peerless steel, of the Crucible Steel Co., is in several grades of tungsten-chromium-vanadium. Such steels as Tungo, of the Colonial Steel Co., and Par-Exc, of the Vanadium Alloys Steel Co., with lower tungsten and chromium and some vanadium, are not high heat-resistant but are suitable for die-casting dies. Because of their resistance to shock they are used for hot upsetting dies.

**Hydrochloric acid.** Also called Muriatic acid, and originally called Spirits of salt. An inorganic acid used for pickling and cleaning metal parts, production of glues and gelatin from bones, manufacture of chlorine, pharmaceuticals, dyes, pyrotechnics, and for tanning, etching, reclaiming rubber, and treating oils and fats. It is a water solution of Hydrogen chloride, HCl, and is a colorless

or yellowish fuming liquid, with pungent, poisonous fumes. The specific gravity of the gas is 1.269, the solidifying point −112°C., and boiling point −83°C. It is made by the action of sulphuric acid on sodium chloride, or common salt. The commercial acid is usually 20°Bé., equaling 31.45% of HCl gas, and has a specific gravity of 1.16. Other grades are 18 and 22°Bé. Fuming hydrochloric acid has a specific gravity of 1.194, and contains about 37% of hydrogen chloride gas. Hydrochloric acid is shipped in glass carboys. Anhydrous hydrogen chloride gas is also marketed in steel cylinders under a pressure of 1,000 lb. per sq. in. for use as a catalyst. The boiling point is 85.03°C.

**Hydrocyanic acid.** Also called Prussic acid, Formonitrile, and Hydrogen cyanide. A colorless, highly poisonous gas of the composition HCN. The specific gravity is 0.697, liquefying point 26°C., and it is soluble in water and in alcohol. It is usually marketed in water solutions of 2 to 10%, and is used as a disinfectant and fumigant, as a military poison gas, and in mining and metallurgy in the cyanide process. It is so poisonous that death may result within a few seconds after it is taken into the body. It was used as a poison by the Egyptians and Romans, who obtained it by crushing and moistening peach kernels. It is obtained by distilling a solution of potassium cyanide and sulphuric acid. The French war gas known as Vincennite was hydrocyanic acid mixed with stannic chloride. Manganite was a mixture with arsenic trichloride. HCN discoids, of the American Cyanamid Co., are cellulose disks impregnated with 98% hydrocyanic acid, used for fumigating closed warehouses.

**Hydrofluoric acid.** A water solution of Hydrogen fluoride, HF. It is a colorless, fuming liquid, highly corrosive and caustic. It dissolves most metals except gold and platinum, and also glass, stoneware, and organic material. The choking fumes are highly injurious. It is widely used in the chemical industry, for etching glass, and for cleaning metals. In cleaning iron castings it dissolves the sand from the castings. The specific gravity of the gas is 0.713, and liquefying point −19°C. Hydrofluoric acid is made by treating calcium fluoride or fluorspar with sulphuric acid. It is shipped in lead carboys or in composition bottles.

**Hydrogen.** A colorless and highly inflammable gaseous element, symbol H. It is used for producing the oxygen flame for welding, and also to produce a nonoxidizing atmosphere for heat-treating steels. It is also employed for the hydrogenation of oils and for the production of ammonia. Oils and gasoline can be produced from coal by treatment with hydrogen. Hydrogen liquefies at −252°C. The specific gravity is 0.0695. Its lightness makes it useful for filling balloons, but it is largely replaced for this purpose by the noncombustible helium gas except for emergency signal balloons. For this use the hydrogen is produced easily and quickly from lithium hydride. Hydrogen is produced by the electrolytic dissociation of water, or by the action of water on an alloy of magnesium and lead, or is produced by passing steam through incandescent carbon, then catalyzing the carbon monoxide, and separating the carbon dioxide. It comprises about one-ninth of all water and is found in all organic material. It is marketed compressed in cylinders.

**Hydrogenated oils.** Vegetable or fish oils that have been hardened or solidified by the action of hydrogen in the presence of a catalyst. Partial hydrogenation also clarifies and makes odorless some oils. Finely divided nickel is generally used as the catalyst. The solidifying process is carried on to any desired extent, and these oils have a variety of uses. For mechanical uses they are employed in cutting oils, and in place of palm oil in tinplate manufacture. By hydrogenation the fatty acids, such as oleic acid, are converted into stearic acid. Peanut oil, coconut oil, and cottonseed oil can thus be made to have the appearance, taste, and odor of lard, or they can be made like tallow, though they do not have the food value of lard. Lard compound, previous to the passage of the Food and Drugs Act of 1906, was cottonseed oil mixed with oleostearin from beef tallow. It was later sold under trade names, but has now been replaced by hydrogenated oils under trade names. Hydrogenated oils have lower iodine values and higher melting points than the original oils.

**Indigo.** Once the most important of all vegetable dyestuffs and valued for the beauty and permanence of its color. Commercial blue indigo is obtained from the plants *Indigofera tinctoria,* and several other species, of India and Java, and the plant *Isatis*

*tinctoria,* of Europe, by steeping the freshly cut plants in water, and after decomposition of the glucoside Indican, $C_{14}H_{17}O_6N$, the liquid is run into beating vats where the indigo separates out in flakes which are pressed into cakes. About 4 oz. of indigo are produced from 100 lb. of plants. Indigo red, or Indirubin, $C_{16}H_{10}N_2O_2$, is a crimson dyestuff obtained in the proportion of 1 to 5% in the manufacture of indigo. Indigo white is obtained by reducing agents and an alkali. Another product obtained in the manufacture of synthetic indigo is Indol, a white crystalline product with melting point of 52°C. In concentrations it has a powerful disagreeable odor, but in extreme dilution has a pleasant floral odor and is used in many perfumes. It occurs naturally in oils of jasmin, neroli, orange blossom, and others.

**Indium.** A metallic element, symbol In, discovered first in zinc blende in 1863. It is more silvery-white than tin with a bluish luster, and is valued as a plating metal for jewelry and novelties because of its fine color and corrosion resistance. Although the plate is originally soft, a lustrous hard surface is produced by heating the article to diffuse the metal. Indium-plated light reflectors are highly efficient. Indium is softer than lead, malleable and ductile. It is not easily oxidized as a metal, but above its melting point it oxidizes easily and burns with a brilliant violet flame. The melting point is 155°C., specific gravity 7.31, and Brinell hardness 1. In spite of its softness small amounts of indium will harden copper and lead alloys and increase the tensile strength. It is used in aviation-engine bearing alloys. In gold and silver dental alloys it increases the hardness, strength, and smoothness. The metal usually remains alloyed with the zinc in the reduction of zinc from its ores. Indium oxide, an amorphous powder of the composition $In_2O_3$, is used to give a beautiful yellow color to glass.

**Industrial jewels.** Hard stones, usually ruby and sapphire, used for bearings and impulse pins in instruments and for phonograph needles. Ring jewels are divided into large and small. The large rings are above 0.050 in. in diameter and 0.012 in. in thickness with holes above 0.006 in. in diameter. Ring jewels are used as pivot bearings in instruments, timepieces, and dial indicators. From 2 to 14 are used in a watch. Vee jewels are used in electrical instruments

and in compasses. Cup jewels are used for electric meters and compasses. End stones are flat undrilled stones with polished faces to serve as end bearings. Pallet stones are rectangular impulse stones for watch escapements. Jewel pins are cylindrical impulse stones for the escapement of a timepiece. In the production of bearing jewels the synthetic sapphire boules are split in half, secured to wooden blocks, and then sawed to square blanks. These are then rounded on special centerless grinding machines, and flat ground to thickness by means of copper wheels with diamond powder. Quartz bearings are made from fused quartz rods. A notch is ground in the end of the rod, then polished and cut off, repeating the process for each bearing. Quartz has a hardness of only 7 Moh, while the synthetic ruby and sapphire have a hardness of 8.8, but quartz has the advantage of low thermal expansion.

**Ingot iron.** Nearly chemically pure iron made by the basic open-hearth process and highly refined, remaining in the furnace 1 to 4 hr. longer than the ordinary time, and maintained at a temperature of 2900 to 3100°F. In England, it is referred to as Mild steel, but in the United States the line between iron and steel is placed arbitrarily at about 0.15% content of carbon. Ingot iron has as low as 0.02% of carbon. It is obtainable regularly in grades 99.8 to 99.9% pure iron. Ingot iron is cast into ingots and then rolled into plates or shapes and bars. It is used for construction work where a ductile, rust-resistant metal is required, especially for tanks, boilers, enameled ware, and for galvanized culvert sheets. The tensile strength, hot-rolled, is 48,000 lb. per sq. in., elongation 30%, and Brinell hardness 82 to 100. Dead soft, the tensile strength is 38,500 lb. per sq. in., elongation 45%, and Brinell hardness 67. Armco ingot iron, of the American Rolling Mills Co., is 99.94% pure, with the carbon 0.013 and the manganese 0.017%. It is used as a rust-resistant construction material, for electromagnetic cores, and as a raw material in making special steels. The specific gravity is 7.858, and melting point 1530°C. Enamelite is a sheet iron especially suited for vitreous enameling, produced by the Sharon Steel Hoop Co. Ingot iron may also be obtained in grades containing 0.25 to 0.30% of copper, which increases the corrosion resistance. Plastiron, of Henry Disston & Sons, Inc., is a

very low-carbon iron used for molds and dies which are to be hobbed. The iron is quite plastic under the hob and is then hardened by carburizing.

**Ink.** Colored liquids, or liquids containing finely divided precipitate in suspension. Black writing inks usually contain tannogallate of iron obtained by adding an infusion of nutgalls to a solution of ferrous sulphate. The coloring matter of the older inks consisted of particles that remained upon the surface of the paper. Modern inks soak into the fibers of the paper and then oxidize and become insoluble. Good, clear inks are filterable solutions, not ordinary solutions. The black color develops upon oxidation. Aniline dyes and various toners are added to adjust the color. Gums may also be added. Carbon inks are composed of lampblack or carbon black in solutions of gums or glutenous materials.

India ink is a heavy drawing ink. The original India ink, or Chinese ink, was made with a jet-black carbon pigment produced by burning tung oil with insufficient air. India ink originally referred only to black inks, but the name is now used also for colored heavy drawing inks. Printing inks are lampblack, bone black, barite, or other pigments suspended in linseed oil and resin oils. Invisible, or invisible-writing, inks, called Sympathetic inks, are made with salts of metals made visible by heat, or by the application of another chemical such as a solution of lead acetate to be developed with hydrogen sulphide. Indelible ink for marking textiles has silver nitrate and ammonium hydroxide in water solution mixed with sodium carbonate and gum arabic. It resists alkali washing. An Encaustic ink is one that penetrates the body of the paper to make erasure difficult.

**Insecticides.** Chemical products, or natural products with definite chemical properties, used to kill or to control insects, particularly agricultural pests. Chemicals used against fungi are sometimes classed with insecticides; they are more properly Fungicides and are usually organic mercury compounds. Not more than 1% of the insecticides marketed in the United States are of this class. A Larvacide is a chemical, such as chloropicrin, used to destroy fungi and nematodes in soils, and eggs and organisms in ware-

houses. Insecticides are classed as Stomach poisons or as Contact poisons. Stomach poisons include Calcium arsenate, a white powder of the composition $Ca_3(AsO_4)_2$, which comprises more than half of all insecticides used, and also paris green, lead arsenate, and white arsenic. Contact poisons include rotenone dust, sulphur dust, and nicotine sulphate solutions.

Insecticides may also be classed as solids and liquids. Among the solids are pyrethrum, rotenone, sodium fluoride, sodium arsenite, lead arsenate, boric acid, white arsenic, sodium arsenate, beta naphthol, and thallium sulphate. Sodium fluosilicate, a white, easily soluble powder of the composition $Na_2SiF_6$, is also used extensively. Usually the poison is mixed with a mineral powder in the proportion of 2 to 5%. The mineral carrier should be gritless and inert to the insecticide. Dusting clay for this purpose is a light, fluffy, air-floated kaolin. For some dust sprays finely ground soft limestone is preferred. Liquids are kerosene or other petroleum hydrocarbons in combination with materials such as rotenone. Bordeaux mixture is basic copper sulphate made by reacting copper sulphate with lime, resulting in a product with an excess of hydrated lime. It is used dry or in liquid sprays. Some essential oils such as citronella oil have limited use as insecticides but not for agricultural purposes.

Dimethyl phthalate, a liquid of the composition $C_6H_4(CO_2CH_3)_2$, is a mosquito repellent with an effect lasting 1½ hr. in the open air. Thiourea is used to kill mosquito larvae in water and is harmless to fish. Sabadilla is used in cotton sprays. It is also known as Cevadilla or Indian barley, and consists of the dried ripe poisonous seeds of the plant *Veratrum sabadilla* of the lily family growing in Central America. The seeds contain Veratric acid from which is derived Veratraldehyde, or Vetraldehyde, a crystalline solid of the composition $(CH_3O)_2C_6H_3 \cdot CHO$, which gives the heliotrope flavor to the vanilla of Samoa and to some synthetic vanilla from coniferin. Bone oil, normally used in sheep dips and disinfectants, is also used in insecticides and fungicides. It is a chemically complex oil with a pungent disagreeable odor derived as a by-product in the destructive distillation of bones. It contains nitrides, pyrroles, pyridine, and aniline. Anabasine, $C_{16}H_{14}N_2$, is derived from the plant *Anabasis aphylla* of Russia. The commercial insecticide is sold in the sulphate form as a sirupy liquid having the same odor

and toxic effects as nicotine. The plant contains 2.3% of alkaloids. The cresols in various forms are also used as insecticides. Dinitro ortho cresol, a yellow crystalline material melting at 83.5°C., is used in fruit tree sprays. Thanite, of the Hercules Powder Co., is a terpene product derived from naval stores, used in insecticides and cattle sprays. Sodium antimony lacto phenate, known as Salp, is an effective insecticide against chewing insects.

The insecticide known as DDT is Dichloro diphenyl trichlorethane, $C_6H_3Cl_2(C_6H_4 \cdot CH_2CCl_3)$, used effectively during the war against flies, mosquitoes, body lice, and agricultural pests. It has no noxious odor, but in concentration is toxic to man and to other warm-blooded animals. Oil paints containing 0.5 to 5% of DDT kill flies that roost on walls painted with it. Deenate, of E. I. duPont de Nemours & Co., Inc., is DDT combined with a carrier for use as an agricultural insecticide. Santobane, of the Monsanto Chemical Co., is formulated DDT. Gix is a German variant of DDT. It is Difluoro diphenyl trichlorethane, and is more effective but more expensive.

The insecticide known as 666, of the Imperial Chemical Industries, is Hexachlorocyclohexane, or Benzyl hexachloride, $C_6H_6Cl_6$, made by passing chlorine into benzol with ultraviolet light as a catalyst. The gamma isomer, called Gammexane, which has a melting point of 112.5°C., is separated out as it is the most active poison. It is soluble in naphtha, benzene, and in alcohol. It is a hundred times more toxic against roaches than DDT, but nearly parallels that chemical for other uses. Both kill insects and larvae, but do not have the quick kill of pyrethrum. The Fungicide known as Dowicide 7, of the Dow Chemical Co., is a phenol derivative, Pentachlorophenol, $C_6(OH)Cl_5$, an odorless brownish flaky powder soluble in most organic solvents. It is insoluble in water and is an effective fungicide and preservative for woodwork and textile fibers such as jute. Dowicide G is the sodium salt, $C_6(ONa)Cl_5$, soluble in water, used as a fungicide and preservative in insulation board and water-soluble paints. A solution of Thioacetamide, $CH_3CSNH_2$, is used to spray oranges in storage to kill the fungi that cause blue and green molds. Fermate, of E. I. duPont de Nemours & Co., Inc., is Ferric diethyl dithiocarbamate, a fine black powder used as a fruit fungicide.

**Insulators.** Any materials that retard the flow of electricity, used to prevent the passage or escape of electric current from conductors. No materials are absolute nonconductors; those rating lowest on the scale of conductivity are therefore the best insulators. Glass and porcelain are the most common line insulators because they are cheap, hard, and not affected by moisture. Hard rubber, fiber, synthetic resins, slate, and stone slabs are the usual insulators for panel boards and apparatus. Mica is used as an insulating separator, but it must be free from traces of iron. Various varnishes, resin solutions, and asphalt mixtures are used as insulating impregnating compounds for covering wires or metals. They are also used to impregnate paper or cardboard to make insulating sheet materials. A typical insulator of this type is Armite, of the Spaulding Fibre Co., Inc., which consists of impregnated fish paper in thicknesses from 0.004 to $\frac{1}{8}$ in. The dielectric strength is 500 volts per mil, and tensile strength 8,500 lb. per sq. in. lengthwise. It is used in motors and transformers. Vulcoid, of the Continental-Diamond Fibre Co., is a laminated fibrous material impregnated with a thermoplastic resin. Vulcabeston, of Johns-Manville, is an electric insulating material made of asbestos with a binder of rubber. It is fibrous and can be molded into various shapes. The softening temperature is 175°C. An important requirement of a good insulator is that it will not absorb moisture which would lower its resistivity. Insulating oils are mineral oils of high dielectric strength and high flash point employed in circuit breakers, switches, transformers, and other electric apparatus. An oil with a flash point of 285°F. and fire point of 310°F. is considered safe. A clean, well-refined oil will have a minimum dielectric strength of 22,000 volts, but the presence of as low as 0.01% of water will reduce the dielectric strength drastically. The insulating oils, therefore, cannot be stored for long periods because of the danger of absorbing moisture. Any impurities, such as acids or alkalies, also detract from the strength of the oil. Since insulating oils are used for cooling as well as for insulating, the viscosity should be low enough for free circulation, and they should not gum.

**Iodine.** A purplish-black, crystalline, poisonous elementary solid, chemical symbol I, best known for its use as a strong antiseptic in medicine, but also used in many chemical compounds and war gases. The Chilean production of iodine is as a by-product of the nitrate industry. In Scotland, Norway, and Japan it is produced by burning seaweed and treating the ashes. A ton of seaweed produces about a pound of iodine. It is also produced from salt brines and from sea water. As much as 1,000 tons of iodine is present in a cubic mile of sea water. The specific gravity of iodine is 4.98, melting point 114.2°C., and boiling point 184°C. It is insoluble in water, but is soluble in alcohol, ether, and alkaline solutions. Tincture of iodine, a 7% alcohol solution of iodine in a 5% solution of potassium iodide, is used in medicine as a caustic antiseptic. Iodine cyanide, ICN, an extremely poisonous colorless crystalline material soluble in water, is used as a preservative for furs and museum specimens.

**Ionium.** The parent substance of the metal radium, chemical symbol Io. It is found in all minerals and rare earths that contain uranium and radium. It is so similar in all properties to the element thorium that it is difficult to separate it from thorium when the two have become mixed. Ionium is obtained from uranium ores by fractionating the rare-earth constituents; the resulting preparation contains the radio-inactive thorium. Ionium gives out the alpha rays of radium and has some of the uses of radium, but it is the most expensive of all materials. It has been used in minute quantities in spark-plug wire.

**Iridium.** A grayish-white metal of extreme hardness, symbol Ir. It is insoluble in all acids and in aqua regia. The melting point is 4260°F., and specific gravity 22.42. The annealed metal has a hardness of 172 Brinell. Iridium is found in its natural state in alloy with the metal osmium, known as Osmi-iridium, used chiefly for making fountain-pen points. Iridium is employed as a hardener for platinum, the jewelry alloys usually containing 10%. It is sold by the troy ounce, a cubic inch of the metal weighing 11.82 troy oz. It is also employed as a catalyst.

**Irish moss.** Also called Chondrus (pronounced chone-droosh), Pearl moss, and Carageen. A variety of brown seaweed, or Kelp,

*Chondrus crispus,* found along the Irish and New England coasts. It is bleached and treated to produce gelatin used in soaps and foodstuffs, as a clarifying agent, and as a sizing for textiles. Krim-Ko gel, of the Krim-Ko Co., is the dry concentrate from Irish moss in light buff-colored scaly powder easily soluble in water, used as a colloidal gelling agent. It is neutral, with a pH of 6.4 to 7.2. Carragar is the purified edible material used for pharmaceuticals and foodstuffs. Unlike agar, it contains the natural salts of potassium, sodium, calcium, and magnesium which increase the food value. The Irish name Dulse is applied to the dried or cooked seaweed, *Rhodymenia palmata,* used by the people of the Canadian Maritime Provinces for food. It is purple in color and rich in iodine and mineral salts. Other species, known as Laver and Murlins, are also used in Iceland, Ireland, and Scotland for food. When used for producing iodine in Scotland, the seaweed goes under the general name of Tangle. Much of the kelp now used for producing gelatinizers, agar-agar, and kelp meal comes from giant seaweeds of the Pacific Coast which are fast growing and more plentiful. The kelp found along the Chilean and Peruvian coasts, when dried for making algin products, is called by the Quichua name Cochayuyo.

**Iron.** The most common of the commercial metals, although not as plentiful as aluminum. It has been in use since the most remote times, but it does not occur native except in the form of meteorites, and early tools of Egypt were apparently made from nickel irons from this source. The common iron ores are magnetic pyrites, magnetite, hematite, and carbonates of iron. To obtain the iron the ores must be fused to drive off the oxygen, sulphur, and impurities. The melting is done in a blast furnace directly in contact with the fuel and with limestone as a flux. The latter combines with the quartz and clay, forming a slag which is readily removed. Iron is a grayish metal, which until recently was never used pure. It melts at 1525°C., and boils at 2450°C. Even very small additions of carbon reduce the melting point. It has a specific gravity of 7.85. All commercial irons except ingot iron and electrolytic iron contain perceptible quantities of carbon, which affect its properties. Iron containing more than 0.15% of chemi-

cally combined carbon is termed steel. When the carbon is increased to above about 0.40%, the metal will harden when cooled suddenly from a red heat. Iron, when pure, is very ductile, but a small amount of sulphur, as little as 0.03%, will make it hot-short, or brittle at red heat. As little as 0.25% of phosphorus will make iron cold-short, or brittle when cold. Iron forms carbonates, chlorides, oxides, sulphides, and other compounds. It oxidizes easily under atmospheric conditions and is also attacked by many acids. The Reduced iron, used for special chemical purposes, is a fine gray amorphous powder made by reducing iron oxide by heating in a stream of hydrogen. Iron 55 is a very pure radioactive iron produced in minute quantities by cyclotronic bombardment of manganese and used in medicine for increasing the red blood pigment, Hemoglobin, in the human system.

Electrolytic iron is a chemically pure iron produced by the deposition of iron in a manner similar to electroplating. Bars of cast iron are used as anodes and dissolved in an electrolyte of ferrous chloride. The current precipitates almost pure iron on the cathodes which are hollow steel cylinders. The deposited iron tube is removed by hydraulic pressure or by splitting, and then annealed and rolled into plates. The iron is 99.9% pure, and is used for magnetic cores and where ductility and purity are needed. Highly refined nearly pure iron is marketed by the Westinghouse Electric Corp. under the name of Puron in rod form for use for spectroscopic and magnetic standards. It contains 99.95% of iron, with only 0.005 carbon, 0.003 sulphur, and less than 0.001 phosphorus. By high-temperature hydrogen annealing the carbon can be reduced to 0.001%, bringing the purity to 99.99%. Busheled iron is an inferior grade of iron or steel made by heating bundles of scrap iron or steel in a furnace and then forging and rolling into bars. It is not uniform in composition or in the welding together, and is used only in isolated places or in wartime.

**Iron ores.** Iron-bearing minerals from which iron can be extracted on a commercial scale. The chief iron ores in order of importance are hematite, magnetite, limonite, and siderite. The greatest producers are the United States, France, Russia, Great Britain, Brazil, and Germany. More than 90% of the iron ores

mined in the United States are red hematites, $Fe_2O_3$, containing theoretically 70% of iron, but usually not over 60%. The districts include the Lake Superior region and northern Alabama. It is also the ore from the Furness district in England and parts of Spain and Germany. The color is various shades of reddish brown, and the structure is usually earthy. The variety known as Kidney ore is columnar with a fibrous appearance; Specular hematite has a brilliant luster and foliated structure. The specific gravity is 4.8 to 5.3. Brown hematites contain from 35 to 55% of iron. Ores containing more than 50% of iron are considered high grade. The hematite ores are preferred for the Bessemer process because of their freedom from phosphorus and sulphur. Natural iron is the percentage of iron in the ore before drying; Dry iron is the percentage of iron in the ore after drying at 212°F. Magnetite, or Magnetic iron ore, is found in northern New York, in New Jersey, and in Pennsylvania. It has the composition $FeO \cdot Fe_2O_3$, containing theoretically 72.4% of iron but usually only about 62%. The ore mined in Norway and Sweden is very pure, and it is the ore used for the Dannemora iron made with charcoal as a fuel. Magnetite may also contain some nickel or titanium. The specific gravity is 5.18, melting point 1540°C., the color iron black with a metallic luster, and it is strongly magnetic. The natural magnet known as Lodestone is magnetite.

Siderite and carbonate ores are used in Great Britain, Germany, and Russia, much of which is not considered commercial in the United States, but the Dogger iron ore of Germany contains as high as 35% of iron. Siderite is the chief iron ore in Great Britain. It is found in Staffordshire, Yorkshire, and Wales, and in the United States in Pennsylvania and Ohio. It is an Iron carbonate, $FeCO_3$, containing theoretically 48.2% of iron, or it may be hydrated ferric oxide, $2Fe_2O_3 \cdot 3H_2O$, with about 42% of iron. It usually occurs granular or compact and earthy. Its specific gravity is 4.5 to 5, and the hardness is 3.5 to 4. The color is light to dark brown, with a vitreous luster. It often is impure, with a mixture of clay materials or forming stratified bodies with coal formations. It is also known as Carbonate ore, Ironstone, and as Spathic iron ore. Impure forms mixed with clay and sands are called Clay ironstones, Black band, and Niggerhead ores. The Ironstone and

black-band ores are the important ores of England and Scotland, but there is only a slight usage of carbonate ore in the United States.

Limonite, also called Brown hematite, Brown ore, Bog iron ore, and Shot ore when in the form of loose rounded particles, was the common iron ore of early New England. It is a mineral of secondary origin formed by the water solution of other iron minerals. Its composition is $2Fe_2O_3 \cdot 3H_2O$, containing theoretically 59.8% of iron, but usually 30 to 55%. It occurs earthy or in stalactitic forms of a dark-brown color. The specific gravity is 3.6 to 4. Limonite is found in Alabama, Tennessee, and Virginia, and is also an English and German ore. Goethite is a minor ore of iron of the composition $Fe_2O_3 \cdot H_2O$, found in the Lake Superior hematite deposits and in England. It is yellowish brown in color with a specific gravity of 4.3. It is also called Turgite. The world supply of high-grade ores is placed at 66 billion tons, of which 23% is located in Brazil and 17% in the United States. Newfoundland and Cuba also have large deposits. The hematite of Minas Gerais, Brazil, has 57 to 71% iron. The nearest approach to a native iron is the iron-nickel mineral Awaruite, $FeNi_2$, found in gravel in New Zealand and Alaska, and Josephinite, $FeNi_3$, found in serpentine in Oregon.

**Iron pyrite.** A common mineral sometimes mined for the zinc, gold, or copper associated with it, but chiefly used for making sulphuric acid and copperas. It is an iron disulphide, $FeS_2$, containing 53.4% of sulphur. It often occurs in crystals, also massive or granular. It is brittle, with a hardness of 6 to 6.5 and a specific gravity of 4.95 to 5.1. The color is brass yellow, and it is called Fool's gold because of the common error made in detection. Pyrite is found in rocks of all ages associated with different minerals. It was formerly roasted to obtain the sulphur, and the residue, known as Blue Billy, was used as iron ore. The pyrites mined in Missouri, known as Marcasite, also used for gem stones, have the formula FeS, and the gem specimens have a yellow color with a greenish tinge.

**Iron shot.** An abrasive material made by running molten iron into water. It is employed in tumbling barrels and also in the

cutting and grinding of stones. The round sizes between No. 30 and No. 20 are used for the shot peening of mechanical parts to increase fatigue resistance. Peening shot is marketed by S.A.E. numbers from 6 to 157, the size numbers being the diameter in thousandths of an inch. Grit numbers in shot for grinding are from No. 10 to No. 200, the No. 10 is 0.0787 in., and the No. 200 is 0.0029 in. in diameter. Steel grit is made by forcing molten iron through a steam jet so that the metal forms into small and irregular pieces of chilled iron. The regular globules are screened and graded into Steel shot in sizes from No. 6 to No. 35, and the irregular pieces and large globules are crushed into Steel grit in sizes from No. 8 to No. 80. It is preferred to sand for sandblasting some material. Steelblast, of the Steelblast Abrasives Co., is this material for tumbling and sandblasting.

**Ironwood.** A name for several varieties of wood, and may refer to any exceedingly hard wood that is used for making bearings, gears, tool handles, or parts of machinery. In the United States ironwood is most likely to refer to Hackia, the wood of the hackia tree, *Ixora ferrea,* of the West Indies and of tropical South America, or it may refer to the wood of the quebracho tree. Hackia is brown in color, has a coarse, open grain, and is very hard and tough. The weight is about 55 lb. per cu. ft. It is also used for furniture. The Burmese tree, *Mesua ferrea,* furnishes the wood Gangaw, which is also known as ironwood. It is a tough, extremely hard wood of a rose-red color weighing 70 lb. per cu. ft.

**Isinglass.** A gelatin made from the dried swimming bladders of sturgeon and other fishes. Russian isinglass from the Sturgeon is the most valued grade and is one of the best of the water-soluble adhesives. It is used in glues and cements, and in printing inks. It is also used for clarifying liquids. It is prepared by softening the bladder in water and cutting it into long strips. These dry to a dull-gray, horny, or stringy material. Isinglass is also known as Ichthyocolla. Ichthyol is an entirely different material. It is a reddish-black sirupy liquid with a peculiar odor and burning taste, distilled from an asphaltic shale found in the Austrian Tyrol. It is used as an antiseptic astringent. The name isinglass is also used for mica when employed as a transparent material for stove doors.

**Ivory.** The material that composes the tusks and teeth of the elephant. It is employed mostly for ornamental parts, such as the keys of pianos. The color is the characteristic ivory white, which yellows with age. The best grades are from the heavy tusks weighing more than 55 lb., sometimes 6 ft. long. The ivory from animals long dead is a gray color and inferior. The softer ivory from elephants living in the highlands is more valuable than the hard and more brittle of the low marshes. The west coast of Africa, India, and Southern Asia are the chief sources of ivory. The tusks of the hippopotamus, walrus, and other animals, as well as the fossil mammoth of Siberia, also furnish ivory, although of inferior grades. Odontolite is ivory from fossil mammoths of Russia. Ivory can be sawed readily, and is made into thin veneers for various ornamental uses. It takes a fine polish. Artificial ivory is usually celluloid or synthetic resins. The specific gravity of ivory is 1.87.

**Ivory nut.** Called Tagua nut in Colombia and Ecuador, and Jarina in Brazil. The source of Vegetable ivory, which is used for making various small articles, mostly buttons. The ivory nut is the seed of the low-spreading palm tree, *Phytelephas macrocarpa,* which grows in tropical America. The nuts are about 2 in. in diameter, growing in clusters and encased in shells. They have a fine white color and an even texture. They can be worked easily and harden on exposure to the air. They take dyes readily and show fine polished colors. A similar nut called the Dom nut is used in Eritrea for making buttons and novelties.

**Japan wax.** Sometimes called Sumac wax and Japan tallow. A vegetable fat used largely for adulterating beeswax, and in candles and polishes. It is a vegetable fat contained between the kernel and the outer skin of the berries of plants of the genus *Rhus,* which grow in Japan and are also cultivated in California. The fat, which is misnamed wax, is extracted by steaming and pressing the berries, and is refined by melting and pressing through cotton cloth. The crude wax is a coarse greenish solid, but the bleached wax is in cream-colored cakes which darken to yellow. Japan wax melts at 51°C. The specific gravity is about 0.975. It contains chiefly palmitic acid in the form of Glyceryl palmitate with also stearic and oleic acids, and a characteristic acid, Japonic

acid, which is also found in catechu. The saponification value is 220. It is sometimes adulterated with common tallow. Lac is a variety of lacquer oil obtained from the same sumach plants, notably *R. vernicifera, R. sylvestris,* and *R. acuminata,* of Japan and Korea. It is used as a drying oil in baking enamels and for transparent lacquers. It is a gum exudation of the wood and is not obtained from the berries. The plants are cultivated primarily for this Lac and the Japan wax is a by-product. Lac is not to be confused with shellac from the lac insect.

**Jewelry alloys.** An indefinite term which is most likely to refer to the soft white alloys used for casting jewelry novelties to be plated, and to the miscellaneous harder alloys used for plated cheap jewelry, rather than to the alloys of the precious metals. The soft white alloys of this type are not now as important as they were before the advent of plastics when large amounts were cast into jewelry boxes, novelties, and ornaments. Articles now produced in metals are likely to be cast from standard white metal ingots, and cheap jewelry is now largely made from standard brasses, nickel brasses, and cupro-nickels. Formerly, a great variety of trade names were used for jewelry alloys. Argentine metal was a silvery alloy for casting statuettes and small ornaments. It contained 85.5% of tin and 14.5 antimony, and makes silvery-white, hard, and clean-cut castings. An alloy known as Alger metal contained 90% tin and 10 antimony. A harder but more expensive white alloy known as Warnes metal contained 10 parts of tin, 7 nickel, 7 bismuth, and 3 cobalt. Fahlum metal, used for stage jewelry, contained 40% of tin and 60 lead. When faceted, it makes highly reflective brilliants. Rosein was a white metal for jewelry and ornamental articles containing 40% of nickel, 30 aluminum, 10 tin, and 10 silver. When polished it has a high white luster without plating. Mock silver was an aluminum alloy containing about 5% of silver and 5 copper. Argental was a rich low brass whitened and strengthened with about 5% of cobalt. Kuromi, a Japanese white jewelry alloy, is copper whitened with tin and cobalt. Argent français, or French silver, is cupro-nickel containing considerable silver. Platinoid was a nickel-silver-tungsten alloy with the small amount of tungsten added to the melt in the form of phosphor

tungsten. Proplatinum, another substitute for platinum, was a nickel-silver-bismuth alloy. Nuremberg gold, with a nontarnishing golden color, contained 90% of copper, 7.5 aluminum, and 2.5 gold.

**Jojoba wax.** Also called Jojoba oil, pronounced ho-hó-bah. A liquid wax obtained by pressing or solvent extraction from the seed beans of the evergreen shrub *Simmondsia californica* growing in the semiarid region of Southwest United States and northern Mexico. The beans contain 50% of oil which has high-molecular-weight acids and alcohols and no glycerin and is a true wax. It is used as a substitute for sperm oil in lubricants, in leather dressing, and also in cosmetics.

**Jujube.** The oval fruit of the small spiny tree *Ziziphus jujuba* of the buckthorn family growing in dry alkaline soils. It is native to North China, but is also grown in the Mediterranean countries and in Southwestern United States. It is also known as the Chinese date, or Tsao. The fruit has high food value, being higher in sugars than the fig, 65 to 75%, and higher in protein than most fruits, 2.7 to 6%, but is very acid, containing up to 2% of acid. Some varieties develop butyric acid in ripening. Jujube is used for flavoring, and in confections, preserves, and sweet pickles, and as a fresh or dried fruit.

**Juniper.** The wood of the juniper tree *Juniperus virginiana* growing in the Eastern United States from Maine to Florida. It is also called Red cedar, Red juniper, and Savin. The heartwood has a bright to dull-red color, and the thin sapwood is nearly white. The wood is light in weight, soft, weak, and brittle, but is durable. It is used for chests, cabinets, and closet lining because of its reputed value for repelling moths. It was formerly employed on a large scale for lead-pencil wood, and was known as Pencil cedar, but it is now scarce and other varieties are used for this purpose, notably Incense cedar, *Libocedrus decurrens,* of California and Oregon, a close-grained brown wood with a spicy resinous odor. African pencil cedar is from the tree *Juniperus procera,* of East Africa. It is harder and heavier and less fragrant than incense cedar. There are more than 40 species of juniper. The fruit or

Juniper berries of the common varieties are used in flavoring gin. Cade oil is a thick brownish essential oil, of specific gravity 0.950 to 1.055, distilled from the wood of the European juniper, and used in antiseptic soaps. It is also called Juniper tar oil. The juniper oil known as Savin oil is distilled from the leaves and tops of the Juniper bush, *J. sabina,* of North America and Europe. It is used in medicine as a diuretic and vermifuge, and also in perfumes. Cedarwood oil, used in perfumes and soaps, is distilled from the sawdust and waste of the eastern red cedar. The red heartwood contains 1 to 3% of oil.

**Jute.** A fiber employed for making burlap, sacks, cordage, ropes, and upholstery fabrics. It is obtained from several plants, of which *Corchorus capsularis* of India is the most widely cultivated, growing in a hot, steaming climate. This fiber in Brazil is called Juta indiana, or Indian jute. Most of the commercial jute comes from Bengal. The plant grows in tall slender stalks like hemp, and the fiber is obtained by retting and cleaning. The fiber is long, soft, and lustrous, but is not as strong as hemp. It also loses its strength when damp, but is widely used because of its cheapness and because of the ease with which it can be spun. The crude fiber may be as long as 14 ft., but the commercial fibers are from 4 to 8 ft. The butts, or short ends of the stalks, and the rough fibers are used for paper stock. Jute paper, used for cement bags, is a strong paper made of these fibers usually mixed with old rope and old burlap in the pulping. It is tan in color.

Brazilian jute is fiber from plants of the mallow family, *Hibiscus kitaibelifolius,* or *H. ferox,* cultivated in the state of São Paulo, Brazil. It is also called Juta paulista. The fiber is long, strong, resilient, and durable. It is used for making burlap for coffee bags. The fiber known as Paco-paco is from the *H. cannabinus,* of Bahia and Minas Geraes. It is used for cordage, burlap, and calking. In the East Indies it is called Java jute. In India it is called Bimlipatam jute and Deccan hemp, and is mixed with *Corchorus* fibers as jute and in burlap. The species known as Amaniurana is from the *H. furcellatus* of the Paraguay River Valley. The fibers are soft and silky and are made into sacks and bags. The species *H. sabdariffa,* known as Vinagreira, is used as a

substitute for jute. In the East Indies it is called Roselle fiber and has characteristics similar to Indian jute. Brazilian hemp is from the *H. radiatus,* and is stronger than true hemp. It is cultivated in Bahia. Aramina fiber is from the very long stalks of a plant of the mallow family, *Urena lobata,* of Brazil. In the north of Brazil it is known as Carrapicho. The fiber is used for cordage, twine, and burlap fabrics. In Cuba this fiber is known as White malva and Bowstring hemp. Cuba jute is from the *Sida rhombifolia.* Both Cuba jute and aramina fiber belong to the mallow family, *Malvaceae,* and in Cuba and Venezuela are also known as Malva fiber. The *U. lobata* is also grown in the Belgian Congo where it is known as Congo jute.

Pitá fiber, used in Colombia and Central America for coffee bags, is from a plant of the pineapple genus, *Ananas magdalenae.* The fiber is a light cream color, lustrous, very long, and finer and more flexible than most hard fibers, so that it is useful for ropes, twines, and fabrics although most of the fibers of this botanical class are brush fibers. It has excellent resistance to salt water. The word Pitá means yellow in the Indian language, and this name is also used for grades of yucca and other fibers. Tucum fiber is from the leaves of the oil palm *Astrocaryum tucuma* of Brazil. The fibers are long, flexible, water-resistant, and durable. They are used for ropes, hammocks, and marine cordage, but are not classed as burlap fiber. Another fiber of great length and noted for resistance to insect attack is Curana, from the stalks of the plant *Bromelia sagenaria* of northeast Brazil. There are two chief grades: the white and the roxo or purple.

**Kangaroo leather.** A strong, supple, and durable leather made from the skins of the Australian kangaroo, used chiefly for shoe uppers and gloves. The skins measure from 2 to 12 sq. ft. in area, and the small ones are known as Wallaby. The fibers have an interwoven structure, and the leather does not scuff easily. It takes a brilliant polish. It is rated as the strongest shoe leather per unit of weight.

**Kaolin.** Also called China clay. A pure form of hydrated Aluminum-silicate clay. There are three distinct minerals, Kaolinite, Nacrite, and Dickite, all having similar composition. The

formula for kaolin is usually given as $Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$, but is also expressed as $Al_2Si_2O_5(OH)_4$. It occurs in claylike masses of specific gravity 2.6, and of a dull luster. Kaolin is used for making Porcelain for Chinaware, and chemical porcelain for valves, tubes, and fittings, as a refractory for bricks and furnace linings, for electric insulators, as a pigment and filler in paints, as a filler in plastics, and as an abrasive powder. In firebricks it resists spalling. Its melting point is 3200°F., but this lowers with impurities. It is a decomposition product of granite and feldspar, and its usual impurities are quartz, feldspar, and mica, which can be washed out. Kaolin is white, but inferior qualities burn to a yellow color. It should never contain iron. The Cornwall kaolin of England and the Limoges kaolin of France are the best known. English china clays contain little or no iron oxide, and the yellow clays contain only organic materials that can be bleached out. The best grade of English clay is used for coating and filling paper. Cornish clay, known as China stone, is used for the best grades of porcelain glazes. Cheaper grades of kaolin, called Mica clay, are used for earthenware glazes, and as an absorbent in oil purifying. The clay of Kentucky and Tennessee, known as Ball clay, occurs in massive beds of great purity; it has high plasticity and good bonding strength, and is light in color when fired. It is used for high-grade porcelain and for wall tiles. Impure varieties of kaolin, called Kaolinic earth, are used for refractories.

Halloysite has about the same composition as kaolinite but contains more alumina and water. It occurs with kaolinite. In association with alunite in Arkansas it is called Newtonite. Some varieties, such as Glossecollite, are waxlike. Indianaite, or Allophane, is an impure halloysite. It is a white, waxy clay found in Indiana, and is used for pottery. The Indiana halloysite used for refractories is called Malinite. When kaolin is employed as an inert colloidal pigment with zinc oxide, it is called Chinese white. It is insoluble in water. Bone clay is a pure kaolin from feldspar and granite. It makes a strong porcelain. But Bone china is a name given to high-grade English pottery made with china clay and 25% of calcined bone. Flesh clay is formed from feldspar and quartz. It gives resilience to the porcelain. Clays can be proportioned to give desired characteristics. Hartporzellan is a

German Hard porcelain having a high resistance to temperature changes. It is marketed in tube form for conveying hot chemicals. Thyrite, of the General Electric Co., is a specially compounded porcelain that possesses the property of being an insulator at low potentials and a conductor at high potentials. It is used for lightning arresters. Vitrolain, of the Star Porcelain Co., is an Electrical porcelain of high strength and density, having a porosity as low as 0.25%. Micronized clay is pure kaolin ground to a fineness of 400 to 800 mesh, used as a filler in rubber. Dixie clay, of the R. T. Vanderbilt Co., is ground kaolin of 300 mesh, used as a stiffening or reinforcing agent in rubber and adhesives. Osmose kaolin is an extremely microscopic powder made by the electrolytic deposition of kaolin from a water solution. It is used for making synthetic mica insulation. Osmo, of E. Fougera & Co., is finely ground kaolin for cosmetics. Aluminum flake, of the Aluminum Flake Co., is a white, flaky kaolinic clay from Missouri, ground for use in paints, adhesives, and rubber.

**Kapok.** A silky fiber obtained from the seed pods of the silk-cotton trees of the genera *Ceiba, Bombax, Chorisia,* and *Ochroma,* common in most tropical countries. It is employed for insulation and fine padding work. It is extremely light and resilient. Most of the commercial kapok normally comes from Java and is from the *Ceiba pentandra.* The tree is very large, and the fiber grows in bolls, which burst when ripe. The fibers are long, white, and silky, similar in appearance to cotton, but are too brittle for spinning. It is also known as Java cotton and Illiani silk. A silky cotton somewhat similar but inferior to kapok is Madar, from the shrub *Calotropis gigantea* of India and the East Indies. Another species, Akund, is from the *C. procera.* Both fibers are sometimes mixed with kapok, but are less resilient. They are known in the East Indies as Vegetable silk. Red silk cotton, known as Simal, is from the large tree *Bombax ceiba* or *B. malabaricum,* of India. The fiber is reddish. White silk cotton is from the tree *Cochlospermum gossypium* of India. It is quite similar to kapok. The kapok of Ecuador is from various species of the tree *Chorisia.* The fiber from the balsa trees, of the genus *Ochroma* of Central America, Colombia, and Ecuador, is dark in color. Mexican kapok

is from the *Bombax palmeri* and from the *Ceiba schottii* and *C. acuminata,* the fibers from the two latter being more buoyant than the Java fiber. The kapok from the Lower Amazon region is from the *C. samauma.* Paina kapok is from a ceiba tree of Brazil. Kapok oil is a semidrying oil obtained from the seeds of the kapok tree. It is used in margarine and for soaps.

A substitute for kapok for sound and heat insulation, and as a stuffing for life jackets, cushions, furniture, and toys, is Typha, or Cattail fiber. It is the fluffy fiber from the cylindrical flowers of the *Typha latifolia* which grows in swamps throughout the temperate climates of North America. As an insulating material the fiber has about 90% the efficiency of wool. Milkweed floss, used also as a substitute for kapok, is the bluish-white silky fiber from the seed pods of the common milkweed, *Asclepias syrica,* of the Eastern United States. It is not grown commercially, but was gathered on a large scale by children during the war.

Karakul. The curly lustrous fur pelts of newly born lambs of the karakul sheep originally of Afghanistan and Siberia, but now grown extensively in southwest Africa for the fur. The wool of the older sheep is clipped for carpet wool, but the fur pelts of the young animals are highly valued for coats and garment trim. The best qualities are those with small curl and medium curl to the fur. The fur skins are also graded by color, the gray and flora being most valued and the brown the least valued. Persian lambskin is a name for pelts of small tight curl.

Kauri gum. A fossil gum dug from the ground in New Zealand and New Caledonia, used in varnishes and enamels to increase the body and increase the elasticity and hardness. It is also used in adhesives, and the lower grades of chips are used in linoleum. It was first known as New Zealand gum, and first spelled cowrie, although Cowrie is the name of a genus of mollusk shells found in the Indian Ocean and formerly used as money in China. Kauri is a product of kauri tree exudations buried for long periods, but it also comes from the conifer tree *Agathis australis.* There is little extraction of the gum from the present kauri forests, whose wood is employed for lumber, but some Bush gum is obtained by collecting the deposits in the forks of branches. Range gum is found

in clay deposits, and some is transparent. Swamp gum is brown in color and varies from hard to friable. The fossil gum has a specific gravity of 1.05, a melting point of 182 to 232°C., and is soluble in turpentine, benzol, and alcohol. The kauri tree grows to a height of 100 ft. and great diameters, and yields a yellowish-brown, straight-grained wood free from knots much prized as a useful softwood. It weighs 36 lb. per cu. ft. Mottled and figured Kauri pine is used as a cabinet wood.

**Kermes.** A brilliant red natural dyestuff similar in color to cochineal, having a beautiful tone and being very fast. It is one of the most ancient dyes, but is now largely replaced by synthetic dyestuffs. Kermes is an insect found on the kermes oak tree, *Quercus coccifera,* of southern Europe and Asia. The body of the animal is full of a red juice, and the coloring matter, Kermesic acid, $C_{18}H_{12}O_9$, is separated out in brick-red crystals. It has only about one-tenth the coloring power of cochineal.

**Kerosene.** Known in some localities as Coal oil. A light, oily liquid obtained in the fractional distillation of petroleum. It distills off after the gasoline, and between the limits of temperatures of 174 and 288°C. It is a hydrocarbon of the composition $C_{10}H_{22}$ to $C_{16}H_{34}$, with a specific gravity between 0.747 and 0.775. Commercial kerosene may be as high a distillate as 325°C., with a corresponding higher specific gravity up to 0.850, but in states where it is distinguished from gasoline in the tax laws it is more sharply defined. In Pennsylvania, kerosene is defined as having a flash point above 114°F., with not over 10% distillable at 175°C. and not over 45% at 200°C. Kerosene is employed for illuminating and heating purposes, and as a fuel in internal-combustion engines. The heaviest distillate known as Range oil is sufficiently volatile to burn freely in the wick of a heating range, but not so volatile as to be explosive. It is nearly free from odor and smoke. Deodorized kerosene, used in insect sprays, is a kerosene highly refined by treatment with activated earth or activated carbon.

**Khaya.** A class of woods from trees of the genus *Khaya,* growing chiefly in tropical west Africa and known commercially as African mahogany. The woods closely resemble mahogany, but

they are more strongly figured than mahogany, are slightly lighter in weight, softer, and have greater shrinkage. The pores are larger, and the wood coarser. The wood is used for furniture and store fixtures, musical instruments, and boat paneling. It is not as suitable for patterns as mahogany. African mahoganies are marketed under the names of the shipping ports, as the shipments from the various ports usually differ in proportion to the different species cut in the region. The chief wood of the genus, from which the native name Khaya derives, is known commercially as Dry zone mahogany, *K. senegalensis*. It is also known as Kail and Oganwo. It grows from Gambia to Angola on the west coast and eastward to Uganda. The heartwood is dark reddish brown, and the thick sapwood is grayish to pinkish red. The most favored commercial wood is that of the Red Khaya, or Red mahogany, *K. ivorensis,* known locally as Dukuma and Dubini. This wood is highly figured, with interlocking grain, and when quartered shows a ribbon figure with alternate light and dark stripes. It comes chiefly from the Ivory Coast, Gold Coast, and Nigeria. Sassandra mahogany is chiefly this species. Duala mahogany is chiefly White mahogany, *K. anthoteca,* known also as Diala, Krala, and Mangona. The wood is lighter in color but tinged with red. Big-leaf mahogany, *K. grandifolia,* has a reddish-brown color. Much African mahogany is cut into veneer; the standard thickness of the face veneer is $\frac{1}{28}$ in.

Gaboon mahogany and Port Lopez mahogany are chiefly Okume wood, from the tree *Aucoumea klaineana* of French Africa. The tree belongs to the family *Meliacaea* to which khaya belongs, and the wood resembles African mahogany but is lighter in weight and softer. It is light pinkish brown in color. It is shipped chiefly to Europe where it is used for furniture, chests, boxes, and boats. Cola mahogany, from the Ivory Coast and Gold Coast, is Niangon, *Tarrietia utilis*. The heartwood is light reddish brown, and the wood shows a herringbone figure on the quartered surface. It is heavier than khaya, and the pores are larger and more numerous. Cherry mahogany, or Makore, is a plentiful wood on the Ivory Coast, Gold Coast, and in Nigeria. It is from the tree *Minusops heckelii*. The wood is dark reddish brown without figure. It is heavier than Khaya and is finer in texture.

Kid. A name for leather made from the skins of young goats, but commercial Kidskin leather is now from both young and old animals, and the term Goatskin is not liked in the American trade. It is thin and has a fine, close-grained texture, with tiny groups of pores, and the leather is soft and pliable but strong and non-scuffing. Kid is usually chrome-tanned and dyed to many colors. It has a natural lustrous surface which is heightened by glazing or polishing. The leather is sorted by grain or size of pores, weights, and sizes into 10 grades. India, Argentina, Brazil, South Africa, and northwest Africa are large producers of goatskins. About 70% of the goat and kid leather of the world is tanned in the United States although this country produces less than 1% of the skins. Kidskin is used for shoes, gloves, pocketbooks, jerkins, and for pads and linings. The term Vici kid, used in the shoe industry, was the name originally given to chrome-tanned leather in 1888. The best kidskins come from arid regions, and these are used for the fine French kid leather. In the glove trade the term Chevreau is used to designate young goats that have never browsed, while Chevrette refers to the small skins of older kids that have eaten grass. Capeskin is goatskin from South Africa. Glazed kid is made by pressing a seasoning agent into the leather and then ironing the dry leather with a glass cylinder.

Kieselguhr. A variety of tripoli, or Infusorial earth, obtained in Germany, and employed chiefly as an absorbing material. It is also used as an abrasive, as a heat insulator, for making imitation meerschaum, and as an absorbing material for nitroglycerin in making dynamite. Kieselguhr is very absorbent and will hold 75% of its own weight of sulphuric acid. It is insoluble in water. Desirable characteristics as an insulator are closed cells and high porosity, giving low density and low thermal conductivity. Kieselguhr from Oberhole, Germany, has 88% silica, 0.1 alumina, 8.4 water, and the remainder organic matter. Nonpareil insulating brick, of the Armstrong Cork & Insulating Co., is made of pulverized kieselguhr mixed with ground cork, molded into brick form, and dried. The cork is burned out, leaving small air pockets to increase the insulating effect. The bricks will withstand tem-

peratures up to 1000°C.; the heat transmission is lower than for natural kieselguhr.

**Kino resin.** Also known as Gum kino. The red exudation of the tree *Pterocarpus marsupium,* of India and Ceylon, and of *P. erinaceus,* of West Africa, formerly much used for colored varnishes and lacquers and used in throat medicines. Bengal kino, or Butea gum, from the tree *Butea frondosa,* is now limited to medicinal use, as is also the Australian red kino from species of eucalyptus. Kino belongs to the group of red resins known as Dragon's blood when used in spirit varnishes for musical instruments and furniture, but now replaced by synthetic colors. The dragon's-blood resins from the East Indies are from the ripe fruit of various species of the tree *Daemonorops.* The resin is separated out by boiling and is shipped in small oval drops or long cylindrical sticks. It is used in fine lacquers and varnishes. The dark-red dye known as Red sandalwood is the boiled-down juice of another kino tree *P. santelinus* of India. Still another *Pterocarpus* tree of southern India produces the wood Padouk valued for furniture, cabinetwood, and veneer. The heartwood is red with black stripes. It is hard and takes a high polish.

**Kyanite.** An aluminum silicate mineral of the composition $Al_2O_3 \cdot SiO_2$ used as a refractory especially for linings of glass furnaces and furnaces for nonferrous metals. It is a common mineral but occurs disseminated with other minerals and is found in commercial quantities and grades in only a few places. Most of the world's production is in eastern India. It is also mined in North Carolina, Georgia, Virginia, and California. The related minerals sillimanite and dumortierite are mined in Western United States. The specific gravity is 3.56 to 3.67, and hardness 6 to 7 Moh. Kyanite of 97 to 98% purity is obtained by flotation, but gravity concentrates rarely exceed 90%. Low-grade kyanite ore from California, containing 35% kyanite and much quartz, is used for ceramics. Kyanite is usually marketed ground to finenesses from 35 to 325 mesh. Low-grade kyanite is used in glassmaking as a source of alumina to increase strength and chemical and heat resistance.

**Lacquer.** Originally the name for a kind of Oriental finish made with lac and slow-drying varnishes, but now referring to the quick-drying finishes made from nitrocellulose, or pyroxylin, or from cellulose-acetate resins. The original Chinese lacquer was made from the juice of the *Rhus vernicifera* mixed in oils. The juice is milky but darkens rapidly, and the lacquer is pure black.

Modern lacquers are widely used for finishing automobiles and other articles. They consist of pyroxylin or other resin, one or more gums, a pigment, a softener, and one or more volatile solvents. Various kinds of gums are used for increasing the body and giving hardness and gloss to the finished surface. For high gloss and hardness, dammar is used. For a cheaper product elemi may be employed. Kauri is used where good wearing is required. The usual solvents are anhydrous alcohol, ethyl acetate, butyl acetate, butenol, benzol, and toluol. Softeners are such products as amyl, ethyl, and butyl phthalates. Quick drying is the chief advantage of the lacquers, but the time must be made long enough to prevent cloudiness, or blushing, from absorption of moisture from cooling by too rapid drying. For industrial work, lacquers are usually sprayed, and they then dry in about 15 min. Brushing lacquers are made slower in drying to prevent streaks and lumps in their application. The time of drying is controlled by the solvents.

Lacquers are harder and tougher than enamels, but not as elastic, and are more expensive. They are not suitable for exterior woodwork where expansion and contraction occur. The word lacquer is also used to describe a highly transparent varnish used to produce a thin protective film on polished or plated metals to preserve their luster. Lacquers are sold under a variety of trade names such as Duco, of E. I. duPont de Nemours & Co., Inc.; Agateen, of the Agate Lacquer Mfg. Co.; Zapon, of the Zapon Co.; Zelactite, of the Zeller Lacquer Mfg. Co.; and Brevolite, of the Atlas Powder Co. Bronzing liquids are the clear lacquer-base mediums marketed ready for incorporation of bronze or aluminum powders. Cable lacquers are clear, black, or colored lacquers prepared from synthetic resins, and are characterized by high dielectric strength, resistance to oils and heat, and by their ability to give tough, flexible coatings.

**Lampblack.** A soot formed by the smudge process of burning oil, coal tar, resin, or other carbonaceous substances in an insufficient supply of air, the soot being allowed to settle on the walls or floors of the collecting chambers. Lampblack is practically pure carbon, but inferior grades may contain unburnt oil. It is chemically the same as carbon black made from gas but, since it may contain as high as 2.5% of oil, it is not used as a reinforcing agent in rubber. It is used in making paints, lead pencils, metal polishes, electric brush carbons, crayons, and carbon papers. It is grayish black in color, and is flaky and granular. The color is not as intensely black as carbon black. One pound occupies from 200 to 230 cu. in. For use as a pigment for japan the powder should pass through a 325-mesh screen. Lampblack oil is a coal-tar product marketed for making lampblack.

**Lancewood.** The wood of the tree *Guatteria virgata*, of tropical America. It is used for fine work where toughness, uniformity, and durability are requisites, such as for measuring rods. It is used also as a substitute for boxwood. The wood is yellowish in color and has a fine, close, smooth grain. The weight is 52 to 63 lb. per cu. ft. It is very hard and elastic. Yaya is a name given in the Honduras trade to lancewood. Degami lancewood, or Degami wood, is a yellowish wood with a fine, dense grain, from the *Calycophyllum candidissimum* of the West Indies.

**Larch.** The wood of the coniferous tree *Larix occidentalis*, of Northwestern United States and Southwestern Canada. It is also called Western larch, Western tamarack, Mountain larch, Montana larch, and Hackmatack. The wood is somewhat similar to Douglas fir and is strong, moderately hard and heavy, straight grained, and of medium durability. The heartwood is reddish brown and the narrow sapwood is yellowish. It finishes and stains well, but splits easily and is subject to ring shake. Butt logs contain Galactan gum which darkens the color and increases the weight. It is used for railroad ties, car building, and general construction. The stand is estimated at 23 billion bd. ft., of which half is in Montana. The trees reach a diameter of 5 ft., and a height up to 200 ft. at an age of about 400 years. Shipments of Western larch and Douglas fir mixed are known commercially as Larch fir. Larch

is also the name given to the Tamarack tree of New England, *L. laricina.* European larch, *L. europea,* is an important wood in Russia and some other countries.

**Lard.** The soft white fat from hogs. It is used chiefly as a shortening in bakery and food products, and in cooking and frying. The inferior grades are used for the production of lard oil and for soaps. The types of edible lard for use in the United States are defined in regulations of the Department of Agriculture. Steam-rendered lard is made by applying steam directly to the fats in a closed container. Open-kettle rendered lard is made by applying steam to the outside of the kettle. The Neutral lard used for making margarine is produced by applying hot water in place of steam. Rendered pork fat is an edible material that does not meet the specifications for lard. Average production of edible lard is about 24 lb. per animal.

Leaf lard is from around the kidneys and intestines and is the best edible grade. White grease is an inedible lard from the kidneys and the back. Yellow grease is the residue from the parts of the hog remaining after the parts yielding white grease are separated. U.S.P. grade of lard is called Adeps in pharmacy. It is purified internal fat of the abdomen, and is a soft unctuous solid of bland taste. It is used in Benzoated lard and in lead oleate for plasters. Lard oil is an oil expressed from lard by subjecting it to hydraulic pressure. Prime or first-grade lard oils are nearly colorless, or greenish, and have little odor. The commercial oils vary from the clear sweet oil to the acid and offensive-smelling brown oils. The oils contain oleic, stearic, and palmitic acids. They are used in cutting and in lubricating oils, sometimes in illuminating oils. They may be adulterated with cottonseed oil or blown oils. The flash point of pure lard oil is 480°F., saponification value 192, and specific gravity 0.915. Mineral lard oil is a mixture of refined mineral oil with lard oil, the fatty content being 25 to 30%. The flash point is about 300°F. Lardine is an old name for blown cottonseed oil used in lubricants.

**Latex.** The milklike juice of the rubber tree, now much used instead of the cured crude rubber for many rubber applications such as adhesives, rubber compounds, and rubber powder. The

properties of latex vary with the type of tree, age of the trees, method of tapping, and climate. Latex from young trees is less stable than from older trees. Intensive tapping of the trees results in less rubber content, which may vary from 20 to 50%. For shipping, a preservative and anticoagulant is added to the latex, usually ammonia or sodium sulphate. Concentrated 60% latex is a stable liquid of creamlike consistency. Heveatex is the trade name of latex of various grades of the Heveatex Corp. Latex foam is a name given to a type of cellular sponge rubber made by whipping air into latex, pouring into molds, and vulcanizing. Artificial latex is a water dispersion of reclaimed rubber. Dispersite is a trade name of Dispersions Process, Inc., for water dispersions of crude or reclaimed rubbers, produced by swelling and dissolving the rubber in an organic solvent, treating with an organic acid or with ammonia, and emulsifying. It resembles latex, but is softer and more tacky, and is used for adhesives. Lotol and Revertex are brands of latex. The Revertex process consists in the concentration of latex by evaporation in the presence of protective colloids. Neoprene latex is a water dispersion of neoprene synthetic rubber. The dispersed particles are smaller than those of natural rubber, and it thus gives better penetration in coating textiles or paper. Latex is also made from vinyl chloride and other synthetics by water dispersion. Nubun, of the Firestone Tire & Rubber Co., is a modified Buna S latex, used for electrical wire insulation. The coatings are flexible and have good aging and high insulating qualities.

**Lauan.** The wood of trees of several genera of the Philippines, Malaya, and Sarawak, known in the American market as Philippine mahogany. The woods resemble mahogany in general appearance, weight, and strength, but the shrinkage and swelling with changes in moisture are greater than in the true mahoganies. The lauan woods are used for furniture and cabinet woods, and for boatbuilding. The lauans belong chiefly to the genus *Shorea,* and the various species have local or common names. The so-called Dark-red Philippine mahogany is Tangile, S. *polysperma,* and Red lauan, S. *negrosensis.* Tangile is also called Bataan mahogany, and has the closest resemblance to true mahogany of all the species.

The thick sapwood is light red and the heartwood dark brownish red. It has greater tendency to warp than mahogany. Red lauan has larger pores, but is favored for boat construction because of the large sizes available. Tiaong, from the S. *teysmanniana,* resembles tangile but is lighter and softer. Almon, from the tree S. *eximia,* is harder and stronger than red lauan or tangile, but is coarser in texture and less lustrous.

White lauan is from a different genus of the same family and is *Pentacme contorta.* It has about the same mechanical properties as tangile, but is gray with a pinkish tint. Mindanao lauan, *P. mindanensis,* is quite similar but is lighter and softer. Mayapis, from the tree *Shorea palosapis,* is coarser in texture than tangile and is subject to warping and checking like red lauan. It is intermediate in color, and the light-colored wood is marketed as White lauan, while the dark wood is sold as Red lauan. Yellow lauan is from the trees Kalunti, S. *kalunti,* Manggasinoro, S. *philippensis,* and Malaanonang, S. *polita.* Yellow lauan is yellowish in color and has lower strengths and greater warpage than other lauans. Bagtikan, from the tree *Parashorea malaanonan,* is reddish gray in color, not lustrous, but is heavier and stronger than the other lauans. Sometimes mixed with Philippine mahogany is the wood known as Lumbayan, from an entirely different family of trees. It is from the tree *Tarrietia javanica.* The thick sapwood is light gray in color and the heartwood reddish. The weight and strength are about equal to tangile but the pores are larger. When marketed separately, it is a more valuable wood than the other lauans for furniture manufacture. The woods from Sarawak, Sumatra, and Malaya known as Meranti, or Morenti, are *Shorea* species of the lauan types. In the East Indies morenti is used for barrels, casks, and tanks for palm oil. Similar woods from North Borneo are called Seraya, or known as Borneo cedar or Borneo mahogany. The *shorea* trees yield Borneo tallow and Dammar. Merawan is a wood from various species of trees of the genus *Hopea* of Malaya. It is valued for furniture and interior work. Much of the so-called mahogany normally shipped from the Philippines is Apitong, the wood of the tree *Dipterocarpus grandiflorus* also grown in Borneo and Malaya. The wood is of a reddish-brown color and weighs 44 lb. per cu. ft.

**Lava.** A name given to ceramic material used for molding gas-burner tips, electrical insulating parts, nozzles, and handles. It may be calcined talc, steatite, or other material. As produced by the American Lava Corp., it is molded from magnesium oxide, and it is hardened by heat-treatment after shaping and cutting. It is baked at 2000°F. The compressive strength is from 20,000 to 30,000 lb. per sq. in. It will resist moisture and has high dielectric strength. Rods as small as 0.020 in. in diameter can be made. Alsimag is the trade name of a lava produced by this company from ground talc and sodium silicate. Porcelava is a similar ceramic produced by Burgess & Co., for electric heating appliances. Isolantite, of the Isolantite Co. of America, Inc., is a steatite ceramic molded with a binder and then vitrified. It can be machined or threaded before firing and, by allowing for the contraction, parts can be made with great accuracy. The specific gravity of the vitrified material is 2.5, hardness 8 to 9 Moh, crushing strength 80,000 to 120,000 lb. per sq. in., and the dielectric strength of ⅛-in. thickness 40,500 volts. Lavalloy, of the Lava Crucible Co., is a high-strength ceramic made from a mixture of mullite and alumina. Lavolain, of the Star Porcelain Co., is a strong, dense, heat-resistant ceramic for electric insulation.

**Lead.** A soft, heavy, bluish-gray metal with a granular structure and a strong metallic luster. Its chemical symbol is Pb. Lead is obtained chiefly from the mineral galena. It surface-oxidizes easily, but is then very resistant to corrosion. It is soluble in nitric acid but not in hydrochloric or sulphuric, and is one of the most stable of metals. However, it becomes hard and brittle on repeated melting owing to the formation of oxides. Lead is believed to be the ultimate substance produced by the disintegration of uranium and radium. Its specific gravity is 11.38, melting point 621°F., and boiling point 2787°F. The tensile strength is low, about 3,000 lb. per sq. in., but it is very malleable. The coefficient of thermal expansion is 0.0000183. Lead and its compounds are highly poisonous. Lead is used for pipes and cable coverings. It alloys easily with tin and other metals, and forms many commercial alloys, including solders and babbitts. It is also used for lining acid tanks, and for storage-battery plates. Its compounds are used

in paints, especially white lead. About 30% of all lead is used for storage batteries, 20% for pigments, and 10% for cable coverings. Commercial lead is sold in pigs weighing 100 lb. Seven grades of pig lead are marketed. Corroding lead, 99.99% pure, is for making white lead. Chemical lead, 99.92% pure, with some silver and copper, is used for storage batteries, sheet, and for pipes and cable coverings. Chemical lead has a hardness of 80 Rockwell B compared with 60 for the purer corroding lead. Desilverized lead is produced from the silver-lead ores of the Rocky Mountain states and is at least 99.85% pure. Common lead is not less than 99.73% pure. Work lead is the pig lead from the blast furnaces before the silver is extracted. About 60% of the world production of lead is in the United States, Australia, Mexico, Germany, and Canada, though the ores are widely distributed and many other countries produce lead.

Lead wool is lead in a shredded form used for calking. The strands are 0.005 to 0.015 in. in diameter, and come in ropes $\frac{5}{8}$ to $\frac{3}{4}$ in. in diameter. Blue lead is a term meaning all lead products such as pipe and shot that have not been changed chemically in manufacture. Blue lead is also a name for Basic lead sulphate, a by-product of the smelting of lead ores obtained by collecting and filtering the smoke from the furnace. It is a mixture of the products of the partial combustion of the ore and coal. It consists of lead sulphate, lead sulphide, lead sulphite, lead oxide, zinc oxide, and carbon. It is used in base-coat paints for steel. Lead-coated copper, used for roofing and for acid-resistant tanks, is 16-oz. copper sheet, coated on both sides with lead, made with either a rough or smooth finish. Leadtex, of Revere Copper & Brass, Inc., is a lead-coated sheet copper. Roofloy, of this company, is a strong, stiff, creep-resistant sheet lead used as a substitute for sheet copper for flashings and gutters. It contains 99.7% of lead, 0.20 tin, 0.015 calcium, and 0.012 magnesium. Tea lead, used for wrapping tea, is lead with 2% of tin. Shot lead is lead hardened with a small quantity of arsenic.

**Lead alkali metals.** Lead hardened with small amounts of alkali metals used chiefly as bearing metals. Alloys of this type are also called Tempered lead and Alkali lead. The original alkali lead, known as Bahnmetall, was made under a German patent. It con-

tains 0.73% of calcium, 0.04 lithium, 0.55 sodium, and the balance lead, and is made by electrolysis of the fused alkali salts, using a molten lead cathode. Calcium-lead alloy is made in the same manner, and contains up to 1% of calcium. The calcium forms a chemical compound, $Pb_3Ca$, with part of the lead and the crystals of this compound are throughout the lead matrix. The Brinell hardness is 35, and the compressive strength 25,000 lb. per sq. in., being thus superior in strength to the high-tin bearing metals. But the metal is difficult to melt without oxidation, and is easily corroded. The melting point is 370°C., and it retains its bearing strength at more elevated temperatures than babbitts. Calcium lead, with about 0.04% of calcium, is used as cable sheathing to replace antimonial lead, giving greater fatigue resistance. It is also used for grids in storage batteries, and has a lower rate of self-discharge than antimonial lead. The small amount of lithium in Bahnmetall is intended to prevent the corrosion set up by the calcium. It also increases the compressive strength to about 30,000 lb. per sq. in. Mathesius metal, another German alloy, contains calcium and strontium to form $Pb_3Sr$ crystals. Frary metal, of the National Lead Co., is a lead-calcium-barium alloy containing about 1.5% of the alkali metals. These alloys give low friction loss at low temperatures, but they have higher coefficients of friction than the lead-tin alloys at temperatures above 65°C. A European lead-calcium-barium alloy known as Ferry metal contained 0.25% of mercury to decrease the coefficient of friction. Another bearing alloy, Noheet metal, contained slight amounts of antimony and tin in addition to the alkali metals. B metal, a German alloy, contains 0.73% of calcium, 0.66 sodium, 0.05 lithium, and 0.03 potassium.

**Lead ores.** The chief ore of the metal lead is Galena, a lead sulphide, PbS, containing theoretically 86.6% of lead. The ore, however, contains many other minerals and usually carries only 4 to 11% of lead. It is concentrated by wet gravity methods to contain 40 to 80% of lead. Galena has a bright metallic luster, streaked gray, a specific gravity of about 7.5, and hardness of 2.75. It frequently contains silver and sometimes cadmium, bismuth, and copper. The lead is obtained from the concentrated ore by roasting to remove the sulphur, and smelting. The ingot lead

from the blast furnace contains silver, copper, zinc, and other impurities. It is refined and desilverized. Southern Missouri is the chief source of galena lead production in the United States.

The abundant lead ores Cerussite and Anglesite are secondary minerals formed by the oxidation of galena. Cerussite is a lead carbonate, $PbCO_3$, found in crystals or in granular crystalline aggregate or massive. Its color is white to gray, transparent to opaque. The hardness is 3 to 3.5, and the specific gravity 6.55. Anglesite is found usually in the oxidized portions of lead veins associated with galena and other minerals. It is a common mineral occurring in many localities. Anglesite is a lead sulphate of the composition $PbSO_4$, containing 68% of lead. It occurs in crystals, massive, or granular. Its hardness is 2.75 and specific gravity 6.12 to 6.39. The color may be white or pale shades of yellow or blue, or it may be colorless.

Vanadinite is a minor ore of lead and a source of vanadium. It is a mineral of secondary origin found in the upper oxidized parts of lead veins. It is found in Arizona, New Mexico, Mexico, and Spain. It has the composition $Pb_4(PbCl)(VO_4)_3$, with sometimes phosphorus and arsenic replacing part of the vanadium. It occurs in reddish crystals and globular forms and as incrustations. The specific gravity is 7, and hardness 3.

**Lead pigments.** Chemical compounds of lead used in paints to give color. They are to be distinguished from the lead compounds such as lead oleate, used as driers for paints. White lead is the common name for Basic lead carbonate, the oldest and most important lead paint pigment, and also used in putty and in ceramics. It is a white, amorphous, poisonous powder of the composition $2PbCO_3 \cdot Pb(OH)_2$. It is insoluble in water, and decomposes on heating. The specific gravity is 6.7. It is made from metallic lead, and is marketed dry, or mixed with linseed oil and turpentine in paste form. Lead carbonate, $PbCO_3$ is used as a pigment in the same way as the basic compound, but it discolors more easily. Basic lead sulphate, called Sublimed white lead, makes a fine white pigment. Commercial sublimed white lead contains 75% of lead sulphate, 20 lead oxide, and 5 zinc oxide. Commercial white lead may be mixed with lithopone, magnesium oxide, antimony oxide,

witherite, or other materials. Chrome yellow, or Leipzig yellow, is Lead chromate of the composition $PbCrO_4$, and comes in yellow, poisonous crystals. The specific gravity is 6.123. It is insoluble in water and decomposes at 600°C. Basic lead chromate, $2PbO \cdot CrO_3$, is red in color and is used for anticorrosive base coats for steel. American vermilion, also called Chinese scarlet and Chrome red, is basic lead chromate made from white lead. Orange mineral is the red oxide, $Pb_3O_4$. Cassel yellow, or Montpelier yellow, is oxychloride of lead. Mixtures of white lead and heavy spar are known as Venetian white. Dutch white is composed of three parts of sulphate and one part of carbonate. Lead thiosulphate, $PbS_2O_3$, is a white insoluble powder, used chiefly in matches. All of the lead compounds are poisonous by skin absorption or when taken internally.

**Leaded high brass.** An alloy containing approximately 65% of copper, from ½ to 1½ of lead, and the remainder zinc. It is one of the standard grades of brass, and is also called Free-cutting brass, or High-speed brass. It is easier to machine than high brass but is less ductile. It is used especially for cupped, drawn, or formed parts on which a clean thread must be cut. The property of free cutting is gained at the expense of its drawing capacity, but the material is mostly employed in the form of rods for screw-machine work or in sheets for blanking. The free-cutting brass rod of the Bridgeport Brass Co. contains 61.5% of copper, 35.5 zinc, and 3 lead. All impurities, including iron, are below 0.25%, since as little as 0.50% of iron will harden brass 20 points Rockwell. The free-cutting brass of the Chase Brass & Copper Co. has the same amount of copper, but has 3.5% of lead. A brass of this class will have a tensile strength of 57,000 lb. per sq. in., elongation of 25%, and Brinell hardness up to 110. Ledrite brass is the name of the Bridgeport Brass Co. for leaded brass containing 60 to 63% of copper and 2.5 to 3.75 of lead. The alloy known as Architectural bronze, used for extruded moldings and for forgings, contains 57% of copper, 40 zinc, 0.25 tin, and 2.75 lead. The free-machining alloy known as Arsenical bronze is a leaded high brass modified with other elements. A typical analysis is copper, 56.5%; zinc, 39; lead, 0.70; nickel, 2; iron, 1.20; and arsenic, 0.60. The tensile

strength is 65,000 to 87,000 lb. per sq. in., elongation 11 to 40%. It is wear-resistant and corrosion-resistant.

**Leaded steel.** A free-machining steel containing about 0.25% of lead. Lead does not alloy with iron but is distributed in finely divided particles and strings. It gives free machining without imparting to the steel the unfavorable characteristics given by sulphur or phosphorus. The lead is in such a fine state of dispersion that it cannot be detected except with the most powerful microscope, and there is no weakening effect on the physical properties of the steel. Ledloy, of the Inland Steel Co., contains 0.15 to 0.30% of lead in the regular S.A.E. grades of steel.

**Leather.** The skin or hides of animals, cured by the chemical action of tannins. Leather is used for belting, gaskets, shoes, jackets, handbags, linings, coverings, and a variety of other purposes. The action of tannins precipitates the protein of the hide, changes its colloidal structure, and makes it more pliable and capable of resisting decay. The process of tanning hides consists essentially in soaking them in solutions of the tanning material after they have been unhaired in caustic lime. This soaking may be prolonged for several months, after which the hides are washed, oiled, and rolled. Cheap leathers are tanned quickly with strong solutions of tannin, but rapid action does not produce the desired chemical changes. The quality of leather depends upon the type of animal, its physical condition, the care used in taking off the hide, the method of preserving the hide before tanning, and the care used in tanning. Leather is made from many kinds of skins, including sheep, goat, deer, alligator, seal, and shark, although the bulk of commercial leather is made from cattle hides. Animals raised in the open have hides that produce tough, close-grained leather; breeded cattle raised for meat produce the weakest leather. But in general, packing-house hides, well skinned and packed in brine, make the best leather if properly tanned.

Belting leather is usually made from salted hides free from cuts and scratches, and is either oak- or chrome-tanned. It is then stuffed with oils or tallows. Belting leather weighs about 0.035 lb. per. cu. in. and has an ultimate strength of about 3,800 lb. per sq. in. Belting is now sold by the thickness instead of the weight

because of the old practice of weighting the leather by the addition of heavy impregnations. Leather was once used widely for packings and gaskets but has now been largely replaced for such use by special compounded materials. Where it is used for this purpose, oak-tanned or chrome-tanned is preferred. The Wax calf leather, once popular for men's shoe uppers, was a leather heavily stuffed with oil, grease, and wax. It sheds water and is wear-resistant, but oily leathers are no longer desired in shoes. Cordovan is a tough, smooth, close-grained leather made from the hind quarters of horsehides. It takes a beautiful polish and is used for fancy articles. Another fancy leather is Ostrich leather used for handbags. The skin is marked with tiny rosettes where the quills are extracted. It is imitated in embossed calf. Lace leather, for lacing machinery belting, was originally made from the skins of porpoises, or dolphins, and the fishskins were tanned with alum and salt. After they had dried hard, they were then moistened with water and oiled with cod oil. The leather is very tough, pliable, and strong. It is now made with alum-tanned and oil-treated cowhide or calfskin. Helvetia leather, for belt laces and light belts, is weak-tanned with gambier or spent oak liquor and treated with grease and salt.

**Leather board.** Also called Imitation leather, or Fiber leather. A solid paper type of board made from pulped scrap leather sometimes mixed with jute, wood pulp, or kraft paper to harden and stiffen it. It is used for making trunks and cases. Artificial leather, used for making washers, gaskets, and clutch linings, is made from pulped leather scrap compressed with a binder. Fagelan is a German general trade name for leather substitutes made up of artificial or synthetic fibers bound together and coated with lacquers, gums, or resins. Fabinette is a German artificial leather made up of natural fibers, animal or vegetable, with a suitable binder. Nifarine is a similar material made up with binders of synthetic rubber or synthetic resins in various types and grades. They are waterproof. Positex is the trade name of textile fibers waterproofed with deposited rubber latex and matted into special felts and shoe fabrics, or made into substitute leathers or fiber boards. It was developed by the British Rubber Producers' Research Association and the Wool Industries' Research Association. Leather board for built-up

shoe heels is made with or without a binder. It is sometimes sold under trade names such as Herkolite of the Herkimer Fiber Co. Reletha, of the Prospect Mills, Inc., is a leather substitute for shoe linings made of scrap-leather fibers. The Fibrated leather of the Armstrong Cork Co. is shredded leather impregnated with a protein binder and made into continuous sheets on a paper machine. It is resistant to liquids, resilient, and will withstand temperatures to 300°F. It is used for gaskets, packing, and sealing. Cotton-leather, of the Southern Friction Materials Co., is made from two to six plies of cotton fabric impregnated with a thermosetting resin, calendered and surface-ground to resemble leather. It is made in weights of 4½ to 10 iron, and is flexible and resistant to oil and water. It is used for shoe soles, stair treads, buffing wheels, and machinery mountings.

**Leather dust.** The light, fluffy material blown from the buffing and suèding wheels in tanneries. It has a limited use as a covering material for Artificial suède or Suèded fabrics. In Europe it is more extensively collected, and is also used as a filler in calking compounds. It is very light, giving 20 bbl. to the ton. Its disadvantage for commercial use is its lack of uniformity, being the refuse from many varieties of leather with different tannages and colors not kept separate in American tanneries. Leather flour is ground and graded leather, uniform in color and in mesh. It is used for filler and for suèded fabrics.

**Lecithin.** A light-brown, soft, salvelike substance of bland taste and odor obtained from soybeans by solvent and steam extraction. It is also obtained from cottonseed, and occurs in small amounts in animal and plant cells. Lecithin is a glyceride of complicated chemical structure containing an amine, phosphoric acid, and choline. It bleaches to a faint gold color, is insoluble in water but soluble in oils and in alcohol. At about 150°F. it melts to an oil that will disperse readily in edible oils taking up glycerides to remain fluid when cooled. It is used in chocolate and other foods as an antioxidant to prevent spoilage, as a stabilizer and emulsifier, and as a dietetic. It is also employed in casein paints, as a softener and wetting agent in other products, and as a curing accelerator in

synthetic rubbers. The Choline, $CH_2OHCH_2N(CH_3)_3OH$, is a heart stimulant.

**Lemongrass oil.** A pale reddish essential oil distilled from various species of *Cymbopogon* grass of the East Indies, Malaya, and tropical America. It contains about 75% of Citral, $C_9H_{15}CHO$, which is an aldehyde of several essential oils. The chief constituents are Citronellal, $C_{10}H_{18}O$, and Geraniol, $C_{10}H_{17}OH$. It also contains some Ionone, $C_{13}H_{20}O$, a terpene used as a base for violet perfumes. The oil has a powerful lemonlike odor. The plant is a tall, rapid-growing grass. Three tons of the East Indian grass yield 24 bottles of oil, each bottle being 25 oz. by volume. Florida lemongrass yields 6.3 lb. of oil per ton of grass. The residue Lemongrass pulp in Florida is dehydrated and mixed with cane molasses for cattle feed. The oil is soluble in 70% alcohol. It is used as a stabilizer and perfume in soaps and in cosmetics. The two chief grades are East Indian lemongrass, from *C. flexuosus,* and West Indian lemongrass, from *C. citratus.* The latter contains less citral and is less soluble, but partly owing to a difference in the method of distillation. Citronella oil is a yellow oil with a pleasant odor, distilled from the grass *C. nardus* of Ceylon, Java, and India. Java citronella is called Serah grass. It contains high percentages of geraniol and citronellal. It is used as a stabilizer and perfume in soaps, as an insect repellent, and as a base product for the production of Synthetic menthol and of geraniol. The Java citronella oil is highest in citronellal, which yields about 20% of levo menthol or about 12% of U.S.P. menthol. The Ceylon oil is highest in geraniol, being sold on the basis of 85%, and is used in soaps and insecticides. Palmarosa oil, also called Turkish geranium oil because the original shipments were through Turkey, is from the Motia grass, *C. martini,* of India and Java. It contains 75 to 90% of geraniol. Another variety of *C. martini,* known as Sofia grass, Sofia meaning mediocre, yields the product called Ginger grass oil, inferior to palmarosa, and containing less geraniol.

**Lepidolite.** A lithia mica occurring usually in small plates, with muscovite, or common mica. The composition is $KLi(Al\cdot 20HF)\text{-}Al(SiO_3)_3$. It is one of the chief ores of the metal lithium, and also carries more rubidium than any other known mineral, con-

taining from a trace to 3% of Rubidium oxide, $Rb_2O$. It may also have as much as 0.77% of Cesium oxide. It is the most widespread of the lithium minerals, being found in various parts of the United States, Canada, Northern Rhodesia, South Africa, India, China, Japan, Russia, and Germany. The hardness is 2.5 to 4, and specific gravity 2.8. It has a pearly luster, and color pink and lilac to grayish white. It is insoluble in acids. Lepidolite is employed as a source of lithium compounds, and of the metals rubidium and cesium. It is also used in making opal and white glasses. Glassmakers' lepidolite contains 4% of $Li_2O$; West African lepidolite usually contains 3.75%. Amblygonite, plentiful in Sweden, has the formula $Al_2O_3 \cdot 2LiF \cdot P_2O_5 \cdot Li_2O$, and contains 4.24 to 5.26% of lithium. Other Lithium ores are Lithiophilite, $Li_2O \cdot 2MnO \cdot P_2O_5$, containing 4.6 to 5% of lithium; Cryolithionite, $3LiF \cdot 3NaF \cdot 2AlF_3$, with 5.35% of lithium; Petalite, $Li_2O \cdot Al_2O_3 \cdot 8SiO_2$, with 1.4 to 2.26% of lithium; and Manandonite, $7Al_2O_3 \cdot 2LiO \cdot 2B_2O_3 \cdot 6SiO_2$, with 2.13% of lithium. Lithium concentrate, containing about 20% of $Li_2O$, is obtained by treating the brine of Searles Lake, Calif.

**Licorice.** The sweet roots of a group of plants of the order *Fabraceae*. The common licorice of the Near East and Spain is *Glycyrrhiza glabra,* and of Italy, *G. echinata.* Certain other species, all native to the Mediterranean countries, are also employed. The roots are crushed and boiled in water, and the juice strained and evaporated. Finely ground root is added to aid in hardening, but starch or other adulterant may be added. Licorice is employed in confectionery, in medicines, in tobacco, and in beverages, but industrially it is used for fire extinguishers to produce a froth to smother the fire. The dark-colored extracted juice of the roots contains a glucoside, which will not ferment. Licorice also contains a saponin, or froth-producing substance. In fire extinguishers it is sold under trade names. An insulating building board made with a proportion of the residue fibers after extraction of the licorice extract is produced by the National Gypsum Co. It is tough, strong, and resistant to insect attack.

**Lignin.** A colorless to white crystalline product recovered from paper-pulp sulphate liquor, and used in furfural plastics, as an ex-

tender of phenol in phenolic plastics, as a corrosion inhibitor, in adhesives and coatings, as a natural binder for compressed wood products, and for the production of synthetic vanilla when it contains coniferin. It is also used as a fertilizer, providing humus and organic material and some sulphur to the soil. For this use it may be mixed with phosphates. The melting point of lignin is 250 to 275°C. It is a complex carbohydrate. The waste liquors from sulphite process paper mills contain about 5% of lignin. Alkali lignin is produced by acidulation of the black liquors from the soda process. It is used as the organic expander in the negative plates of storage batteries, as an emulsifier for asphalt to reduce cold flow, and as a binder in paperboard plastics. Alkali lignin may also be hydrogenated to make methanol, methane, and tar acids.

**Lignite.** Also called Brown coal. A variety of organic mineral of more recent age than coal, occurring in rocks of tertiary age, and intermediate in composition between wood and coal. It is widely distributed over Europe, and found in many other parts of the world. Freshly cut lignite often contains a large quantity of water, up to 40%, and is sometimes also high in ash. When dried it breaks up into fine lumps and powder. Dry lignite contains 75% of carbon, 10 to 30 oxygen, and 5 to 7 hydrogen. It kindles easily but burns with a low calorific power and a smoky flame. In retort gas production lignite loses its gas in half the time required for gas removal from bituminous coal, with a temperature of 1270°F., compared with 1655°F. for bituminous. The color of lignite varies from brown to black, and the lower grades of brown lignite show the woody structure. The Pitch coal is brownish black, breaks with a pitchlike fracture, and shows no woody structure. Lignite is briquetted by crushing and pressing with a binder under heat. Belgian lignite briquettes have a binder of 8% of asphalt, with 2 flour to assist binding. The reserves of lignite in the United States are estimated at 1,000 billion tons, and form a future fuel for use in powdered form, or for distillation of oils and coal-tar products. Jet is a hard, compact, black lignite found in Colorado and in Europe. It can be turned in the lathe and will take a fine polish. It was formerly much used for making buttons and ornamental articles, but has been largely replaced by synthetic plastics.

**Lignum vitae.** The wood of the guayacum trees, *Guaiacum Offinale* and *G. sanctum,* of tropical America, but the commercial shipments of lignum vitae are likely to contain also other species. The wood of the Guayacan tree of Brazil and Paraguay is also called by this name. The best quality of the true lignum vitae comes in logs up to 18 ft. long and up to 3 ft. in diameter, and originates mostly from Cuba, Haiti, Yucatan, Dominican Republic, and the west coast of Mexico and Central America, but species of the trees grow as far south as Paraguay. It is very hard, heavy, and tough. The color is brown to greenish black. The grain is very finely twisted, and the wood has a greasy feel. The weight is from 72 to 88 lb. per cu. ft., and the crushing strength is 10,0000 lb. per sq. in. The wood is used in places where extreme hardness is needed, such as for pulley blocks. It is also used for rollers, mallet heads, handles, novelties, bearings, and furniture. In machine bearings it withstands pressures up to 4,000 lb. per sq. in., and is used for propeller-shaft bearings in steamships. Palo santo, *Bulnesia sarmenti,* known as Guayacan, of Argentina and Paraguay, and also Vera, *B. arborea,* of Colombia and Venezuela, are closely related to lignum vitae and were formerly classified as *Guaiacum.* The latter is called Maracaibo lignum vitae, and the former is known as Paraguayan lignum vitae. The trees are larger than true lignum vitae, but the wood is not as hard. Philippine lignum vitae is a hard, heavy wood with interwoven grain, from the tree *Xanthestemon verdugonianus* of the Philippines. Yellow guayacan, deriving its name from the yellow flowers, is from the *Tecoma guayacan,* an important timber tree of Panama and Central America. The wood is very hard and strong, but neither this wood nor that of the Philippine wood has the self-lubricating bearing properties of the oily true lignum vitae. Ibera vera, of Argentina and Paraguay, is called also guayacan locally. It is from the tree *Caesalpinia melanocarpa,* and resembles lignum vitae in hardness, strength, and durability, but is lacking in the oily gum resin.

Artificial lignum vitae, or Compressed wood, or Densified wood, sold under trade names, is ash or a soft wood impregnated with liquid resin and compressed hydraulically to about the specific gravity of lignum vitae. It is used for bearings, or as a substitute for very hard woods. The material developed by the U.S. Forest

Products Laboratory under the name of Staypak, is made by compressing veneered softwood containing no resin except that used to bond the veneers. It has a smooth satiny finish, a specific gravity of 1.3 to 1.4, and about double the tensile and flexural strengths of birch. The color is darker than the original wood because of the flow of lignin.

Guaiacum oil, distilled from the wood of the guayacan tree of Paraguay, is used in medicine, in soaps, and in perfumes. It is light gray in color, and is solid at temperatures below 45°C. The odor is that of a combination of tea leaves and roses. It is also called Guaiacwood oil. The wood yields 5 to 6% of the oil. Guaiac gum, also called Guaiacum, is the gum resin of the true lignum vitae trees used in varnishes as a chemical indicator, and to prevent rancidity and loss of flavor in preserved and dehydrated foods. It is an effective antioxidant, although its chief use is in medicine as a stimulant and laxative. The resin comes in greenish-brown tears.

**Lime.** A Calcium oxide, CaO, chemically known as Calcia, occurring abundantly in nature, chiefly in combination with carbon dioxide as calcium carbonate, in limestone, marble, chalk, coral, and shells. Lime is employed in mortars, cements, as a flux in iron melting, in many chemical processes, as an absorbent, and for liming acid soils. It is obtained by heating limestone in a furnace, or kiln to about 1000°F. to burn out the carbonic acid gas. The residue is called Quicklime or Caustic lime. Pure quicklime is white and amorphous or crystalline. The specific gravity is 3.2 and melting point 4660°F. Chemical lime, used in the chemical industries and for water softening, is a high-calcium lime with minimum impurities. A typical analysis is 97.9% of CaO, 0.43 silica, 0.45 iron and aluminum oxides, and 0.52 magnesium oxide.

Commercial limes for building purposes contain about 94% of calcium oxide, some calcium carbonate, and less than 0.50% of magnesia. Water causes the lime to slake with much heat, leaving a white powder, $CaO \cdot H_2O$. High-calcium limes slake rapidly and expand greatly on slaking and are the strongest. Limes with much magnesia slake slowly, but magnesia produces the slip that makes easier working. The so-called lean limes contain considerable silica,

alumina, and iron oxide, and are slow slaking and difficult to work. Lime is marketed in lumps or ground to 20 mesh, and as mill run. Hydrated lime is made by grinding quicklime, slaking the powder with water, and sifting to a fine powder. It is easier to handle and is a more reliable product than ordinary lime. High-grade hydrated lime will have a fineness so that 98% will pass through a 100-mesh sieve and will contain not over 2% of magnesia. Some grades contain less than 0.50% of magnesia, and 98% pass through a 200-mesh sieve. Hydraulic lime that will set under water is a hydrated lime with more than 10% of silica. The Grappier cement of France and Belgium is made from limestones that contain 20 to 22% of silica and 2 alumina. The pure hydrated lime for the chemical industry has 98.2% $Ca(OH)_2$, or 74.4% CaO, and is a fine impalpable powder. Lime is usually marketed in barrels of about 200 lb. each. Hydrated lime comes in 100-lb. burlap sacks or 40-lb. paper bags. Lime mortar, made of a mixture of hydrated lime, sand, and water, will have a compressive strength up to 400 lb. per sq. in. Soda lime, used for freeing air of carbon monoxide, as a chemical purifying agent, and in gas masks, is a mixture of hydrated lime with sodium hydroxide.

**Lime oil.** An essential oil expressed from the rind of the Lime, the fruit of the small tree *Citrus aurantifolia,* native to India but now grown in many tropical and subtropical countries. The fruit is smaller than the lemon, and is greenish yellow in color. Montserrat in the West Indies, Italy, and Florida are the chief commercial centers. Lime oil is used in flavoring and to give freshness to perfumes. Lime juice, from the pulp of the fruit, is used in beverages and as a source of citric acid. It was early used to prevent scurvy, but contains only about a quarter as much vitamin C as orange juice. Lemon oil is a bright-yellow oil of pleasant odor, expressed from the rind of the Lemon, the fruit of the tree *C. limonia,* grown commercially in the Mediterranean countries, California, and the West Indies. About 1,000 lemons are required to produce a pound of oil. The oil is high in Citral with also limonene, terpineol, and citronellal. It is used in flavors, soap, and in perfumery. Lemon juice is from the pulp. It contains 5% of citric acid, and is used for beverages and as a bleaching agent. About

two-thirds of the commercial production of Lemons is in Italy. The Citric acid produced from lemons, limes, and pineapples is a colorless, odorless crystalline powder of the composition $(CO_2HCH_2)_2C(OH)COOH$, specific gravity of 1.542, and melting point of 153°C. It is used in medicine, flavoring extracts, and in soft drinks, but is toxic in excess. It is also used in inks, etching, and as a "resist" in textile dyeing and printing.

**Limestone.** A term applied to a great variety of rocks that contain lime. Immense quantities of limestone are used as flux in the melting of iron, for the manufacture of lime, and as a building stone. In its broad sense limestone includes dolomite, chalk, marble, or any mineral consisting largely of $CaCO_3$, but many limestones contain considerable magnesium carbonate, $MgCO_3$. On calcination limestone yields lime, CaO. The Portland stone of England consists of fossils cemented together with lime. Indiana limestone, used for building, is a noncrystalline massive rock with aggregate, filler, and matrix of pure carbonate of lime in gray and buff colors. The average weight of Indiana limestone is 144 lb. per cu. ft., and crushing strength 6,000 to 8,000 lb. per sq. in. The mill blocks range from 8 to 12 ft. in length, and are 3 ft. 6 in., or 4 ft. 4 in. square. Limestone is very widely distributed, and nearly 70% of all the crushed and broken stone marketed for construction purposes in the United States is limestone. The agricultural limestone, known in the trade as Agstone, and used for liming soils, has a content of 99% $CaCO_3$, and is ground to a fineness of 200 to 325 mesh.

**Linen.** A general name for the yarns spun from the fiber of the flax plant, or for the cloth woven from the yarn. Linen yarns and fabrics have been made from the earliest times, and the ancient Egyptian linen fabrics were of exceeding fineness containing 540 warp threads per inch, not equaled in Europe until the twentieth century. Ireland, Belgium, and France are the principal producers of linen. Linen yarns are used for the best grades of cordage, and linen fabrics are employed industrially wherever a fine, even, and strong cloth is required. Linen fabrics are sold under a wide variety of trade names. They are graded chiefly according to the fineness of the yarns and the class of weave and may

contain some fine hemp fibers. Lisle was formerly a fine, hard linen thread, made at Lille, France, but is now a fine, smooth yarn made of long-staple cotton spun tightly in a moist condition. Tow yarns are the coarsest linen yarns, used for making Crash, a coarse, plain-woven fabric used for towels or covers. Chintz is a plain-woven linen fabric in brightly colored designs. It is also made in cotton as Cotton chintz. The name is from the Hindu word meaning color. Damask is a jacquard reversible woven linen fabric for table linen. It is now also made in cotton, silk, wool, or rayon.

**Linoleum.** A general name for floor-covering material consisting of a fabric impregnated and covered with a compound of blown linseed oil, ground cork or wood flour, and rosin or other gum. It is rolled under great pressure, and then dyed in plain colors or printed with designs. In good-quality linoleum the cork is ground to a 50-mesh screen, and the pressed material will take printing or coloring evenly. A filler of lithopone or other material may be used. The fabric may be of jute or other coarse material. Linoleum was invented and patented in 1863 and displaced the older Kamptulicon floor covering, which was made of rubber, cork, rosin, and boiled oil, and was more expensive. Battleship linoleum is very heavy linoleum in plain colors or mosaics. Federal specifications describe it as made with oxidized linseed oil, fossil or other resins or oxidized rosin, and an oleoresinous binder, mixed with ground cork, wood flour, and pigments, processed on a burlap back.

**Linseed oil.** This oil is the most common of the drying oils, and is widely used for paints and varnishes, and for linoleum, printing inks, and soaps. It is obtained by pressure from the seeds of the flax plant, *Linum usitatissimum,* which is cultivated for oil purposes in Russia, India, North and South America. Argentina is the greatest producer of linseed. It is sometimes referred to as Flaxseed, though this name properly belongs only to the seed of the flax plant for producing flax fiber. The varieties producing fiber do not yield much seed. The seed contains up to 40% of oil, but the usual conversion factor is 34%. The commercial oil is hot-pressed and has a bitter taste, but a cold-pressed oil is used in Russia for food purposes. The residue Linseed cake is used for cattle feed and fertilizer.

Linseed oil contains about 48% of linoleic and 34 of linolenic acids. The specific gravity is 0.925 to 0.935. It is a yellowish oily liquid with a peculiar odor and a bland taste. It is soluble in turpentine, ether, and benzene. It dries with a distinct gloss and makes a hard film.

The best Baltic oil is used as a standard in measuring the drying power of other oils. Genuine linseed oil has an iodine value of at least 170, and the best approach 190. The linseed grown in cooler climates yields oils of higher iodine value than those grown in warm climates. For varnish use the oil is bleached by heating and forcing oxygen through it, or used as Boiled linseed oil, prepared by boiling in a kettle or by heating with oxidizing driers such as the salts of lead or manganese. When prepared with driers, it is called Bung oil. Stand oil, also known as Lithographic oil, is linseed oil heated for several hours without blowing, at a temperature of 550 to 650°F. It has the consistency of honey and is used in oil enamel paints. Blown oils and boiled oils are not greasy like the original oil. Linoxyn is a trade name for blown linseed oil. The purity and adulteration of linseed oil for paint and varnish use are controlled by state laws. The law of the state of Ohio, which is typical, defines Boiled linseed oil as prepared from pure, raw linseed oil heated to a temperature of 225°F., and incorporating not to exceed 4% by weight of drier, and with specific gravity at 60°F. of not less than 0.935 and not greater than 0.945. Esskol and Solinox, of Spencer Kellogg & Sons, Inc., are hydrogen-treated linseed oils used as substitutes for tung oil and castor oil.

**Linters.** The short cotton fibers that adhere to the seed after ginning. Cotton linters removed from the cottonseed are ⅛ in. long or shorter, gray and brown in color, and are used as a filling and padding material especially for mattresses, and also for producing cellulose for the manufacture of rayon, nitrocellulose, and plastics. The No. 1 grade is spinnable, and can be used for mixing with cotton for yarns. This grade is also used for absorbent cotton. The Nos. 2, 3, and 4 grades are for felting and for filling. The Nos. 5, 6, and 7 grades are called chemical grades and constitute about 60% of the production. The extremely short fibers ob-

tained from second-cut seeds are called Hull fiber. About 100 lb. of linters are obtained per short ton of seed.

**Liquid air.** Atmospheric air liquefied under great pressure. The boiling point is about −310°F. One cubic foot of liquid air makes 792 cu. ft. of free air. It is used in explosives, for cold-treating metals to be shrunk into place, and as a source of oxygen. It contains more than 20% of free oxygen. It is marketed in vacuum bottles, and as the evaporation is 4 to 8% a day, it is shipped only just prior to use. Liquid air mixed with alcohol was used as the propellant in the German 15-ton rocket known as the V-2. The mixture is highly explosive, and the reaction was controlled with hydrogen peroxide and potassium permanganate which also added to the power.

**Litharge.** The yellow Lead monoxide, PbO, also called Massicot. It is a yellow powder used as a pigment and also in the manufacture of glass, and for the fluxing of earthenware. An important use is as a filler in rubber. With glycerin, litharge is used as a plumbers' cement. The specific gravity is 9.375. Litharge is produced by heating lead in a reverberatory furnace and then grinding the lumps. For storage-battery use the black oxide, or suboxide of lead, is now largely substituted.

**Lithium.** The lightest of all metals, with a specific gravity of 0.534. It is abundant, and is found in more than 40 minerals, but is obtained chiefly from lepidolite and spodumene and from the brine of Searles Lake. Lithium melts at 356°F. and boils at 2550°F. It is unstable chemically and burns in the air with a dazzling white flame when heated to just above its melting point. It tarnishes quickly in the air, and in moist atmospheres $Li_3N$ is formed. The metal is kept submerged in kerosene. Lithium resembles sodium, barium, and potassium, but has a wider reactive power than the other alkali metals. It combines easily with oxygen, nitrogen, and sulphur, to form low-melting-point compounds which pass off as gases, and is thus useful as a deoxidizer and degasifier of metals.

Lithium metal is produced by the fusion of Lithium chloride, LiCl, in a mixture of chlorides. The commercial metal is 99.4%

pure. Its salts burn with a crimson flame, and lithium chloride is used in pyrotechnics. Lithium is used for alloying with other metals. It hardens lead by the formation of a compound, $Pb_3Li_2$, and is used in small quantities in bearing metals. Lithium also hardens aluminum alloys, and a very small percentage is used in such strong alloys as Skleron. The metal has also been alloyed with beryllium. An alloy of 65% of lithium and 35 beryllium is as light as water but corrodes easily. By adding small quantities to aluminum or zinc the hardness, strength, and resistance to corrosion are increased. The addition of as little as 0.025% to zinc will change it from a coarse-grained to a fine-grained metal.

Lithium salts are used in storage batteries to increase the electrical capacity. Lithium chloride, LiCl, is used in spray solution for dehumidifying air for industrial drying and for air conditioning as it absorbs water rapidly. It is also used in welding fluxes for aluminum. Lithium hydride, LiH, a colorless to white powder of specific gravity 0.82 and melting point 680°C., is used for the production of hydrogen for emergency signal balloons. A 1-lb. can of hydride when immersed in water will liberate 45 cu. ft. of hydrogen gas. Lithium metal is also used in light-sensitive control cells which depend on the change in resistance of the cell due to varying electron emission with changing light sensitivity. A form of the metal known as Lithium six consists of the light atoms and is a silvery-white metal of extreme lightness.

**Lithium alloys.** Lithium is soluble in most commercial metals. It is a powerful deoxidizer and desulphurizer of steel, but no lithium is left in the Lithium-treated steel. The steel, however, has increased elastic limit. In stainless steels it increases fluidity to produce dense castings. Cast iron treated with lithium has high impact value, a fine grain structure, and increased density. Not more than 0.01% of lithium remains in the casting when treated with lithium copper. In magnesium alloys the tensile strength is increased 30% by the addition of 0.05% of lithium. In Lithium-lead the lithium combines chemically and the solid solubility of lithium in lead is not over 0.09% of lithium. The lead becomes harder and tougher, with a fine-grained structure and increased strength. The alloys are known as alkali lead.

Lithium-copper master alloys consist of a group of foundry alloys containing usually 90, 95, or 98% of copper with the balance lithium, used for deoxidizing and degasifying nonferrous alloys. Lithium combines easily in the molten bath with oxygen, hydrogen, nitrogen, sulphur, and the halides. The compounds formed are stable, of a nonmetallic nature, of low melting points, and volatilize easily so as to pass off as vapors at the pouring temperature of the metals. Lithium copper is a high-conductivity, high-density copper containing a minute quantity of residual lithium, 0.005 to 0.008%, made by treating copper with a 50-50 lithium-calcium master alloy. The conductivity of lithium copper is 101.5% I.A.C.S. The tensile strength is 31,500 to 36,500 lb. per sq. in., with elongation of 60 to 72%. The wrought metal is tougher than phosphorized copper, and has exceptional deep-drawing properties. The cast metal has a density of 8.92. Lithium is an excellent desulphurizer for nickel alloys. From 1 to 7% of calcium may also be included in lithium-copper master alloys. Lithium-calcium alloys usually contain 30 or 50% lithium, with the balance calcium. They are silvery white in color, with a metallic luster, and are hard and brittle. The melting range is 230 to 260°C. They must be kept in tight containers under kerosene. The alloys are used for treating steel, cast iron, or nickel where no residual copper is to be left. Copper-manganese-lithium contains 60 to 70% of copper, 27 to 30 manganese, 0.5 to 5 lithium, and sometimes 5 to 7 calcium. Copper-silicon-lithium contains 80 to 84% of copper, 10 to 11 silicon, 2.5 to 10 lithium, and sometimes 2.5 calcium.

**Lithopone.** Also known under various trade names: Ponolith, Albalith, Sunolith, Beckton white, Zincolith, Sterling white, and others. A white pigment consisting of barium sulphate and zinc sulphide. A standard lithopone is 66% barium sulphate and 34 zinc sulphide. High-strength lithopones contain about 50% of zinc sulphide, which latter is one of the whitest pigments. Titanated lithopone contains a percentage of titanium dioxide. Tidolith is a titanated lithopone of the United Color & Pigment Co. having 85% lithopone and 15 titanium oxide. Commercial lithopone is a fine white powder used in the manufacture of paints, inks, oil-

cloth, linoleum, and rubber goods. For paints the powder should pass through a 325-mesh screen. The ground paste should contain 76 to 80% of pigment and 20 to 24 of linseed oil. As a paint pigment, lithopone has good hiding power and is lower in cost than other whites, but is not as durable for outside use as white lead or zinc white. It is the most used white pigment for interior work. Albalith is a 70-30 lithopone of the New Jersey Zinc Co., also used in rubber goods, inks, and paper.

**Litmus.** A dyestuff prepared from several varieties of the lichen, *Variolaria,* chiefly *Rocella tinctoria,* by allowing them to ferment in the presence of ammonia and potassium carbonate. When completely fermented, the mass assumes a blue color and is mixed with chalk and made up into tablets, or made in paper form. It is used for dyeing textiles, staining wood, and coloring foods. Litmus gives a deep-blue color with alkalies and a red with acids, and is used as an indicator of acidity. Azolitmin, $C_7H_7O_4N$, is the coloring matter of litmus, and is a reddish-brown powder. Orchil, or Cudbear, is a red dye from another species. Litmus paper is paper treated with litmus marketed for acidity testing.

**Locust.** The wood of the locust tree, *Robinia pseudacacia,* also known as Acacia, False acacia, Black locust, and Red locust. The tree is native to North America, but is also grown in Europe. The wood is strong and durable, with a weight of 43 to 52 lb. per cu. ft. Its hardness is about the same as ash, and the strength, flexibility, and shock resistance greater than oak. The grain is coarse, but the surface is lustrous and satiny. Locust is used for furniture, wheel spokes, posts, crossties, and in construction. Honey locust is a lighter and weaker wood from the tree *Gleditsia triacanthos.* The name locust is also applied to the wood of the tree *Hymensea courbaril* of tropical America. This wood has a brownish color, with an open grain, and takes a beautiful polish. The wood of the Australian locust, *Acacia melanoxylon,* known as Australian blackwood and Tasmanian blackwood, and employed for cabinetwork, is reddish brown to black in color and beautifully grained. It is similar in durability and appearance to rosewood, but lighter in weight. Various species of true acacia trees furnish the

tannins catechu and wattle. The Silver wattle of New Zealand, *A. prominens,* used for ax handles and fruit cases, is hard and tough.

**Locust bean gum.** Also called Locust bean flour, and Carob flour. A tasteless and odorless white powder obtained by milling the bean kernels of the locust trees of tropical America and the Mediterranean countries, notably *Cerafonia siliqua* of Cyprus and Syria. When dissolved in water and boiled, it produces an adhesive, transparent jelly, which dries into a colorless, strong elastic film. It is not a starch but is composed of galactan and mannan. It is used for coating textiles and also as a thickener and binder in glues, pastes, and latex, in leather finishes, and in sizings for yarn and paper. The flour is marketed in 50, 100, 150, and 175 mesh. It dissolves in cold water and swells in warm water. The flour is edible and is also used in jellies and in bakery products. The dried pods, or Carob beans, holding 6 to 10 hard seeds or beans, are used in flavoring dog biscuit and tobacco. In the Near East they are eaten like candy, and are also used as cattle and horse feed. The pods also yield Tragasol gum, which is used as a textile size and in leather tanning. The Algaroba tree, *Prosopis chilensis,* growing in semiarid regions of Mexico, Central and South America, called also Mesquite, and in Hawaii called Keawe, furnishes an important stock feed from the pods and beans, which are similar to the locust.

**Logwood.** An extract obtained from the wood of the tree *Haematoxylon campechianum,* of tropical America, used as a black dye or as a darkening agent in browns and grays. The wood yields 15% of extract. The coloring matter, Hematine, $C_{16}H_{12}O_6$, forms brownish-red crystals and is produced only in the aged wood or by oxidation of the white extract of fresh wood. Logwood, or Hematine, is marketed in crystals, solid extract, or water extract.

**Loofa sponge.** A yellowish porous skeletal fibrous body obtained by retting the fruit or seed pods of the tropical edible cucumber, *Luffa cylindrica* and *L. acutangula,* obtained in India, Japan, and the Caribbean countries. It is also called Vegetable sponge, although it is harder and coarser than a sponge. The paper-thin skin is easily removed when the pod dries. The skinned

sponge is washed to remove the slimy interior, and when redried the seeds are shaken out. The seeds are used to produce a food oil similar to olive oil but colorless and tasteless. The sponges vary in size from 8 to 24 in. long. The plants grow rapidly, giving four annual crops in Brazil, and a hill of 3 seeds can produce 300 sponges. Loofa sponges are used chiefly for filters in feed tanks of ships. A stiff curly fiber used for making hats is obtained from the product by further retting.

**Low-alloy steels.** Any steel that has small amounts of alloying elements below the normal amounts in standard alloy steels may be termed low-alloy, but the name has come to refer to steels with balanced proportions of alloying elements designed to give high strength while conserving chromium, nickel, and other strategic elements. A number of such steels classified during the war by the Iron & Steel Institute were designated as National emergency steels. They were primarily intended as a conservation measure to use alloy scrap directly in the mix, and the alloying elements were not uniform. But the advantages of these low-alloy steels for a wide range of use were so apparent that they were then made under controlled conditions to uniform specifications. Plain carbon steel hardens only near the surface, leaving the core soft and weak, but with the small amounts of alloying elements the hardening and strengthening effect is carried deeper and distortion in heat-treating is reduced. Chromium and manganese are important in these steels. Both form hard carbides and both are soluble in ferrite. Manganese is an austenite-forming element, and austenite is easily cold-worked. But with considerable manganese in steels where chromium is present martensite and manganese carbide are formed and the steels have low ductility. Tensile strengths of 70,000 to 95,000 lb. per sq. in. can be obtained with 1.25% manganese and 0.5 chromium, and low carbon, 0.10 to 0.20%. Such a steel is balanced when normalized, but for structural steels to be used in the as-rolled state about 0.75% of silicon is added to balance the effect of rolling and cooling. Cromansil, with 1.25% of manganese, 0.50 chromium, and 0.75 silicon is typical of this class of high-strength, low-alloy structural steel. Typical of a balanced steel for carburized and heat-treated articles subject to heavy

dynamic stress is one having 1.5% of chromium, 1 manganese, 0.5 silicon, and 0.15 carbon. It can be heat-treated to a strength of 175,000 lb. per sq. in. Nickel is also added in low-alloy steels to balance the chromium and give high strength. Molybdenum also gives high fatigue and impact strength. A structural steel is N-A-X high-tensile steel, of the Great Lakes Steel Corp. A typical composition is carbon, 0.13%; manganese, 0.70; silicon, 0.80; copper, 0.23; chromium, 0.60; nickel, 0.15; molybdenum, 0.10; zirconium, 0.12. In structural shapes it has a tensile strength of 80,000 lb. per sq. in. with elongation of 24% and is resistant to fatigue. The N-A-X 9100 steels are in four grades with carbon from 0.08 to 0.70, including a high-tensile grade, a carburizing grade, a shallow-hardening and a deep-hardening grade. These contain small amounts of silicon, chromium, and zirconium, with sometimes a small amount of molybdenum. The minimum tensile strength of N-A-X 9112 steel, as rolled, is 75,000 lb. per sq. in. with elongation of 27%.

Small amounts of copper refine the grain and also give added corrosion resistance, especially when up to 0.20% of phosphorus is present. Mayari R steel, of the Bethlehem Steel Co., is a low-alloy, high-strength, corrosion-resistant structural steel with tensile strength of 70,000 lb. per sq. in. and elongation of 22%. It contains 0.12% of carbon, 0.50 to 1 manganese, 0.20 to 1 chromium, 0.25 to 0.75 nickel, 0.50 to 0.70 copper, and 0.05 to 0.50 silicon. Aldecor, of the Alloys Development Co., is a high-strength structural steel containing chromium, nickel, molybdenum, and copper, low in manganese. A typical casehardening high-strength steel is Carpenter No. 872, which is a commercial adaptation of NE steel 8715. It contains 0.10% of carbon, 0.80 manganese, 0.50 chromium, 0.50 nickel, and 0.22 molybdenum. When heat-treated, it has a tensile strength up to 130,000 lb. per sq. in., and elongation of 18 to 25%. This steel with 0.45% carbon, Carpenter No. 874, when heat-treated, has a tensile strength from 115,000 to 225,000 lb. per sq. in., with elongation of 10 to 24%, and Brinell hardness of 235 to 444.

A typical Bolt steel used in the automotive industry contains 0.37% of carbon, 0.90 manganese, 0.55 nickel, 0.50 chromium, and 0.20 molybdenum. NE steel 8630, for aircraft tubing, con-

tains 0.40 to 0.70% of nickel, 0.40 to 0.60 chromium, and 0.15 to 0.25 molybdenum. The tensile strength is 90,000 lb. per sq. in., with elongation of 35%. S.A.E. steel X4340, used for aircraft engine crankshafts and connecting rods, contains 1.5 to 2% of nickel, 0.60 to 0.90 chromium, and 0.20 to 0.30 molybdenum. The tensile strength of the heat-treated steel is 230,000 lb. per sq. in. and elongation 12%. Otiscoloy, a low-alloy steel of the Otis Steel Co., has 0.90 to 1.25% of manganese and only 0.08 to 0.12 carbon, with 0.30 copper, 0.10 nickel, 0.05 chromium, and 0.10 silicon. It has a minimum tensile strength of 70,000 lb. per sq. in., with elongation of 25%. Its corrosion resistance is three times that of plain copper-bearing steel, and it is abrasion resistant.

**Low-expansion alloys.** Alloys, usually of nickel and iron, which have a very low coefficient of expansion at ordinary temperatures, used chiefly for instrument parts and for lead wires to be sealed in glass or other material. The alloy first developed in France under the name of Invar has an expansion so low for measuring purposes, under ordinary conditions, it is generally taken as zero. This is taken as 0.0000004 per deg. C., but above 120°C. the coefficient rises. Invar is used for the measuring guides of accurate instruments and for parts for watches. A typical composition is 63.5% of iron, 36 nickel, 0.5 manganese, with sometimes 0.20 selenium to make it free machining. Such an alloy is also very resistant to corrosion. Nivar is another alloy similar in composition. The tensile strength of Invar is 65,000 lb. per sq. in., elongation 35%, and hardness 125 Brinell when annealed. The cold-drawn metal has a tensile strength of 90,000 lb. per sq. in., elongation 20%, and hardness 185 Brinell.

Elinvar, used for chronometer balances and springs for gages and instruments, has low thermal expansion and almost invariable modulus of elasticity. Elinvar for hair springs for watches contains 33 to 35% of nickel, 53 to 61 iron, 4 to 5 chromium, 1 to 3 tungsten, 0.5 to 2 manganese, 0.5 to 2 silicon, and 0.5 to 2 carbon. Platinite, a French alloy with a coefficient of expansion about the same as that of glass, contains 46% nickel and 54 iron. It is used in light bulbs. Dilver and Adr are also French low-expansion, nickel-iron alloys. Super-Invar is a Japanese product containing

5% of cobalt to replace an equal amount of nickel. It has a nearly zero coefficient of expansion at ordinary temperatures. Nilvar, of the Driver-Harris Co., used for instrument parts, measuring tapes, and connections through glass, is in various grades with about the same coefficient of expansion as glass or with the zero expansion of invar. Fernico, of the General Electric Co., is an alloy used for sealing vacuum tubes.

Low-expansion alloy 42, of the Carpenter Steel Co., is an invar with 42% of nickel and 0.10 carbon, used for temperatures above 400°F. It has an electrical resistance of 430 ohms per cir. mil ft. The hot-rolled material has a tensile strength of 82,000 lb. per sq. in., and elongation of 30%. It can be hardened by cold work to Rockwell B-102, with a tensile strength of 125,000 lb. per sq. in. and elongation of 3%. Dumet, of the Westinghouse Electric Corp., is a composite metal for lead-in wires for electric lamps and electronic tubes. It is made of a nickel-steel core with a thin coating of brass and an outer shell of copper tubing. This composite rod is then drawn into wire of diameters 0.010 to 0.040 in. The radial expansion is 0.000009 per deg. C., which is close to that of soft glass. The tensile strength is up to 79,000 lb. per sq. in., with elongation 18 to 26%. Kovar, of the Stupakoff Ceramic & Mfg. Co., is an alloy of 29% nickel, 17 cobalt, 0.3 manganese, and the balance iron, having an expansion the same as that of heat-resistant glass for all temperatures up to the softening point of the glass. It is used for making gastight window assemblies, instrument and radio-tube sealing, and for metal attachments to glass. When the metal is heated to a red heat and applied to the glass, the metal oxide formed dissolves in the glass and gives a gastight seal. Sealmet alloy, of the Allegheny Ludlum Steel Co., used for wire and strip to be attached directly to glass, contains 27% chromium and the balance iron.

**Lubricating grease.** Usually a compound of a mineral oil with a soap, employed for lubricating machinery where the speed is slow or where it would be difficult to retain a free-flowing oil. The soap is one that is made from animal or vegetable oils high in stearic, oleic, and palmitic acids. The lime soaps give water resistance, or a mineral soap may be added for this purpose. Alumi-

num stearate gives high film strength to the grease. All of these greases are more properly designated as Mineral lubricating grease. Originally, Grease for lubricating purposes was hog fat or the inedible grades of lard, varying in color from white to brown. Some of these true greases were stiffened with fillers of rosin, wax, or talc which were not good lubricants. The stiffness of such a grease should be obtained with a mineral soap. A.S.T.M. specifications for heavy journal bearing grease require 45% soap content. About 2% of calcium benzoate increases the melting point. Mineral lubricating grease may contain from 80 to 90% of mineral oil and the remainder a lime soap. Federal specifications prescribe 85% of mineral oil.

Lime greases do not emulsify as readily as those made with a soda base, and are thus more suitable for use where water may be present. Hard grease flows at a temperature of about 90°C.; medium grease flows at 75 to 80°C. Paraffin wax, sometimes added, is an adulterant and not a lubricant. Graphite grease contains 2 to 10% of amorphous graphite, and is used for bearings, especially in damp places. Federal specifications call for 2 to 3% of graphite. For large ball and roller bearings a low-lime grease is used, sometimes mixed with a small percentage of graphite. Cylinder grease is made of about 85% of mineral oil or mineral grease and 15% of tallow. Compounded greases are also marketed containing animal and vegetable oils, or are made with blown oils and compounded with mineral oils. The fatty acids in vegetable and animal oils, however, are likely to corrode metals. Tannin holds graphite in solution; in the gear grease sold under the name of Gredag by the Acheson Oildag Co. a graphite-tannin mixture is used. Metaline, of the R. W. Rhoades Metaline Co., Inc., is a compound of powdered anti-friction metal, oxide, and gums, which is packed in holes in the bearings to form self-lubricating bearings.

Sett greases are a mixture of the calcium soaps of rosin acids with various grades of mineral oils. They are low-cost semisolid greases used for lubricating heavy gears or for greasing skidways. Clay fillers may be added to improve the film strength, or copper or lead powders may be incorporated for heavy load conditions. Solidified oil is also a name given to grease made from lubricating oil with a soda soap and tallow, used for heavy bearings. Cup

grease is made with soda soap and light lubricating oils. Greases made with potash and soda soaps tend to form soap fibers when water is present. A metallic soap that contains no fibers is called a Neat soap, and gives a smooth grease. Slushing oil, for use in protecting machine parts from corrosion in shipping or storage, is usually a low-melting grease preferably compounded with a waxy fat such as lanolin. Paralan, of the American Lanolin Corp., is such a slushing oil having a lanolin base.

Lubricating oils. Oils used for lubricating the bearing parts of machinery. They are usually the heavy distillates following kerosene in the fractional distillation of petroleum, between the temperatures 253 and 317°F. They are separated into grades, light, medium, and heavy, depending upon the molecular weight. They are also classed as pale, when yellow to reddish, and dark, when brownish black in color. The flash points range from 300 to 600°F., and the specific gravities usually from 0.860 to 0.940. Neutral oils are light oils obtained by distillation without cracking, and they will not emulsify in contact with water as do the paraffin oils. They are thus desirable for crankcase lubrication and in circulating systems. Lubricating oils may be bleached with acid, and they may be mixed with vegetable or animal oils.

Animal oils are more greasy than mineral oils, but they are acid. Vegetable oils are greasy and have more oiliness, but they oxidize easily and are also acid. They are likely to gum in use unless an anti-oxidant is used. Vegetable and animal oils add the property of adhesion to the lubricating oil, but in no case should any element be added to an oil that will cause emulsification. Federal specifications for marine engine oil call for 15 to 20% of blown refined rapeseed or peanut oil. This lubricating oil has a flash point of 350°F. Steam cylinder oil has 5 to 10% of fatty acid vegetable oils, and the flash point is 450°F. Absorbed oil is a name of a combination oil of E. F. Houghton & Co. which acts as both film and lubricant. Amlo is a trade name of a mineral oil refined wax-free, used for low-temperature lubrication. Anti-oxidants used in oils to reduce oxidation and minimize sludging and acid formation are usually tin compounds such as tin dioxide, tin tetraphenyl, and tin ricinoleate. Tin dust alone has also an

inhibitory action. Tetraethyl lead is an effective antioxidant for high temperatures. High percentages of animal or vegetable oils may be added to lubricating oils for use on textile machinery. They are called Stainless oils for this purpose, since such oils wash out of the textile more easily than mineral oils. They also give lower coefficients of friction.

The nature of the bearing metals often has an effect upon the action of the lubricating oil. In highly alloyed metals some elements act as catalyzers to oxidize the oil, or the acids or moisture in the oils may act to break down the metal. In lead-bearing metals free magnesium causes disintegration of the lead in contact with moisture. The alkali-lead metals also tend to dissolve in contact with animal or fish oils. Normally, however, none of the white bearing metals are attacked by the animal and vegetable oils used for lubrication unless there are perceptible amounts of a freely oxidizing element present. Graphite adds to the effectiveness of a lubricating oil and can be held in suspension with a tannin. Graphite lubricants are used where continuous lubrication is difficult, for running in, for springs, or for bearing where heavy films are desired. Oildag, of the Acheson Colloids Corp., is a graphite-tannin mixture in oil used for lubricating internal-combustion engines. Glydag, of this company, is a solution of 10% of graphite in glycerin, used as a low-temperature lubricant, and Castordag is a 10% mixture of colloidal graphite in castor oil used for high-temperature conditions. The silicones are now much used to replace lubricating oils for many applications, especially for very high or very low temperatures.

**Luminous paint.** Paints which when applied to a surface make that surface visible in the dark. They are used for road signs, watch hands, or signals. Luminous paints are of two types. The permanently luminous variety contain a radioactive substance, usually radiothorium or mesothorium. These are called Radioactive paints and obtain their energy from the decomposition of their radioactive pigment, though they may also contain a phosphorescent salt pigment. They are used on watch hands and for printing on instrument dial faces. Phosphorescent paints must obtain their energy from an outside source. They depend upon

the ability of certain chemicals to absorb energy and to emit it again in the form of photons of light. This variety usually has a base of calcium, strontium, or barium sulphide with traces of other metal salts to improve luminosity, and the vehicle contains a moistureproof gum or oil. Temporary luminous paints may be visible for long periods after the activating light is withdrawn. A paint activated by 5 min. of exposure to sunlight may absorb sufficient energy for 24 hr. of luminosity.

Phosphorescent paints are lower in cost than radioactive paints, but are not as durable. They may be obtained in various colors. In general, the yellow and orange phosphorescent pigments are combinations of zinc and cadmium sulphides, the green is zinc sulphide, and the violet and blue pigments are combinations of calcium and strontium sulphides. They are marketed in powder form to be stirred into the paint or ink vehicle since mixing by grinding lowers the phosphorescence. The natural minerals are too weak and impure for use, as the pigments must be of a high degree of purity. These phosphorescent pigments are also called Phosphors. For the manufacture of fluorescent screens the phosphors must have a rapid rate of extinguishment so that there will be no time lag in the appearance of the events. For television, electron microscope, and radar screens the phosphors must cease to glow $\frac{1}{50}$ sec. after withdrawal of excitation. They must also be of very minute particle size so as not to give a blurred image. For a white television screen, mixtures of blue zinc sulphide with silver and yellow zinc-beryllium silicates are used. For technicolor television the screen is completely covered with a mixture of various colored phosphors. Fluorescent fabrics for signal flags and luminescent clothing are impregnated with fluorescent chemicals which can be activated by an ultraviolet light that is not seen with the eye. Fluorescein, made from phthalic anhydride and resorcinol, has the property of fluorescence in a solvent. Since cellulose acetate will keep it in a permanently solvent state, acetate rayon is used as the carrier fabric. Signal panels are distinguishable from a plane at great heights even through a haze, and at night they give a brilliant glow when activated with ultraviolet light. Uranine, the sodium salt of fluorescein, is used by

flyers to mark spots in the ocean. One pound of uranine will cover an acre of water to a brilliant yellowish green easily seen from the air. One part of uranine is detectable in 16 million parts of water.

**Lutes.** Adhesive substances, usually of earthy composition, employed for closing pipe joints or seams to make them tight, or for coating pipes or boilers to protect them from high temperatures. Various clays are used for this purpose, or sulphur, white lead, and oil. Plaster of paris mixed with a weak glue will withstand a dull-red heat. Fat lute is pipe clay mixed with linseed oil. Linseed meal with lime is also used. Many prepared compounds for this purpose are marketed under trade names. Spence's metal is the name of an old lute for pipe joining. It was made by introducing iron disulphide, zinc blende, and galena into melted sulphur. It melts at 320°F. and expands on cooling. It makes a good cast joint which is resistant to water, acids, and alkalies. It is not a metal, but is a mixture of sulphur with metallic oxides. Sulphur cements, or lutes, usually have fillers of silica or carbon to improve the strength. They are poured at about 235°F. They form a class of acidproof cement used for ceramic pipe connections. The term lute also properly belongs to the class of adhesive used for sealing in wires in light bulbs, and sealing over connections in electrical apparatus. These lutes are usually compounds of sodium silicate with a filler, but they may also be compounds of mineral waxes or bitumen mixtures.

**Madder.** Formerly the most important dyestuff with the exception of indigo. It is now largely replaced by the synthetic mauve dye Alizarin, the manufacture of which from anthracene was patented in 1869 by Sir William Perkin. Madder was grown on a large scale in France and the Near East and was known by its Arabic name Alizari and by the name Turkey red. Madder is the ground root of the plant *Rubia tinctorum,* which has been stored for a time to develop the coloring matter, the orange-red Alizarin, $C_{14}H_{18}O_4$. Purpurin, $C_{14}H_{18}O_5$, is also developed, but this is now also produced synthetically. Madder gives fast colors. Madder lake is a pigment consisting of an inorganic powder colored with madder; Madder red is a lead pigment.

**Magnesite.** A white to bluish-gray mineral used in the manufacture of bricks for basic refractory furnace linings and as an ore of magnesium. The ground, burned magnesite is a light powder, is shaped into bricks at high pressure, and baked in kilns. Magnesite is a magnesium carbonate, $MgCO_3$, with some iron carbonate and ferric oxide. Magnesite releases carbon dioxide on heating, and forms Magnesia, MgO. When heated further it forms a crystalline structure known as Periclase, MgO, with a melting point of 5070°F. and specific gravity of 3.65. The mineral periclase occurs in nature but is rare. The product known as Dead-burned magnesite is in the form of dense particles used for refractories. It is produced by calcining magnesite at a temperature of 1450 to 1500 C. Caustic magnesite is a product resulting from calcination at 700 to 1200°C. which leaves from 2 to 7% of carbon dioxide in the material and gives sufficient cementing properties for use as a refractory cement. Magnesium oxide, or magnesia, obtained by calcining magnesite, is put through a complex purifying process to obtain the fine white magnesia powder used in pharmaceuticals, cosmetics, and in rubber compounding. This Magnesia powder has a particle size of 0.5 micron and weighs 6 lb. per cu. ft.

Magnesite is sold on the basis of the MgO content. British India magnesite has 92.7% magnesia. Manchurian dead-burned magnesite has 90.9% magnesia with 4 silica, and some iron oxide and aluminum oxide. Magnesite for use in producing magnesium metal should have at least 40% MgO, with not over 4.5% CaO and 2% FeO. Brucite, a natural hydrated Magnesium oxide found in Ontario, contains a higher percentage of magnesia than ordinary magnesite and is used for furnace linings. Austrian magnesite has from 4 to 9% of iron oxide, which gives it the property of fritting together more readily. Magnesite occurs in compact earthy forms, or in granular masses. The crystalline form is Breunnerite. Its hardness is 3.5 to 4.5, and its specific gravity is 3.1. It has a vitreous luster, and the color is white, gray, yellow, or brown. It fuses at 2165°C. The high-melting and softening points of magnesite and its chemical resistance make it a valuable refractory. The chief disadvantage is its low resistance to sudden temperature changes. The American production of crude magne-

site is in Nevada, Washington, and California. Magnesite materials are usually sold under trade names. It is also employed as an insulating covering for steam pipes. The pure magnesium carbonate is used in boiler compounds. Ritex is a magnesite brick having strong basic characteristics, which is marketed by the General Refractories Co. Magnesite is also used in Germany to produce the artificial stone known as Kunststein. Ramix is the name of a magnesite refractory of Basic Dolomite, Inc. Basifrit is a name given to impure Canadian magnesitic dolomite.

**Magnesium.** A silvery-white metal, symbol Mg, which is the lightest metal that is stable under ordinary conditions and produced in quantity. It is the sixth most abundant element, and is only 64% the weight of aluminum and 23% the weight of iron. By volume, 1 lb. of magnesium produces five times as much rolled metal as 1 lb. of copper. It was originally called Magnium by Sir Humphrey Davy. The specific gravity is 1.74, melting point 651°C., and boiling point 1120°C. It has a tensile strength when cast of 14,000 lb. per sq. in. The rolled metal has a tensile strength of 25,000 lb. per sq. in., and an elongation of 4%. The strength is somewhat higher in the forged metal. Magnesium is too brittle to roll cold, but can be rolled at 300 to 500°C. It is the easiest to machine of the metals. Magnesium ingot is marketed 99.9% pure, but the metal is not ordinarily used alone. It is alloyed with aluminum and small amounts of other metals. Rolled sheet magnesium for special purposes is made in thicknesses down to 0.005 in. Magnesium alloys are used for parts where lightness is needed, especially in transportation equipment. It is also a major constituent in many aluminum light alloys. It cannot safely be used for parts that are to be subjected to temperatures above 450°F. Because of its sound-damping characteristics it is valued for diaphragms, speaker cones, and resonators. It is immune to attack by alkalies, and is resistant to sea water, and is thus used for many marine parts. Because of its close-packed hexagonal crystal structure the thin metal can be drawn in dies without folding and wrinkling. When heated to 450°F. the metal is plastic and draws easily. Thinstrip magnesium, of the Burgess Battery Co., is commercially pure magnesium sheet in thicknesses

from 0.005 to 0.010 in. for die forming and for paneling. One pound of the 0.005-in. sheet will cover 22.2 sq. ft.

Magnesium alloys with most of the common metals except those in the iron and chromium groups. The pure metal ignites easily, and even when alloyed with other metals the fine chips must be guarded against fire. In alloying, it cannot be mixed directly into molten metals because of flashing, but is used in the form of master alloys. The metal is not very fluid just above its melting point, and casting is done at temperatures considerably above the melting point so that there is always danger of burning and formation of oxides. In sand-casting magnesium alloys, sulphur and boric acid are used to prevent oxidation of the molten metal. The addition of small amounts of lithium, as little as 0.001%, reduces the fire risk in melting and working the metal. Molten magnesium decomposes water so that green sand molds cannot be used as explosive hydrogen gas is liberated. For the same reason water sprays cannot be used to extinguish magnesium fires. The affinity of magnesium for oxygen, however, makes the metal a good deoxidizer in the casting of other metals. Flashlight powder is also made of magnesium, and the powder is also used in flares and fireworks.

Magnesium is produced commercially by the electrolysis of a fused chloride or fluoride obtained either from brine or from a mineral ore, or it can be vaporized from some ores. Much of the magnesium produced in the United States is from brine wells of Michigan, which brine contains 3% of $MgCl_2$, and from sea water. From sea water the magnesium hydroxide is precipitated, filtered, and treated with hydrochloric acid to obtain a solution of magnesium chloride from which the metal is obtained by electrolysis. One pound of metal is obtained from 770 lb. of sea water. Magnesium is also obtained from dolomite by extracting the oxide by reacting the burned dolomite with crushed ferrosilicon in a sealed retort under vacuum. The dolomite of Ohio averages 20% magnesium oxide, and the metal is obtained 99.98% pure in a solid, dense, crystalline mass which is then melted with a flux and poured into ingots. In Russia, magnesium is produced from the mineral Carnallite, $KCl \cdot MgCl_2 \cdot 6H_2O$. In Germany it is produced from dolomite, carnallite, magnesite, and from the end lyes of the potash

industry. The metal can also be produced from serpentine, olivine, and other siliceous ores by heating the powdered ore in a vacuum retort and driving off the metal as a vapor which is condensed to the pure metal.

**Magnesium alloy.** An alloy of magnesium, usually with aluminum, noted for extreme lightness, the specific gravity seldom exceeding 1.83. In general the magnesium alloys have a strength-weight factor 14 times that of steel. The alloys are easily machined and are used for aircraft engine parts, pistons, propellers, and structural shapes, where weight saving is an important factor, or where light reciprocating parts are required. Wrought alloys usually contain aluminum and manganese; forgings contain aluminum, manganese, and zinc; and die-casting alloys contain aluminum, manganese, and silicon. Aluminum up to 8% refines the grain, increasing hardness, strength, and rigidity; with higher percentages the alloys become brittle. Zinc has a somewhat similar effect. Small amounts of manganese give added corrosion resistance and high strength. Some alloys with no aluminum have as high as 1.5% of manganese. Cadmium improves the physical properties of the casting and extruding alloys, and a patented alloy contains up to 6% of cadmium. Copper softens but weakens the structure. Beryllium strengthens the alloy and reduces fire hazard.

Alloy AM240, of the Aluminum Co. of America, has 9 to 11% of aluminum and 0.10 manganese. It is for sand and permanent-mold castings, and has a tensile strength of 20,000 lb. per sq. in. with elongation of 2%. Alloy AM403, for sand castings, has 1.2 to 2% of manganese with no aluminum. The tensile strength is 14,000 lb. per sq. in. and elongation 5%. This alloy in hot-rolled sheet or extruded bar has a tensile strength of 34,000 lb. per sq. in. Revere alloy M, of the Revere Copper & Brass, Inc., is this metal. Revere alloy JS-1 for sheet plate has 5% of aluminum, 1 zinc, and 0.25 manganese. The tensile strength is 40,000 to 47,000 lb. per sq. in., elongation 10 to 18%. This is AN-M-28 alloy in U.S. Government aeronautical specifications. Alloy AM74S, for forgings, has 2.5 to 3.5% of aluminum, 0.2 manganese, and 2.5 to 3.5 zinc. When aged it has a tensile strength of 42,000 lb. per sq. in. and elongation of 14%. Eclipsaloy 56, of the Eclipse-Pioneer Div.,

Bendix Aviation Corp., contains 8.3 to 9.7% of aluminum, 1.7 to 2.3 zinc, 0.30 max. silicon, 0.10 max. manganese, 0.05 max. copper, 0.01 max. nickel, and the balance magnesium. It has a tensile strength up to 34,000 lb. per sq. in., elongation 6%, and Brinell hardness 50 to 70. Eclipsaloy 15A has less aluminum and up to 3.5% zinc, and has higher strength. The German alloy Elektron has 9 to 11% of aluminum, 4 zinc, and up to 2.5 manganese. Zinc gives good salt-water resistance, but when the zinc is high the alloys do not cast easily as they are hot-short and have a narrow temperature pouring range. The British Air Ministry specification of Electron calls for 1.3 to 1.7% manganese and the remainder magnesium. Dowmetal M has this composition, with tensile strength of 45,000 lb. per sq. in. Alloys containing 6% of aluminum, 3 zinc, and small amounts of manganese have good salt-water resistance. They have tensile strengths, as cast, up to 30,000 lb. per sq. in., which by heat-treatment can be increased to 42,000 lb. per sq. in., with added hardness up to 70 Brinell. Dowmetal H, of the Dow Chemical Co., and Mazlo alloy AM265, of the Aluminum Co. of America, are of this type. Dow alloy No. 251, for sheet, has 5% of aluminum and 1 zinc. It is tough and ductile. Dowmetal B has 12% aluminum. Dowmetal F has 4% of aluminum and 0.3 manganese. In extruded rod it has a tensile strength up to 42,000 lb. per sq. in. High amounts of magnesium are used in some aluminum alloys stabilized and strengthened with beryllium and boron. Almag 55, of the Acme Aluminum Alloys, Inc., has 11% of magnesium, 0.5 beryllium, and 0.4 boron. The tensile strength, cast, is 55,000 lb. per sq. in.

**Magnesium carbonate.** A white, insoluble powder of the composition $MgCO_3$, containing also water of crystallization. The specific gravity is 3.10. It is made by calcining dolomite with coke, slaking with water, saturating with carbonic acid gas, and crystallizing out the magnesium carbonate. It is employed as an insulating covering for steam pipes and furnaces, for making oxychloride cement, in boiler compounds, and as a filler for rubber and paper. Montax, of the R. T. Vanderbilt Co., used as a filler, is a mixture of hydrated magnesium carbonate and silica powder. Magnesium carbonate is a good heat insulator because of the great number of microscopic dead-air cells in the material. As an insulating pipe

covering it is usually mixed with asbestos fibers to give structural strength. Federal specifications for "magnesia" call for the hydrated magnesium carbonate, $4\,MgCO_3 \cdot Mg(OH)_2 \cdot 5H_2O$, combined with 10% of asbestos fibers, for use in heat-insulating blocks. The hydrated carbonate is a fine white powder called Magnesia *alba levis,* slightly soluble in water, and used in medicine.

**Magnesium-nickel.** An alloy of magnesium and nickel used for adding nickel to magnesium alloys and for deoxidizing nickel and nickel alloys. A magnesium-nickel marketed by Alloys & Products, Inc., contains about 50% of each metal, is silvery white in color, and is furnished in round bar form. Magnesium-monel made by the same company contains 50% magnesium and 50 monel metal. Alloys of magnesium with nickel, monel, zinc, copper, or aluminum, used for deoxidizing and cleaning nonferrous metals, are called Stabilizer alloys.

**Magnesium powder.** A fine powder for pyrotechnic and chemical uses, made by reducing metallic magnesium into particles in the shape of curly shavings to give maximum surface per unit of weight. It is produced in four grades: Cutting powder, Standard powder, Special specification, and Fireworks powder. Cutting powder is finely cut shavings in a matted condition, made from magnesium of 99.8% purity. Standard powder is loose powder in fineness from 10 to 200 mesh. Fireworks powder is 100 mesh. The speed of ignition increases rapidly with decreasing particle size. A 200-mesh powder is used for Flashlight powder, and a 30- to 80-mesh for more slowly burning flares. For flares, magnesium gives a brilliant light of high actinic value. Incendiary powder, for small-arms incendiary ammunition, is magnesium powder mixed with barium peroxide. Ophorite is an English name for magnesium powder and potassium perchlorate used as an igniter for incendiaries. The material known as Goop, used in block-burner bombs, is a rubbery mixture containing magnesium powder coated with asphalt, gasoline, and chemicals.

**Magnesium sulphate.** A colorless to white, bitter-tasting material occurring in sparkling needle-shaped crystals of the composition $MgSO_4 \cdot 7H_2O$. The natural mineral is called Epsomite,

from Epsom Spa, Surrey, England. In medicine it is called Epsom salt. It is used in leather tanning, as a mordant in dyeing and printing textiles, as a filler for cotton cloth, for sizing paper, in water-resistant and fireproof magnesia cements, and as a laxative. It can also be obtained in the anhydrous form, $MgSO_4$, as a white powder. The specific gravity of the hydrous material is 1.678, and of the anhydrous 2.65. It occurs naturally as deposits from spring waters, and is also made by treating magnesite with sulphuric acid. In Germany it is produced from the mineral Kieserite, $MgSO_4 \cdot H_2O$, which is abundant in the Strassfurt district, and is used as a source of sulphuric acid and magnesium. The magnesium sulphate from the waters at Seidlitz, Bohemia, was called Seidlitz salt, but Seidlitz powder is now a combination of rochelle salt and sodium bicarbonate. Synthetic kieserite is made from the olivine of North Carolina. The mineral Langbeinite, found in the potash deposits at Carlsbad, N. M., is a potassium-magnesium-sulphate, containing 22% of potassium oxide and 18 magnesia, and is used in the production of potassium sulphate and magnesium metal. The crude langbeinite with the halite and clay washed out is called Sulpomag.

**Magnet steels.** Steels employed for making permanent magnets, that is, magnets that retain their magnetism after they are removed from the magnetic field, as distinct from electromagnets, which are of soft iron and are magnetized only while in the magnetic field. Magnet steels were originally good grades of crucible tungsten steel, sometimes containing chromium and manganese. Tungsten magnet steels contain 5 to 6% of tungsten, and about 0.65 carbon. They can be hot-forged, and machined when annealed. They are hardened in water without drawing the temper, they are then aged by heating in oil at a temperature of about 250°F., and afterward placed in a vibrating device. With increased carbon the coercive force increases, but the maximum induction and the residual magnetism decrease. Molybdenum may be used instead of tungsten in magnet steels. Molybdenum-iron magnet alloys have been made with 20% or more of molybdenum having high residual magnetism and high coercive force.

Chromium magnet steels are less expensive, and contain up to 5% of chromium, usually 3, and about 1 of carbon. A standard

grade contains 2.25 to 4% of chromium, 0.45 manganese, and 0.95 carbon. The magnetic properties are similar to those of the tungsten steels, and they have the same difficulty in hardening because of breakage when the carbon is high. Cobalt magnet steels contain from 18 to 60% of cobalt, part of which may be replaced by the less expensive chromium, or some tungsten may be used. Some cobalt magnet steels contain 1.5 to 3% of chromium, 3 to 5 tungsten, 0.50 to 0.80 carbon, with high cobalt. A Japanese alloy, K. S. magnet steel, contained 30 to 40% of cobalt, 5 to 9 tungsten, 1.5 to 3 chromium, and 0.4 to 0.8 carbon. The coercive force of this steel is about three times that of a 5% tungsten steel. A cobalt steel containing 36% of cobalt, 3.5 carbon, with the balance iron, is hard and strong, can be hot-forged, and can be machined when annealed. Its coercive force is 210 compared with 70 for the 5% tungsten steel with 1% carbon. A nonferrous magnet alloy contains 41% of cobalt, 24 nickel, and 35 copper. It has a coercive force of 440. It is ductile and can be cold-rolled. Cobalt steel and cobalt-chromium magnet steel may contain molybdenum, which gives them air-hardening properties. A magnet alloy marketed by the General Electric Co. under the name of Comol contains 12% of cobalt, 17 molybdenum, and 71 iron. The coercive force is 245. It can be cast to shape or hot-forged. Vectolite is a lightweight magnet of this company made by molding iron oxide and cobalt oxide powders and sintering. Armat is a magnet steel of the Jessop Steel Co. Tuncro, of the Allegheny Ludlum Steel Co., is a tungsten-chromium magnet steel. Alnico, of the General Electric Co., is an aluminum-nickel-cobalt-iron alloy in which precipitation hardening occurs with AlNi crystals dissolved in the metal. Alnico I contains 63% iron, 20 nickel, 12 aluminum, and 5 cobalt. The alloy is cast to shape as it is hard and brittle and cannot be reworked. The coercive force is 400. Alnico IV contains 12% aluminum, 28 nickel, 5 cobalt, and the balance iron. It has a coercive force of 700, or 10 times that of a plain 5% tungsten magnet steel.

**Mahogany.** A name applied to a variety of woods. All of the true mahogany, however, comes from trees of the family *Meliaceae*, but of various genera and species. The tropical cedars, Spanish

cedar and Paraguayan cedar, belong to this family. Mahogany, of the tree *Swietenia mahogani,* and other species of *Swietenia,* is obtained from Mexico to as far south as northern Argentina. The Central American has the best reputation and is frequently referred to under the Spanish name Caoba. The mahogany from Cuba and Santo Domingo has a close grain and beautiful color and is valued for furniture. Baywood is an English name originally applied to a superior, straight-grained mahogany from the shores of the Bay of Honduras. Colombian mahogany is the wood of the tree *Carini-ana pyriformis* of northern South America. It resembles mahogany but is heavier and harder.

The wood of the mahogany tree is obtainable in large logs. It has a reddish color of various shades. The grain is often figured, and it has a high luster when polished. It seasons well and is much prized for furniture and cabinetwork. It is often used for small patterns in foundry work where they must be employed frequently and should not alter in shape. The cheaper grades are used for this purpose. The weight varies from 32 to 42 lb. per cu. ft. The hardness and closeness of the different mahoganies also vary considerably. The beautiful curled-grain specimens are from selected forks or crotches of the trees.

The various species of mahogany formerly used for airplane propellers were either African *Khaya* or American *Swietenia,* with average specific gravities kiln-dried of 0.47 to 0.51. The compressive strength is up to 1.760 lb. per sq. in. perpendicular to the grain, and the shearing strength 860 lb. per sq. in. parallel to the grain. The *Swietenia* is used for small naval boats and for trim on large boats. Australian red mahogany is from the tree *Eucalyptus resinifera* of Australia. It is hard, durable, of a dark-red color, with a coarse, open grain. Crabwood, used as a substitute for mahogany, is the wood of the Carapa tree, *Carapa guianensis,* of Brazil and the Guianas. It has a deep reddish-brown color with a coarse grain and weighs 40 lb. per cu. ft. This tree produces the seed nuts from which Carapa fat is pressed, used for soap, candles, and as an edible fat. Oleo vermelho, from the tree *Myrospermum erythoxylum* of Brazil, is a fine-grained reddish cabinet wood similar to mahogany. The specific gravity is 0.954. It has an agreeable odor. Cameroon mahogany is from the tree *Bassia toxisperma* of West Africa. The

kernels of the nuts of the tree yield about 60% of a yellowish-white semisolid oil known as Djave butter, or Adjab butter, used in Europe for soapmaking. It is used locally for food by steaming off the traces of hydrocyanic acid.

**Malleable iron.** A high-tensile-strength white cast iron produced by a long heat-treatment of white chilled castings. Iron for malleable iron is usually melted in the reverberatory furnace, which gives it greater strength and ductility than iron melted in the cupola in contact with the fuel. The iron contains 1 to 1.5% of silicon and is cooled rapidly to produce white iron. The castings seldom exceed 10 lb. in weight. After casting, the parts are packed in annealing pots with hammer scale or mill scale, or oxidized turnings or borings, and subjected to an increasing temperature to about 1650°F., for a period of 48 to 60 hr. They are then cooled slowly with temperature decreasing 8 to 10°F. per hr. to below 1275°F. The resulting iron has the carbon in regular tiny particles instead of flakes as in gray cast iron. With high annealing temperatures and a long annealing period the total carbon is reduced in the shell, resulting in a coarse-grained casting known as Whiteheart which has reduced strength. The ordinary American malleable iron called Blackheart has a white shell and a dark core, the outside being completely decarbonized. Slight additions of copper accelerate the annealing of blackheart iron. An iron known as Quick malleable iron, used for automotive engine castings, has 2.2% of carbon, 1.5 silicon, 0.30 to 0.60 manganese, and 0.75 to 1 copper. The copper also increases the tensile strength. For ease of machining, malleable iron normally should have 2.60% or more of carbon, although less carbon is desirable for strength and ductility. An average composition is carbon, 2%; silicon, 0.60 to 1.10; manganese, under 0.30; phosphorus, under 0.20; and sulphur, 0.06 to 0.15. About 1% of copper is used for corrosion-resistant castings.

Malleable iron is used for castings, for implements, pipe fittings, building hardware, and small machine parts requiring strength. The tensile strength is about 50,000 lb. per sq. in., elongation 15%, and Brinell hardness 115. Federal specifications call for two grades, with strengths of 50,000 and 53,000 lb. per sq. in. Modern Pearlitic malleable iron, with a matrix of pearlite and temper carbon, may

have tensile strengths above 100,000 lb. per sq. in. with elongation of 5%, and Brinell hardness of 250. It is made by giving special heat-treatment to arrest graphitization, or to recombine some of the carbon. Chromium gives a stabilizing effect. Other alloying elements used are manganese and molybdenum in small quantities. Malleable irons are sold under trade names. Certified malleable iron, of the Erie Malleable Iron Co., has a tensile strength up to 57,000 lb. per sq. in. and hardness up to 120 Brinell. Promal is a specially processed malleable iron of the Link-Belt Co., used for chain links. The hardness is up to 170 Brinell, and it has high fatigue resistance. Supermal, of the Jeffrey Mfg. Co., is a similar type of iron. Flecto iron, of the Ohio Brass Co., is a malleable iron specially annealed to prevent brittleness when hot-galvanized. Z-metal, of the Ferrous Metals Corp., used for pump and chemical machine parts, has 2 to 2.6% of total carbon, with 0.30 to 0.80 combined carbon, 0.90 to 1.10 silicon, and 0.75 to 1.25 manganese. It has a tensile strength of 70,000 lb. per sq. in., elongation of 8 to 18%, and a hardness of 180 Brinell. It is a pearlitic malleable iron. Cu-Z metal contains also about 1% copper. Another grade with copper and molybdenum has higher strength, ductility, and fine grain with high density. Belmalloy is the trade name of an electric-melted pearlitic malleable iron.

**Manganese.** A metallic element, symbol Mn, found in the minerals manganite, pyrolusite, and others, with most iron ores and traces in most rocks. Manganese has a silvery-white color with purplish shades. It is very brittle. Distilled manganese, with no iron, and with carbon and silicon not over 0.006% total, has a fine silvery-gray luster very resistant to corrosion. It is brittle but hard enough to scratch glass. The specific gravity is 7.42, melting point 2237°F., and weight 0.268 lb. per cu. in. Manganese is used in the steel industry as a deoxidizer and as a hardener, and nearly all steel now contains some manganese. For this purpose it is used largely in the form of ferromanganese. More than 80% of the manganese charged into an open-hearth furnace for making ordinary steel goes off in the slag. Manganese is also added to steel in considerable amounts for the production of wear-resistant alloy steels. Manganese metal, for adding manganese to nonferrous alloys, is marketed

in crushed form containing 95 to 98% of manganese, 2 to 3 max. iron, 1 max. silicon, and 0.25 max. carbon.

Electro manganese, or Electrolytic manganese, is produced from low-grade ores by the electrolytic process and is 99.9% pure metal, with not more than 0.1% sulphur and iron. It comes in cathode chips ⅛ in. thick, up to 1 sq. in. in size. Manganese powder is powdered metal of high purity, of 150 to 325 mesh, employed for pyrotechnic and metallurgical uses. Manganese tablets, for use in steelmaking, are made by pressing electrolytically reduced powder in an inert atmosphere and then coating the tablets with ammonium chloride to prevent oxidation.

**Manganese alloy.** A series of nonferrous alloys containing manganese, copper, and nickel. They can be forged readily and machined, and then age-hardened at 500 to 1000°F. to a hardness of 400 to 500 Brinell with tensile strengths of 200,000 lb. per sq. in. and high wear resistance. Chace alloy No. 720, of the W. M. Chace Co., contains 60% of copper, 20 manganese, and 20 nickel. It is soft and ductile, but can be hardened to 400 Vickers. The tensile strength of the forged metal varies from 98,000 to 220,000 lb. per sq. in. depending upon the hardness. The specific gravity is 8.25. It is used for high-strength, corrosion-resistant parts and for springs. Wyndaloy 720, of the Wyndale Mfg. Co., is this metal in forgings. These alloys are also noted for their high electrical resistivity, the 20% manganese alloy having a resistivity of 300 to 500 ohms per cir. mil ft., and a conductivity of only 2 to 3.5% I.A.C.S. It is thus used for resistor wire and strip. A high-manganese alloy used for rheostat resistors and electrically heated expansion elements is Chace alloy No. 772. It contains 72% of manganese, 18 copper, and 10 nickel. It can be machined, drawn, and stamped. The cold-rolled metal has a hardness of 220 Vickers, and a tensile strength of 115,000 lb. per sq. in., with elongation of 6.5%. It is nonmagnetic, has a heat conductivity of only 12% that of steel, and a vibration damping constant 25 times that of steel. The electrical resistivity is 1,050 ohms per cir. mil ft. Manganese alloy resistor wire is produced by the Driver-Harris Co.

**Manganese-aluminum.** A Hardener alloy employed for making additions of manganese to aluminum alloys such as Duralumin.

Manganese lowers the thermal conductivity of aluminum but increases the strength and increases the contraction. Manganese up to 1.5% is used in aluminum alloys when strength and stiffness are required. A manganese-aluminum marketed by the Niagara Falls Smelting & Refining Corp. contains 25% of manganese and 75 aluminum. The Manganese-aluminum of the Electro Manganese Corp. has 92% of aluminum and 8 manganese. Above 2% aluminum the alloy is very brittle. Manganese-boron is another hardener alloy used for deoxidizing and hardening bronzes. It contains 20 to 25% of boron, with small amounts of iron, silicon, and aluminum. For deoxidizing and hardening brasses, nickel bronze, and cupro-nickel, Manganese copper, or Copper manganese, may be used. The alloys used contain 25 to 30% of manganese and the balance copper. The best grades of manganese copper are made from metallic manganese and are free from iron. For nickel bronzes and nickel alloys the manganese copper must be free of both iron and carbon, but grades containing up to 5% of iron can be used for manganese bronze. Grades made from ferromanganese contain iron. Manganese copper is usually marketed in slabs with notched sections, or as shot. It has a lower melting point than metallic manganese and is thus more easily dissolved in the brass or bronze. The 30% alloy melts at about 1600°F.

Manganese bronze. A brass containing iron and manganese which, because of its hardness and crystalline structure, is called a bronze. It casts easier than aluminum bronze and is used for propeller blades, valve stems, engine frames, and machinery parts requiring high strength and resistance to sea water. Manganese is a deoxidizer in the alloys, but in excess, usually up to 3.5%, it hardens and strengthens the alloy, increases the solubility of the iron in the brass, and acts to stabilize the aluminum when this metal is used. Manganese has nearly the whitening power of nickel in copper alloys. Turbadium bronze was an old name used by the British Admiralty for manganese bronze containing 50% of copper, 44 zinc, 1 iron, 1.75 manganese, 2 nickel, and 0.5 tin, used for casting propellers and marine parts. The original Turbiston's bronze contained 55% of copper, 41 zinc, 1 aluminum, 2 nickel, and 1 iron. A.S.T.M. and Federal specifications for manganese bronze call

for 55 to 60% of copper, 38 to 42 zinc, up to 3.5 manganese, up to 1.5 tin, 1.5 aluminum, and up to 2 iron. This alloy has a minimum tensile strength of 65,000 lb. per sq. in. and elongation of 30% as cast; the wrought metal has a strength of 72,000 lb. per sq. in. Even very small amounts of lead decrease the strength of manganese bronze and lower the ductility. Phosphor copper is sometimes added to make the metal easier pouring. Manganese bronze has high shrinkage, $\frac{3}{16}$ in. per ft., and large fillets are necessary between changes in section thickness.

A Super manganese bronze, used for aircraft engine parts, contains 69% of copper, 20 zinc, 2 manganese, 2.5 iron, and 6.5 aluminum. It has a tensile strength of 110,000 lb. per sq. in. and Brinell hardness of 225 when heat-treated. A Manganese-aluminum brass, under the name of Hy-Ten-Sl, marketed by the American Manganese Bronze Co., contains 66% of copper, 19 zinc, 10 aluminum, and 5 manganese. The castings have a tensile strength up to 105,000 lb. per sq. in., elongation 15%, and Brinell hardness 175. It is also made in wrought forms. The alloys known as Manganese casting brass are usually muntz metal containing a small amount of manganese. The original manganese brass patented in 1876 under the name of Parsons' alloy, contained 56% of copper, 41.5 zinc, 1.2 iron, 0.7 tin, 0.1 manganese, and 0.46 aluminum. An alloy used by one automotive company has 58% of copper, 40 zinc, and 2 of a master alloy consisting of tin, iron, manganese, and aluminum. The lead content is not permitted to exceed 0.15%. The tensile strength is 70,000 lb. per sq. in. and elongation 20%. It is used as a substitute for malleable iron or drop-forged steel. Lumen manganese brass, of the Lumen Bearing Co., is a 60-40 brass with 3% of the copper replaced with 1% of iron and small amounts of manganese, tin, and aluminum.

**Manganese ores.** Manganese is a widely dispersed metal, occurring in many ores and in many parts of the world, but normally less than 10% of the manganese used in the United States is produced domestically as most of the American ores are low-grade. The ores are used largely for producing ferromanganese, but some low-grade ores are reduced electrolytically to the metal, and the oxide ores are used directly in dry batteries, glassmaking, and in

the chemical industry. Pyrolusite is the most important manganese ore. It is a manganese dioxide, $MnO_2$, with a black color and a metallic luster. The specific gravity is 4.75 and hardness 2 to 2.5. It is mined in various parts of Europe, Australia, Brazil, Argentina, Gold Coast, Cuba, India, Canada, and the United States. It is valued for glass manufacture, and the high-grade lead-free Montana and Gold Coast ores are used for batteries. When used as a decolorizer for glass, it has been called Glassmakers' soap. Bog manganese, known as Wad, is an impure mixture of $MnO_2$ and MnO, together with other oxides. It is a soft friable mineral of black or brown color.

Rhodochrosite, found in several parts of the United States and in central Europe, is a manganese carbonate, $MnCO_3$, with usually some iron replacing part of the manganese. It has a rose-red to dark-brown color, with a vitreous luster, specific gravity of 3.5, and hardness of 3.5 to 4.5. It usually has a massive cleavable structure. Manganite, found with other manganese minerals and with iron, is an iron-black mineral of the composition $Mn_2O_3 \cdot H_2O$, containing theoretically 62.4% of manganese. It is found in Germany, England, and in the Lake Superior region of the United States. Hausmanite, found in Washington state, is another hydrated oxide, $Mn_3O_4 \cdot 2H_2O$, containing theoretically 62.26% of manganese. It is used for coating welding rods. Bementite, from the same area, is a hydrated silicate, $8MnO \cdot 7SiO_2 \cdot 5H_2O$, containing 40.8% of manganese. The high silica makes it difficult to use.

In general, an ore for ferromanganese should contain at least 35% of manganese. Much of the American ore contains only 5 to 10% manganese. Arkansas ores are low-grade, with as little as 18% manganese, and high-grade with more than 70%. The low grades of Montana ore are concentrated by a nodulizing process up to 58% manganese. In Germany, low-grade ore is made into ferromanganese by first smelting to spiegeleisen and then treating part in an acid and part in a basic converter before mixing. The three grades of ore designated by the Metals Reserve Co. are: High grade, with 48% min. manganese and 7% max. iron; Low grade A, with 44% min. manganese and 10% max. iron; and Low grade B, with 40% min. manganese and no maximum on iron. Chemical grade manganese ore should have 80 to 90% $MnO_2$, equivalent to 51% min.

manganese, and not more than 2% iron. Indian ore is classed as first grade when it has 50% min. manganese, second grade with 48 to 50%, and third grade with 45 to 48%.

**Manganese steel.** All commercial steels contain some manganese which has been introduced in the process of deoxidizing and desulphurizing with ferromanganese, but the name was originally applied only to steels containing from 10 to 15% of manganese. Steels with from 1.0 to 1.5% of manganese are known as Carbon-manganese steel, Pearlitic manganese steel, or Intermediate manganese steel. Medium manganese steels, with manganese from 2 to 9%, are brittle and are not ordinarily used. The original Hadfield manganese steel made in 1883 contained 10 to 14.5% of manganese and 1% of carbon.

Manganese increases the hardness and tensile strength of steel. In the absence of carbon, manganese up to 1.5% has only slight influence on iron; as the carbon content increases, the effect intensifies. Air hardening becomes apparent in a 0.20 carbon steel with 1.5% of manganese, and in a 0.35 carbon steel with 1.4% of manganese. The manganese steels used for dipper teeth, tractor shoes, and wear-reistant castings, contain 10 to 14% of manganese, 1 to 1.4 carbon, and 0.30 to 1 silicon. The tensile strength is up to 125,000 lb. per sq. in., elongation 45 to 55%, weight 0.286 lb. per cu. in., and Brinell hardness, when heat-treated, of 185 to 200. Cold working hardens this steel, and dipper teeth in service will work-harden to a hardness up to 550 Brinell.

High-manganese steels are not commercially machinable with ordinary tools, but can be cut and drilled with tungsten carbide and super high-speed tools. The Austenitic steels, with about 12% of manganese, are exceedingly abrasion-resistant and harden under the action of tools. They are nonmagnetic. The coefficient of expansion is about twice that of ordinary steel. Various trade names are used to designate the high-manganese steels. Rol-man steel, marketed by the Manganese Steel Forge Co., contains 11 to 14% of manganese and 1 to 1.4 carbon, and has a tensile strength of 160,000 lb. per sq. in. and elongation up to 50%. Amsco steel, of the American Manganese Steel Co., contains 12 to 13% of manganese and 1.2 carbon. The tensile strength is 125,000 lb. per sq.

in., and it will work-harden to 500 Brinell. Tisco steel, of the Taylor-Wharton Iron & Steel Co., has up to 15% of manganese, and is used for rails and crossovers where high resistance to abrasion is needed. Timang, of this company, is a high-manganese steel made in the form of wire for rock screens. A German stainless type of steel, made without nickel, has 12% of manganese. It is called Roneusil steel. High-manganese steels are brittle when cast and must be heat-treated. For castings of thin sections or irregular shapes where the drastic water quenching might cause distortion, nickel up to 5% may be added. The Manganese-nickel steels have approximately the same characteristics as the straight manganese steels. Nickel is also used in high-manganese steel wire, and the hard-drawn wire has strengths up to 300,000 lb. per sq. in. Manganal is a hot-rolled plate steel of high strength and wear resistance marketed by Joseph T. Ryerson & Son, Inc. It contains 11 to 13% manganese, 2.5 to 3.5 nickel, and 0.60 to 0.90 carbon. The tensile strength is 150,000 lb. per sq. in.

Structural steels with 0.50% of carbon and from 1 to 2 of manganese have tensile strength above 90,000 lb. per sq. in. Martinel steel, or Martin elastic limit steel, of Alfred Holt & Co., was an early English steel of this type. D-steel, developed by the British Admiralty for warship construction, contains 1.1 to 1.4% of manganese, 0.33 carbon, and 0.12 silicon. The tensile strength is 96,000 lb. per sq. in. and elongation 17%. N.Y. Central rails have 1.30 to 1.60% of manganese and 0.65 carbon. Man-Ten steel, of the U.S. Steel Corp., is a medium-carbon, medium-manganese structural steel. Steels containing 1.30 to 1.90% of manganese are now being used in automobile manufacture to replace more expensive alloy steels. Most mills now list these steels as Special alloy machinery steels; those containing about 0.10% of sulphur are designated as Manganese screw stock. The S.A.E. steels X1330 and X1340 are of this type. E.Z. Cut plate steel, of Joseph T. Ryerson & Son, Inc., is a free-machining steel for molds, gears, and machine parts. It has 0.14 to 0.21% of carbon, 1.15 to 1.4 manganese, and 0.17 to 0.23 sulphur. The tensile strength is 65,000 lb. per sq. in and elongation 30%, but when carbonized and water-quenched the tensile strength is 100,000 lb. per sq. in. The sulphur is in the form of manganese sulphides. The manganese steels with about 1.5%

manganese and low carbon are much used for railway castings, and when deoxidized with titanium have tensile strengths close to 100,000 lb. per sq. in. and elongation of 30%.

Intermediate manganese steels are also sold under trade names such as Hylastic, of the American Steel Foundries. Max-El No. 4, of the Crucible Steel Co., is a pearlitic manganese steel with a small amount of chromium and 0.75% carbon, used for spring collets and called Collet steel. Slight amounts of chromium will increase the strength and hardness of the intermediate manganese steels. A forging steel for shafts and crankpins, designated as Manganese-vanadium steel, contains 1.5 to 1.75% of manganese, 0.15 vanadium, and 0.25 carbon. The strength is 90,000 lb. per sq. in. and elongation 30%. Moloie is the name of a Manganese-molybdenum steel of W. T. Flather, Ltd. Pearlitic Nickel-manganese steel contains 1.25% of manganese and 1.25 nickel. It has high yield point and ductility. A steel used by the Union Pacific Railway for draft yokes has 1.4% of nickel and 1.5 manganese. The strength is 95,000 lb. per sq. in.

**Mangrove.** An extract from the bark of the mangrove tree, *Rhizophora mangle,* of Venezuela and Colombia, the Red mangrove, *R. racemosa,* of Nigeria, the East African mangrove, *R. mucronata,* and other species of Africa, the East Indies, southern Asia, and tropical America, used for tanning leather. In Java it is called Baku bark. The East African bark contains 22 to 33% of tannin, and the Nigerian bark contains 15 to 29%, usually at the low level. The South American barks range in tannin content from 5 to 45%. In the Brazilian mangrove, the leaves contain 24%. The solid extract marketed in blocks contains 62 to 63% of solids and contains 53 to 54% tannin. The liquid extract contains 25 to 35% tannin. Red mangrove contains a red coloring matter which is objectionable in tanning, but can be decolorized with albumen. White mangrove produces a pale pinkish-brown leather, fairly soft and of firm texture. Mangrove from East Africa is called Mangrove cutch.

**Manila hemp.** A fiber obtained from the leaf stalks of the Abaca plant, *Musa textilis,* a tree of the banana family growing in the Philippines, the East Indies, and Central America. It is

employed for rope and cordage and is the strongest of the vegetable fibers. The fibers are also very long, from 4 to 8 ft., and do not stiffen when wet. It is thus valued for marine cordage. The best grades are light in weight, soft and lustrous, and white in color. The finest fibers, called Lupis, are used in the East for weaving into cloth. The plant grows to a height of 20 to 30 ft., with huge leaves characteristic of the banana. Each successive layer of leaves toward the stalk yields fibers that are lighter in color, higher in strength, and of finer texture than those outside. There are 15 grades in the Philippines.

**Maple.** The wood of maple trees native to the United States and Canada which includes 13 species in the United States. Of these the Sugar maple, *Acer saccharum,* is the most plentiful and the most important. Other names for this tree and wood are Hard maple and Rock maple. The wood is heavy and hard, and is used for furniture, shoe lasts, handles, fine floors, and woodenware. Black maple, *A. nigrum,* is similar to sugar maple and is marketed with it. The Broad-leaved maple, also known as Bigleaf maple and Oregon maple, is *A. macrophyllum,* and is the only species native to the Western states. Silver maple, *A. saccharinum,* grows most extensively in the Middle states. It is also called Soft maple, White maple, River maple, and Swamp maple. Box elder, *A. negundo,* grows over the Northern states east of the Rocky Mountains. The Red maple is *A. rubrum,* and the Vine maple is *A. circinnatum.* The wood of the maples may be white or yellowish to brownish, and is close-grained and hard. It often has a curly, twisted grain. The weight is about 40 lb. per cu. ft. Sugar maple heartwood is light reddish brown with a wide white sapwood. The wood of the soft maples is not as heavy or as strong as that of the sugar maple. Maple is used for furniture, cabinetwork, flooring, rollers, measuring rules, shoe heels and lasts, and where a hard, fine-grained wood is needed. Sugar maple has an average specific gravity when kiln-dried of 0.67, compressive strength perpendicular to the grain of 2,170 lb. per sq. in., and shearing strength parallel to the grain 1,520 lb. per sq. in.

**Marble.** A compact crystalline limestone used for ornamental building, for large slabs for electric-power panels, and for ornaments and statuary. In the broad sense, marble includes any lime-

stone that can be polished, including Breccia, onyx, and others. Pure limestone would naturally be white, but marble is usually streaked and variegated in many colors. Carrara marble, from Italy, is a famous white marble, being of delicate texture, very white and hard. In the United States the marbles of Vermont are noted and occur in white, gray, light green, dark green, red, black, and mottled. A typical white Vermont marble slightly mottled with gray is 99% pure carbonates with only slight amounts of manganese and aluminum oxides and organic matter. But about 60% of American marble is quarried in Tennessee and Georgia. It is highly crystalline, and is colored white, gray, bluish, or pink. The Alabama marble is a pure, low-porosity material of good statuary grade. For great variety of beautiful colors the marbles of southern Uruguay are famous and occur in immense blocks.

The weight of marble is about 170 lb. per cu. ft., the specific gravity is 2.72, and the crushing strength 10,000 lb. per sq. in. It will ordinarily withstand heat up to 1200°F. without injury. Translucent marble is selected and processed marble, semitransparent to light. Marble chips are irregular small graded pieces of marble marketed for making artificial stone. It is a by-product of marble quarrying. Marble flour, or Marble dust, is finely ground chips used as a filler or abrasive in hand soaps. Marbelite is an Artificial marble used for casting statues and small ornamental articles. It is made by heating potassium alum in water and adding about 10% of heavy spar, and then casting in rubber molds. Marble dust may be added to increase the weight.

**Mastic.** The gum exudation of the tree *Pistacia lentiscus,* native to the Mediterranean countries. It is used in lacquers, varnishes, and adhesives. Mastic is obtained by making an incision in the tree, each tree yielding 6 to 11 lb. annually. There are two general grades, the purer resin adhering to the tree, and the resin collecting on the ground. It is easily soluble in turpentine but is more expensive than many other natural resins, and is used for high-grade pale varnishes for art work. The name mastic is also erroneously applied to asphalt when used in calking or adhesive compounds.

**Mauritius hemp.** The fiber obtained from the fleshy leaves of the plant *Furcraea gigantea,* of Mauritius, Nigeria, and Gold Coast,

used for rope and cordage. The product from West Africa is often erroneously termed sisal. The plant belongs to the lily family. Similar fibers are obtained from other species, notably *F. foetida,* of Brazil. The *F. gigantea* is also grown in Brazil under the name of Piteira. Each plant yields about 40 leaves annually, from 10 to 12 ft. in length, each leaf giving 35 gm. of fiber. The plant *F. cabuya* produced the ancient cordage fiber of the Mayas. The term Cabuya, which means cordage, is applied to the fibers of the several species growing through Central America, the West Indies, and northern South America to Ecuador. The fibers of the *F. cabuya* of Costa Rica are up to 100 in. long. The leaves yield up to 3.5% of their green weight in dry fiber, which is coarser than henequen but is used for coffee-bag fabric. The fibers of the cabuya of Ecuador, *F. andina,* are not as long. They are used extensively for burlap for bagging. Fique fiber, of Colombia, used for rope and for coffee bags, is from the leaves of the *F. macrophylla.* The leaves are longer than those of henequen, and the fiber is finer and more lustrous.

**Meerschaum.** A soft, white or gray, clay'ike mineral of the composition $3SiO_2 \cdot 2MgO \cdot 2H_2O$, used for making pipes and cigar holders, but also employed for making various other articles, as it can be cut easily when wet and will withstand heat. When fresh the mineral absorbs grease and makes a lather; its German name means seafoam. It is used as a filler in soaps in Germany. The hardness is about 2 and the specific gravity 1.28. Most of the commercial meerschaum comes from Asia Minor; the mines at Eskisehir have been worked for 20 centuries. A little is produced in New Mexico and some in Spain. Artificial meerschaum is made from meerschaum shavings, kieselguhr, and from silicates of aluminum, calcium, and magnesium.

**Melamine resin** . A synthetic resin of the alkyd type made by reacting melamine with formaldehyde. The resin is thermosetting, colorless, odorless, and is resistant to organic solvents. It is more resistant to alkalies and acids than urea resins, has better heat and color stability, and is harder. The melamine resins have the general uses of molding plastics, and also are valued for dishes for hot foods or acid juices as they will not soften or warp when washed

in hot water. Melamine, a derivative of cyanamid, has the composition $(N{:}C \cdot NH_2)_3$. It has a specific gravity of 1.56 and melting point of 354°C. Melamine alone imparts to other resins a high gloss and color retention. The melamine resins are too hard for use alone in coatings and varnishes, but they are combined with alcohol-modified urea-formaldehyde resins to give coating materials of good color, gloss, flexibility, and chemical resistance. Uformite MU-56, of the Resinous Products & Chemical Co., is a urea-modified melamine-formaldehyde resin used for coatings and varnishes. Melmac 1077, of the American Cyanamid Co., is a melamine-formaldehyde molding resin with cellulose filler. It has a tensile strength of 7,500 lb. per sq. in., and dielectric strength of 325 volts per mil. Melmac 592 has a mineral filler. It has a dielectric strength of 400 volts per mil and will withstand temperatures to 300°F. Melurac 300 is a melamine-urea-formaldehyde resin with a lignin extender used as an adhesive for water-resistant plywood. Melmac 483 is a phenol-modified melamine-formaldehyde resin solution used for laminating fibrous materials. Lanoset is a methylol-melamine made by alkylating a melamine-formaldehyde resin with methyl alcohol. It is used for shrinkproofing woolen fabrics. Resimene 812, of the Monsanto Chemical Co., is a colorless melamine-formaldehyde resin powder that can be dissolved in water or ethyl alcohol, for impregnating paper or fabrics, or for laminating.

**Menhaden oil.** An oil obtained by steaming or boiling the fish *Brevoortia tyranus,* caught along the North Atlantic Coast of America. It was first called Porgy oil, the Maine name for the fish. In Connecticut it is called Whitefish. In the South it is known as Fatback and Mossbunker. The fish from Southern waters yield only small amounts of oil. The fish, when fully grown, are 12 to 15 in. long, weighing about a pound. They yield up to 15% of oil, which is used as a substitute or adulterant for linseed oil, for dressing leather, mixing in cutting oils, and for making blown oils. The residue Fish meal is sold for fertilizer. The meal is not as rich in vitamins A and D as that from some other fish, but much is used for poultry feed. The better qualities of the oil are bleached as it has a natural yellow-brown color. In-

ferior qualities are obtained by pressure from the residue or may be from putrid fish. Menhaden oil contains about 23% of palmitic acid. The drying power is good, though it does not form an elastic film as do the vegetable oils. Its strong odor is due to Clupanodonic acid, $C_{17}H_{27}COOH$. The specific gravity is 0.927 to 0.933 and iodine value 180. It is soluble in benzene, naphtha, and ether.

**Mercerized cotton.** Cotton yarns treated with sodium hydroxide. The treatment gives a fine, silky luster to the yarn, makes it stronger, and practically nonshrinking. It was discovered in 1851 by John Mercer of Lancashire. The present process consists in immersing the yarns in a stretched condition in the soda, and after washing, neutralizing the remaining alkali with dilute sulphuric acid. The stretching of the yarns prevents excessive shrinking. Mercerized cotton has a greater affinity for dyes than untreated cotton. Mercerized yarns have a variety of uses and, when mixed with silk, cannot be detected easily.

**Mercury.** Also called Quicksilver. A metallic element, symbol Hg. It is the only metal that is a liquid at ordinary temperatures. Mercury has a silvery-white color and a high luster. Its specific gravity is 13.596. The solidifying point is −40°F., and its boiling point is 662°F. It does not oxidize at ordinary temperatures, but when heated to near its boiling point it absorbs oxygen and is converted into a red crystalline powder, Mercuric oxide, HgO, used as a pigment in marine paints. Mercury is derived chiefly from the mineral cinnabar. Spain, Italy, Russia, Mexico, and Western United States are the chief producers. The metal is marketed in steel flasks holding 75 lb. European flasks hold 76 lb. It is used for separating gold and silver from their ores, for coating mirrors, as an expansive metal in thermometers, in mercury-vapor lamps, rectifiers, mercury vapor motors, in amalgams with other metals, and in its compounds for fungicides, pharmaceuticals, paint pigments, and explosives. The black mercurous oxide $Hg_2O$, is used in skin ointments. Mercuric chloride, or Corrosive sublimate, $HgCl_2$, is an extremely poisonous, white crystalline powder soluble in water and in alcohol, used as a wood preservative, as an insecticide and rat poison, in tanning, as a mordant, and as a caustic antiseptic in medicine. Mercurochrome, $C_{20}H_8O_6Na_2Br_2Hg$, is a green

crystalline powder which gives a deep-red solution in water, and is used as an antiseptic. Mercury forms a vast number of compounds, all of which are poisonous and some are explosive.

**Mesothorium.** A radioactive substance found in the rare-earth minerals. It is separated out of monazite sand and other thorium ores as a by-product of thorium production. Mesothorium is identical in chemical properties with radium, and cannot be separated from radium if mixed with it. A disadvantage of mesothorium, however, is that it decays, decreasing to half value in 5.5 years. The radiations from mesothorium are the same as from radium, $\alpha$, $\beta$, and $\gamma$ rays being sent off. As it decomposes, it forms radiothorium, which is identical in chemical properties with thorium but gives off a powerful $\alpha$ radiation. Mesothorium is used in luminous paints. It is a better activator than radium for this purpose, but is scarcer and more expensive.

**Metallic soap.** A term used to designate compounds of the fatty acids of the vegetable and animal oils with metals other than the alkali metals. They are not definite chemical compounds like the alkali soaps, but may contain complex mixtures of free fatty acid, combined fatty acid, and free metallic oxides or hydroxides. The name distinguishes the water-insoluble soaps from the soluble soaps made with potash or soda. Metallic soaps are made by heating a fatty acid in the presence of a metallic oxide or carbonate, and are used in lacquers, leather and textiles, paints, inks, ceramics, and grease. They have the properties of being driers, thickening agents, and flattening agents. They are characterized by ability to gel in solvents and oils, and by their catalytic action in speeding the oxidation of vegetable oils.

When made with fatty acids having high iodine values, the metallic soaps are liquid, such as the oleates and linoleates, but the resinates and tungstates are unstable powders. The stearates are fine, very stable powders. The fatty acid determines the physical properties, but the metal determines the chemical properties. Aluminum stearate is the most widely used metallic soap for colloid products. Aluminum soaps are used in polishing compounds, in printing inks and paints, for waterproofing textiles, and for thickening lubricating oils. The resinates, linoleates, and naphthanates are used

as driers, the lead, cobalt, and manganese being the most common. Soaps of copper, arsenic, and mercury are used in Antifouling marine paints. Calcium resinate is an insoluble soap of the composition $Ca(C_{44}H_{62}O_4)_2$ produced by boiling rosin with lime water, and filtering. It is also called Calcium abietate, and is a yellow powder of high molecular weight, 1349.06, used as a paint drier and for waterproofing. Calcium linoleate is a white amorphous powder of the composition $Ca(C_{18}H_{31}O_2)_2$ used in paints and in waterproofing. It is insoluble in water but soluble in alcohol. Calcium stearate, $Ca(C_{18}H_{35}O_2)_2$, is a white fluffy powder of 250 mesh. It is used as a flatting agent in paints, for waterproofing cements and stucco, as a dusting powder for rubber molds, as a softening agent in lead pencils, and in drawing compounds for steel-wire drawing. Barium stearate, $Ba(C_{18}H_{35}O_2)_2$, is a waxy nontacky white powder with molecular weight of 703 and melting point of 140 to 150°C. It is used as a dry lubricant for molding plastics, greaseless bearings, wax compounding, and wire drawing. Strontium stearate, $Sr(C_{18}H_{35}O_2)_3$, is a white powder with molecular weight of 654 and melting point of 130 to 140°C. It is partly soluble and gels in benzol, mineral spirits, and hydrocarbons. It is used in grease and wax compounding and in crimson flares and signals. Chromium stearate is a dark-green powder of the composition $Cr(C_{18}H_{35}O_2)_3$ which melts at 95 to 100°C. It is used in ceramics, plastics, and in plastic waxes and greases, and as a catalyst. Manganese stearate is a pink powder of the composition $Mn(C_{18}H_{35}O_2)_2$, with a melting point of 100 to 110°C. It is used in wax and grease compounding. Cerium stearate, $Ce(C_{18}H_{35}O_2)_2$, is a very inert, waxy white powder melting at 100 to 110°C., used as a catalyst and in waterproofing compounds. Nickel stearate is a green powder, $Ni(C_{18}H_{35}O_2)_2$, with a melting point of 150 to 160°C., soluble in aromatic hydrocarbons, and forming gels with petroleum oils. It is used in lubricants, waterproofing compounds, leather finishes, and as a flux in nickel welding.

**Metalized wood.** Wood treated with molten metal so that the cells of the wood are filled with the metal. The fusible alloys, with melting points below the scorching point of wood, are used. The wood is immersed in molten metal in a closed container, and air

pressure applied. Only a short treatment is needed to impregnate the wood; it can be controlled to give various degrees of penetration. The tensile strength of the wood is not affected, but the hardness, compressive strength, and resistance to flexure are increased. The wood also becomes an electrical conductor lengthwise of the grain. Metalized wood is costly but is used where the special characteristics are needed.

**Methane.** Also known as Marsh gas, in coal mines as Firedamp, and chemically as Methylhydride. A colorless, odorless gas, $CH_4$, employed for carbonizing steel, in the manufacture of formaldehyde, and as a starting point for many chemical compounds. It occurs naturally from the decomposition of plant and animal life, and is also one of the chief constituents of illuminating gas. It is made synthetically by the direct union of carbon or carbon monoxide with hydrogen. It is also produced by the action of water on Aluminum carbide, a gray, massive substance of the composition $Al_4C_3$. Methane has a specific gravity of 0.560 and, since it is much lighter than air, it is easily diffused in air. In air the gas is highly explosive, although the gas alone is not explosive. Pintsch gas, once used widely for car lighting, contained up to 60% methane and was made by spraying petroleum oil into a hot retort. This type of gas, under the name of Oil gas, or Carbohydrogen, and containing as high as 85% hydrogen, gives a low-temperature flame used for flame-cutting torches. Nitromethane is nitrated methane. It is a liquid explosive more powerful than TNT.

**Methyl alcohol.** Commonly known as Wood alcohol, and called Methanol when made synthetically. A colorless, poisonous liquid of the composition $CH_3OH$, obtained from the distillation of hard woods. It is used as a solvent in lacquers, varnishes, and shellac. On oxidation it yields formaldehyde, and is used in making the latter product for synthetic molding materials. The specific gravity of methyl alcohol is 0.795, the solidifying point is $-98°C.$, and the boiling point is $65°C.$

**Mica.** Known originally as Muscovy glass. A group of minerals with monoclinic crystals which break off easily into thin, tough scales, varying from colorless to black. Muscovite is the common

variety of mica, and is called Potash mica, or Potash silicate, $H_2KAl_3(SiO_4)_3$. It has dielectric properties superior to Phlogopite and is valued for radio condensers. Sheets as thin as 0.001 in. are used as electrical insulators. The Magnesium mica known as phlogopite, of the composition $H_2KMgSi(SiO_4)_3$, is distinguished from muscovite by its decomposition in sulphuric acid. It is known as Amber mica and is superior to muscovite in heat resistance, but is softer. It has a brownish-yellow color, and is valued for electrical work. It comes from India, Canada, Madagascar, and Tanganyika. The colorless muscovite used for doors in stoves was called isinglass for this purpose. Fuchsite is Chromium mica. It is known only in small emerald-green flakes. The rare greenish Vanadium mica known as Roscoelite is usually in fine scales, and where there are considerable amounts, as in the sandstones of Colorado, Utah, and Arizona, it is most valuable as a source of vanadium as it contains 1.5 to 3.5% of vanadium. Margarite is a yellow or purple Calcium mica, $CaO(SiO_2)_2 \cdot (Al_2O_3) \cdot H_2O$, and is a transition product. The chief uses of mica are as an electrical insulator, a heat insulator, and as a filler in plastics and insulating materials. The value of sheet mica depends greatly upon the absence of staining, especially from iron inclusions which decrease the electric insulating value. Most stains are black, which are from magnetite or other iron oxide. Reddish stains are usually red iron oxide. The brown-colored micas containing much iron are valueless as electric insulators.

The specific gravity of mica is 2.7 to 3.1, and the hardness from 2 to 3. India, Brazil, and Argentina are the largest producers of block mica. Ruby mica is the finest grade of Indian mica for electrical condenser use. India is the largest producer of phlogopite. About 80% comes from Bihar and is ruby mica. Madras mica is greenish, and is not high-quality electric mica. Indian mica is graded as No. 5 first and second quality bookform; No. 6 loose with powder; extra loose, first quality and second quality; special loose, second quality; and No. 6A loose, third quality. Argentine mica runs 80% stained, 15% semiclear, and 5% clear. It has eight size grades from No. 6 in sheets of 1 to 3 sq. in. to AA, or Special, in sheets of 48 sq. in. or more.

Mica is marketed as cut or uncut block, sheet, splittings, and ground. The value is usually on the size of clear, flat sheets. The

sheets vary from clear to black, stained in six grades. Splittings are usually only 0.001 in. in thickness, and only 1 or 2 in. in diameter, but are readily cemented together for use. Indian mica has been obtained in books as large as 15 ft., and sheets as large as 24 by 30 in. without flaws. Small pieces are made into mica powder. Micanite is an old name for small splittings molded together with an adhesive for insulating use. The original Micanite made in India in 1892 was made from small pieces cemented together with shellac. Mycalex, of the Mycalex Corp., and the General Electric Co., are Glass-bonded micas. That of the latter company is composed of ground mica and lead borate heated together to the softening point of the borate, 675°C., and compressed while plastic. Part of the mica combines to form a lead borosilicate, giving greater insolubility. It has good mechanical strength, is a good heat and electrical insulator, is impervious to water, resistant to arcing, and has a low coefficient of expansion. The tensile strength is 5,000 to 7,000 lb. per sq. in., and compressive strength 22,000 to 30,000 lb. per sq. in. Mykroy sheet, of the Electronic Mechanics, Inc., is glass-bonded mica in large brownish-gray sheets ground on the sides and used for electrical panels and structural parts of radio equipment. The dielectric strength is 620 volts per mil, and hardness 63 to 70 Brinell. Mykroy No. 51 is made from ground mica, boric acid, lead oxide, and a small amount of cryolite, and is injection-molded to intricate shapes and fired at 1100 to 1450°F. It is used for radio and electrical parts. The dielectric strength is 500 to 620 volts per mil, Brinell hardness 63 to 70, and it will withstand temperatures to 1000°F. Lamicoid is a synthetic plastic with mica filler produced by the Mica Insulator Co. Micabond is a trade name of the Continental-Diamond Fiber Co. for mica bonded with shellac and resin to form sheets, tubes, and molded parts. Micabond cloth is mica splittings faced on one side with tissue and on the other with cotton cloth. Watsonite is the name of a mica substitute consisting of scrap or flake mica dehydrated by heating and then sheeted with a flexible binder. A Synthetic mica, known as Alsifilm, is produced from bentonite, and is made in thin, transparent sheets with many of the characteristics of mica. The German mica substitute known as Glushartgewebe is made by impregnating very fine high-alkali glass-

fiber cloth with an alcohol solution of osmose kaolin and synthetic resin and compressing the plies under high pressure at 160°C. The synthetic mica, of the Charles Lenning Co., is made with a dispersion of colloidal magnesium silicate and synthetic resin which polymerizes to a thin sheet of high dielectric strength. Synthetic mica made by Siemens & Halske during the war was produced by melting a mixture of 11.6% of aluminum oxide, 32.6 magnesium oxide, 30.7 kieselguhr, and 25.1 $K_2SiF_6$. The crucible of melted material was enclosed in a silicon carbide crucible with the space filled with fused alumina sand, and brought to a temperature of 1500°C. After cooling slowly the material is removed by breaking the inner crucible. The soldified mass splits into thin clear sheets equal to high-grade natural mica.

**Mica powder.** Mica in very small flakes used as a filler in plastics, in paints, in roofing and asphalt shingles, and for making glass-bonded mica. When produced by grinding, the small scrap pieces from mica workings, it is known as Ground mica. The ground mica from Canada is phlogopite. It comes in 20, 60, 120, and 150 mesh. Mica in paints helps to bond the film and prevent cracking, acting similarly to aluminum leaf. Mica powder for plastic filler and paints is produced directly from mica schists by froth flotation. The powder recovered averages more than 50% of sizes smaller than 200 mesh and 20% between 150 and 200 mesh. The recovered mica equals in every way the powder made by grinding mica scraps. Sericite mica, or Damourite, from North Carolina kaolin workings, is a type of potash mica related to muscovite but softer. Mixed with aluminum powder it produces a finish paint superior to aluminum alone. It has some activating properties, and is a substitute for zinc oxide in rubber. It is also used as a filler in plastics, and replaces graphite as a foundry core and mold wash. The recovery from North Carolina clay is 10% of the gross weight of the clay. Water-ground mica is ground to a fineness of 90% through a 325-mesh screen and 9% on a 325-mesh. It is for paint and rubber use. The mica powder known as Micalith G, of the Glidden Co., is sericite mica from Pennsylvania washings with 0.5% of graphite embedded in the mica crystals. The graphite improves the wetting and dispersion in paints. Micronized mica is a powder

of a fineness of 400 to 1,000 mesh, used as a filler. Mica flake, used in the manufacture of shingles and roofing, is washed from pegmatite deposits.

**Milk.** The secretion of the mammary glands of mammal animals. Commercial milk in the United States is almost entirely from the cow. Besides its use as a food for direct consumption and in bakery products, it is employed for making cheese, butter, casein, ice cream, lactic acid, and lactose chemicals. The production of cow's milk in the United States is about 120 billion pounds from 28 million animals. Although the average production from registered dairy animals is only about 4,700 lb. per year, the average yield from 800,000 cows under the Dairy Herd Improvement Assoc. is 8,000 lb. per year. The composition of milk is 87.34% of water, 3.75 butter fat, 3 caseinogen, 0.4 lactalbumin, and 0.75 mineral salts. It also contains vitamins A, B, and C. The vitamin A content is low during the winter months when the animals do not feed on green grasses. More than half a billion pounds of milk per year are used in the production of evaporated and condensed whole milk. Dried milk, or Milk powder, is made largely from skimmed milk, or milk from which the cream has been separated. One gallon of milk yields 1.2 lb. of dried milk. It is used mostly in bakery products. Milk is pasteurized by heating to kill disease organisms, and in most countries the handling of milk is regulated as it is easily contaminated. Under the U.S. Food and Drugs Act milk must contain not less than 3% of milk fat and 8.5 solids not fat. In natural milk the fat and proteins are in colloidal solution, and the milk is homogenized by pressure or by sonic vibration which breaks up the fat globules and distributes them evenly. Cow's milk for direct consumption and for industrial use is produced on a large scale in the United States, Canada, Europe, Argentina, New Zealand, and Australia. Kumyss is sweetened cow's milk fermented with yeast, used as a nutrient. Soy milk is a water solution of soybean solubles combined with sugar, calcium phosphate, irradiated sesame oil, and vitamins. It has the approximate composition of cow's milk and is almost indistinguishable from it.

**Millet.** The very small seeds of a number of grasses. It is one of the most ancient of food grains, and is a most important grain in

Asia, being used as food by a third of the population of the world. Nearly 40 million acres are cultivated to this grain in India alone. The plant is very drought-resistant, but will not withstand frost. The seeds are high in phosphate, protein, minerals, and oil. In the United States millet seed is used as a birdseed, and the plant is grown for pasturage and silage. German millet, also known as Foxtail millet and as Hungarian grass, is from the grass *Setaria italica.* The seed contains phosphates and many minerals and vitamins A and E. It is an important food in Europe and Asia, but in North America is a forage crop. White millet, or Proso millet, from the grass *Panicum miliaceum,* is one of the richest grains in food value, but is employed in the United States only as a birdseed. It is much used in Russia as a food. The millet from the plant *Sorghum vulgare* is a staple food in India. Sanwa millet, from the *Echinochloa frumentacea,* is an important food in Japan. The plant will produce as many as eight forage crops per year.

**Millstone.** Any stone employed for grinding paint, cement, grain or minerals. Millstones are made from sandstone, basalt, granite, or quartz conglomerate. Burrstone is a millstone made from chalcedony silica of cellular texture, usually yellowish in color. The stone is also used as a building stone. Esopus stone is a conglomerate of this type from Ulster County, New York. The most noted burrstones for grinding grains are the European stones cut in wedge-shaped blocks 6 in. long, 3½ to 4 in. wide, and 2 to 2½ in. thick bound together with iron hoops. The French stones are chalcedony quartz, creamy white, with a cellular structure, the cavities formerly occupied by fossil shells. German burrstones are basaltic lava. Millstones vary greatly in sharpness of grain and size of grain, but should be of even texture throughout. Chaser stones are very large stones run on edge in mills for grinding minerals.

**Mineral wool.** A fibrous material employed as a heat insulator in walls or as a sound insulator. It was first obtained as a natural product from volcanic craters in Hawaii and was known as Pele's hair. It is made by mixing stone with molten slag from blast furnaces and blowing steam through it. Slag wool is made from slag without the rock. Mineral wool usually consists of a mass of

fine, pliant, vitreous fibers, which are incombustible and a nonconductor of heat. Rock wool is made by blowing molten rock in the same manner, and is more uniform than common mineral wool, with physical qualities depending, however, on the class of rock used. The rock wool marketed by Johns-Manville under the name of Banrock is made from high-silica limestone and is used for insulating oven walls for temperatures up to 1000°F. Zerofil is a nonsweating, low-temperature insulating material of the same company consisting of rock wool coated with asphalt. The rock wool of the Philip Carey Co., known as Rocktex, has a heat conductivity of 0.22 B.t.u. per hr. per sq. ft. per deg. F. difference in temperature. Rock cork is a name for a low-temperature insulating material made of rock wool molded in sheet form with a waterproof binder, used for walls in cold-storage rooms.

Granulated mineral wool, of the Keasbey & Mattison Co., is milled to ½-in. diameter size which can be poured into the space to be insulated. It has a density of 4 to 6 lb. per cu. ft. Supertemp block, of the Eagle Picher Lead Co., an insulator for temperatures up to 1700°F., is made of a cement composed of small rolled pellets of mineral wool and asbestos fibers combined with a mineral binder, making a block with tiny dead-air pockets. The thermal conductivity at 100°F. is 0.40 B.t.u. per sq. ft. per in. of thickness per hr. Mineral-wool board, of the Armstrong Cork Co., is a moisture-resistant board in thicknesses of 1, 1½, 2, 3, and 4 in. for cold-storage insulation. The thermal conductivity is 0.31 to 0.33 at 90°F. Mono-Block, of the Baldwin-Hill Co., is rock wool made into standard blocks and slabs by a felting process. It is used for both cold and heat insulation to temperatures up to 1600°F. The weight is 18 lb. per cu. ft. The heat conductivity at 200°F. is 0.325 B.t.u. per sq. ft. per hr. per in. thickness per deg. F. Insulating blocks are also made of granulated mineral wool or the fiber compressed with a binder of clay or bentonite for elevated temperatures, or with a plastic binder for temperatures below 400°F. Rock-wool quilt consists of felted fibers stitched between layers of treated kraft paper. Rock-wool blankets for insulation are made of long fibers felted and bonded with a synthetic resin. They are water-repellent and verminproof. Rock wool is marketed as loose wool of fine silky fibers, in granulated pellets, and in batts or matted pads. Selected

mineral, to give various characteristics, may be used to make rock wools. Wollastonite, a natural Calcium metasilicate, $CaSiO_3$, found in California, is melted to produce a rock wool.

**Mixed acid.** A name for a mixture of nitric and sulphuric acids used in making nitrocellulose and dyestuffs, and also called Nitrating acid. Standard mixed acid contains 36% of nitric and 61 sulphuric. Other grades are 80-15, or 80% nitric and 15 sulphuric, and 85-12, 60-35, and 45-53. Mixed acid is used chiefly in the preparation of nitrocellulose, and for making nitrostarch.

**Mohair.** The long, lustrous fleece of the Angora goat, *Capra angorensis,* important as a textile fiber because of its luster, length, strength, and spinning qualities. Mohair fabrics are used for upholstery material for hard service, and valued for summer wearing apparel, linings, and plushes. Mohair commonly contains shorter fibers, coarse and difficult to dye. These are known as Kemp and sometimes comprise 18% of the fiber. They are removed by combing. Mohair has a natural curl but no crimp, and does not felt like wool. The American fiber is 6 to 8 in. long, and the Turkish fiber is up to 10 in. long. South Africa produces much mohair.

**Mold steel.** A term that generally refers to the steels used for making molds for plastics. Mold steel should have a uniform texture that will machine readily with die-sinking tools. It must have no microscopic porosity, and be capable of polishing to a mirrorlike surface. When annealed, it should be soft enough to take the deep imprint of a hob, and when hardened it must be able to withstand high pressure without sinking and have sufficient tensile strength to prevent breakage of the small mold sections. It should not warp under ordinary heat-treating processes. For most plastic molding a casehardening, low-carbon, low-alloy steel is used, but it must be of tool-steel quality and not of structural-steel grade. For hot sinking a typical analysis is 0.10% of carbon, 0.50 manganese, 0.60 chromium, and 1.25 nickel. Such a steel has an annealed hardness of 120 Brinell, but will give a hardened case of Rockwell C-62 and core of C-21, with a tensile strength up to 120,000 lb. per sq. in. For molds that are machined and not hobbed a higher carbon content is used which increases the strength of the steel. For molds

that must withstand the highest hydraulic pressures the nickel content is increased to 3.5% and the chromium also increased. For severe pressures and resistance to abrasion high-carbon manganese steels may be used. A typical analysis is 0.90% of carbon, 1.6 manganese, and 0.25 silicon. These steels are deep-hardening and withstand high compression, but are not as strong in tension. Stainless steels are also used for molds where high strength, long wear life, and chemical resistance are required, but these are difficult to machine. A carburizing steel for plastic molds is S.A.E. steel 3312, containing 3.5% nickel and 1.2 chromium. Carpenter No. 158 steel has 3.5% of nickel, 1.5 chromium, 0.40 manganese, and 0.10 carbon. It gives a surface hardness of Rockwell C-62 with a core strength of 165,000 lb. per sq. in. Hoballoy, of the Crucible Steel Co., is a steel of this type with 0.10% carbon. Plastalloy, of Henry Disston & Sons, Inc., is a low-carbon, low-alloy, fine-grained steel for molds to be hobbed.

**Molding sand.** Called also Foundry sand. Any sand employed for making molds for casting metals, but especially referring to sands that are refractory and have also binding qualities. Pure silica is ideal for heat resistance, but must contain enough alumina to make it bind together. Molding sands may contain from 80 to 92% of silica, up to about 15% of alumina, about 2% of iron oxide, and not more than a trace of lime. Some molding sand contains enough clay or loam to bond it when tamped into place. The amount of bond in Grant and in Tuscarawa sand is 17 to 18%. About 33% of these natural sands pass through a No. 100 screen, and 20 through a 150 screen. The finer the grain, the smoother the casting, but fine-grained sand is not suitable for heavy work because of its impermeability to the gases. Sands without natural bond are more refractory and are used for steel molding. Sands for steel casting must contain over 90% of silica, preferably 98%, and are mixed with 6 to 10% of fireclay. These are usually called Silica sands as distinct from foundry or molding sands.

Zircon sand has high heat resistance, and is used for alloy steel casting. Zircon flour is finely milled zirconite sand used as a mold wash. Zirconite sand for molding is 100 to 200 mesh in its natural state. It is 70% heavier than silica sand, and has a higher heat

conductivity that gives more rapid chilling of castings. The zirconite sands have melting points from 3650 to 3850°F. Common molding sand may contain from 5 to 18% of clay materials, and be mixtures of sand, silt, and clay, but they must have the qualities of refractoriness, cohesiveness, fineness of grain, and permeability. To have refractory quality they must be free of calcium carbonate, iron oxide, and hydrocarbons. Core sands also have these qualities, but they are of coarser grain, and always require a bond that will bake solidly but will break down easily at the temperature of pouring. About 25% of a medium molding sand will be retained on a 150-mesh sieve, and about 10% on a 200-mesh sieve. Sand with rounded grains is preferred, and the grains must be very uniform in size to prevent filling. When a molding sand is burned out, it is made suitable for re-use by adding bond but, when fireclay is used as a bond, it adheres to the sand grains and makes it unsuitable for re-use. Parting sand is a round-grained sand without bond used on the joints of molds. Foundry parting is usually tripoli or bentonite. Cores are made with sand mixed with core oils. Green-sand cores are unbaked cores made with molding sand.

**Molybdenum.** A silvery-white metal, symbol Mo, occurring chiefly in the mineral molybdenite but also obtained as a by-product from copper ores. About 90% of all molybdenum is produced in the United States, the remainder coming from Chile, Mexico, Peru, and Norway. The metal has a specific gravity of 10.2, and melting point of 4750°F. It is ductile, softer than tungsten, and is readily worked or drawn into very fine wire. The tensile strength of rolled molybdenum is 260,000 lb. per sq. in. and Brinell hardness 147. Because of the high melting point, the extraction of the metal is similar to that of tungsten. The commercial metal is 99.95% pure. It is used for grids, hooks, and support members in radio and light bulbs, for windings in electric furnaces, welding electrodes, and as an alloying element in steels and special alloys. The pure metal is marketed in rods up to ¾ in. in diameter, in sheets as thin as 0.001 in., and in wire as fine as 0.004 in. About 95% of the molybdenum used is employed in alloy steels, and for this purpose it is used in the form of Ferromolybdenum, which is made directly

from the ore by reduction with carbon, lime, and silicon, and adding iron. The standard grade of ferromolybdenum contains 50 to 60% of molybdenum with up to 2.5% of carbon. It is marketed in steel drums on the basis of the contained molybdenum metal. Calcium molybdate is also used for adding molybdenum to steels. Briquettes of Molybdic oxide, containing 70 to 75% of molybdenum trioxide and 12 carbon, are also used for alloying steel.

**Molybdenum cast iron.** Cast iron containing small amounts of molybdenum added to the iron as ferromolybdenum or as calcium molybdate. Molybdenum in iron is not a carbide-former or a graphitizer. It goes into direct solid solution and refines the matrix, increasing the strength, toughness, and wear resistance. Usually the manganese is increased when molybdenum is added, and the irons are more uniform in structure than plain cast iron. A plain molybdenum cast iron with 0.65% of molybdenum has a tensile strength of 44,000 lb. per sq. in. and Brinell hardness of 223, which can be raised by heat-treatment to above 60,000 lb. per sq. in. with a hardness above 300 Brinell. Greater hardness can be obtained in the iron with the addition of small amounts of chromium. A Chrome-molybdenum cast iron with 0.50% of chromium, 0.50 molybdenum, and 1.25 manganese added to the cupola, resulting in an iron of 3.1% of total carbon, 0.30 molybdenum, 0.33 chromium, and 0.75 manganese, has a tensile strength of 48,000 lb. per sq. in., Brinell hardness of 240, and an increase of about 40% in transverse strength over the plain iron. Raising the amount of molybdenum increases the hardness, but the machinability is kept by the addition of nickel or copper. Nickel-molybdenum cast irons have hardnesses as high as 300 Brinell without massive carbides that interfere with machining. An iron with 0.80% each of molybdenum and nickel, without chromium, has a tensile strength of 50,000 lb. per sq. in. and a hardness of 270 Brinell. It has great uniformity, and can be cast in combined thin and heavy sections.

**Molybdenum ores.** Molybdenite is the chief ore of the metal molybdenum. It is a molybdenum disulphide, $MoS_2$, containing 60% of molybdenum, occurring in granite, gneiss, and granular limestone. Molybdenite resembles graphite in appearance, with a lead-gray color, metallic luster, and greasy feel. The hardness is 1,

and specific gravity 4.75. It is infusible. The American production of molybdenite is from Colorado, New Mexico, and Nevada. Wulfenite, another important ore, is a Lead molybdate, $PbMoO_4$, and occurs in lead veins with other ores of lead. It is found in Utah, Nevada, Arizona, and New Mexico. Wulfenite occurs in crystals and also massive granular. The specific gravity is 6.7 and hardness 3. Its color is yellow, orange, gray, red, or white. Molybdite, another ore, is a hydrous ferric molybdate of the composition $Fe_2O_3 \cdot 3MoO_3 \cdot 7H_2O$. It occurs either crystalline massive or as an earthy powder. It is yellowish, with a specific gravity of 4.5 and a hardness of about 1.5. Molybdenum ores are converted into ferromolybdenum or into calcium molybdate for use in adding molybdenum to steel.

**Molybdenum steel.** Next to carbon, molybdenum is the most effective hardening element for steel. It also has the property like tungsten of giving steel the quality of red-hardness, requiring a smaller amount for the same effect. It is also used in hot-work steels, and to replace part of the tungsten in high-speed steels. It is added to heat-resistant irons and steels to make them resistant to deformation at high temperatures and to "creep" at moderate temperatures. It increases the corrosion resistance of stainless steels at high temperatures. Molybdenum in small amounts also increases the elastic limit of steel, reduces the grain size, strengthens the crystalline structure, and gives deep hardening. It goes into solid solution, but when other elements are present it may form carbides and harden the steel, giving greater wear resistance. It also widens the heat-treating range in tool steels. As it decreases the temper brittleness of aluminum steels, small amounts are added to nitriding steels.

Plain Carbon-molybdenum steels are easier to machine than other steels of equal hardness. Molybdenum structural steels usually have from 0.20 to 0.75% of molybdenum. S.A.E. steels 4130 and 4140 contain about 1% of chromium and 0.20 molybdenum, and are high-strength forging steels for such uses as connecting rods. Allenoy, used by the Allen Mfg. Co. for hollow-head screws, is S.A.E. 4150 steel. S.A.E. steels 4615 to 4650 have no chromium but contain about 1.75% of nickel. S.A.E. 4650 Nickel-molyb-

denum steel is used for forming dies and, when hardened and drawn to a hardness of 435 Brinell, has a tensile strength of 215,000 lb. per sq. in. Hyten M steel, of Wheelock, Lovejoy & Co., and Durodi steel, of A. Finkl & Sons, are high-strength nickel-chromium-molybdenum steels. Up to 3% of molybdenum is used in stainless steels for cast parts for hot oil and chemical equipment. Lebanon 22-XM steel has 19.5% of chromium, 9 nickel, and 3 molybdenum. Welmet, of the Welland Electric Steel Foundry, is a similar steel.

The old Damascus steel and Toledo steel were molybdenum steels, the molybdenum being in the original ore. Damascene steel is a name referring to the wavy marks on blades by forging and was not necessarily a molybdenum steel. But the original Wootz steel, or Indian steel, of this type, contained small percentages of aluminum incorporated in some unknown manner. Wootz steel was made in the crucible, although the crucible method was not used in Europe until 1740.

**Monazite.** A mineral occurring as sand or in granular masses, usually as sea sand. It is the chief source of thorium oxide and of the rare-earth metals. Most of the monazite comes from Brazil, India, and the East Indies. Brazilian monazite usually contains 6 to 8% of thorium oxide. The Indian ore may have as high as 10%, but is marketed on the basis of 7.5 to 8% of thorium oxide and 60 rare-earth metals. Monazite is a phosphate of the cerium metals, $(CeLaY)PO_4$, with Thorium silicate, $ThSiO_2$, having a specific gravity of 5.2 and a hardness of 5.5. It has a reddish-brown color with a resinous luster. Monazite also contains about 3.5 grams per 1,000 tons of mesothorium. It usually has also 30 to 35% of the oxides of lanthanum, neodymium, praseodymium, and yttrium, and a small amount of the element Europium. Monazite sand comes in 112-lb. cloth bags.

**Monel metal.** A natural alloy produced directly from Canadian Bessemer matte by reducing the nickel ore. It was introduced in 1905 by the International Nickel Co. The average composition is nickel, 67%; copper, 28; iron, manganese, silicon, and other elements, 5. The alloy may be cast, rolled, or forged, and can be annealed after cold working. It is resistant to corrosion and to the action of many acids, and will retain its bright nickel-white surface

under ordinary conditions. The melting point is about 2460°F. and weight 0.318 lb. per cu. in. The tensile strength is 65,000 lb. per sq. in., with elongation up to 50% depending upon the condition of hard rolling. The cast metal may have a tensile strength up to 100,000 lb. per sq. in. Monel metal is employed for parts for chemical and mining equipment, marine fittings, kitchen and restaurant equipment, and valves. A synthetic alloy of this type is Mond metal, of the American Nickel Corp. It contains higher manganese; the composition is 70% of nickel, 26 copper, and 4 manganese.

S Monel is an alloy of monel metal with 3.75% of silicon. It is used for valves and for castings subject to wear and corrosion. It has a hardness of 275 to 390 Brinell when heat-treated. K Monel is an alloy of Monel metal with a small amount of aluminum. It can be hardened by heat-treatment. A typical composition is 63.3% of nickel, 30.8 copper, 3.5 aluminum, 1.5 iron, 0.5 manganese, with small amounts of carbon, sulphur, and silicon. The soft alloy, with a hardness of 145 Brinell, will have a hardness above 300 Brinell when heat-treated, and a tensile strength up to 160,000 lb. per sq. in. It will retain its hardness up to 700°F. and is suitable for high-pressure steam valves. R Monel contains 67% of nickel, 30 copper, and 0.035 sulphur. The cold-drawn rods have a tensile strength of 90,000 lb. per sq. in., elongation 25%, and Brinell hardness 180. H Monel is a sand-casting alloy containing 65% of nickel, 29.5 copper, 3 silicon, and 1.5 iron. The tensile strength is 100,000 lb. per sq. in., elongation 15%, and Brinell hardness 210. Ebonized Monel is monel metal in commercial form with a lustrous ebony finish obtained by an oxidizing process.

**Mordant.** A substance used in dyeing for fixing the color. A mordant must have an affinity for the material being dyed and at the same time the property of combining with the dyestuff. The vegetable fibers, such as cotton and linen, frequently require mordants. The mordant may be applied first, usually in a hot solution or simultaneously with the dye. Besides fixing the color, mordants sometimes also increase the brilliancy of the dye. A common mordant is alum. Salts of aluminum, chromium, and other metals are used. Sodium stannate, used both as a mordant and for fireproofing

textiles, is a gray-white water-soluble powder of the composition $Na_2SnO_3 \cdot 3H_2O$ made by treating tin oxide with caustic soda. Chromium acetate, used as a mordant for chrome colors, and to produce khaki shades with iron solutions, is a grayish-green powder of the composition $Cr(C_2H_3O_2)_2 \cdot H_2O$. It is soluble in water. In gilding, the term mordant is used to mean a viscous or sticky substance employed to make the gold leaf adhere, but such a material does not have the chemical action of a mordant.

**Mother of pearl.** The hard, brilliant-colored internal layer of the pearl oyster shell and of certain other marine shellfish. It is employed for knife handles, buttons, inlay work, penholders, and other articles. Large oysters of the Indian Ocean, especially off Ceylon and in the Persian Gulf, furnish much of the mother of pearl. Other producers are Australia and the lands bordering the Coral Sea. The large Hawaiian pearl oyster is *Pinctada galtsoff*. The iridescent appearance is due to the structure of the nacre coating, and the shells are also called Nacre. Mother of pearl is brittle but can be worked with steel saws and drills using a weak acid lubricant. The shells are thick and heavy, and disks cut from them are split for buttons. Fresh-water shells from mussels of the Mississippi River are also used for buttons but do not have the iridescence of mother of pearl. The waste shell from the manufacture is crushed and marketed for poultry feed and for fertilizer.

**Mucilage.** A sticky substance obtained from linseed or other seeds, and employed as an adhesive, as a thickening agent, and as a stabilizer for solutions. The seeds are infused in hot water, bruised, and strained. The gummy substance, which contains arabinose, glucose, and galactose, is precipitated, and a heavy solution is known as mucilage. It is easily soluble in water, and is used as a light cementing material for paper. Mucilage as a general name also includes water-soluble gums from various parts of many plants and has the same uses. It is the stored reserve food of plants. There are two types: the cell-content mucilage which acts as a disorganization product of some of the carbohydrates, and membrane mucilage which acts as a thickening agent to the cell wall. Membrane mucilage occurs in the acacias, algae (Seaweeds), linum (flax plants), ulmus (elms), and astragalus. When it is collected

in the form of exudations from the trees, it is called a gum. Cherry gum, from the *Prunus ceresus,* is this type of water-soluble gum, as is also Medlar gum, from a small tree *Mespilus germanica,* of the same family as the cherry, grown in Europe and the Near East.

**Mullite.** A mineral found originally in the Isle of Mull and employed as a refractory material for firebrick and furnace linings. The natural material occurs as fused argillaceous sediment inclusions in the mineral Buchite, but it is rare and is produced artificially. It can be made by decomposing Sillimanite by heating to 1850°C. Artificial mullite, or Synthetic mullite, made by a prolonged fusing in the electric furnace of a mixture of silica sand or diasporic clay and bauxite, has the composition $3Al_2O_3 \cdot 2SiO_2$. It is valued as a refractory because it does not soften below its high melting point, 3290°F., and will withstand continuous temperature changes. Sillimanite, as well as Andalusite found in California, has the composition $Al_2O_3 \cdot SiO_2$, with the same melting point and a specific gravity of 3.20. Diaspore andalusite from Mono County, California, is used for spark plugs. Mullite is also made by burning silica clay and alumina at a very high temperature, and is used for making spark plugs, chemical crucibles, and extruding dies. For spark-plug cores it is fired at a temperature of 1450°C. and aged before use. The tensile strength is above 9,000 lb. per sq. in., or double that of porcelain, and it has high dielectric strength. The hardness is 6 to 7 Moh. Sillimanite is decomposed to mullite and silica when heated above 1550°C. Dumortierite, produced in Nevada, has the composition $8Al_2O_3 \cdot B_2O_3 \cdot 6SiO_2 \cdot H_2O$. A high-grade electric porcelain material marketed by Champion Sillimanite, Inc., under the name of Champion Sillimanite, is a mixture of andalusite and dumortierite. Shamra is the trade name of a mullite refractory produced by the Mullite Refractories Co. Mullfrax is a mullite refractory of the Carborundum Co. A synthetic mullite made by fusing a mixture of kyanite and alumina is known as Durox and is used for spark-plug porcelains.

**Muntz metal.** A yellow brass containing 60% copper and 40 zinc, invented in 1832 by George F. Muntz. In England it is called Yellow metal. It is also known as Malleable brass, and is now a standard product of the brass mills. Muntz metal has a tensile

strength, when annealed, of 52,000 lb. per sq. in., elongation 50%, and Rockwell B hardness of 30. When hard-rolled, the strength is 85,000 lb. per sq. in. The weight is 0.3015 lb. per cu. in. It is used for sheathing, marine fittings, bolts, and parts exposed to corrosion. Wrought muntz metal is frequently modified with small amounts of tin to give greater hardness and corrosion resistance, and is then called Naval brass or Naval bronze. The usual composition is 60% of copper, 39.25 zinc, and 0.75 tin. The Roman bronze of the Revere Copper & Brass, Inc., has this composition, and the naval brass of this company has 60% of copper, 39 zinc, 0.75 tin, with 0.2 lead to make it easy machining. Roman bronze has a tensile strength, annealed, of 60,000 lb. per sq. in., and elongation of 45%. When hard-drawn, the strength is 82,000 lb. per sq. in. and elongation 20%. The leaded naval brass is slightly lower in strength.

Federal specifications for naval brass rod call for 0.5 to 1.5% of tin and 0.20 lead. Chamet bronze, of the Chase Brass & Copper Co., has this composition. The naval brass marketed by the American Brass Co. under the name of Tobin bronze contains 59 to 60% of copper, 0.5 to 1 tin, and the balance zinc. In rod form it has a fine-grained structure. The tensile strength of the soft rod is 52,000 lb. per sq. in., and of the hard-drawn bar 67,000 lb. per sq. in. The electrical conductivity is 25% that of copper.

Forging brass is usually muntz metal containing up to 1.75% of lead, with frequently some iron. The Mueller Brass Co. uses alloys with 56 to 63% of copper, 0 to 3 lead, and 0 to 3 tin. With the copper content below 56% the brass is brittle; with copper above 63% the wear on dies is high. Brass forgings made in smooth dies are tough and compact and need no polishing, being simply pickled in a nitric acid bath to bring out the color. Forging brass in England is called Hot-stamping brass. The British standard, B.E.S. 218, calls for 58% of copper, 40.5 zinc, and 1.5 lead. The 60-40 brass modified with lead is also called Extruding brass.

Muntz metal is also modified with small amounts of iron and manganese. Delta metal, first marketed by Alexander Dick in 1883, was a 60-40 brass modified with iron, manganese, and a small amount of lead. An earlier brass known as Aich's metal had 60% of copper, 38.2 zinc, and 1.8 iron. Somewhat similar casting

brasses were called Gedge's metal and Sterro metal, and a forging alloy was called Macht's metal. Iron above 0.35% forms a separate iron-rich constituent which is stable and gives hardness and high strength to the alloys. The addition of manganese helps to absorb the iron and also hardens the alloy. These alloys were also called High-strength brass, and were employed for such uses as hydraulic cylinders and marine forgings, but are now largely replaced by manganese bronze or aluminum bronze. Durana metal was a forging brass with 1.5% of iron and 1.5 aluminum.

**Music wire.** A high-grade, uniform steel originally intended for strings for musical instruments, but now employed for the manufacture of spiral springs. It is the highest grade of spring wire and is made of acid open-hearth steel or electric steel, free from slag or dirt, and low in sulphur and phosphorus. The carbon content is about 0.80%. The tensile strength, when hard-drawn, is from 225,000 to 400,000 lb. per sq. in., but it should be tough enough to bend 180 deg. flat upon itself without cracking, or wind into a close helix with inside diameter 1 to 1½ times the diameter of the wire. The wire 0.187 in. in diameter has an ultimate strength of 230,000 lb. per sq. in.; 0.015 wire has a strength of 400,000 lb. per sq. in. The wire is usually marketed in gage sizes according to the Washburn & Moen and the music-wire gages. Wire below 0.034 in. in diameter (No. 15 gage) is furnished on reels. Larger sizes are in coils. Music wire for springs is from No. 00, which is 0.0085 in. in diameter, to No. 36, which is 0.102 in. Piano wire, intended for piano strings but also used for springs, is a cold-drawn, high-quality wire usually drawn from Swedish billets or rods. Piano wire ranges in diameter from 0.03 to 0.065 in. Starting with No. 7 rod there may be as many as 40 draws before the finished wire is produced. The tensile strength of piano wire is from 350,000 to 400,000 lb. per sq. in.

**Muslin.** A plain, white cotton fabric with a downy nap on the surface. It has a great variety of uses, and industrially is employed for filtering, sacking, and lining. The full-bleached muslin is usually made of finer yarns than the unbleached. In the cheaper grades it is sometimes heavily sized, which disappears on washing. For polishing cloths it should be unsized.

**Mustard.** A pungent yellowish powder produced from the seeds of the Black mustard, *Brassica nigra,* and the White mustard, *B. alba,* an annual plant of the turnip family grown in most temperate-climate countries. The ground seeds are treated with water, and the enzyme action yields a complex sulphur compound with a sharp taste and pungent action. It is used as a condiment, and in medicine as a counterirritant and emetic. It is one of the most ancient of the condiments and has a stimulating effect on the salivary glands. The product from the black mustard is more pungent than that from the white, and ground mustard may be a mixture of the two to give the desired pungency. Mustard oil is a volatile oil obtained from the seeds. It is a powerful vesicant and has a pungent aromatic odor. It is used in medicine and in flavors. Mustard seed which yields on expression the fixed Mustard-seed oil used extensively in India as a food oil and in lubricants is *B. juncea.* It is closely related to rape oil, containing about 50% of erucic acid. Another variety of *Brassica* of India yields Jamba oil, which contains 46% of erucic acid and is a substitute for rape oil for lubricants.

**Myrobalan extract.** A liquid or solid extract made from the dried, unripe fruit of several species of *Terminalia,* especially *T. chebula* of India and China. The *Phyllanthus emblica* of India also yields the fruit. The dried fruit, which resembles a plum, contains 30 to 40% of tannin in the pulp. The fruit is graded and marketed as Myrobalans chiefly on the basis of color, the lighter the color the higher the grade. The best grades of fruit are oval, pointed, and solid in structure. Inferior grades are round and spongy. The Bimlies from Madras are rated best. Liquid myrobalan extract contains 25 to 30% of tannin, and solid extract contains about 53%. It is used in tanning light leathers, and gives a quick tan. The natural acidity of myrobalan plumps the leather, but when used alone on heavy hides it makes a porous leather. It is used with other tannins.

**Naphtha.** A light, colorless to straw-colored liquid which distills off from petroleum between 70 and 90°C. The specific gravity is from 0.631 to 0.660, or slightly higher, ranging from $C_6H_{14}$ to $C_7H_{18}$. The lightest of the distillates used as solvents

for fats, rubber, and resins approaches petroleum ether; the heaviest distillates approach benzine and gasoline, and are used for fuel. Benzine is a light distillate ranging from $C_8H_{18}$ to $C_9H_{20}$, with specific gravity from 0.635 to 0.660, and boiling point limits from 120 to 150°C. Petroleum ether, or Petroleum spirits, ranges from $C_5H_{12}$ to $C_6H_{14}$ and is distilled off between 40 and 60°C. Benzine is used as a solvent, as a cleaner, and in lighters. Varnolene and White spirit are old names for petroleum ether used as a varnish solvent.

The name naphtha is also applied to various grades of light oils obtained in the distillation of coal tar. These include Solvent naphtha, having a specific gravity of 0.862 to 0.872, with a boiling point below 160°C., and Heavy naphtha, a dark liquid of specific gravity between 0.925 and 0.950, and boiling point between 160 and 220°C. High-flash naphtha for solvent purposes is a petroleum fraction with a specific gravity within the range of the gasolines and a boiling point from 150 to 200°C. Various trade names are given to the light petroleum distillates used as solvents and in paints and varnishes. Naphtholite, of the Globe Chemical Co., has a specific gravity of 0.737, and an initial boiling point at 102°C. Solvesso, of the Esso Marketers, is a hydrogenated distillate in various grades with specific gravities from 0.797 to 0.937. Grade 1 has a boiling range from 93 to 135°C. Stoddard solvent is a standardized fraction of petroleum, or naphtha, used in dry cleaning or as a solvent. It is water white in color, flash point above 100°F., and consists in the distillation fraction not over 410°F. with 50% below 350°F.

**Naphthalene.** Also called Tar camphor. A white solid of the composition $C_{10}H_8$, which is one of the heavy distillates from coal tar, and may also be obtained from natural gas. Crude naphthalene has a melting point of 70 to 78.5°C. The pure crystalline flakes melt at 79.4°C. and boil at 218°C., but vaporize slowly at room temperature. It burns with a smoky flame. It is not soluble in water, but is soluble in benzene and in hot alcohol. The refined product is marketed in balls, flakes, and pellets, largely for use as an insect repellent. The crude is used in making dyestuffs, phthalic anhydride, synthetic resins, chlorinated products, coatings, seal-

ing compounds, and in celluloid. Halowax, of the Halowax Co., is a noninflammable chlorinated naphthalene used for waterproofing and fireproofing fabrics and cable coverings. Halowax oil is used as a solvent for rubber and resins. Monoamyl naphthalene, used to give plasticity to synthetic resins at low temperatures, is an amber liquid, $C_{10}H_7C_5H_{11}$, specific gravity 0.96, and boiling point 279°C. On hydrogenation, naphthalene yields the solvents tetralin and decalin. Tetralin, $C_{10}H_{12}$, has a specific gravity of 0.975, and boiling point of 206°C. It is a clear liquid that is a good solvent for fats, oils, and resins. It burns with a bright flame and can also be used as a fuel. The flash point is 78°C. Decalin, $C_{10}H_{18}$, is a liquid with specific gravity of 0.884, and boiling point 190°C.

**Neatsfoot oil.** A pale-yellow, inedible oil obtained by boiling the feet of cattle or sheep in water, skimming the oil from the surface, and pressing through a filter. The oil is used for leather finishing, and for lubricants for fine mechanisms. For high-grade cold-test lubricating oil for fine instruments the stearin is pressed out. The specific gravity of neatsfoot oil is 0.916, iodine value 74, and saponification value 197. The oil is noted for its resistance to rancidity. It contains a high percentage, 79%, of oleic acid, and some bone oil which acts as a stabilizer.

**Neon.** A rare gas, symbol Ne, which occurs in minute quantities in the atmosphere with helium and argon. It is procured from the air by liquefaction. It is an emitter of light and is used for sign lighting and in glow lamps. The specific gravity, compared with air, is 0.674. It liquefies at −245°C. It is colorless, but gives a reddish-orange glow in lamps to which an electric current is applied. Neon is also used in voltage-regulating tubes for radio apparatus, and will respond to low voltages. In television the neon lamp will give fluctuations from full brilliancy to total darkness as many as 100,000 times a second. In the atom of the gas neon there are claimed to be ten negative electrons revolving in regular orbits around one positive nucleus. The ionization, or tearing away of an electron, and the recombination produce the glow. All colored electric advertising signs are often referred to as neon signs, but the colors other than orange are produced by different gases. Argon gives a purple light when an electric current is

passed through it. Krypton, an elementary gas, occurring in the air to the extent of 1 part in 1 million, gives a pale violet light. It liquefies at −152°C. Xenon, another gas occurring in the air to the extent of 1 part in 11 million, gives a sky-blue to green light.

**Nickel.** A silvery-white metal with a yellowish cast first isolated in 1751, but used in alloy with copper since ancient times. Nickel has a specific gravity of 8.84, melts at 2646°F., and is magnetic up to 680°F. It is marketed in grains or powder, in electrolytic sheets, blocks, shot, and in malleable forms. The metal is resistant to corrosion and to most acids except nitric. The electrical conductivity is 16% that of copper. The tensile strength of hard-rolled sheet is 115,000 lb. per sq. in., elongation 5%, and Rockwell B hardness 100. The tensile strength when annealed is 70,000 lb. per sq. in., elongation 45%, and hardness 60. Nickel is difficult to cast when pure as it absorbs oxygen and also dissolves carbon and sulphur. Z nickel, of the International Nickel Co., is a 98% nickel with alloying elements. The tensile strength, hot-rolled, is 105,000 lb. per sq. in., with 15 to 35% elongation. When cold-drawn, the tensile strength is 120,000 to 175,000 lb. per sq. in., elongation 15 to 25%, and Brinell hardness 220 to 340. The electrical conductivity is 12% that of copper. D nickel contains 95.2% of nickel and 4.5 manganese. In the annealed state it has a tensile strength of 75,000 lb. per sq. in., elongation 40%, and Brinell hardness 140. Nickel has its greatest use in alloys, particularly in alloy steels, cupro-nickel, nickel brasses, and German silver. It is also used to make white gold, 15% of nickel changing the color of gold to white. Nickel steels have high strength and resistance. Nickel is also used in coinage alloys and in commercial heat-resistant and corrosion-resistant alloys.

More than 85% of the world's nickel production comes from Ontario, Canada, and most of the remainder from the garnierite ores of New Caledonia. The standard A.S.T.M. grades of virgin nickel ore are Electrolytic, containing 99.5% of nickel; X shot, containing 98.9; A shot, with 97.75; and Ingot, with 98.5. But electrolytic nickel is available 99.95% pure, including not over 0.04 cobalt. Nickel shot, for adding nickel to iron in the ladle, is a master alloy of nickel and iron containing 50% nickel.

**Nickel alloys.** Any alloy containing nickel as the base metal, or as the chief alloying element. Nickel goes into solution in copper in all proportions and continually raises the melting point of copper alloys. In brasses and bronzes, nickel is used for the color effect and for toughening and strengthening the alloys. Nickel is employed in both ferrous and nonferrous alloys to produce heat-resistant and acid-resistant metals. Nickel-manganese alloys are used for electric-resistance wire. These alloys are also used as Cold-resistant alloys in places where steel or iron would be brittle at low temperatures. AMF alloy, for liquid-air valves, is a French alloy containing 55 to 60% of nickel, up to 3 manganese, 0.4 carbon, and the balance iron, which will withstand shocks at low temperatures. A group of Acid-resistant alloys is produced with nickel as the base and silicon as the hardener, with sometimes other elements. A group of acid-resistant alloys marketed by the Burgess-Parr Co. under the names of Illium and Parr metal, are complex alloys. A typical analysis of illium is nickel, 60.65%; chromium, 21.07; copper, 6.42; molybdenum, 4.67; tungsten, 2.13; silicon, 1.04; aluminum, 1.09; manganese, 1; and a small amount of iron. It is a very dense metal and has been used for chemical pump castings. Illium R has a tensile strength of about 100,000 lb. per sq. in. when cold-rolled and annealed, and up to 150,000 lb. per sq. in. with hardness of 365 when hard-rolled.

Copper-nickel-iron alloys, used for hardware and plumbing fixtures, are white in color and resistant to acids and corrosion. Aterite, of the Aterite Co., is a group of casting alloys containing 10 to 40% of nickel, 30 to 60 copper, 5 to 10 iron, and sometimes up to 5 of zinc or 2 of lead. Grades for wrought metals contain little iron. Alcumite, of the Duriron Co., is a yellow, copper-base alloy containing nickel, aluminum, iron, and manganese. Hastelloy is the trade name of the Haynes Stellite Co. for a group of corrosion-resistant alloys that have high strength at elevated temperatures. They are marketed as castings, plate, rod, tube and welding rod. Hastelloy A is particularly resistant to hydrochloric acid. It contains 60% of nickel, 20 molybdenum, and 20 iron. It has a specific gravity of 8.8, tensile strength, annealed, of about 115,000 lb. per sq. in., and Brinell hardness of 97. It casts easily and resists most acids except nitric. Hastelloy C

contains chromium and is resistant to nitric acid and to free chlorine. The tensile strength is 122,500 lb. per sq. in., and Brinell hardness 160 to 210. Hastelloy D contains 90% of nickel, 3 copper, 1.5 aluminum, and about 5 silicon. It is resistant to hot sulphuric acid. The tensile strength is 38,000 lb. per sq. in.

Strong and wear-resistant cast irons usually contain nickel, such as Cariron and Bryiron, of the Fillmore Foundry, Inc., and Diamite, of the Weatherly Foundry & Mfg. Co. The former two have about 1.5% nickel, and the last one 4.5% of nickel with 1.5 chromium. Many jewelry alloys, for cheap jewelry, contain nickel. An old alloy known as Paris metal and Lutecine, contained 80% of copper, 16 nickel, 1 cobalt, 2 tin, and small amounts of iron and zinc. Nickel is added to many aluminum alloys to increase the tensile strength and to improve the finish. For this purpose it is added in the form of a master alloy, Nickel-aluminum, containing 20% nickel and melting at 1418°F.

**Nickel brass.** The alloys that come naturally into this designation are more usually termed nickel silver or are known under a wide variety of trade names. Nickel-silicon brass contains very small percentages of silicon, usually about 0.60%, which forms a nickel silicide, $Ni_2Si$, increasing the strength and giving heat-treating properties. Rolled nickel-silicon brass, containing 30% of zinc, 2.5 nickel, and 0.65 silicon, has a tensile strength of 114,000 lb. per sq. in. Imitation silver, for hardware and fittings, is a nickel brass containing 57% of copper, 25 zinc, 15 nickel, and 3 cobalt. The bluish color of the cobalt neutralizes the yellow cast of the nickel and produces a silver-white alloy. Silvel is a nickel brass containing 67.5% of copper, 16 zinc, and 6.5 nickel, with sometimes a little cobalt. Nickel brass is an alloy used where white color and corrosion resistance are desired.

Seymourite is the trade name of an alloy of 64% of copper, 18 nickel, and 18 zinc, produced by the Seymour Mfg. Co. It has a white color and is corrosion-resistant. Nickeline, used by the Yale & Towne Mfg. Co. for hardware, has 58 to 60% of copper, 16.5 nickel, 2 tin, and the remainder zinc. It has high strength, a white color, and casts well. Nickelene is an old name applied to nickel brass of various compositions, but an alloy patented in 1912

under this name had 55% of copper, 12.5 nickel, 20.5 zinc, 10 lead, and 2 tin. Most of these alloys have good casting qualities, but they do not machine easily unless they contain some lead. Up to 2% of lead does not affect the color and does not decrease the strength greatly. Tuc Tur, of the Tuc Tur Metal Corp., is a nickel brass containing 15% of nickel and 22 zinc. Sterlite, of the Sterlite Foundry & Mfg. Co., contains 25% nickel and 20 zinc, with small amounts of iron, manganese, silicon, and carbon. A series of corrosion-resistant nickel brasses is marketed by the American Brass Co. under the name of Ambrac. Ambrac No. 850 contains 75% of copper, 20 nickel, and 5 zinc. The tensile strength is 50,000 lb. per sq. in., soft, and 110,000 hard-drawn. Other alloys contain more nickel.

**Nickel bronze.** A name given to bronzes containing nickel, which usually replaces part of the tin, producing a tough, fine-grained, and corrosion-resistant metal. A common nickel bronze containing 88% of copper, 5 tin, 5 nickel, and 2 zinc, has a tensile strength of 48,000 lb. per sq. in., elongation of 42%, and Brinell hardness of 86 as cast. When heat-treated or age-hardened, the tensile strength is 87,000 lb. per sq. in., elongation 10%, and Brinell hardness 196. Small amounts of lead take away the age-hardening quality of the alloy, and also lower the ductility. But small amounts of nickel added to bearing bronzes increase the resistance to compression and shock without impairing the plasticity. A bearing bronze of this nature, U.S. Navy 46B22, for heavy loads at high speeds, contains 15 to 20% of lead, 73 to 80 copper, 5 to 10 tin, and 1 nickel. For decorative bronze parts, nickel is used to give a white color. In the hardware industry the old name Chinese bronze is sometimes used for these white alloys, and at least 10% of nickel is needed to give a white color. This amount also gives corrosion resistance to the alloy. When more than 15% nickel is used, the bronzes are difficult to machine unless some lead is added. Hardware and plumbing fixtures of these alloys do not require plating. Eclipse bronze is a white bronze of Sargent & Co. M-M-M alloy, of Manning, Maxwell & Moore, Inc., used for pressure valves for superheated steam, contains 60 to 65% of nickel, 24 to 27 copper, 9 to 11 tin, and small amounts of iron,

silicon, and manganese. Mercoloy, of the Merco Nordstrom Valve Co., is a white valve bronze containing 60% of copper, 25 nickel, 10 zinc, 1 tin, 2 lead, and 2 iron. It has a tensile strength of 44,000 lb. per sq. in., with elongation of 20%.

**Nickel cast iron.** A high-strength cast iron containing nickel. Nickel, like silicon, assists the graphite formation and the carbide decomposition, and therefore reduces chill and acts to eliminate hard carbide spots, chilled edges, and mottled areas. About 1% of nickel is equivalent to ½% of silicon, but the effect of nickel is progressive, and does not make the iron brittle like silicon. Nickel in amounts from 0.5 to 10% will also progressively harden cast iron. A gray cast iron which will have a Brinell hardness of 174 is raised to 350 by the addition of 9% nickel. Since the nickel promotes the formation of the graphite in fine crystals, the iron has a high resistance to wear. Tensile strengths up to 65,000 lb. per sq. in. are obtained in these irons. Nickel obstructs the passage of electric currents in iron, and iron with 5% of nickel is used for resistance grids. High-nickel iron is also nonmagnetic.

Most nickel irons contain small amounts of chromium to increase the chilling power and refine the grain. It also increases the strength and hardness. Ni-Tensyliron is the trade name of the International Nickel Co. for a nickel cast iron made by adding to the melt a graphitizer of nickel-silicon to cause partial decomposition of the combined carbon. With 1.75% of nickel this iron has high strength and a hardness of 320 Brinell. Nicrosilal, developed by the British Cast Iron Research Assoc., contains 5% of silicon, 17 nickel, and 3 chromium. It has high-heat distortion resistance, and is used for heat-resistant castings. Lectrocast, of the Detroit Gray Iron Foundry, used for automobile body dies, has 2.75% of nickel and 0.70 chromium. Tensloy, of the Ensign Foundry Co., and Novite, of the Novo Engine Co., have about 1.5% of nickel and 0.50 chromium. Mitchalloy A, of the Robert Mitchell Co., Ltd., has 2.5% of nickel and 0.90 chromium.

High nickel-chromium irons are used for pump and compressor parts handling hot liquids and may contain up to 30% of nickel and 5 chromium. Nogroth metal, of the Q. & C. Co., is a heat-resistant nickel-chromium cast iron. Pyrocast is a high-test nickel-

chromium cast iron of the Pacific Foundry Co. Niresist, developed by the International Nickel Co., is an alloy cast iron containing Monel metal with also chromium and manganese. A typical analysis range is nickel, 12 to 15%; copper, 5 to 7; chromium, 1.25 to 4; manganese, 1 to 1.5; silicon, 1 to 2; and total carbon, 2.75 to 3.1. The tensile strength is 20,000 to 35,000 lb. per sq. in., with a Brinell hardness of 130 to 170. It can be chilled to a hardness of 350 to 400. It has a low coefficient of expansion, 0.0000100 per deg. F., or about the same as the aluminum-silicon alloys used for pistons.

Vanadium in nickel irons adds strength and wear resistance. Vanick is the name of a Nickel-vanadium cast iron of the Malleable Iron Fittings Co. Nickel cast irons and Nickel-chromium cast irons are marketed under many trade names, such as Frankite, of the Frank Foundries Corp., Alco Ni-Iron, of the American Locomotive Co., Elfur iron, of the Cramp Brass & Iron Foundry, Tylerite, of the W. S. Tyler Co., Domite, of the Dominion Wheel & Foundry Co., and Maxtensile, of the Farrel-Birmingham Co. The nickel-chromium cast irons may also contain molybdenum for greater hardness and wear resistance. Ni-Chillite, of the Mackintosh-Hemphill Co., is a nickel-chromium-molybdenum chilled cast iron for heavy rolls. Mocasco iron, of the Motor Casting Co., is a wear-resistant iron capable of being cast into thin sections without chill. Mocasco 30, for cylinders, has 1 to 1.35% of nickel, 0.25 to 0.30 chromium, and 0.75 molydenum. Strenes metal is the name of the Advance Foundry Co. for a nickel-chromium-molybdenum cast iron for heavy dies. Durite is a wear-resistant iron of the Birdsboro Steel Foundry & Machine Co. Ironite, of the Kinite Corp., is a chromium-nickel-vanadium cast iron used for cams, gears, and wear-resistant parts.

**Nickel-chromium alloys.** A group of alloys of nickel and chromium employed as heat-resistant metals, for resistance wires, and as corrosion-resistant metals for chemical machinery. An alloy of 80% nickel and 20 chromium will withstand temperatures up to 2100°F. without oxidation. Chromel A, of the Hoskins Mfg. Co., has this composition. The resistivity is 650 ohms per cir. mil ft., tensile strength 120,000 lb. per sq. in., and melting

point 1420°C. A group of heat-resistant and corrosion-resistant alloys, under the name of Misco alloys, is produced by the Michigan Steel Casting Co. Misco metal contains 35% of nickel and 10 chromium, with the balance iron. Misco C contains 29% of chromium, 9 nickel, 0.55 manganese, 0.60 silicon, and 0.25 carbon. Miscrome is very resistant to nitric acid. It contains 28% chromium with no nickel. Centricast alloys, of this company, are these corrosion-resistant alloys centrifugally cast for pipes.

A group of heat-resistant and acid-resistant nickel-chromium alloys is produced by the Standard Alloy Co. under the name of Standardalloy. Another group is marketed by the Cooper Alloy Foundry Co. under the names of Sweetaloy and Cooper alloys. Cooper alloy S-16 has 14 to 20% of chromium and 65 nickel; Cooper alloy S-21A is this combination with 3% of molybdenum and 1.5 silicon. Cimet, of the Driver-Harris Co., used for mine pump parts, has 26% of chromium, 10 nickel, and the balance iron. Gridnic alloys, of this company, are nickel-chromium alloys used for radio grids. Nirex, of the same company, has 80% nickel, 14 chromium, and 6 iron. In annealed sheet form it has a tensile strength of 90,000 lb. per sq. in. with elongation of 50%. Chromel No. 502 has 36% of nickel, 20 chromium, and the balance iron. It is used for furnace fixtures, either rolled or cast. Inconel, developed by the International Nickel Co., used for dairy and food equipment, contains 79.5% of nickel, 13 chromium, 6.5 iron, 0.08 carbon, and slight amounts of copper, manganese, and silicon. The tensile strength of the hot-rolled plate is 100,000 to 140,000 lb. per sq. in. with elongation of 20 to 40%, and Brinell hardness 160 to 240. Heat-treating boxes of this alloy produced by the Michigan Steel Casting Co. give furnace service life of 12,000 hr. at 2000°F.

Nickel-chromium-iron alloys, with silicon and other elements forming complex alloys, are employed for acid-resistant and corrosion-resistant castings and wrought metals for high temperatures. Durimet, of the Duriron Co., Inc., is marketed in various grades normally containing 19.5 to 23% of nickel, 18 to 22 chromium, 2.75 to 3.75 silicon, 0.50 to 0.75 manganese, 1 to 1.5 molybdenum, and 0.25 to 0.45 copper. Durimet 20 contains 29% of nickel, 19 chromium, 3 molybdenum, 4 copper, 1 silicon, and 0.07

max. carbon. The heat-treated castings have a tensile strength of 65,000 to 75,000 lb. per sq. in., elongation 35 to 50%, and Brinell hardness 120 to 150. It is especially resistant to sulphuric and mixed acids. Rezistal, of the Crucible Steel Co., is marketed in many grades resistant to heat, acids, and corrosion. They include stainless steels and special composition nickel-chromium alloys. Rezistal 2600, formerly known as Atha's 2600 alloy, contains 22% of nickel, 8 chromium, 1.75 silicon, 1 copper, 0.70 manganese, and 0.25 carbon. It is nonmagnetic, resistant to acids, and is easily machinable.

**Nickel-chromium steel.** Steel containing both nickel and chromium, usually in a ratio of 2 to 3 parts of nickel to 1 of chromium. The 2 : 1 ratio gives great toughness, and the nickel and chromium are intended to balance each other in physical effects. The steels are especially suited for large sections which require heat-treatment, because of the deep and uniform hardening power. Hardness and toughness are the characteristic properties of these steels. Nickel-chromium steel containing 1 to 1.5% of nickel, 0.45 to 0.75 chromium, and 0.38 to 0.80 manganese, is used throughout the carbon ranges for casehardened parts and for forgings where high tensile strength and great hardness are required. Steel with from 3 to 5% of nickel, 1.8 to 2.5 chromium, and 0.30 to 0.40 carbon is employed for heavy armor plate, while armor-piercing projectiles are made from steel containing 0.50% of nickel, 2.5 chromium, and 0.50 carbon.

Low nickel-chromium steels, but with more carbon, from 0.60 to 0.80%, are used for drop-forging dies and other tools. R.D.S. steel, of the Carpenter Steel Co., is an oil-hardening, tough, tool steel containing 1.75% of nickel, 1 chromium, 0.50 manganese, and 0.75 carbon. An industrial steel of this company, Carpenter No. 5-317, contains the same amounts of nickel and chromium, but 0.50 carbon and less manganese. It is oil-hardening, and used for gears, shafts, and shock-resisting parts. The tensile strength is up to 295,000 lb. per sq. in. Samson steel, of this company, used for machinery parts for severe service, contains 1.25% of nickel, 0.60 chromium, 0.50 manganese, and various amounts of carbon. The 0.40 carbon steel, when heat-treated, has a tensile strength of

240,000 lb. per sq. in. and Brinell hardness of 440. This steel, with 0.10% carbon, is used for making molds for plastics. Beaver steel, of the Colonial Steel Co., used for water-quenched forging-die blocks, contains 1.5% of nickel, 0.75 chromium, 0.60 manganese, and 0.55 carbon. Colona steel, of the same company, used for oil-quenched forging dies, has the same nickel and chromium content, but somewhat more manganese and carbon. Nikro-Trimmer steel, of this company, used for hot trimming dies, has higher carbon, 0.85%, but only small amounts of nickel and chromium, 0.30 to 0.55%, respectively. Simplex steel, of the Crucible Steel Co. of America, used for forgings, has 1.25% of nickel and 0.60 chromium. In the low-carbon, casehardening grades, for gears, it has a tensile strength of 90,000 lb. per sq. in. S.A.E. steel 3330, containing 3.5% of nickel and 1.5 chromium, when oil-tempered, has a tensile strength of 205,000 lb. per sq. in. and elongation of 13%. Quality steel is the trade name of Quality Steels, Ltd., for nickel-chromium steels in various grades.

Nickel-chromium steels may have temper brittleness, or low impact resistance, when improperly cooled after heat-treatment. A small amount of molybdenum is sometimes added to prevent this brittleness. Encem steel, of W. T. Flather, Ltd., is a molybdenum steel of this type. Miraculoy, of the Sivyer Steel Castings Co., contains 1.25% of nickel, 0.65 chromium, 0.40 molybdenum, and 1.55 manganese. The tensile strength is 115,000 lb. per sq. in., with elongation of 18% and Brinell hardness of 275. Miscoloy No. 60, of the Michigan Steel Casting Co., is another steel of this type. A nickel-chromium Coin steel, used by the Italian Government for coins, was a stainless type containing 22% of chromium, 12 nickel, and some molybdenum.

Low-carbon nickel-chromium steels are water-hardening, but those with appreciable amounts of alloying elements require oil quenching. Air-hardening steels contain up to 4.5% of nickel and 1.6 chromium, but are brittle unless tempered in oil to strengths below 200,000 lb. per sq. in. The alloy known as Krupp analysis steel contains 4% of nickel and 1.5 chromium. The steel under the name of Millaloy, used by Doelger & Kirsten, Inc., for heavy shear blades, is of this analysis with 0.40% of carbon. Blades hardened to 530 Brinell have an ultimate strength of 312,000 lb.

per sq. in. and elongation of 11%. Nikrome is a nickel-chromium steel of Joseph T. Ryerson & Son, Inc. Nikrome M contains 2.25% of nickel, 1 chromium, and 0.45 molybdenum, with 0.40 carbon. It is characterized by very high strength and uniform hardening, and can be machined up to 450 Brinell. H.T.M. Steel, of this company, is a 2% nickel steel with chromium and molybdenum. Nykrom is a steel of W. T. Flather, Ltd. Ohioloy is a nickel-chromium steel of the Ohio Steel Foundry Co. All of the nickel-chromium steels require special heat-treatment to bring out their best qualities, and all are difficult to machine.

**Nickel-cobalt alloys.** A group of alloys containing 20 to 30% of cobalt and 70 to 80 nickel. Nickel has a yellowish cast and cobalt a blue cast; alloys of the two metals are almost pure white in luster and resemble silver. They are expensive, because of the high cost of cobalt, but the two metals are codeposited in an electroplating bath to form an alloy deposit on iron, steel, or nonferrous metals. The alloy is harder than either nickel or cobalt alone, and is also more corrosion-resistant. Another type of nickel-cobalt complex alloy is Konal, developed by the Westinghouse Electric Corp., as a heat-resistant and acid-resistant alloy. It contains 73% of nickel, 17.5 cobalt, 6.5 iron, 2.5 titanium, and 0.2 manganese. At a temperature of 600°C. this alloy has a tensile strength of 66,000 lb. per sq. in. At ordinary temperatures the strength is 100,000 lb. per sq. in. It was developed for radio-tube filaments.

**Nickel copper.** An alloy of nickel and copper employed for adding nickel to nonferrous alloys. A 50-50 nickel copper has a melting point of 2330°F. and dissolves readily. Nickel-copper shot of this composition is marketed for ladle additions to iron and steel. The Copper-nickel master alloy designated in Federal specifications contains 60% of nickel, 33 copper, 3.5 manganese, and may contain up to 3.5 iron. Such an alloy is used for alloying high-strength bronzes. Copper-nickel alloy is also used for special purposes. Thermalloy, of the Electro Alloys Co., used as a temperature-sensitive magnetic metal for magnetic shunts in watt-hour meters, has 66.5% of nickel, 30 copper, and 2 iron. The permeability falls off with increase in temperature and compensates for errors due to temperature changes.

**Nickel-molybdenum iron.** A group of alloys used for high acid resistance. They may contain up to 40% of molybdenum, which takes the place of the chromium used in the more common corrosion-resistant alloys. The most usual alloy in this class contains about 20% of iron, 20 molybdenum, 60 nickel, and small amounts of carbon. This alloy is very resistant to hydrochloric and sulphuric acids, but for high general acid resistance the iron content should be below 10%. Iron adds hardness and stiffness to the alloys, but decreases the acid resistance. Manganese improves the workability, but more than 3% decreases the acid resistance. With chromium the alloys are almost as resistant to corrosion as the noble metals. One authority gives the best combination for acid resistance as 60% of nickel, 15 chromium, 2.5 to 7 molybdenum, 2 manganese, and the balance iron. The alloys cast easily, and the 20-20-60 alloy is readily machinable. It can be hot-rolled into sheet, or cold-rolled. The melting point is 1300°C., and weight is 0.315 lb. per cu. in. The tensile strength, forged, is 118,000 lb. per sq. in. and Brinell hardness 207. This alloy is resistant to all acids except nitric.

**Nickel-molybdenum steel.** An alloy steel which is most used in compositions of 1.5% of nickel and 0.15 to 0.25 molybdenum, with varying percentages of carbon up to 0.50%. These steels are characterized by remarkably uniform properties, are readily forged and heat-treated. Molybdenum produces toughness in the steels, and in the casehardened steel gives a very tough core. Roller bearings are made of this class of steel. A steel used by the Ingersoll Steel & Disc Co. for hand-shovel blades contains an average of 0.45% of carbon, 0.50 manganese, 1.35 nickel, and 0.40 molybdenum. When hot-rolled and heat-treated, it has a tensile strength of 240,000 lb. per sq. in. and elongation of 6%. Superalloy steel, of this company, is S.A.E. 3160. A 5% nickel steel with 0.30% of carbon and 0.60 molybdenum has a tensile strength of 175,000 to 230,000 lb. per sq. in., with elongation of 12 to 22%, depending upon the heat-treatment. Molybdenum is more frequently added to the steels containing also chromium, the molybdenum giving air-hardening properties, reducing distortion, and making them more resistant to oxidation.

**Nickel ores.** Nickel occurs in minerals as sulphides, silicates, and arsenides, the most common being Pyrrholite, or Magnetic pyrites, a sulphide of iron of the theoretical formula $Fe_{11}S_{12}$, but carrying nickel in considerable proportion. The chief sulphide ore deposit at Sudbury, Ont., Canada, contains sulphides of iron, nickel, and copper. The ore is partly roasted to remove sulphur, and smelted to a matte containing about 45% iron. This is then bessemerized to a matte containing 75 to 80% nickel and copper. Some of the product is used as Monel metal without separating the natural alloy. The Garnierite, or Noumeite, of New Caledonia is a nickel silicate containing also iron and magnesium. It is amorphous and earthy, of an apple-green color, with a specific gravity of 2.2 to 2.8, and hardness of 3 to 4. The ore contains about 5% nickel, and is smelted with gypsum to a matte of sulphides of nickel and iron, the sulphur coming from the gypsum. This is then bessemerized, and the matte crushed, roasted to oxide, and reduced to nickel.

Millerite is a minor ore of nickel occurring in Europe and in various parts of the United States. It is a Nickel sulphide, NiS, containing theoretically 64.7% of nickel. It is found usually in radiating groups of slender crystals with a specific gravity of 5.6, hardness 3.5, and of a pale-yellow color and metallic luster. Niccolite, NiAs, is a minor ore containing theoretically 43.9% of nickel, usually with iron, cobalt, and sulphur. It is found in Canada, Germany, and Sweden. The mineral occurs massive, with a specific gravity of 7.5, hardness 5 to 5.5, and a pale copper color. Nickel is also produced as a by-product from copper ores.

**Nickel silver.** A name applied in the machine industries to an alloy of copper, nickel, and zinc, which is practically identical with alloys known in the silverware trade as German silver. Packfong, meaning White copper, is an old name for these alloys. The very early nickel silvers contained some silver and were used for silverware. Wessell's silver contained about 2%, and Ruolz silver about 20%. Baudoin alloy, a French metal, contained 72% of copper, 16 nickel, 1.8 cobalt, 2.5 silver, and the balance zinc.

Nickel silver is made in regular grades of 5 to 30% nickel, with up to 65% copper, and the balance zinc. Nickel whitens

brass and makes it harder and more resistant to corrosion, but the alloys are more difficult to cast because of shrinkage and absorption of gases. They are also subject to fire cracking and are more difficult to roll and draw than brass. The most common nickel silver is the 18% nickel alloy with 55 to 65% of copper, and the balance zinc. The higher copper grades are used for parts where there is much fabricating. As a spring material, with 55% of copper, this alloy has a tensile strength of 110,000 lb. per sq. in., and Brinell hardness of 160, when cold-rolled. The 12% alloy is a dense white metal, readily machinable, and much used for cast plumbing fixtures. Benedict metal, of the American Brass Co., has 12.5% of nickel, with 2 parts of copper to 1 of zinc. The cast metal has a strength of 35,000 lb. per sq. in. with elongation of 15%. The higher nickel alloys have more permanent white finish for parts subject to corrosion. Ambrac 854, of the American Brass Co., is a wrought metal with 65% of copper, 30 nickel, and 5 zinc. Pope's Island white metal, of this company, used for jewelry, has 67% of copper, 19.75 nickel, and 13.25 zinc. Victor metal is an alloy of 50% copper, 35 zinc, and 15 nickel, used for cast fittings. It is a white metal with a yellow shade. It casts easily and machines well.

For threaded parts and for casting metals, the nickel silvers usually contain some lead for easier machining. Federal specifications for casting metals call for 65% of copper, 20 nickel, 4 tin, 5 lead, and 6 zinc. The White nickel brass, used for automotive cast parts for trim, is a standard 18% nickel alloy with or without lead. Silveroid, an English alloy for this use, is a cupro-nickel without zinc. An English alloy for tableware, under the name of Newloy, contains 35% of nickel, 64 copper, and 1 tin.

**Nickel steel.** Steel containing nickel as the predominating alloying element. The first nickel steel produced in the United States was made in 1890 by adding 3% of nickel in a bessemer converter. The first nickel-steel armor plate, with 3.5% nickel, was known as Harveyized steel. Small amounts of nickel steel, however, had been used since ancient times, coming from Meteoric iron. The nickel iron of meteorites, known in mineralogy as Taenite, contains about 26% nickel.

Nickel added to carbon steel increases the ultimate strength, elastic limit, hardness, and toughness. It narrows the hardening range but lowers the critical range of steel, reducing danger of warpage and cracking, and balances the intensive deep-hardening effect of chromium. The nickel steels are also of finer structure than ordinary steels, and the nickel retards grain growth. When the percentage of nickel is high, the steel is very resistant to corrosion. Above 20% of nickel the steel becomes a single-phase austenitic structure and appears under the microscope like a single metal. The steel is nonmagnetic above 29% nickel, and the maximum value of permeability is at about 78% nickel. The lowest expansion value of the steel is at 36% nickel. The percentage of nickel employed usually varies from 1.5 to 5%, with up to 0.80% of manganese. The bulk of nickel steels contain 2 and 3½% of nickel. They are used for armor plate, structural shapes, rails, heavy-duty machine parts, gears, automobile parts, and ordnance.

The standard A.S.T.M. Structural nickel steel used widely for building construction is an open-hearth steel containing not over 3.25% of nickel, 0.45 carbon, and 0.70 manganese. This steel has a tensile strength from 85,000 to 100,000 lb. per sq. in. and a minimum elongation of 18%. An automobile steel used by one of the largest companies contains 0.10 to 0.20% of carbon, 3.25 to 3.75 nickel, 0.30 to 0.60 manganese, and 0.15 to 0.30 silicon. When heat-treated, it has a tensile strength up to 80,000 lb. per sq. in. and an elongation of 25 to 35%. Forgings for locomotive crankpins containing 2.5% of nickel, 0.27 carbon, and 0.88 manganese, have a tensile strength of 83,000 lb. per sq. in., elongation of 30%, and reduction of area of 62%. A Nickel-vanadium steel, used for high-strength cast parts, contains 1.5% nickel, 1 manganese, 0.28 carbon, and 0.10 vanadium. The tensile strength is 90,000 lb. per sq. in. and elongation 25%. Univan steel, of the Union Steel Casting Co., for high-strength locomotive castings, is a nickel-vanadium steel of this type. Unionaloy steel, of this company, is an abrasion-resistant steel.

The Federal specifications for 3½% nickel carbon steel calls for 3.25 to 3.75% nickel, and 0.25 to 0.30 carbon. This steel has a tensile strength of 85,000 lb. per sq. in. and an elongation of 18%. A hot-rolled 3½% nickel medium-carbon steel, S.A.E.

2330, when oil-quenched develops a strength up to 220,000 lb. per sq. in., and Brinell hardness from 223 to 424, depending upon the drawing temperature. Steels with more than 3.5% of nickel are too expensive for ordinary structural use. Steels with more than 5% nickel are difficult to forge, but the very high-content nickel steels are used when corrosion-resistant properties are required. Standard 3½ and 5% nickel steels are regular products of the steel mills, although they are sold under many trade names.

**Nickel sulphate.** A crystalline compound, $NiSO_4 \cdot 7H_2O$, used in nickel plating and for blackening brass and zinc. It is the most widely used salt for nickel-plating baths. It is known in the plating industry as Single nickel salts. It is prepared by dissolving nickel or nickel hydroxide in sulphuric acid. Nickel sulphate is sold in the form of crystals about the size of peas, and pea green in color. The specific gravity is 1.98, and the melting point is 100°C. It is soluble in water. Double nickel salt is Nickel ammonium sulphate, $NiSO_4 \cdot (NH_4)_2SO_4 \cdot 6H_2O$, used for baths for plating on zinc. Nickel chloride, $NiCl_2 \cdot 6H_2O$, a green crystalline material soluble in water, is used with boric acid for nickel plating. It gives a finer-grained, smoother, harder, and stronger nickel coating than with the nickel sulphate electrolyte. The bath is easier to control and the power required is less. Nickel carbonate is another salt of nickel used for electroplating. It comes in green crystals of the composition $2NiCO_3 \cdot 3Ni(OH)_2 \cdot 4H_2O$. It is not soluble in water, but is soluble in acids and in solutions of ammonium salts.

**Nickel-tantalum alloy.** Nickel containing a percentage of tantalum in alloy. The usual composition is 70% of nickel and 30 of tantalum. The alloy is hard but is easily rolled or drawn into wire. It is nonmagnetic and does not oxidize when heated to a high temperature. It is prepared by heating at a white heat a highly compressed mixture of the two metals in powdered form, and is formed by diffusion rather than fusion. The metal is used for electrical-resistance wires or for electrical apparatus.

**Nitric acid.** Also called Aqua fortis, and Azotic acid. A colorless to reddish fuming liquid of the composition $HNO_3$, hav-

ing a wide variety of uses for pickling metals, etching, and in the manufacture of nitrocellulose, pyroxylin plastics, dyestuffs, and explosives. It has a specific gravity of 1.502 (95% acid), boiling point of 86°C., and is soluble in water. Its fumes have a suffocating action, and it is highly corrosive and caustic. Fuming nitric acid is any water solution containing more than 86% of acid and having a specific gravity above 1.480. Nitric acid is made by the action of sulphuric acid on sodium nitrate, or purified Chilean saltpeter, and condensation of the fumes. It is also made synthetically directly from ammonia. The acid is sold in various grades, depending on the amount of water. The strengths of the commercial grades are 38, 40, 42, and 43°Bé. containing 67.2% of acid. C.P., or reagent grade, is 43°Bé., with 70.3% of acid, very low in iron, arsenic, or other impurities. It is usually shipped in glass carboys. Nitrogen tetroxide, $N_2O_2$, is a dark-red, poisonous, corrosive liquid of specific gravity 1.5, and boiling point 21.15°C., used as a nitrating agent.

**Nitrocellulose.** A compound made by treating cellulose with nitric acid, using sulphuric acid as a catalyst. Since cotton is almost pure cellulose, it is the usual raw material. Waste cotton and cotton linters are employed after thoroughly scouring and digesting in a weak solution of soda. The cellulose molecule will unite with from 1 to 6 molecules of nitric acid. Trinitrocellulose, $C_{12}H_{17}O_7(NO_3)_3$, contains 9.13% of nitrogen, and is the product used for plastics, lacquers, adhesives, and celluloid. It is classified as cellulose nitrate. The higher nitrates, or Pyrocellulose, are employed for making explosives. It was originally called Guncotton, and the original U.S. Government name for the explosive was Indurite, from the Indian Head Proving Ground. The nitrated cellulose is mixed with alcohol and ether, kneaded into a dough, and squeezed through orifices into long multitubular strings which are cut into short cylindrical grains. Solid grains become smaller as they burn, so that there would be high initial pressure and then a decreasing pressure of gases. When the multitubular grains burn, the surface becomes greater and thus there is increasing pressure.

**Nitrogen.** An element, symbol N, which at ordinary temperatures is an odorless and colorless gas. The atmosphere contains 79%

of nitrogen in the free state. It is nonpoisonous and does not support combustion. Small quantities of nitrogen are used in incandescent lamps to prevent arcing. Nitrogen atmospheres are also used for bright annealing of steel. It can be combined with many metals to form nitrides and is thus applied to the hardening of steel, the usual source for this purpose being from ammonia. Nitrogen in small amounts in steel inhibits grain growth at high temperatures. It refines the grain and increases the strength and corrosion resistance of high-chromium steels. The natural nitrates, soda niter and niter, are employed for the making of nitric acid and explosives, but for these uses they may be replaced by atmospheric nitrogen, which has been produced in increasing quantities. Fixation of nitrogen is a term applied to any process whereby nitrogen from the atmosphere is transferred into nitrogen compounds, or Fixed nitrogen, such as ammonia. Calcium cyanamid, $CaCN_2$, is used as fertilizer, as is also urea produced from ammonia. A nitrogen-containing gas, developed by the General Electric Co. under the name of Drycolene for furnace atmospheres for heat-treating steel and for sintering, contains 78% $N_2$, 20% CO, and 2% $H_2$. It is produced by burning hydrocarbon gases and air, removing the moisture, and passing through incandescent charcoal to convert any $CO_2$ to CO and $H_2$.

Nitroglycerin. A heavy, oily liquid known chemically as Glyceryl trinitrate and having the empirical formula $C_3H_5(NO_3)_3$. It is made by the action of nitric acid on glycerin in the presence of sulphuric acid or some other substance having an affinity for water. It is a highly explosive compound, detonating upon concussion. Liquid nitroglycerin when exploded forms carbonic acid, $CO_2$, water vapor, nitrogen, and oxygen; 1 lb. is converted into 156.7 cu. ft. of gas. The temperature of explosion is about 6280°F. For use as a commercial explosive it is mixed with absorbents, usually kieselguhr or wood flour, under the name of Dynamite. Cartridges of high density explode with a greater shattering effect than those of low density. By varying the density and also the mixture of the nitroglycerin with ammonium nitrate, which gives a heaving action, a great diversity in properties can be obtained.

Dynamites are rated on the percentage, by weight, of the nitro-

glycerin that they contain. In Extra dynamite half of the nitroglycerin is replaced by nitrate of ammonia. It is not so quick and shattering, but is useful in earth excavation. Durox is an Ammonium dynamite marketed by E. I. duPont de Nemours & Co., Inc. Agritol is a low-density ammonium dynamite of the same company for blasting stumps and boulders. Gelatin dynamite is made by dissolving a special grade of nitrocotton in nitroglycerin. This type has less fumes, and is thus adapted for underground work. Its plasticity also makes it more adaptable for loading solidly in holes. It is marketed as straight gelatin or as Ammonium gelatin. Blasting gelatin is a strong and quick grade, and is waterproof. Gelobel is a gelatin dynamite, and Monobel is an ammonium dynamite marketed by duPont for mine blasting. The Gelodyn explosive of the Atlas Powder Co. is a combination of ammonium gelatin dynamite that is plastic, gives a shattering effect, and does not produce excessive fumes. It is used for construction blasting.

**Nondeforming steel.** Also called Nonshrinking steel. A group of alloy steels which have the characteristic that they do not easily deform, or go out of shape, when heat-treated. This property makes them suitable for making dies, gages, or tools that must be accurate. The usual nondeforming steel contains from 1 to 1.75% of manganese, with or without chromium or other alloying elements. The carbon content is the same as tool steels of the same grade. The phosphorus, sulphur, and silicon impurities are kept as low as possible. The steels are oil hardening, and do not have the tough core of ordinary tool steels. They have low resistance to shock and are thus not suited to bending or forming dies, except when they have additional alloying elements.

The nondeforming steel marketed by the Cyclops Steel Co., under the name of Wando, contains 1.05% of manganese, 0.50 chromium, 0.50 tungsten, and 0.95 carbon. Invaro, of the Firth-Sterling Steel Co., is an oil-hardening steel containing 1.15% of manganese, 0.90 carbon, 0.50 tungsten, and 0.50 chromium. Mansil die steel, of Henry Disston & Sons, Inc., has the same composition. It is deep-hardening, and is used for blanking dies, broaches, reamers, and gages. Mangano, of the Latrobe Electric Steel Co., contains about 1.60% of manganese, 0.20 chromium, and 0.95 carbon.

Stentor, of the Carpenter Steel Co., is a nondeforming tool steel containing 1.6% of manganese, 0.25 silicon, and 0.90 carbon. It hardens at a low temperature range, 1400 to 1440°F., which aids in avoiding warpage. Vega steel, of this company, is an air-hardening nondeforming steel that hardens uniformly at low temperatures even in large sections and does not require pack hardening. It contains 0.70% of carbon, 2 manganese, 1 chromium, 1.35 molybdenum, and 0.30 silicon. It hardens to 61 Rockwell C from a temperature of 1550°F. Exl-Die Steel, of the Columbia Tool Steel Co., has 1.15% of manganese, 0.90 carbon, 0.50 chromium, and 0.50 tungsten. Saratoga, of the Allegheny Ludlum Steel Co., and Amcoh, of A. Milne & Co., have about the same composition. Truform, of the Jessop Steel Co., is an oil-hardening high-manganese steel with a low coefficient of expansion, used for making cutters and dies. Deward, of the Allegheny Ludlum Steel Co., contains 1.55% of manganese, 0.90 carbon, and 0.30 molybdenum. Paragon steel, of the Crucible Steel Co., has about this amount of manganese with 0.50 to 0.75% of chromium and 0.25 vanadium. Kiski steel, of the Braeburn Steel Co., is a similar steel.

Some of the air-hardening steels are classed as nondeforming. Carpenter No. 485 is an air-hardening steel for dies and tools. It has 5% of chromium, 1 molybdenum, 0.20 vanadium, 0.70 manganese, 0.20 silicon, and 0.95 carbon. Carpenter No. 883 is a tougher tool steel for forging dies and bulldozer dies. It has 5% of chromium, 1.35 molybdenum, 0.45 vanadium, 1.10 silicon, 0.35 manganese, and 0.40 carbon. Airtem steel, of the Lehigh Steel Co., used for blanking and forming dies, has 5.25% of chromium, 1.25 molybdenum, 1 silicon, 0.50 manganese, 0.30 vanadium, and 1.30 carbon. It is also shock-resistant. Air-kool steel, of the Crucible Steel Co. of America, used for blanking and trimming dies and gages, has 5.25% of chromium, 1.15 molybdenum, 0.50 vanadium, and 0.95 carbon. Sagamore steel, of the Allegheny Ludlum Steel Co., has 5% of chromium, 1 molybdenum, 0.25 vanadium, and 1 carbon. Ontario steel, of this company, is a steel for greater resistance to abrasion. It contains 12% of chromium, 0.80 molybdenum, 0.25 vanadium, and 1.5 carbon. Airvan steel, of the Firth-Sterling Steel Co., has 4% of chromium, 0.50 manganese, 1 molybdenum, 0.40 vanadium, and 0.95 carbon. It is used for blanking

and forming dies. Chromovan steel, of this company, is a non-deforming, wear-resistant tool steel containing 12.5% of chromium, 1.6 carbon, 0.80 molybdenum, and 1 vanadium. It is used for thread rolling and coining dies. Invaro, of the same company, is an oil-hardening tool steel for intricate dies, taps, and special tools. It contains 1.15% of manganese, 0.50 chromium, 0.50 tungsten, and 0.90 carbon. Hargus Steel, of the Ziv Steel and Wire Co., for blanking dies, reamers, and gages, contains 1% of manganese, 0.35 nickel, and 1.0 carbon.

**Nonmagnetic steel.** Steel and iron alloys used where it is important that no magnetic circuits be set up or magnetic effects be induced. Manganese steel containing 14% of manganese is nonmagnetic and casts readily but is not machinable. Nickel steel containing high nickel is also nonmagnetic. Many mills produce regularly nonmagnetic steels containing from 20 to 30% of nickel. Manganese-nickel steels and manganese-nickel-chromium steels are nonmagnetic and may be arranged to combine desirable features of the nickel and manganese steels. A nonmagnetic steel of the Jessop Steel Co. has 10.5 to 12.5% of manganese, 7 to 8 nickel, and 0.25 to 0.40 carbon. The electrical resistance is 70 microhms per cu. cm. compared with 5 to 7 for brass. It has low magnetic permeability and low eddy-current loss, can be machined readily and work-hardens only slightly. The tensile strength is 80,000 to 110,000 lb. per sq. in., elongation 25 to 50%, and specific gravity 8.02. It is austenitic and cannot be hardened. The 18-8 austenitic chromium-nickel steels are also nonmagnetic.

**Nonshattering glass.** Also referred to as Shatterproof glass, Laminated glass, or Safety glass, and when used in armored cars it is known as Bulletproof glass. A material composed of two sheets of plate glass with a sheet of transparent resinoid between, the whole molded together under heat and pressure. When subjected to a severe blow, it will crack without shattering. The first of these was a German product marketed under the name of Kinonglas, which consisted of two clear glass plates with a cellulose nitrate sheet between, and was first used for protective shields against chips from machines. Nonshattering glass is now largely used for automobile and car windows. The original cellulose ni-

trate interlining sheets had the disadvantage that they were not stable to light and became cloudy. Cellulose acetate was later substituted. It is opaque to actinic rays and prevents sunstroke but has the disadvantage of opening in cold weather, permitting moisture to enter between the layers. The acrylic resins are notable for their stability in this use; in some cases they are used alone without the plate glass, especially for aircraft windows. Polyvinyl acetal resins, as interlinings for safety glass, are weather resistant and will not discolor and are now used extensively. Flexseal, of the Pittsburgh Plate Glass Co., is a laminated plate glass with a vinyl resin interplate having an extension for sealing into the window frame. It will withstand pressure of 20 lb. per sq. in. with a ⅛-in. plastic interplate, and is used for aircraft windows. Duplate is the trade name of the Duplate Corp. for a nonshattering glass. Standard bulletproof glass is from 1½ in., 3 ply, to 6 in., 5 or more ply.

**Nutmeg.** The brown, round, wrinkled seed of the fruit of the evergreen tree *Myristica fragrans,* native to the Moluccas but now grown extensively also in Grenada. The bright-red aril covering of the seed is called Mace. The trees average about 20 lb. of kernels per year, but a large tree may bear as many as 10,000 nutmegs annually. Nutmeg is a delicately flavored spice for foodstuffs, but in large amounts is highly toxic. Mace has a finer but weaker flavor and is used as a savory. Nutmeg butter is a solid yellow fat obtained from the rejected nutmegs of the spice trade. To obtain the fat the kernels are roasted and ground before extraction. The nutmeg contains about 40% of the fat. It is used chiefly in ointments. Nutmeg oil is an essential oil extracted from the nutmeg and used in medicine, in flavoring tobacco, and in dentifrices. It is also called Myristica oil and is high in Myristicin, which is a yellow poisonous oil of the composition $C_3H_5 \cdot C_6H_2(O_2CH_2)OCH_3$.

**Nux vomica.** The seeds of the ripe fruit of the deciduous tree *Strychnos nux vomica* of India, Ceylon, and Australia, used as the source of the alkaloids Strychnine and Brucine. The powdered seed may also be used. The fruits contain three to five hard grayish seeds which yield 1 to 1.25% of strychnine alkaloid and about the same amount of brucine. Strychnine is an odorless, crystalline,

intensely bitter powder of the composition $C_{21}H_{22}N_2O_2$. It is a spinal stimulant and in quantity is a violent convulsive poison. It is used in proprietary and prescription medicines of the tonic class, and also in rat poisons. For medicinal use it is used mostly in the form of Strychnine sulphate which is easily soluble in water. Brucine is a bitter crystalline alkaloid of the composition $C_{23}H_{26}$-$H_2O_4$ with similar characteristics but much less active. It is also used as a denaturant for rapeseed oil and other industrial oils.

**Nylon.** A group of synthetic plastics which are long-chain polymeric amides in which the amide groups form an integral part of the main polymer chain, and which have the characteristic that when formed into a filament the structural elements are oriented in the direction of the axis. Nylon produced by the reaction of adipic acid and hexamethylene diamene forms fine filament fibers of silklike appearance, great strength, elasticity, and toughness. The fine fibers are spun into yarns for weaving and knitting. Monofilament fibers are used for brushes, surgical sutures, tennis strings, and fishing leaders. Exton, of E. I. duPont de Nemours & Co., Inc., is a monofilament fiber for brushes. The single filaments are also called Monofil. It is more durable than natural bristles for brushes. Nylon is also used as an extrusion coating for insulation on electrical wires. It has a high softening point, 450°F. and, because of its property of taking on an orderly arrangement of the long-chain molecules in drawing, the fiber has a higher tensile strength than most textile fibers. The specific gravity of the filament is 1.068, and tensile strength 53,600 lb. per sq. in. The molded material has a specific gravity of 1.14, tensile strength 9,000 lb. per sq. in., flexural strength 12,600 to 14,600 lb. per sq. in., compressive strength 15,000 lb. per sq. in., and dielectric strength of about 400 volts per mil. The molded material is used for electrical parts where the high softening point is valued. The molded or machined material is also used for pressure valve seats. Nylon valve seats on Navy torpedoes withstand an air pressure of 2,800 lb. per sq. in.

**Oak.** The wood of a large variety of oak trees, all of the natural order *Cupuliferae*, genus *Quercus*. The She-oak of Australia, African oak, and the Roble, or oak of Chile, are not allied to the true oaks. European oak, under various names, such as Austrian oak

and British oak, are from two varieties of the tree Q. *robur*. The wood is light brown in color, with a coarse, open grain, firm texture, and weight of about 45 lb. per cu. ft. American red oak is from the tree Q. *rubra*. It is also called Black oak, although black oak is from the Q. *valutina*, and Red oak of the Lake states is Q. *borealis*. The heartwood is reddish brown, and the sapwood whitish. American White oak is from the tree Q. *alba* of the Eastern states. The heartwood is brown, and the sapwood white. The grain of these species is coarse, but the texture is firm. Post oak, of the Southern states, is Q. *stellata*. Chestnut oak, of the Appalachian range, is Q. *montana*. Scarlet oak, of Pennsylvania, is Q. *coccinea*. Western white oak, Q. *garryana*, has a more compact texture and straighter grain. American oaks are widely distributed in the United States and Canada. Spanish oak, Q. *oblongifolia*, is native to California and New Mexico. The grain is finer and denser.

Oak is used for flooring, furniture, cask staves, and where a hard, tough wood is needed. For cabinetwork the boards are variously sawed at angles and quarters to obtain grain effects known as Quartered oak. Fumed oak is not a kind of oak, but a finish produced by the action of ammonia vapor. Burr oak, or Pollard oak, also known as Burrwood, is the wood of the decapitated European oak trees Q. *pedunculata* and Q. *sessiliflora*, of Great Britain. A pollard tree is one whose head has been cut for ornamentation purposes. The growth in height is permanently arrested and innumerable branches shoot out from the trunk, which produce humps, or burrs, with the grain of the wood running in all directions. Burr oak is valued for ornamental work. Burr oak, of the Northern and Central United States is not a pollard oak but is a name for the tree Q. *macrocarpa*. The commercial red and white oaks have an average gravity when kiln-dried of 0.69. The compressive strength perpendicular to the grain is 1,870 lb. per sq. in., and shearing strength parallel to the grain of 1,300 lb. per sq. in.

Oak extract, which is an important tanning material for the best grades of heavy leather, is chiefly from the bark of the Swamp chestnut oak, Q. *prinus*, and from the tan-bark oak, Q. *densiflora*, but also from the White oak and the Red oak. The extract from the Black oak, Q. *coccinea*, is darker in color and is known as Quercitron extract. The bark of the tan-bark oak yields 10 to 14%

of tannin, but the extract contains 25 to 27% of tannin. Valonia consists of the acorn cups of the oak *Q. aegilops* of Asia Minor and the Balkans. Smyrna valonia contains 32 to 36% of tannin which produces a light-colored, lightweight leather with a firm texture and bloom. When used alone, however, valonia makes a brittle leather, and is thus always used in blends. Valonia is marketed as cups or as extract, the latter containing about 60% tannin.

**Oakum.** A substance used for calking the seams of vessels and wooden tanks, or for water pipes. It consists of old hemp ropes untwisted, pulled into loose fiber, and treated with tar. The hemp employed is from the true hemp, *Cannabis sativa,* coming in normal times from Russia, Italy, and India either as old rope or new fiber. The old rope is used because it is cheaper than new fiber, but new tow may be blended with the rope. The highest grade of Marine oakum is made entirely of new tow fibers. Sunn fiber may be substituted for hemp. Only inferior grades are made with jute fibers. Oakum is marketed in balls or on spools or in coiled rope form.

**Ochre.** A compact form of earth used for paint pigments and as a filler for linoleum. It is an argillaceous and siliceous material, often containing compounds of barium or calcium, and owing the yellow, brown, or red colors to hydrated iron oxides. The tints depend chiefly upon the proportions of silica, white clay, and iron oxide. Ochres are very stable as pigments. They are prepared by careful selection, washing, and grinding in oil. They are inert, and are not affected by light, air, or ordinary gases. They are rarely adulterated, because of their cheapness, but are sometimes mixed with other substances to alter the colors. Chinese yellow and many other names are applied to the ochres. Golden ochre is ochre mixed with chrome yellow. White ochre is ordinary clay. A large part of the American ochre is produced in Georgia. Sienna is a brownish-yellow ochre found in Italy and Cyprus. The material in its natural state is called Raw sienna. Burnt sienna is the material calcined to a chestnut color. Indian red and Venetian red are hematite ochres.

Vandyke brown is a deep-brown pigment made from lignitic ochre from Cassel, Germany. It was named after the Dutch painter Van Dyck, and is also called Cassel brown, Cassel earth, and Rubens

brown. Imitation Vandyke brown is made from a mixture of lampblack, yellow ochre, and iron oxide. Cologne earth is a Vandyke brown made from American clays which are mixtures of ochre, clay, and bituminous matter, roasted to make the color dark. Yellow ochre and Brown ochre are limonite. Umber is a brown siliceous earth colored naturally with iron oxides and manganese oxide. It comes chiefly from Italy and Cyprus. For use as a pigment it is washed with water and finely ground. It is inert and very stable. Cyprus umber is a rich coffee-brown color and as a pigment has good covering qualities. It is a modified marl with impregnations of iron and manganese. Burnt umber is redder in color than umber, and is made by calcining the raw umber. Caledonian brown and Cappagh brown are varieties of umber found in Great Britain.

**Oilcloth.** A fabric of woven cotton, jute, or hemp, heavily coated with turpentine and resin compositions, usually ornamented with printed patterns, and varnished. It is employed chiefly as a floor covering, but a light, flexible variety having a foundation of muslin is used as a covering material. This class comes in plain colors or in printed designs. Oilskin is a cotton or linen fabric impregnated with linseed oil to make it waterproof. It was used for coverings for cargo and for waterproof coats, but has now been replaced by coated fabrics. Oiled silk is a thin silk fabric impregnated with boiled or blown linseed oil which is oxidized and polymerized by heat. It is waterproof, very pliable, and semitransparent. It was much used for linings, but has now been replaced by fabrics coated with synthetics.

**Oils.** A large group of fatty substances which are divided into three general classes: vegetable oils, animal oils, and mineral oils. The vegetable oils are either fixed or volatile oils. The fixed oils are present in the plant in combined form, and are largely glycerides of stearic, oleic, palmitic, and other acids, and they vary in consistency from light fluidity to solid fats. They nearly all boil at 500 to 600°F., decomposing into other compounds. The volatile, or essential, oils are present in uncombined form and bear distillation without chemical change. Oils are found in all plants, particularly in the seeds, and in nearly all parts of animal bodies. Fish oils are thick, with a strong odor. Vegetable and animal oils are obtained

by pressing, extraction, or distillation. Oils that absorb oxygen easily and become thick are known as drying oils and are valued for varnishes, because on drying they form a hard, elastic, waterproof film. Oils and fats are distinguished by consistency only, but waxes are not oils. Mineral oils are derived from petroleum or shale and are classified separately.

Fish oils are obtained from the fat of the cod, herring, sardine, salmon, and sprat by boiling the fish and skimming the oil from the surface. The oil is of pale or brownish color and has an offensive odor. The specific gravity is about 0.930. It is of the nondrying class, and used for lubricants, leather dressing, soaps, oil baths for heat-treating steel, and for fractionating to reblend in paint oils and other products. It is sometimes bleached white. Japan fish oil consists of mixtures of the oils of Japanese sardines and herrings. Fish meal is the by-product scrap used for cattle and poultry feed and fertilizer. Fish oils are also used directly in poultry feeds to add vitamins A and D, especially the inferior grades of cod-liver oil and tuna-liver oil.

Blown oils are fatty oils that have been oxidized by blowing air through them while hot, thereby thickening the oil. They are mixed with mineral oils to form special heavy lubricating oils such as marine engine oil, or are employed in cutting oils. They are also used in paints and varnishes as the drying power is increased by the oxidation. The flash point and the iodine value are both lowered by the blowing. The oils usually blown are rapeseed, cottonseed, linseed, fish, and whale oils.

**Oilstone.** A fine-grained, slaty silica rock used for sharpening edged tools. The bluish-white and opaque white oilstones of fine grain from Arkansas are called Novaculite, and received their name because they were originally used for razor sharpening. They are composed of 99.5% chalcedony silica and are very hard with a fine grain. Novaculite is a deposit from hot springs. It is fine grained and bluish white in color. The finest stones are used for oilstones, and the ordinary grades are employed for the production of silica refractories. Arkansas oilstones are either hard or soft and have a waxy luster. They are shipped in large slabs or blocks. Washita oilstone, from Hot Springs, Ark., is a hard, compact white stone of

uniform texture. Onachita stones come in larger and sounder pieces but are coarser than the Arkansas. Water-of-Ayr stone, also known as Scotch hone, is a fine sandstone used with water instead of with oil. Artificial oilstones are also produced of aluminum oxide. India oilstone was originally blocks of emery, but the name now may refer to aluminum oxide stones.

**Oiticica oil.** A drying oil obtained from the kernels of the nuts of the tree *Licania rigida* of northeastern Brazil. The oil contains about 80% of Licanic acid, which, like the Eleostearic acid of tung oil, gives a greater drying power than is apparent from the iodine value. The specific gravity is 0.944 to 0.971, saponification value 187 to 193, and iodine number 142 to 155. The properties as a varnish oil are much like those of tung oil, both producing wrinkled films when applied pure, and both lacking high gloss. Cicoil is a name for a treated oiticica oil with improved qualities. The oiticica nuts are 1 to 2 in. long with the kernel about 60% of the nut, and yielding about 60% of oil. The average yield per tree is 350 lb. of nuts, but a full-grown tree may yield ten times that amount. Another species of the tree *L. crassifolia,* of Surinam, yields an oil similar to oiticica. Mexican oiticica is from the nuts of another species of tree and is called Cacahuanache oil. The kernels yield 69% of light-colored heavy oil.

**Oleic acid.** Also called Red oil, and Elaine oil. An organic acid having a complex composition, represented empirically by the formula $CH_3[(CH_2)_7CH]_2COOH$. It is used in making soluble oils and cutting compounds, in which it forms Sodium oleate, $C_{17}H_{33}COONa$. It is also used in the manufacture of oil-soluble colors, soaps, and in treating textiles. Oleic acid is found in most fats in combination with glycerol, particularly in liquid fats, or oils, such as olive oil, oleo oil, cottonseed oil, and coconut oil. It can be separated from fats by saponification and is obtained by distillation. It is an oily liquid with a specific gravity of 0.890, boiling point of 286°C., and melting point of 14°C. below which it forms colorless needles. It is soluble in alcohol. The two commercial grades of oleic acid, yellow and red, are known as saponified and distilled red oil.

**Olive oil.** A pale greenish oily liquid extracted from the ripe fruit of the olive tree, *Olea europaea,* a small evergreen grown largely in the Mediterranean countries but also in California and in Argentina. The fruits are eaten ripe (purple) and green. They are rich in oil, and vast quantities are crushed for oil. The oil contains 69 to 85% of oleic acid, 7 to 14 palmitic acid, 4 to 12 linoleic acid, with some stearic, arachidic, and myristic acids. The specific gravity is 1.912, iodine value 85, and saponification value 190. The best grades of the oil are used for food chiefly as a salad and cooking oil, and in canning sardines, but some is used in the manufacture of castile soaps. The industrial oil consists of the Olive oil foots obtained in the third pressing or in the last extraction with carbon bisulphide, and is used for finishing textiles, degumming silk, and in soaps. Florence oil is a grade of Italian olive oil. In Italy olive oil is also known as Luccu oil. Synthetic olive oil, or Olive-infused oil, is used entirely as a foodstuff. It is made from highly refined corn oil by infusing the corn oil with about 20% of a paste made of finely ground, partly dehydrated ripe olives ground with a small amount of corn oil. The olive-infused oil has the flavor of olive oil, and also contains carotene, or vitamin A, contained in the olive pulp. Other fractionated oils reblended to give high oleic acid content are also used as substitutes for olive oil. Olevene, of Jacques Wolf & Co., is a sulphonated synthetic oil used instead of olive oil for treating textiles.

**Olivine.** A translucent mineral, usually occurring in granular form, employed as a refractory. The formula is usually given as $(Mg \cdot Fe)_2 \cdot SiO_4$, but it is a solid solution of Forsterite, $2MgO \cdot SiO_2$, and Fayalite, $2FeO \cdot SiO_2$. The fayalite lowers the refractory quality, but forsterite is not found alone. Dunite deposits in North Carolina yield material carrying up to 90% olivine which has only 5 to 15% of fayalite. It is olive-green in color, vitreous, with a hardness of 6.5 to 7 and a specific gravity of 3.3 to 3.5. As a refractory it is neutral up to about 1600°C. but may then react with silica. The fayalite fuses out at 2700°F., making the material porous and subject to attack by iron oxide. The melting point of forsterite is 3470°F. When used mixed with chrome ore, the low-fusing elements form a black glass which presents a non-

porous face. Some refractory material marketed as forsterite may be olivine blended with magnesite, or may be serpentine treated with magnesite. Forsterite firebrick in the back walls of basic open-hearth steel furnaces gives longer life than silica brick but only two-thirds that of chrome-magnesite brick. The thermal expansion of olivine is lower than that of magnesite. Olivine sand is substituted for silica sand as a foundry sand where silica is expensive. There are large deposits of olivine in the Pacific Northwest. When used as a foundry sand, it is noted that the heat-resisting qualities decrease with particle size. Olivine contains from 27 to 30% of magnesium metal, and is also used to produce magnesium by the electrolysis of the chloride.

**Onyx.** A variety of chalcedony silica mineral differing from agate only in the straightness of the layers. The alternate bands of color are usually white and black, or white and red. Onyx is artificially colored in the same way as agate. It is used as an ornamental building stone, usually cut into slabs, and for decorative articles. Onyx marble is limestone with impurities arranged in banded layers. American onyx comes largely from Arizona, California, and Montana. Mexican onyx is banded limestone obtained from stalactites in caves. These materials are cut into such articles as lamp stands. Argentine onyx is a dark-green or a green-yellow translucent stone of great decorative beauty. In the United States it is called Brazilian onyx and is used for book ends, lamp bases, ink stands, and ornaments. Opalized wood is an onyxlike petrified wood from Idaho. It is cut into ornaments.

**Opacifiers.** Materials used in ceramic glazes and enamels primarily to make them nontransparent, but opacifiers may also enhance the luster, control the texture, promote craze resistance, or stabilize the color of the glaze. An opacifier must have fire resistance so as not to vitrify or decrease the luster. Tin oxide is a widely used white opacifier, and up to 3% also increases the fusibility of the glaze or enamel. Opacifiers may be the pigment colors. Thus, cobalt oxide gives a blue color, and platinum oxide gives gray. Antimony oxide as an opacifier gives opaque white enamels of great brilliance but is expensive and is poisonous. The zirconium opacifiers have a wide range of use from ordinary dishes

to high-heat electrical porcelain and sanitary-ware enamels. The amount of zirconium oxide used is a minimum of 3%. The opacifiers may be in prepared form with lead oxide or other materials to give particular characteristics. Opax, of the Titanium Alloy Mfg. Co., is a zirconium oxide with small percentages of silica, sodium oxide, and alumina. It is used for hard-glaze dinnerware and wall-tile glazes. Zircopax is zirconium silicate with 33.5% of silica. It gives color stability and craze resistance. Lead oxide is used to lower the melting point of a glaze. Matte effects are obtained by adding barium oxide, magnesia, or other materials to the opacifier.

**Open-hearth steel.** Steel made by the process of melting pig iron and steel or iron scrap in a lined regenerative furnace, and boiling the mixture, with the addition of pure lump iron ore, until the carbon is reduced. The boiling is continued for a period of 3 or 4 hr. The process was developed in 1861 by Siemens in England. The furnaces are made in sizes from 10 to 300 tons capacity, and contain regenerative chambers for the circulation and reversal of the gas and air. The fuels used are natural gas, fuel oil, coke-oven gas, or powdered coal. Both the acid- and basic-lined open-hearth furnaces are used, but most steel made in the United States is basic open hearth. Ganister is used as a lining in the acid furnaces, and magnesite in the basic.

An advantage of the open-hearth furnace is the ability to handle raw materials that vary greatly and also to employ scrap. Iron low in silicon requires less heating time. The duplex process consists in melting the steel in an acid Bessemer furnace until the silicon, manganese, and part of the carbon have been oxidized, and then transferring to a basic open-hearth furnace where the phosphorus and the remaider of the carbon are removed. Open-hearth steel is of uniform quality. The open-hearth steel bars used by one large company contain 0.08 to 0.18% of carbon, 0.55 max. manganese, 0.05 phosphorus, and 0.06 sulphur. With 0.12% of carbon, open-hearth steel has a tensile strength of 55,000 lb. per sq. in. and an elongation of 27%; the same steel with 0.18% of carbon has a tensile strength of 68,000 lb. and an elongation of 23%. Shell steel, for heavy projectiles that must burst into many pieces, is mostly open-hearth steel that has been resulphurized.

**Opium.** The dried juice from the unripe capsules of the poppy plant, *Papaver somniferum,* cultivated extensively in China, India, and the Near East, but also growing wild in many countries. The opium poppy is an annual with white flowers. After the petals drop off, the capsules are cut and the juice exudes and hardens. The crude opium is a brownish mass. It contains Morphine, Codeine, and nearly 20 other alkaloids which are used in medicine. Poppy-seed oil is a colorless to reddish-yellow liquid of specific gravity of about 0.925 and iodine number 157 used as a drying oil in artists' varnishes. The cold-pressed white oil is used locally as an edible oil. The very dark grades are used in soaps and in paints.

**Optical glass.** A highly refined glass, usually a flint glass, of special composition, or made from rock crystal, used for lenses and prisms. It is cast, rolled, or pressed. In addition to the regular glassmaking elements, silica and soda, optical glass contains barium, boron, and lead. The highly refractory glasses contain abundant lead oxide or barium oxide, and the low-refracting glasses contain abundant silica or boron oxide. A requirement of optical glass is transparency and freedom from color. Traces of iron make the glass greenish, while manganese causes a purple tinge. First-quality optical glass should contain a minimum of 99.8% of $SiO_2$. Borax is used in purifying and in increasing the strength and brilliance of the glass. Besides the control of chemical composition, careful melting and cooling are necessary to obtain fine transparency, and then intense polishing. The pouring temperature is about 1200°C. The best optical glass has a transparency of 99%, compared with 85 to 90% for ordinary window glass. A Borate glass with lanthanum and tantalum oxides but no silica is used for airplane-camera lenses and for eyepieces for wide-angle field glasses. It has a high refractive index and a low dispersion.

**Ore.** A metal-bearing mineral from which a metal or metallic compound can be extracted commercially. Earths and rocks containing metals that cannot be extracted at a profit are not rated as ores. Ores are named according to their leading useful metals. The ores may be oxides, sulphides, halides, or oxygen salts. A few metals also occur native in veins in the minerals. Ores are usually crushed and separated and concentrated from the Gangue with

which they are associated, and then shipped as Concentrates based on a definite metal or metal oxide content. The metal content to make an ore commercial varies widely with the current price of the metal, and also with the content of other metals present in the ore. Normally, a sulphide copper ore should have 1.5% of copper in the unconcentrated ore but, if gold or silver is present, an ore with much less copper is workable. Likewise, low-grade lead ores can be worked if silver is recoverable. Low-grade manganese and other ores become commercial when the prices are high.

**Osmium.** A rare metal, symbol Os, having the highest specific gravity, 22.50, and a very high melting point, 4890°F. Osmium forms a solid-solution alloy with platinum. Compared with iridium it has more than double the hardening power in platinum, but it volatilizes so readily into the poisonous tetroxide that it is seldom used to replace iridium in platinum alloys. With iridium, however, it is used as an alloy for fountain-pen tips under the name of Osmiridium. Osmium is not affected by the common acids and is not dissolved by aqua regia. The metal is sold by the troy ounce, 1 cu. in. weighing 11.86 troy oz.

**Osnaburg cloth.** Heavy, coarse cloth of plain weave made from waste and scraps of cotton mills, or from low-grade short-staple cotton. It is employed to replace burlap for wrapping and baling and is a standard material in 7.8-oz. weight for inside sacks for burlap flour sacks. In checks and stripes the cloth is used for protective coverings, often waterproofed.

**Oxalic acid.** An organic acid of the composition $(COOH)_2 \cdot 2H_2O$, employed in writing inks, metal polishes, as a tanning agent for leather, mordant in dyeing, a detergent, and as a stain remover from fabrics and porcelain. It occurs in colorless crystals with a specific gravity of 1.653 and melting point of 101.5°C. It is soluble in water and in alcohol. Oxalic acid is obtained by the action of nitric acid on sugar or strong alkalies on sawdust. Or it is prepared commercially by heating sodium formate and treating the resulting oxalates with sulphuric acid to liberate the oxalic acid.

**Oxygen.** The most important and abundant of the elements. Its chemical symbol is O. It constitutes about 89% of all water,

33% of the earth's crust, and 21% of the atmosphere. It combines readily with all elements except fluorine, helium, and argon. It is a colorless and odorless gas and can be produced easily by the electrolysis of water. The specific gravity is 1.1056. It liquefies at −113°C. at 59 atm. Liquid oxygen is a pale, steel-blue, transparent, mobile liquid. Oxygen is the least refractive of all gases. It is the only gas capable of supporting respiration, but is harmful if inhaled pure for a long period. In small quantities it is an exhilarant. Oxygen has many commercial uses and is marketed in steel cylinders under a pressure of 2,000 lb. per sq. in. The chief use is for oxyacetylene welding and metal cutting. For welding it should be at least 99.5% pure. Ozone is an allotropic form of oxygen and is composed of three atoms of oxygen, $O_3$. It is formed by electric discharges in the air, or during the evaporation of water, particularly of spray in the sea. It has a peculiar odor, which can be detected in 500,000 parts of air. Ozone is a powerful oxidizer, destroying most organic compounds and bleaching vegetable colors. Pure ozone is an irritant poison, but in minute quantities in the air is purifying and healthful. As an oxidizer in the rubber industry it is known as Activated oxygen.

Oxygen for bleaching and oxidizing purposes may be obtained from compounds that readily yield the gas, such as the liquid Hydrogen peroxide, $H_2O_2$, or the granular solid Sodium peroxide, $Na_2O_2$. The C.P. grade of hydrogen peroxide is a colorless liquid with 90% of $H_2O_2$ and 10% of water. It contains 42% active oxygen by weight, and one volume yields 410 volumes of oxygen. Albone, of E. I. duPont de Nemours & Co., Inc., is a hydrogen peroxide, and Solozone is a sodium peroxide having 20% available oxygen. Other Peroxides or Superoxides are also used industrially. These are compounds in which two oxygen atoms are singly linked, and their oxidizing power depends upon their degree of stability. They break down into pure oxygen gas and a more stable reduced oxide. Tetrabutyl hydroperoxide, an organic peroxide, is a powerful oxidizing agent used as an accelerator in curing rubbers, as a drying agent in oils, paints, and varnishes, and as a combustion aid for diesel fuel oils. The commercial 60% solution in water has a boiling point of 82°C. and specific gravity of 0.859. Urea peroxide, $(CO \cdot NH_2)_2O_2$, is a white crystalline material with 16% by weight

of active oxygen, used in bleaching, polymerization, and in oxidization processes. Magnesium peroxide, $MgO_2$, Calcium peroxide, $CaO_2$, and Zinc peroxide, $ZnO_2$, are stable white powders insoluble in water, containing, respectively, 14.2%, 13.6%, and 7.4% of active oxygen. They are used where the oxidation is required to be at high temperatures as in food processing.

**Ozokerite.** Also known as Mineral wax, and as Earth wax. A natural paraffin found in Utah and in central Europe, and used as a substitute or adulterant of beeswax, and in polishes, candles, printing inks, crayons, sealing waxes, phonograph records, and insulation. Ozokerite is a yellowish to black, greasy solid, melting at 55 to 110°C. and having a specific gravity of 0.85 to 0.95. It is soluble in alcohol, benzol, and naphtha, but not in water. The wax occurs in rocks, which are crushed, and the wax melted out. The latter is then refined by boiling, treating with an alkali, and filtering. The refined and treated ozokerite is called Ceresin and is white to yellow in color and odorless. The melting point is up to 142°F. It is used for waxed paper, polishes, candles, and compounding.

A similar wax, called Montan wax, or Lignite wax, is produced in Germany from lignite. Montan wax is white to dark brown in color, and has a melting point of 80 to 90°C., usually 83 to 85°C. The wax is obtained from the powdered lignite by solvent extraction with a mixture of benzene and ethyl alcohol and subsequent removing of the bitumen by oxidation with chromic acid. The brown coals of Oklahoma and Texas also contain as much as 13% of montan wax. IG wax S is extracted and purified montan wax, but IG wax V is a synthetic substitute consisting of the octadecyl ether of vinyl alcohol, $C_{17}H_{34}CH_2 \cdot O \cdot CH:CHOH$. Montan wax is valued for leather finishes, polishes, phonograph records, insulation compounds, and as a hard wax in candles. The mineral waxes are sold in white, waxy cakes, or in flakes.

**Paint.** A general name to designate a solution of a pigment in water, oil, or organic solvent, used to cover wood or metal articles either for protection or for appearance. Paints always contain pigments; the solution of gums or resins, known as varnishes, are not paints, although their application is usually termed painting. Enamels and lacquers, in the general sense, are under the classifica-

tion of paints, but specifically the true paints do not contain gums or resins. Stain is a varnish containing enough pigment or dye to alter the appearance or tone of wood in imitation of another wood, or to equalize the color in wood. It is usually a dye rather than a paint. Enamel paint is also a pigment in varnish. The vast bulk of paint is made with about 65% by weight of pigment and 35 of vehicle. The best House paint for outside work consists of high-grade pigment and linseed oil, with a small percentage of turpentine as a thinner and drier. The volatile thinner in paints is for ease of application, the drying oil determines the character of the film, the drier is to speed the drying rate, and the pigment gives color and hiding power.

Paints are marketed in many grades, some containing pigments adulterated with silica, talc, barytes, gypsum, or other material; fish oils, or inferior semidrying oils in place of linseed oil; and mineral oils in place of turpentine. Metal paints contain basic pigments such as red lead, ground in linseed oil, and should not contain sulphur compounds. Red lead is a rust-inhibitor, and is valued in primer paints for iron and steel. White lead has a plasticizing effect which increases adhesion. It is stable and not subject to flaking. Between some pigments and the vehicle there is a reaction which results in progressive hardening of the film with consequent flaking or chalking, or there may be a development of water-soluble compounds. Linseed oil reacts with some basic pigments, giving chalking and flaking. Fading of a paint is usually from chalking. The composition of paints is based on relative volumes since the weights of pigments vary greatly, although the custom is to specify pounds of dry pigment per gallon of oil. A 28-lb. red-lead paint contains 20.3 lb. of red lead per gal. and weighs 25.9 lb. per gal.

Bituminous paints are of coal-tar or asphalt products, dissolved in mineral spirits, and used for the protection of pipes, and for waterproofing cement. Battery paint is usually asphalt or gilsonite in a petroleum solvent. It forms a heavy, chemical-resistant and water-resistant film. Aluminum paint is made with aluminum flake powder in a base of linseed oil, varnish, gloss oil, or synthetic lacquer. It gives a silvery appearance. As it reflects 70% of the light and radiates heat poorly, it is valued for painting tanks, chimneys, and ovens. Since sand does not adhere to it, it is used also

for painting foundry patterns. Aluminum paint for outside work is in a spar varnish. In lacquers the powder does not leaf, and the paint dries to a hard, metallic surface with a frosted effect useful for some finishes. Sericite mica flake is sometimes mixed with aluminum flake as an extender or to give a different color tone.

Water paints may consist of gypsum or whiting with zinc oxide, lithopone, or other material, and with water as the vehicle and glue for adhesion. Kalsomine is an old name for wall paint made with whiting and glue and some linseed oil. Water colors may be added. Whitewash is a cheap white paint made from slaked lime, salt, whiting, and glue, or sometimes quicklime and water alone. It will not withstand weathering. Modern water paints may be made with pigments and extenders in a casein solution. These are more water-resistant and more durable than glue paints. A different type of higher quality water paints is the group of Resin emulsion paints. They are water emulsions of oil-modified alkyd resins and leave tough films of resin on evaporation of the water. With pigments and extenders they form adhesive and resistant paint films. They are sometimes also added to glue or casein water paints to improve the quality. Alabastine, of the Alabastine Co., is a washable casein paint. Luminous paints are made with radium, mesothorium, or with sulphurated compounds. The hiding power of a paint is defined as that quantity which must be applied to a given area of a black and white background to obtain nearly uniform complete hiding. The hiding power is obtained almost entirely from the pigment. Paint removers, for removing old paint from surfaces before refinishing, are either strong chemical solvents or strong caustic solutions. The first type is often very effective in removing the paint but may raise the grain of the wood and discolor it.

**Palladium.** A rare metal found in the ores of platinum, symbol Pd. It resembles platinum, but is lighter in weight and has a more beautiful silvery luster. It is only half as plentiful but is less costly. The specific gravity is 12.16 and the melting point is 1549°C. The Brinell hardness of the annealed metal is 49. It is highly resistant to corrosion and to the action of acids. Like gold, it dissolves in aqua regia. It alloys readily with gold and is employed in some grades of white gold. It also forms solid solutions

with platinum, and the alloys are harder than either of the constituent metals. These alloys are easily workable and are employed for electrical contacts, instruments, and jewelry. Palladium is also used as a plating metal for such articles as electrical appliances. It is plated on steel over a thin undercoat of silver. Palladium leaf is palladium beaten into an extremely thin foil used for ornamental work like gold leaf on pocketbooks, picture frames, and decorative surfaces. It has a white color and is resistant to tarnishing even when exposed to sulphur atmospheres. A book of 500 sheets, or 35 sq. ft. of leaf, weighs less than ¼ oz. Palladium-silver alloys are used for fountain-pen nibs. A dental alloy to replace gold contains 20 to 30% of palladium, up to 15 copper, and the remainder silver. Palladium sponge absorbs much hydrogen and is used for gas lighters.

**Palm oil.** An oil obtained from the fleshy covering of the seed nuts of several species of palm trees, chiefly *Elaeis guineensis*, native to tropical Africa. A large use of the oil is as a fluxing dip in the manufacture of tin plate, but it is also used for soaps, candles, and butter substitutes. Fresh palm oil has an agreeable odor and a bright-orange color, but the oil often has a rancid stench and is of varying colors. Palm oil contains 50 to 70% of Palmitic acid, $C_{15}H_{31}COOH$, which in the form of glyceride is an ingredient of many fats. When isolated, it is a white crystalline powder of specific gravity 0.866, and melting point 64°C., soluble in hot water. Palmitic acid is used in soap, treating textiles, and in lubricating oils. Usually 10% of glycerin is recovered from palm oil in the making of soaps.

The tree attains a height of about 60 ft., and the nuts occur in large bunches similar to dates. The fruit is of an elongated ellipse shape, about 1½ in. long, enclosing a single kernel. The fleshy part carries about 65% of oil, which is a semisolid fat. The iodine value is about 55, and the saponification value 205. West African palm oil has four grades: Edible, with 11% max. free fatty acid; Soft, with 18% max.; Semihard, with 35% max.; and Hard, with more than 35%. The high-grade edible oil is from fresh unfermented fruits. Palm oil for tin-plate dip may be mixed with cottonseed or mineral oil. Palm kernel oil is an edible oil from

the kernels of the palm nut. It is different in characteristics from palm oil. It contains about 50% of lauric acid, 15 myristic acid, 16 oleic acid, and 7 palmitic acid, together with capric and caprylic acids found in coconut oil, while palm oil is very high in palmitic and oleic acids. The specific gravity is 0.873, iodine number 16 to 23, saponification value 244 to 255, and melting point 24 to 30°C. The American species of palm oil is from the dwarf tree *E. melanococca* growing from Mexico to Paraguay and called Noli palm in Colombia. The pulp of the nuts yields 30% of an oil similar to African palm oil. The tall Paraguayan palm *Acrocomia sclerocarpa* has the fruit also in bunches, and the pulp yields 60% of oil very similar to palm oil.

**Papain.** The dried extract, or enzyme, obtained from the fruit and sap of the papaya tree, *Carica papaya,* of tropical America and Asia. The tree grows to a height of 25 ft. without branches and is crowned with large leaves. The melonlike fruit grows out from the trunk, and has orange-colored flesh. It is eaten raw like a melon, but as it spoils rapidly it is not easily shipped. The Papaya is called Pawpaw in Florida. Papain is used in beverages, and in medicine, as a digestive aid like pepsin.

**Paper.** The name given to cellulose made into paste form from plant sources and rolled into thin sheets, used as a material for writing, printing, and wrapping. The original Egyptian paper, known as Papyrus, was made from the stems of the rush *Cyperus papyrus* growing along the Nile. It was made in sheets, sometimes as long as 130 ft. There are many varieties and grades of paper, depending upon the source of the cellulose and the method of manufacture. Wood is a lignified form of cellulose, and the wood is chipped and cooked with chemicals to dissolve out the lignin. The material so treated is known as Chemical wood pulp to distinguish it from Mechanical wood pulp used for making wallboard and newsprint paper, the latter requiring some chemical pulp to give fiber and strength. There are three processes for producing chemical pulp: the sulphite, with calcium sulphite; the soda, with caustic; and the sulphate, with sodium sulphate. Book paper is usually a mixture of sulphate and Soda pulp, the latter process producing a bulky pulp. Wrapping paper is a strong, coarse paper made usually

from mixed pulps. Kraft paper is a heavy, brown, sulphate pulp paper of high strength, sized with rosin, used for wrapping or as building paper. Manila paper is a strong wrapping paper originally made from Manila hemp, but the name is now applied to any strong chemical wood pulp or mixed pulp paper of Manila color. Absorbent paper, such as for Blotting paper and Filter paper, is made from spongy bulky fibers, such as poplar, or is loosely felted fiber. Granite paper is made by adding a small percentage of colored fibers to the pulp or by adding several shades of dyed pulp to the regular stock. Oatmeal paper, used chiefly for wallpaper, has a flaky finish produced by washing a solution of wood flour over the sheet on the forming wire in the paper machine. The wood flour may be natural or dyed in colors. Cartridge paper is 50-80-lb. Manila paper, waxed on one side, used for containers for dynamite. Glassine is a transparent thin paper used for envelope windows and for sanitary wrapping. It is made of sulphite pulp subjected to long-continued beating and supercalendered. Glassoid is a more highly finished transparent paper. Onionskin paper is a lightweight, highly finished, transparent writing paper made transparent by hydration of the pulp in the beaters. Albanene tracing paper, of Keuffel & Esser Co., is a thin rag paper treated with a transparent synthetic resin. It takes ink readily and erases easily.

Cotton is nearly pure cellulose and makes an excellent paper material. Old cotton rags are thus scoured and used for papermaking. Linen fabrics are also used and produce a fine grade of writing paper. The best quality writing and printing papers are 50, 75, or 100% rag papers. Bond paper is a hard-finished writing paper. Highly rolled and coated printing papers are called Supercalendered papers. They are used for printing fine-screen half tones. In England this paper is called Art paper. Fine linen Ledger paper is made with 100% white rags. Good quality bond Typewriter paper may have 80% white rags. Ordinary papers are sold by weight per ream, a ream usually consisting of 500 sheets of a specified size in inches.

To make paper smooth-surfaced and resistant to the spreading of inks, sizing materials such as resins, starch, alum, and glue are used. Fillers, such as China clay, are used to give body, weight, opacity, and strength to the paper. Paper may be partly water-

proofed with a copper-ammonium solution and hot-rolled. A type of Waterproof paper, or Rubberized paper, is made by coating paper with rubber latex to which has been added powdered glass or kaolin and a creaming agent such as metallic soap. It has about the same appearance as ordinary writing paper, and will take writing well. Wet-strong paper is specially processed paper in which the water resistance is due to the processing and interlocking of the fibers as well as to impregnation with a small amount of synthetic resin. Resistall, of the L. L. Brown Paper Co., is a paper of this type. But some wet-strong papers are made by sizing with a urea-formaldehyde resin. It is used for maps, documents, and for wrapping. Fish paper is a thin hard paper impregnated with zinc chloride and is used for electric insulation. Insulating paper, commonly called Varnished paper, is a standard material for insulation of electrical equipment. It is usually bond or kraft paper coated on both sides with black or yellow insulating varnish. The thicknesses are 0.002 to 0.020 in., with dielectric strengths of 500 to 2,000 volts per mil. The heavier papers may be 2 or 3 ply. Flameproofed paper is paper treated with ammonium sulphate and ammonium and sodium phosphates.

Building paper, used for sheathing houses, is a heavy kraft paper, plain or rosin-sized. Specially treated building papers are also marketed under trade names. Weatherite, of Johns-Manville, is a kraft building paper treated with a black waterproofing. Copperskin is an insulating construction material made by facing 1-oz. electrosheet copper on one or two plies of heavy building paper impregnated with bitumen. Cop-O-Top, of the Chase Brass & Copper Co., and Copper-kote, of the Cheney Co., are similar materials. Sisalkraft, of the Sisalkraft Co., is a waterproof building paper made with sisal fibers. Fibreen, of this company, is a tough, strong, flexible, waterproof paper used for wrapping bundles of steel and other heavy products. It is made of two layers of kraft paper reinforced with two crossed layers of sisal fibers embedded in asphalt, and the whole combined under heat and pressure. Brownskin is a waterproof sheathing paper of the Angier Corp. of high-strength building paper impregnated with a bituminous compound and crimped to give it stretch and resiliency. Sta-Tite, of this company, is a building paper composed of three sheets of kraft

paper with layers of asphalt between, in which are set a layer of crossed cords and one of parallel cords. Burlap-lined paper, used for wrapping leather and machinery, is heavy kraft paper coated with asphalt to which 4- to 10-oz. burlap is stuck.

**Paper plants.** Cellulose for papermaking is obtained from a wide variety of plant life, made directly into Paper pulp, or obtained from old rags which were originally made from vegetable fibers. Animal fibers incorporated into some papers are fillers for special purposes and not papermaking materials. The original Egyptian paper, or Papyrus, was made from a reed, and that of India, Baobab, was from the *Adamsonia digitata.* The famous Rice paper of China comes largely from the *Tetrapanax papyriferum,* but the so-called rice paper used for cigarettes in the United States is made from linseed fiber. Cigarette paper is also made in the United States from ramie and sunn hemp. The distinction between cigarette paper and the Tissue paper used for wrapping is that it must be free of any substance that would impart a disagreeable flavor to the smoke and it must be opaque, pure white, burning at the same rate as tobacco, and tasteless. Wood pulp is now the most important papermaking material. Spruce is the chief wood used for the sulphite process, but hemlock and balsam fir are also used. Aspen and other hardwoods are used in the soda process, and also southern pine. Hemlock, spruce, tamarack, pine, and fir are used for the sulphate process. Spruce and fir are the notable Pulpwoods of the Northwest. Yellow pine is extensively used in the United States, especially for Kraft paper, paperboard, and book paper. Poplars are also used for pulpwood. In England fine printing papers are made by the soda process from Esparto grass. It gives a soft, opaque, light paper, although the cellulose content is less than 50%. Esparto is the wiry grass *Stipa tenacissima* of the dry regions of North Africa. In Tunisia it is called Alfa. Some grades of cardboard are made from straw. Deluwang paper of the East Indies is made from the scraped and beaten bark of the Paper mulberry tree, *Broussonetia papyrifera.* It is an ancient industry in Java, and the paper is used for lampshades and fancy articles. Under the name of Tapa cloth the sheets were dyed and

used as a muslinlike fabric by the Polynesians. The strips are welded together by overlapping and beating together the wet material.

**Papier maché.** Comminuted paper or paper pulp made into a paste with a binder, and molded into the desired form. It is then painted or enameled, or the paste itself may be dyed. Papier maché, originated in France in 1740, was widely employed for toys, dishes, and novelties before the invention of the synthetic molding materials. It is easy to mold, but has little strength and is not suited for mechanical parts. Dishes and novelties now made of paper stock are usually made directly from the wood pulp.

**Paraffin.** A general name often applied to paraffin wax, but more correctly referring to a great group of hydrocarbons obtained from petroleum. Paraffin compounds begin with methane, $CH_4$, and are sometimes called the methane group. The substances in the series have the general formula $C_nH_{2n+2}$, and include the gases methane and ethane, and the products naphtha, benzine, gasoline, lubricating oils, vaseline, and the common paraffin. The name paraffin indicates little affinity for reaction with other substances. In common practice the name is limited to the paraffin waxes that follow vaseline in the distillation of petroleum. These waxes melt at from 40 to 60°C., and consist of the hydrocarbons between $C_{22}$ and $C_{27}$; the refined waxes may range up to 90°C. They burn readily in the air. Paraffin occurs to some extent in some plant products, but its only commercial source is from natural petroleum. Chlorinated paraffin is a pale to amber-colored, odorless, soft wax or viscous oil of specific gravity 0.900 to 1.50. It is flame-resistant, and is used in treating paper and textiles. Chlorowax, of the Diamond Alkali Co., is a chlorinated paraffin for adhesive, fire-resistant, and water-resistant compounds. It is a cream-colored powder containing 69 to 73% chlorine, and is insoluble in water but soluble in organic solvents. Clorafin 42, of the Hercules Powder Co., is an amber-colored viscous liquid chlorinated paraffin containing 42% chlorine. Clorafin 70 is a yellow solid containing 70% chlorine and softening at 90 to 100°C. The former is used as a plasticizer in resins and for coatings; the latter is for flameproofing and waterproofing textiles.

**Paraffin oil.** The drip oil from the wax presses in the process of extracting paraffin wax from the wax-bearing distillate in the refining of petroleum. The oil is treated, redistilled, and separated into various grades of lubricating oils from light to heavy. They may be treated and bleached with sulphuric acid, and neutralized with alkali. When decolorized with acid and sold as filtered, they are brilliant liquids, but are not suitable as crankcase lubricants, or in places where they may be in contact with water, since the sulpho compounds present cause emulsification. The specific gravities of paraffin oils are between 21 and 26°Bé. Triton oil is a 100% pure paraffin oil produced by the Union Oil Co. of California.

**Paraffin wax.** The first distillate taken from petroleum after the cracking process is known as wax bearing, and is put through a filter press and separated from the oils. The wax collected on the canvas plates is called Slack wax, and contains 50% of wax, and 50 oil. This is put through a sweating process which frees it from oil. The sweated wax is separated into grades with melting points varying from 105 to 136°F. The yellow wax may be melted and filtered to make refined wax, which is colorless, odorless, and tasteless. Paraffin wax is soluble in ether, benzine, and essential oils. Match wax has a melting point of 105 to 112°F.; white crude wax, 111 to 113°F.; yellow crude, 117 to 119°F.; and special white, 124 to 126°F. The refined waxes are in various melting-point ranges from 115 to 132°F. The refined paraffin wax used for molded goods and for rubber compounding is a white solid having a melting point of 122°F. and a specific gravity of 0.903. Borneo wax has a very high melting point and a hard crystalline structure which makes it valuable for coatings and for high-quality candles. By treatment of the American wax to remove the lower melting constituents a higher melting point and harder crystalline structure approaching that of the Borneo wax is obtained. Aristowax, of the Union Oil Co. of California, is a treated wax of this kind with melting points from 145 to 165°F. Wax is marketed in barrels, 20-lb. slabs, and cases. It is used for sealing, waterproofing paper, as a filler for leather, and for many other things. Wax tailings is the name for the distillate that comes from petroleum after the wax-bearing distillate is removed. It contains no wax,

but at ordinary temperatures looks like beeswax. It is very adhesive and is employed in roofings and for waterproof coatings. Microcrystalline wax is a name given to highly refined American waxes of the hard Borneo type and of high melting point. Petrolite wax, of the Petrolite Corp., with a melting point of 195°F., is a wax of this kind.

**Parchment.** Originally, goat- or sheepskin specially tanned and prepared with a smooth hard finish for writing purposes. It was used for legal documents, maps, and fancy books, being more durable than the old papers. Parchment now is usually Vegetable parchment. It is made from a base paper of cotton rags or alpha cellulose called Waterleaf which contains no sizing or filling materials. The waterleaf is treated with sulphuric acid which converts a part of the cellulose into a gelatinlike Amyloid. When the acid is washed off, the amyloid film hardens on the fibers and in the interstices of the paper. The strength of the paper is increased, and it will not disintegrate even when fully wet. The paper now has a wide usage in food packaging as well as for documents as a competitor of the resin-treated wet-strong papers. The wet strength and grease resistance are varied by differences in acid treatment and subsequent sizing. Patapar, of the Paterson Parchment Paper Co., is a vegetable parchment marketed in many grades. Parchment papers are also waterproofed by dipping in the solution of copper hydroxide and ammonium hydroxide known as Schweitzer's reagent, and then hot-rolling. Vellum is a thick grade of writing paper made from high-grade rag pulp to imitate calfskin.

**Pasteboard.** A class of thick paper used chiefly for making boxes and cartons, and for spacing and lining. It may be made by pasting together several single sheets, but more usually by macerating old paper and rolling into heavy sheets. It may also be made of straw, certain grasses, and other low-cellulose paper materials, and is then known as Strawboard. Colloquially, the term pasteboard applies to any paper-stock board used for making boxes. Cardboard is usually a good quality of chemical pulp or rag pasteboard used for cards, signs, or printed material, or for the best quality boxes. Ivory board, for art printing and menu cards, is a highly finished cardboard clay-coated on both sides. Bristol board is a

high-class white cardboard, supercalendered with china clay, or it may be made by pasting together sheets of heavy ledger paper, but the name is also applied to any high-grade printing or drawing board over 0.006 in. thick. Index bristol is always made solid on a Fourdrinier machine to prevent splitting in use or warping. The original board made in Bristol, England, was made in this way. Jute board, used for folding boxes, is a regular product of the paper mills, and is a strong solid board made of kraft pulp. Chipboard is a cheap board made from mixed scrap paper, used for boxes and book covers. When made with a percentage of mechanical wood pulp, it is called Pulpboard. A heavy rope-pulp paper or board, usually reddish in color and used for large expansion filing envelopes, is called Paperoid.

**Pattern woods.** Sugar pine is the most widely used wood for patterns employed in all kinds of foundry work in the United States. It replaces eastern white pine, which is scarcer and now usually more costly. Poplar is used for patterns where a firmer wood is desired; cherry or maple is employed where the pattern is to be used frequently or will be subject to severe treatment. Mahogany is used for small and intricate patterns where a firm texture and freedom from warpage are needed. However, for small castings made in quantities on gates, aluminum or brass is more frequently used.

**Peanut oil.** Also known as Groundnut oil. A pale-yellow oil with a distinctive nutty taste and odor, obtained from the pressing of the seed kernels of the peanut, a legume of the genus *Arachis*, of which there are many species. It was native to Brazil, brought to Africa in slave ships and thence to the United States. It is now grown in many countries. The Spanish peanut, cultivated in temperate climates, has small seeds, while the common variety, *A. hypogaea*, known in the United States as the Virginia peanut, has pods up to 1½ in. long with seeds twice the length of the Spanish varieties. The Spanish peanut, however, is easily grown and gives a high yield per acre. The Brazilian peanut, *A. nambyquarae*, has pods up to 3 in. in length. Vast quantities of peanuts are roasted and marketed as food nuts or for confections or ground to make edible Peanut butter. The best grades of cold-pressed oils are

marketed as edible oils, but the oil is also used industrially for soaps, in diesel-engine fuels, and for blending in lubricating and varnish oils. The Arachidic acid, $CH_3(CH_2)_{18}COOH$, contained in the oil to the extent of 4% however, makes a hard soap. The oil also contains 52 to 62% of oleic, 21 to 25 linoleic, besides palmitic, stearic, and lignoceric acids. The specific gravity is from 0.916 to 0.922, saponification value 189 to 196, and iodine value 83 to 101. The oil known as Arachis oil, or as Katchung oil when imported from the Orient, is from the peanut *A. hypogaea.* It is used in lubricating, for varnishes, and for softening leather. Peanut meal, left after extraction of the oil, is sold as stock feed, or that from the final extraction of the inedible oil is used for fertilizer.

**Peat.** An earthy mass formed by the rapid accumulation of quick-growing mosses and plants, and valued as a fuel in countries where fuels are expensive. Large quantities are used for fuel in Finland, Switzerland, Ireland, and some other countries. In the United States it is used for fertilizer, for insulation, and for packing. The dried Peat moss is used for making insulating board. Peat bogs, or beds, are found mainly in moist districts in temperate climates. The top layers are only slightly decayed, are brown in color, and of low specific gravity. But at greater depths peat is nearly black and is very compact. The reserves of peat are very large in the states bordering on the Great Lakes, those in the state of Minnesota alone being estimated at 7,000 million tons. Fresh peat often contains as high as 80% of moisture and must be dried before use. Wicklow dried peat contains about 71% of volatile matter, 27% being fixed carbon, and 28% coke. The calorific value of peat is about 5,000 B.t.u. It is sometimes semicarbonized and made into fuel briquettes. Charred peat is peat that has been subjected to a temperature to cause partial decomposition. It is marketed as fertilizer. Peat is also distilled, yielding mainly gas and tar.

**Pentaerythritol.** A tetrahydric primary alcohol of the composition $HOH_2C \cdot C(CH_2OH)_3$ produced by the condensation of formaldehyde and acetaldehyde. It is a white, crystalline solid melting at about 262°C. The commercial grade is 85 to 90% pure. It is employed for the production of explosives, plastics, dry-

ing oils, and chemicals. Pentaerythritol will combine with the fatty acids of vegetable oils to form esters that are superior to linseed oil as drying oils. Combined with the fatty acids of linseed oil, it will give a drying oil that will dry completely in 6 hr. compared with 16 hr. for a bodied linseed oil, and as a varnish oil it gives higher gloss and greater water resistance. Synthetic waxes are also made by combining pentaerythritol with long-chain, saturated, fatty acids, and these waxes have higher melting points than beeswax or carnauba wax, but do not have the natural gloss of carnauba. Pentawax 177, of the Heyden Chemical Co., is a pentaerythritol stearate. It is a light-brown wax melting at 53°C., used for coating paper, in printing inks, and in cosmetics. Pentamull 126 of this company is an ester of pentaerythritol and oleic acid. It is an amber-colored oil used as an emulsifying agent. Pentex is a technical grade of pentaerythritol containing 85% mono pentaerythritol and the balance higher polymers. It produces fast-drying and glossy varnishes.

**Pepper.** One of the oldest and most important of the spices. Black pepper, the common household spice, is the ground, dried, unripe fruit of the evergreen shrub or vine, *Piper nigrum* of India and Malaya. There are two grades of Indian pepper, Alleppey and Tellicherry; the latter is bolder and heavier and the more expensive grade. The fruits are small, berrylike drupes. They change in ripening from green to bright red to yellow. When dry the unripe berries are reddish brown or black. The vine comes into full production in 3 years and lives for 20 to 30 years. A vine yields 5 to 10 lb. of pepper. White pepper, preferred for the preparation of commercial foods, is from the nearly ripe berries. It has a yellow to gray color. Pepper is used as a condiment and stimulates the flow of gastric juices. White pepper is not as pungent as black pepper. Commercial pepper is often a blend of the two kinds. Pepper oil, used for flavoring, is a yellowish essential oil of specific gravity 0.873 to 0.916 with a pepperlike odor and flavor but not pungent like pepper. It is extracted from the common pepper berries. Long pepper, highly esteemed in some countries for preserves and curries, is more aromatic and is sweeter. It is from the tiny fruits of the climbing plant *P. retrofractum* of

Malaya and the *P. longum* of India and the East Indies. Ashanti pepper, of West Africa, is from the vine *P. guineense,* also known as Guinea pepper, although this name is applied to Grains of Paradise which are the pungent peppery seeds of the perennial herb *Aframomum melegueta* of West Africa, used for flavoring and in medicine. The seeds are also called Alligator pepper, and Melegueta pepper, and are used as pepper in Europe, but the plant is of the ginger family. Cubeb is the dried unripe fruit of the climbing vine *P. cubeba* of India, East Indies, and West Indies. The berries resemble those of black pepper, but have a strong peculiar odor, and a bitter aromatic taste. Cubeb is used in medicine and cigarettes. Cubeb oil is from the berries, which yield 10 to 16% of the colorless to pale-green oil with a pepperlike odor. It is used in perfumery and in soaps. Paprika is the ground dried fruit of the *Capsicum annum* of Europe and America. When full, red, ripe pods are used, and the seeds, cores, and stems are removed, a uniform maximum red color is produced. Yellow pods give low red value. Paprika is used as a condiment. Chili pepper is from the smaller podlike berries of species of *Capsicum* which grow as small trees or shrubs. It is a tropical plant. The ground fruits as a condiment are known as Red pepper, or Cayenne pepper. In medicine it is known as Capsicum, and is used as a stimulant and carminative and as a source of vitamin P. It is also used in soft drinks in place of ginger.

**Peppermint.** An oil distilled from the perennial herb *Mentha piperita* which grows in the temperate climate of America, Europe, and Asia. The oil has a pleasant odor and a persistent cooling taste and is valued as a flavor and in soaps, toothpastes, perfumes, and pharmaceuticals. The oil contains Menthol, $C_{10}H_{20}O$, which is extracted for use as an antiseptic, in perfumery, and in medicine for colds and as an antispasmotic and anodyne. Japanese peppermint is from the *M. arvensis* grown extensively in Japan, Brazil, and California. The oil is less fragrant and has a bitter taste, and is used for the production of menthol as it has a higher menthol content. The plant is propagated from roots and grows to a height of 2 to 3 ft. It is cut when it blooms and partly cured like hay. The crude oil is obtained by steam distillation; the menthol is ob-

tained by freezing and recrystallization, with a yield of 50% menthol crystals to total crude oil. The residue oil is called Cornmint oil. It retains the peppermint flavor and is used in perfumery and flavoring. Spearmint is from the *M. viridis,* grown largely in Michigan. The oil is sharper in odor and taste and used chiefly in chewing gums. Pennyroyal oil is distilled from the dried leaves and tops of the small annual plant *Hedeoma pulegioides* or *M. pilegium* which grows in Eastern United States. The oil is a counterirritant and is used in liniments. It is also used in insect repellents and for the production of menthol. The plant yields 0.7% of oil, and the oil will yield 65% of menthol with a melting point of 33 to 35°C., or 40% of 42°C. menthol. Horsemint oil is from the plant *M. canadensis,* used for the production of thymol.

**Perfume oils.** Volatile oils obtained by distillation or by solvent extraction from the leaves, flowers, gums, or woods of plant life, although a few are of animal origin. Perfumes have been used since earliest times, not only for aesthetic value, but also for antiseptic value and for religious purposes. Simple perfumes usually take their name from the name of the plant, but the most esteemed perfumes are blends, and the blending is considered a high art. It is done by tones imparted by many ingredients. Some oils with repugnant odors have an attractive fragrance in extreme dilution and a persistence which is valued in blends and for stabilization. Some oils with heavy odors, such as coumarin, are used in dilution to give body. Some odors are never extracted from the flowers, but are compounded. Crab apple, for example, which is a peculiarly sweet odor, is compounded of 16 oils, including bois de rose, ylang ylang, nutmeg oil, jasmine, musk, heliotropin, coumarin, and others. Wisteria, or Glycine, is the honeylike odor of the mauve and white flowers of the climbing plant *Wisteria sinensis.* The oil is never extracted but is compounded from geranium, peru balsam, benzoin, bois de rose, and synthetics. Some oils, such as Lavender, from the flowers of the *Lavandula vera,* have no value when used alone but require skillful blending to develop the pleasant odor. Synthetic perfumes are made from coal-tar products or from other essential oils.

Fixatives are used for the finer perfumes. They are essential oils

that are less volatile and thus delay evaporation. The animal oils, such as musk and civet, are of this class, and also the balsam oils. Some evil-smelling distillates from chemical manufacture may also be used as fixatives. Musk is from the male musk deer of Tibet. It is one of the most expensive of materials. It has not been chemically appraised, and is thus much adulterated. Synthetic musk is as powerful as the natural. The synthetic musk of E. I. duPont de Nemours Co., Inc., is called Astrotone. Ambrette oil has a strong musklike odor distilled from the Musk seed, the seed of the plant *Hibiscus abelmoschus* of India and Egypt. The palmitic acid is removed which then makes a clear liquid. Civet is an odorous yellow fluid from the civet cat of tropical Asia. Patchouli oil is one of the best fixatives for heavy perfumes. It is a powerfully odorous viscous liquid obtained by distilling the fermented leaves of the shrub *Pogostemon patchouli* of India, China, and the Philippines. The odor resembles sandalwood. Cassie is a valuable oil with an odor similar to violet obtained by maceration in oil of the flowers of the shrub *Acacia farnesiana* of the Mediterranean countries and the West Indies. It is used to scent pomades and powders. Another oil with the odor of violets is Orris, from the dried root of the *Iris florentina.* The oil is used to adulterate violet, and the powdered root is used as a basis for violet powder. It is also used as a flavor. Attar of rose is one of the most ancient and popular of perfume oils. The name is derived from the Persian Atar, and is sometimes incorrectly given as Otto or Ottar but with the same pronunciation. The finest attar of rose is from Bulgaria, where it is distilled from the flowers of the Damask rose, *Rosa damascena.* The fresh oil is colorless, but turns yellowish green. About 20,000 lb. of flowers are needed to make 1 lb. of essence, and it is so valuable that it is usually adulterated with geraniol or synthetic rose. In France the oil is obtained from the *R. centifolia.* Rose water is the scented water left after distillation, or is made by dissolving attar in water.

Geranium oil is obtained from the leaves or flowers of the *Pelargonium graveolens* of the Mediterranean countries and other species of geranium. It is used as an adulterant or substitute for rose oils in perfumes and soaps. Many geranium and rose oils are derived from geraniol obtained from citronella and other oils. A syn-

thetic rose-geranium is Diphenyl methane, $(C_6H_5)_2CH_2$, a colorless solid melting at about 25°C. Geraniol is a colorless liquid with a sweet, delicate rose odor. Vetiver, a very sweet-scented oil used in high-grade perfumes and in medicine, is distilled from the roots of the Khuskhus plant *Vetiveria zizanioides* native to India but now grown in other tropic and subtropic countries. Jasmine oil, a highly valued perfume material, is from the fragrant flowers of the shrub *Jasminum grandiflorum,* a species of jasmine grown in southern France especially for perfume. The oil is extracted from the fresh flowers by enfleurage. Mecca balsam, used in oriental types of perfume, is a greenish oleoresin from the plant *Commiphora opobalsamum* of Arabia. It has the odor of rosemary. Rosemary is an oil distilled from the fresh flowering tops of the sweet-smelling evergreen shrub *Rosemarinus officinalis* of the Mediterranean countries. It is used in Eau de cologne, soaps, and in medicine.

Lavender oil, used with rosemary in eau de cologne, and also as Lavender water in a mixture of the oil in water and alcohol, is obtained from the flowers of the shrub *Lavandula officinalis* of southern Europe. The dried flowers are fragrant and are used in sachets. Spike lavender is an inferior oil from the plant *L. latifolia* of France and Spain. It is used in perfumes and sometimes as a food flavor. Bay oil, or Myrcia oil, used in the toilet alcohol known as Bay rum, and also in perfumes, is distilled from the leaves of the bay tree, *Pimenta acris,* of the West Indies, 60 lb. of leaves yielding 1 lb. of oil. It contains a high percentage of eugenol, and has a spicy odor and flavor. Carnation oil is obtained by solvent extraction or by enfleurage from the flowers of the *Dianthus caryophyllus* of which there are more than 2,000 varieties grown in the Mediterranean countries. The less highly cultivated plants give the richest perfumes. Violet oil is derived by solvents or maceration in hot oils from the flowers of the blue and purple varieties of *Viola odorata.* Synthetic violet is made from Ionone derived from lemongrass oil. Ionone is also used for making ascorbic acid. Oak moss was one of the perfumes of ancient Egypt. It is obtained from the lichen *Evernia prunastri* and *E. furfuracea* growing on oak and spruce trees of southern Europe. The resinous extract has the odor of musk and lavender. It is used as a fixative in perfumes of the poppy

type. Rue oil, used for making sweet-pea perfumes, is distilled from the plants *Ruta graveolans* of France and *R. montana* of Algeria.

**Perilla oil.** A light yellow oil obtained from the seeds of the plant *Perilla ocimoides* of China and Japan, and employed as a substitute for linseed oil in varnishes, and in core oils, printing ink, and linoleum. It dries to a harder, tougher, and glossier film than linseed oil. The specific gravity is about 0.935, iodine value 200, and saponification value 191. It contains 41 to 46% of linolenic acid, 31 to 42 linoleic, and 3 to 10 oleic acid. In Japan it is called Egoma oil. Its disadvantage in varnish is its property of forming drops or globules, but this is overcome by boiling or blowing the oil. The blown oil is very rapid-drying and is more weather-resistant than linseed oil.

**Permeability alloys.** A general name for iron-nickel alloys possessing a magnetic susceptibility much greater than iron. An early alloy determined by experiment was made up theoretically of 78.5% of nickel, 21.5 iron, but with other elements approximately as follows: carbon, 0.04%; silicon, 0.03; cobalt, 0.37; copper, 0.10; and manganese, 0.022. It is produced by the Western Electric Co., sometimes with chromium or molybdenum, under the name of Permalloy, and is used in construction of magnetic cores for apparatus that operates on feeble electric currents, and in the loading of submarine cables. It has very little magnetic hysteresis. Another permeability alloy known as Mumetal, of the Telegraph Construction & Maintenance Co., Ltd., has 76% of nickel, 6 copper, and 1.5 chromium. Permafy is a French alloy of this type. It has a lower initial permeability than the plain nickel-iron type, but has a higher resistivity to keep down eddy-current losses. Perminvar, of the Western Electric Co., is an alloy containing 45% of nickel and 25 cobalt, intended to give a constant magnetic permeability for variable magnetic fields. A-metal is a nickel-iron alloy containing 44% of nickel and a small amount of copper. It is used in transformers and loud-speakers to give nondistortion characteristics when magnetized. Permax is a French high-permeability alloy of nickel and iron with small additions of manganese and other elements.

Conpernik, of the Westinghouse Electric Corp., contains equal amounts of nickel and iron with no copper. It is called constant permeability nickel and it has little permeability variation. It differs from Hipernik of the same company only in heat-treatment. When heat-treated, Hipernik has higher and lower loss than silicon transformer steel up to flux density of about 10 kilogausses. Both alloys are used in transformers cores. Hiperco, of this company, is an iron-cobalt alloy with 1 to 2% of other elements. It is ductile and easy to machine, but when annealed it is brittle and the tensile strength is reduced from 80,000 to 25,000 lb. per sq. in. The annealed metal has high permeability and low hysteresis loss. Vicalloy, developed by the Bell Laboratories, is a high-permeability alloy containing 36 to 62% of cobalt, 6 to 16 vanadium, and the balance iron. It is cast and hot-swaged, then drawn into wire or tape as fine as 0.002 in. It retains high permanent magnetism.

Iron-nickel permeability alloys are used as loading by wrapping a continuous layer around the full length of the cable. When nickel-copper alloys are used, they are employed as a core for the cable. Magnetostrictive alloys are iron-nickel alloys which have the characteristic that they will resonate when the frequency of the applied current corresponds to the natural frequency of the alloy. They are used in radios to control the frequency of the oscillating circuit. Temperature compensator alloys are iron-nickel alloys with about 30% of nickel. They have the characteristics that they are fully magnetic at −20°F. but lose the magnetic permeability in proportion to rise in temperature until at about 130°F. they are nonmagnetic. Upon cooling they regain permeability at the same rate. They are used in shunts in electrical instruments to compensate for errors due to temperature changes in the magnets.

**Persimmon wood.** The wood of the common persimmon trees *Diospyros virginiana*, of the Southeastern United States, and the Black persimmon, *D. texana* of western Texas. It is used for shuttles, golf-stick heads, and tools, and takes a fine polish. The tree belongs to the ebony family, of which there are listed about 160 species. The persimmon is a small tree not over 50 ft. high and 12 in. in diameter. The wood is very hard, strong, and compact, and retains its smoothness under long rubbing. The sap-

wood is light brown in color, 2 to 5 in. wide, and the heartwood is black but very small, like a pencil in a 6-in. tree. The weight is 49 lb. per cu. ft. The fruit is cultivated for food, and there are only limited quantities of the wood. A fine wood used for fancy articles is Olive wood, from the olive fruit tree of California. It is yellow with beautifully streaked dark lines.

**Petitgrain.** An essential oil obtained by distillation of the leaves and small twigs of the Bitter orange tree, *Citrus aurantium,* native to tropical Asia, but now grown in other countries. In Spain it is known as the Seville orange. Paraguay is the chief producer of high-grade petitgrain, which is one of the best fixatives for fine perfumes and is also used in flavoring extracts. One pound of petitgrain is obtained from 100 to 150 lb. of leaves. The fruits of the tropical bitter orange are large and of the finest golden appearance, but the pulp is very acid. The juice is used only for blending in orange drinks. The rind is used in Marmalade and Candied orange peel. An essential oil distilled from the rind is known as Curaçao, and is used in perfumery and in Curaçao liqueur. The flowers are very fragrant, and from them Neroli oil is distilled. Neroli is used in perfumery blends and for mixing with synthetic perfumes. Neroli Portugal is inferior, and comes from the sweet orange *C. sinensis* by extraction. Orange oil, obtained by expression from the ripe rind of the sweet orange, is a less valuable oil. Bergamot oil is from the rind of the fruit of the small spiny tree *C. bergamia* of Italy. It has a soft sweet odor, and is used in perfume blends and in soaps. The golden-yellow pear-shaped fruit has an acid inedible pulp.

**Petrolatum.** A jellylike substance obtained in the fractional distillation of petroleum. Its composition is between $C_{17}H_{36}$ and $C_{21}H_{44}$, and it distills off above 303°C. It is also called Petroleum jelly. It is used for lubricating purposes and for compounding with rubber and resins. When highly refined for the pharmacy trade, it is used as an ointment. The specific gravity is from 0.820 to 0.865. It is insoluble in water but readily soluble in benzine and in turpentine. For lubricating purposes it should be refined by filtration only and not with acids, and not adulterated with paraffin. The melting point should be between 115 and 130°F.

Petrolatum of Grade O, used as a softener in rubber, is a pale-yellow, odorless semisolid of specific gravity of 0.84 and melting point of 115 to 118°F. Sherolatum is petrolatum of the Sherwood Petroleum Co., Inc.

**Petroleum.** A heavy liquid, inflammable, mineral oil stored under the surface of the earth, and probably of ancient marine animal origin. It consists chiefly of carbon and hydrogen in the form of hydrocarbons, including most of the liquids of the paraffin series, $C_5H_{12}$ to $C_{16}H_{34}$, together with some of the gases, $CH_4$ to $C_4H_{10}$, and most of the solids of the series from $C_{17}H_{36}$ to $C_{27}H_{56}$. It also contains hydrocarbons of other series; the residue contains sulphur, nitrogen, and oxygen. Petroleums from different localities differ in composition, but tests of oils from all parts of the world give the limits as 83 to 87% of carbon, 11 to 14 hydrogen, with sulphur, nitrogen, and oxygen in amounts from traces to 3%. Mexican and Texan oils are high in sulphur. The crude oil is split by distillation into naphtha, gasoline, kerosene, lubricating oils, paraffin, and asphalt. It may also be split by cracking, that is, by subjecting to violent heating in the absence of air. This process yields a higher proportion of volatile products because of the breaking down of the more complex molecules by the high heat. Liquefied petroleum gases, including Propane, Butane, Pentane, or mixtures, are marketed under pressure in steel cylinders as Bottled gas. Propane, $CH_3CH_2CH_3$, is used in cook stoves. Butane, which has an additional $CH_2$ group, is used to enrich illuminating and heating gas. Propane and butane gases have heating values from 2,800 to 3,000 B.t.u. per cu. ft. Liquid gas is also used for internal-combustion engines, as a solvent, and in the chemical industries as a reacting agent. Pyrogen is the trade name of a gas obtained during the process of recovering gasoline from natural gas. It is marketed in cylinders for use in flame cutting torches. Road oil, used on dirt roads, is a heavy residue oil from the refineries.

White mineral oil is petroleum highly refined to color. Russian and Rumanian oils with high naphthene content were particularly suitable for this refining and the oil was called Russian oil. Pennsylvania paraffin-base oils and Texas asphaltic-base oils are difficult

to refine to color and give high losses. The American White Russian oil is refined from Mid-continent and Gulf coast oils which contain high naphthenes. It is used as a laxative and as a carrier of many drugs. It is also used in wool spinning, and is valued for soluble oils as it is self-emulsifying.

Petroleum from Baku was used from ancient times for lighting purposes, and the Bolivian oil was used in the sixteenth century for burning. The first commercial wells in the United States were opened in 1859 at Titusville, Pa. The chief production of petroleum is in Mexico, United States, Russia, Rumania, Asia Minor, Peru, and northern South America, but large reserves exist in many other places.

**Pewter.** A very old name for tin-lead alloys used for dishes and ornamental articles, but now referring to the use rather than to the composition of the alloy. Tin was the original base metal of the alloy, the ancient Roman pewter having about 70% of tin and 30 of lead, although iron and other elements were present as impurities. Pewter, or Latten ware, of the sixteenth century contained as high as 90% of tin, and a strong and hard English pewter contained 91% of tin and 9 antimony. This alloy is easily cold-rolled and spun, and can be hardened by long annealing at 225°C. and quenching in cold water and tempering at 110°C. Pewter is now likely to contain zinc and antimony, and very much less tin; when the proportion of tin is below about 65%, the alloys are unsuited for vessels to contain food products, because of the separation of the poisonous lead. Antimony as an alloying product is also undesirable in food containers because of its poisonous nature; when the tin is low, antimony is needed to make the metal susceptible to polishing. Best pewter, used for high-class articles, contains 100 parts of tin, 8 antimony, 2 bismuth, and 2 copper. Triple has 83 parts of tin, 17 antimony, or some lead to replace part of the antimony. Pewter should have a peculiar bluish-white luster when polished. It can be spun easily. Pewters containing much lead are dark in color and must be plated.

Britannia metal is a type of latten ware which also usually contains copper. The color is silvery-white with a bluish tinge, or with a yellowish tinge if the copper is high. The ordinary com-

position is quite similar to some babbitts, 89% of tin, 7.5 antimony, and 3.5 copper. It takes a fine polish and does not tarnish easily. It is easily worked by stamping, rolling, or spinning, or may be cast. Some zinc may be used in the casting alloys. English Britannia metal has 94% of tin, 5 antimony, and 1 copper. Hanover white metal contains 87% of tin, 7.5 antimony, and 5.5 copper. Dutch white metal has 81.5% of tin, 8.5 antimony, and 9.5 copper.

Queen's metal is a Britannia metal containing a small amount of zinc. A typical composition is 88.5% of tin, 7 antimony, 3.5 copper, and 1 zinc. The zinc helps to strengthen the alloy. Minofor is another grade containing up to 9% of zinc and up to 1 iron. When zinc is used in these metals, the antimony is lowered because both metals tend to make the alloy brittle. Ashberry metal, for tableware, contains some nickel and aluminum. Tutanic metal, a German utensil alloy, had 88 to 92% of tin, up to 3 copper, and 6 to 7.5 lead. Ludensheid plate had 72% of tin, 24 antimony, and 4 copper, with a trace of lead to increase fluidity. Wagner's alloy and Koeller's alloy were names for utensil alloys, the latter containing some bismuth to improve the casting.

**Phenol.** Also known as Carbolic acid. A colorless to white crystalline substance of sweet odor, having the composition $C_6H_5OH$, obtained from the distillation of coal tar and as a by-product of coke ovens, or made synthetically by various methods. It is used industrially largely for the production of phenol resins used as molding materials. Phenol melts at about 43°C. and boils at 183°C. The pure grades have melting points of 39, 39.5, and 40°C. The technical grades contain 82 to 84% and 90 to 92% phenol. The crystallization point is given as 40.41°C. The specific gravity is 1.066. It dissolves in most organic solvents. By melting the crystals and adding water, liquid phenol is produced, which remains liquid at ordinary temperatures. Phenol has the unusual property of penetration of living tissues and forms a valuable antiseptic. It is thus used industrially in cutting oils and compounds and in tanneries. Santobrite, of the Monsanto Chemical Co., is chlorinated phenol, or Sodium pentachlorophenol, used as a preservative.

**Phenol-formaldehyde resin.** A synthetic resin made by the reaction of phenol and formaldehyde, and employed as a molding material for the making of mechanical and electrical parts. Its high dielectric strength, resistance to acids and alkalies, hardness, and imperviousness to moisture make it suitable for such uses as clock cases, electric switch parts, plating barrels, pump vanes, utensil handles, and ornamental parts. The reaction of the chemicals under heat and pressure produces a product physically resembling a resin but chemically dissimilar. This polymerization process is only partly carried out in the original resinoid, so that the material can be mixed with a filler and molded to form before the final set is given by heat and pressure.

The reaction was known as early as 1872 but was not utilized commercially until much later. A condensation product of 50 parts of phenol and 30 parts of 40% formaldehyde made under English patent of 1905, was called Resinite, and was originally offered as a substitute for celluloid. Various modifications were made by other inventors. Redmanol was one of the first of the American products by the Bakelite Corp. Juvelite was made in Germany by condensing the phenol and formaldehyde with the acid of mineral acids, and Laccain was made under an English patent by using organic acids as catalysts. A Russian phenol resin, under the name of Karbolite, employed an equal amount of Naphthalene-sulphonic acid, $C_{10}H_7SO_3H$, with the formaldehyde.

Phenol-formaldehyde resins are transparent, brittle, soluble in alcohols, but insoluble in water, turpentine, or benzol. They are usually mixed with wood flour or other filler, which makes them less expensive and also more pliable and resistant to fracture. They can be easily dyed to any color, or pigments can be incorporated. The tensile strength of the resinoid is about 7,000 lb. per sq. in. and the specific gravity is 1.27; in the molded product the strength is much higher, depending upon the type and quantity of filler employed. Wood-flour filled material is usually supplied in the form of dry, granular powder for molding. The molded material will not melt at any temperature, but begins to char at about 570°F. It is highly resistant to acids, oils, water, and alkalies. The molding is usually done at 350°F. and 2,000 lb. per sq. in. pressure.

The molded article takes the high finish of the dies. The

specific gravity with wood filler is 1.34 to 1.52, tensile strength 6,000 to 11,000 lb. per sq. in., compressive strength 25,000 to 36,000 lb. per sq. in., and dielectric strength 300 to 500 volts per mil. With mineral fillers the specific gravity is higher, the resistance is greater, the strength is lower. Resinox 6952, of the Monsanto Chemical Co., is a phenolic molding compound with a fine fibrous filler which gives very high impact strength. The molded products have a specific gravity of 1.35, tensile strength of 6,000 to 7,000 lb. per sq. in., and flexural strength of 12,000 to 13,000 lb. per sq. in. Moldarta, of the Westinghouse Electric Corp., is a phenol-formaldehyde molding plastic in natural amber, black, or pigmented colors, with cellulose or mineral fillers. For high-impact molded parts, the filler is in macerated or chopped form which gives strength intermediate between molded and the laminated plastics.

Phenol resins may also be cast and then hardened by heating. The cast resins usually have a higher percentage of formaldehyde and do not have fillers. They are poured in sirupy state in lead molds and hardened in a slow oven. Crystallin, of the Crystallin Products Corp., Opalon, of the Monsanto Chemical Co., and Phenalin, of E. I. duPont de Nemours & Co., Inc., are cast plastics. Catalin, of the American Catalin Corp., is a cast phenol plastic. Prystal is the name of water-clear Catalin, and Bois glacé is Catalin-coated wood for desk tops. Fiberlon is a cast phenol plastic of the Fiberloid Corp. Marblette is a cast plastic of the Marblette Corp.

Laminated plastics are made with paper, linen, or canvas. The kraft paper usually has a 35% impregnation of the resin. Rag paper, linen, and canvas bases have higher impregnations. Rods are made by machining from the molded sheets, which gives parallel cords, or by winding sheet stock on a wire and molding when the wire is withdrawn. Bakelite laminated has a specific gravity of 1.32 to 1.41, hardness 30 to 40 Brinell, compressive strength of 30,000 to 43,000 lb. per sq. in., and dielectric strength 400 to 900 volts per mil. A typical paper-base laminated plastic will have a tensile strength of 12,500 lb. per sq. in., compressive strength 35,000 lb. per sq. in., and dielectric strength 700 volts per mil. A laminated plastic with a fine-weave fabric will have a tensile strength of 9,000 lb. per sq. in., compressive strength 35,000 lb. per sq. in., and dielectric strength 200 to 500. The process of

making all the laminated plastics is much the same. The laminations are cut from materials that have been previously impregnated with a resin varnish and dried. The number of laminations is determined by the thickness of the sheet desired. Heat and pressure are applied to the piled-up laminations in the press to complete the chemical reaction and bind the material into a hard, dense, and insoluble solid. Spauldite is a laminated material of the Spaulding Fibre Co., Inc. The paper-base materials for insulating purposes are made in sheets down to $\frac{1}{64}$ in. in thickness. Dilecto is a laminated material of the Continental-Diamond Fibre Co.

The materials known as Micarta, of the Westinghouse Electric Corp., used for gears and electrical parts, Textolite, of the General Electric Co., Phenolite, of the National Vulcanized Fibre Co., and Formica, of the Formica Insulation Co., are Bakelite laminated, although molders and producers of laminated products do not usually confine themselves to one type of resin, and the same trade name may also indicate other synthetic resins. The variegated designs of Micarta and Formica panels are made by placing the design on paper or fabric as the outside lamination. Formica is also produced with asbestos paper and cloth bases. Fabroc is Bakelite combined with asbestos. Tenazit is the name of Textolite material produced in Germany. Celeron is the name of a group of laminated plastics of the Continental-Diamond Fibre Co. Synthane is a laminated plastic of the Synthane Corp. Haveg, of the Haveg Corp., is a phenol resin containing asbestos fibers. It is acid-resistant and heat-resistant to temperatures up to 265°F.

The phenol-formaldehyde resins are sold under many trade names such as Bakelite, of the Bakelite Corp., and Durez, of the General Plastics Corp., and many in turn are marketed under other trade names by the molders. Makalot, of the Makalot Corp., Colasta, of the Colasta Corp., Reynolite, of the Cutler-Hammer, Inc., Indur, of the Reilly Tar & Chemical Corp., are names for molded products, powders, and laminating varnishes. Phenol resins are used in liquid form for cements, waterproof coatings, and as binders for abrasive wheels. For adhesives the resins are plasticized with gums or natural resins and dissolved in a solvent. The formaldehyde may be replaced in some products to make similar molding

materials with somewhat different characteristics, such as Phenol-furfural and Phenol-hexamine resins. Acrolite is the trade name of a dark-colored resin made by the action of phenol on glycerol. Rockite is a phenol plastic marketed in powder form by F. A. Hughes & Co., Ltd. Other English phenol resins are Tufnol, of Ellison Insulations, Ltd., Dekorit and Leukorit, of Uhlhorn Bros. Some German molding resins are Futurit, Resistan, Faturan, and Herolith. For use in paints and varnishes, the phenol resins are modified with rosin or ester gum, or with other synthetic resins. Amberol, of the Resinous Products & Chemical Co., is a series of modified resins of this type for varnishes and printing inks. Paranol, of the Paramet Chemical Co., and Phenac, of the American Cyanamid & Chemical Corp., are modified resins.

**Phonolite.** Also known as Clinkstone. An aluminum-potassium-silicate mineral used in the production of glass, and in Germany for the production of aluminum. Phonolite is a variety of feldspar. It varies greatly in composition, the best of the Eifel Mountains mineral containing 20 to 23% of alumina, 7 to 9 of $K_2O$, 6 to 8 of $Na_2O$, and 50 to 52 of silica. A variety of this mineral, Nepheline, from the Kola Peninsula, is used in Russia to produce aluminum, with soda and potash as by-products. Nepheline syanite from Peterborough Co., Ontario, Canada, is used in the ceramic industry in pottery, porcelain, and tile to increase translucency and reduce warpage and crazing. From 3 to 5% added to structural clay increases the mechanical strength. As a substitute for potash feldspar in wall tiles, it increases the fluxing action and lowers the fusing point. Agalmatolite, a name derived from the Greek words meaning Image stone, is the massive form of phonolite from which the Chinese carve figures and bas-reliefs. It has a soft greasy feel, and varies in color.

**Phosgene.** The common name for Carbonyl chloride, $COCl_2$, a colorless, poisonous gas made by the action of chlorine on carbon monoxide. It was used as a poison war gas, called D-stoff by the Germans and Collongite by the French. But it is also used in the manufacture of metal chlorides and anhydrides, pharmaceuticals, perfumes, and other chemicals. It liquefies at 8.2°C., and solidifies at −118°C. It is decomposed by water. When chloroform is

exposed to light and air, it decomposes into phosgene. One part in 10,000 parts of air is a toxic poison. For chemical warfare it is compressed into a liquid in shells. Lacrimite, also a poison war gas, is thiophosgene mixed with stannic chloride. Diphosgene, $ClCOOC \cdot Cl_3$, called Green cross, Superpalite, and Perstoff, is an oily liquid boiling at 128°C. It is an intense lachrymator, has an asphyxiating odor, and is a lung irritant.

**Phosphor bronze.** Originally called Steel bronze when first produced at the Royal Arsenal in Vienna. It was 92-8 bronze deoxidized with phosphorus and cast in an iron mold. It is now any bronze deoxidized by the addition of phosphorus to the molten metal. It may or may not contain residual phosphorus in the final state. Ordinary bronze frequently contains cuprous oxide formed by the oxidation of the copper during fusion. By the addition of phosphorus, which is a powerful reducing agent, a complete reduction of the oxide takes place, and the resulting bronze has higher strength. Phosphor bronze is not usually a special alloy but is a deoxidized bronze, and all grades of bronze can be converted into it. But when there is residual phosphorus in the metal, the bronze is harder. Phosphor-bronze casting metals for bearings usually contain lead. A.S.T.M. Grade B phosphor bronze has 4.0 to 5.5% of tin, 2.5 to 4 lead, and 0.03 to 0.25 phosphorus. A foundry alloy known as Standard phosphor bronze contains about 80% of copper, 10 tin, and 10 lead, with about 0.25 phosphorus. When chill-cast, it is fine-grained and has a tensile strength up to 33,000 lb. per sq. in., Brinell hardness of 65, and weight of 0.325 lb. per cu. in. One large automotive company lists this metal as Phosphor casting bronze. The phosphor-bronze ingot metal of this composition marketed by H. Kramer & Co. contains 0.50 to 1% of phosphorus, part of which is absorbed in the melting and casting. The residual phosphorus is 0.25%.

Anaconda phosphor bronze, a wrought metal marketed by the American Brass Co., is in grades containing from 5 to 10% of tin and 90 to 95 copper. The 90-10 grade for springs has high resistance to fatigue. Seymour phosphor bronze, of the Seymour Mfg. Co., used for springs, has 95% of copper, 4.75 tin, and 0.25 phosphorus. Carobronze, of the Wrought Bearing Metals, Inc.,

has 91.2% of copper, 8.5 tin, and 0.3 phosphorus. It is produced in hard-drawn tubes and rods to give greater wear resistance and higher impact value than cast bronze for bearings. Corvic bronze, of the Chase Brass & Copper Co., has 98.5% of copper, 1.5 tin, and 0.30 phosphorus. The tensile strength of the spring material is 95,000 lb. per sq. in., and the electrical conductivity is 42% that of copper. Telnic bronze of this company contains 1% of nickel, 0.20 phosphorus, 0.5 tellurium, and the balance copper. Anaconda special phosphor bronze, used for screw-machine parts, contains 88% of copper, 4 tin, 4 zinc, and 4 lead. It is free-cutting and has high strength. Hard-drawn phosphor-bronze wire may have a tensile strength exceeding 120,000 lb. per sq. in. White phosphor bronze, for bearings, contains 72% of lead, 12 antimony, 15 phosphor tin, and 1 copper.

**Phosphor copper.** An alloy of phosphorus and copper, used instead of pure phosphorus for deoxidizing brass and bronze alloys, and for adding phosphorus in making phosphor bronze. It comes in 5, 10, and 15% grades and is added directly to the molten metal. It serves as a powerful deoxidizer, and the phosphorus also hardens the bronze. Phosphor copper is made by forcing cakes of phosphorus into molten copper and holding under until the reaction ceases. Phosphorus is soluble in copper up to 8.27%, forming $Cu_3P$, which has a melting point of 707°C. A 10% phosphor copper melts at 850°C., and a 15% at 1022°C. Alloys richer than 15% are unstable. Phosphor copper is marketed in notched slabs or in shot. In Germany Phosphor zinc is used as a substitute to conserve copper. Metallophos is a name for German phosphor zinc containing 20 to 30% of phosphorus. The name phosphor copper is also applied to commercial copper deoxidized with phosphorus and retaining up to 0.50% of phosphorus. The electrical conductivity is reduced about 30%, but the copper is hardened and strengthened. Phosphor tin is a master alloy of tin and phosphorus used for adding to molten bronze in the making of phosphor bronze. It usually contains up to 5% of phosphorus and should not contain lead. It has an appearance like antimony, with large glittering crystals, and is marketed in slabs. Federal specifications call for 3.5% of phosphorus, with not over 0.50% of impurities.

**Phosphoric acid.** Also known as Orthophosphoric acid. A colorless, sirupy liquid of the composition $H_3PO_4$ used for pickling and rustproofing metals, for the manufacture of phosphates, pyrotechnics and fertilizers, as a latex coagulent, as a textile mordant, as an acidulating agent in jellies and beverages, and as a clarifying agent in sugar sirup. The specific gravity is 1.834, melting point 42.35°C., and it is soluble in water. The usual grades are 90, 85, 75%, technical 50%, and dilute 10%.

**Phosphorus.** A nonmetallic element, symbol P, widely diffused in nature, and found in many rock materials, in ores, in the soil, and in parts of animal organisms. Commercial phosphorus is obtained from phosphate rock by reduction in the electric furnace with carbon, or from bones by burning and treating with sulphuric acid. Phosphate rock occurs in the form of land pebbles and as hard rock. It is plentiful in the Bone Valley area of Florida, and also comes from Tennessee and some other states. Vast quantities are mined in northwest Africa. It is a calcium phosphate high in $P_2O_5$. The mineral Apatite, from Virginia, Brazil, and French Oceania, is also a source of phosphorus, containing up to 20% of $P_2O_5$, with iron oxide and lime. The Egyptian rock contains 62 to 70% of tricalcium phosphate. The Superphosphate used for fertilizers is made by treating phosphate minerals with concentrated sulphuric acid. It is not a simple compound, but may be a mixture of Calcium acid phosphate, $CaHPO_4$, and calcium sulphate. Phosphorus is important in foundry work because of its property of combining and greatly modifying the characteristics of metals, and because of its deoxidizing power, especially in nonferrous metals. It is added to the latter in the form of phosphor copper or phosphor tin. Small amounts in steel increase the strength and resistance to corrosion and also decrease the tendency of steel sheets to stick together. But larger amounts promote cold-shortness in the steel.

There are two forms of phosphorus, yellow and red. The former, also called White phosphorus, $P_4$, is a light-yellow waxlike solid, phosphorescent in the dark and exceedingly poisonous. Its specific gravity is 1.83 and melts at 44°C. It is used for smoke screens in warfare and for rat poisons and matches. Yellow phos-

phorus is produced directly from phosphate rock in the electric furnace. It is cast in cakes of 1 to 3 lb. each. Red phosphorus is a reddish-brown amorphous powder, having a specific gravity of 2.296 and a melting point of 725°C. Both forms ignite easily. Phosphorus sulphide, $P_4S_3$, may be used instead of white phosphorus in making matches. Phosphoric oxide, $P_2O_5$, is used as an opalizer in glass. Phosphorus is an essential element in the human body, a normal adult person having about 1.4 lb. of it in the system. Flour and other foodstuffs are fortified with Ferric phosphate, $FePO_4 \cdot 2H_2O$. Tricalcium phosphate, $Ca_3(PO_4)_2$, is used as an anticaking agent in salt, sugar, and other food products and to provide a source of phosphorus.

**Phthalic anhydride.** A white, crystalline material of the composition $C_6H_4(CO)_2O$, with a melting point of 130.8°C., soluble in water and in alcohol. It is made by oxidizing naphthalene, and is used as a plasticizer in synthetic resins and in the manufacture of alkyd resins. Chlorinated phthalic anhydride is also used as a compounding medium in plastics. It is a white, odorless, nonhygroscopic stable powder containing 50% chlorine. It gives higher temperature resistance and increased stability to plastics. Niagathal is a chlorinated phthalic anhydride of the Niagara Alkali Co. Maleic anhydride, $(CHCO)_2O$, is a white crystalline solid used to replace phthalic anhydride in alkyd resins to increase the hardness for baking enamels and to resist yellowing. Azelaic acid is a strong organic acid, $COOH(CH_2)_7COOH$, used as a substitute for phthalic anhydride to react with glycerin to form alkyd resins less hard and brittle than those made with phthalic anhydride. It melts at 96°C., and is soluble in hot water.

**Piassava.** Also called Para grass and Monkey grass. A coarse, stiff, and elastic fiber obtained from a species of palm tree, *Leopoldinia piassaba,* of Brazil, used for making brushes and brooms. The plant has long beards of bristlelike fibers, which are combed out and cut off the young plants. These fibers sometimes reach a length of 4 ft. The long, finer fibers are made into cordage, and the coarser ones are used for brushes. Piassava is very resistant to water. The fiber for brush manufacture is separated into three classes; the heavy fibers being known as Bass, the medium as

Bassine, and the fine as Palmyra. The bass is used for heavy floor sweeps. The fiber of the palm *Attalea funifera* which grows in the state of Bahia, Brazil, and is also called piassava, is a harder and stronger material than the piassava of Amazonas. It is used for marine cordage, and is resistant to salt water. A substitute for piassava is Acury, from the leaves of the palm *A. phalerata* of Matto Grosso. It is used for cordage and brushes, and the coarser fibers are used for brooms.

Pickling acids. Acids used for pickling, or cleaning castings or metal articles. The common pickling bath for iron and steel is composed of a solution of sulphuric acid and water, 1 part acid to from 5 to 10 parts of water being used. This acid attacks the metal and cleans it of the oxides and sand by loosening them. For pickling scale from stainless steels a 25% cold solution of hydrochloric or sulphuric acid is used, or hydrofluoric acid with the addition of anhydrous ferric sulphate is used. Hydrofluoric acid solutions are sometimes used for pickling iron castings. This acid attacks and dissolves away the sand itself. For cleaning brass a mixture of sulphuric acid and nitric acid, in the ratio 3 : 2, is used. But copper and copper alloys can be pickled with sulphuric acid to which anhydrous ferric sulphate is added to speed the action. Brass forgings are pickled in nitric acid to bring out the color. Since all of these acids form salts rapidly by the chemical action with the metal, they must be renewed with frequent additions of fresh acid.

The temperature of most pickling solutions is from 140 to 180°F. An increase of 20°F. will double the rate of pickling. Acid brittleness after pickling is due to the absorption of hydrogen when the acid acts on iron, and is reduced by shortening the pickling time. Inhibitors are chemicals added to reduce the time of pickling by permitting higher temperatures and stronger solutions without hydrogen absorption. Pennsalt FA-42, of the Pennsylvania Salt Mfg. Co., is a 42% solution of Fluoboric acid, $HBF_4$, used for pickling and also to control the acidity of plating baths. It is a colorless liquid with a specific gravity of 1.33. Phosphoric acid is employed in hot solution as a dip bath for steel parts to be finished to a rough or etched surface. A basic iron phosphate

coating is produced on the steel, which is resistant to corrosion and gives a rough base for the finish. Coslettised steel is steel rustproofed by dipping in a hot solution of iron phosphate and phosphoric acid. Parkerized steel is rustproofed steel treated in a bath of iron and manganese phosphates. Bonderized steel is steel treated with phosphoric acid and a catalyst to give a rough, tough, rust-resistant base for paints. Granodized steel is produced with zinc phosphate.

**Pig iron.** The iron produced from the first smelting of the ore. The melt of the blast furnace is run off into rectangular molds, forming, when cold, ingots called pigs. Pig iron contains small percentages of silicon, sulphur, manganese, and phosphorus, besides carbon. It is useful only for resmelting to make cast iron or wrought iron. Pig iron is either sand-cast or machine-cast. The former has sand adhering and fused into the surface, giving more slag in the melting. Machine cast is cast in steel forms, has a fine-grained chilled structure, with lower melting point. Pig irons are classified as Bessemer or nonbessemer, according to whether the phosphorus content is below or above 0.10%. There are six general grades of pig iron: Low phosphorus, with less than 0.03%, used for making steel for steel castings and for crucible steel making; bessemer, with less than 0.10% of phosphorus, used for bessemer steel and for acid open-hearth steel; Malleable, with less than 0.20%, used for making malleable iron; Foundry, with from 0.5 to 1%, for cast iron; Basic, with less than 1%, and low silicon, less than 1%, for basic open-hearth steel; and basic bessemer, with from 2 to 3%, used for making steel by the basic bessemer process employed in England.

About two-thirds of all pig iron produced in the United States is basic. Since silicon is likely to dissolve the basic furnace lining, it is kept as low as possible, 0.70 to 0.90%, with sulphur not usually over 0.095%. Pig irons are also specified on the content of other elements, especially sulphur. The sulphur may be from 0.04 to 0.10%, but high-sulphur pig iron cannot be used for the best castings. The manganese content is usually from 0.60 to 1%. Most of the iron for steelmaking is now not cast but is carried directly to the steel mill in car ladles. It is called Direct metal.

Foundry pig iron is graded by the silicon content, No. 1 having from 2.5 to 3%, and No. 3 from 1.5 to 2% of silicon. Silvery iron is a name for pig iron of high silicon content because of its silvery fracture. Puddling iron is a grade of pig iron used for making wrought or puddled iron in a puddling furnace. A requirement is that the silicon be low, with manganese 0.5 to 1%.

Chateaugay iron is a low-phosphorus pig iron produced from New York state magnetite ore. The original ore as mined contains about 28% iron. The standard analysis of the pig iron is total carbon 4%, silicon 0.75 to 4.0, sulphur 0.03 max., phosphorus 0.03 max., manganese 0.10 to 0.15. Chateaugay iron is used for casting rolls, gears, and machine parts. Norskalloy is a name for pig iron produced from Norwegian ores containing vanadium and titanium. The standard grade contains from 4 to 4.5% of total carbon, 0.5 to 1.5 silicon, 0.20 manganese, 0.20 to 0.25 phosphorus, 0.30 to 0.40 vanadium, and 0.40 to 0.80 titanium. From 15 to 20% of Norskalloy pig is added to mixtures where vanadium is required. Mayari iron is pig iron made from Cuban ores which contain vanadium and titanium, or is pig iron made to duplicate the Cuban iron. These irons are considered especially suitable for heavy rolls or high-grade castings. Mayari pig, as marketed by the Bethlehem Steel Co., contains 1.60 to 2.50% of chromium, 0.80 to 1.25 nickel, 0.25 to 2.25 silicon, 0.10 to 0.20 titanium, 0.05 to 0.08 vanadium, 3.8 to 4.5 total carbon, 0.60 to 2 manganese, under 0.05 sulphur, and under 0.10 phosphorus. Nikrofer is a name used in Germany for pig iron from Greek ore similar in composition.

**Pigment.** A substance, usually earthy or clayey, which when mixed with oil or other solvent forms a paint. Pigments usually give body as well as color to the paint. The hiding power is measured by comparison tests when in the form of a mixed paint. A pigment is distinct from a filler in that it must retain its opacity when wet. White powdered quartz, used sometimes as a filler, is not a good pigment as it becomes glassy when wet. Fillers that retain their opacity are called Extenders, or Auxiliary pigments, and the final mixed pigment is called a Reduced color. Pigments are mostly of mineral origin, the vegetable pigments such as log-

wood, and the animal pigments such as cochineal, being ordinarily classified as dyestuffs. Bone black, however, is an example of an animal pigment, and vine black is typical vegetable pigment. Pigments are also produced by dyeing clays with aniline dyestuffs. These are called Lakes. Dutch yellow, for example, is a Yellow lake prepared by absorbing a yellow dye such as quercitron on an inert material such as calcium carbonate. Various chemicals such as copper acetate and potassium acetate are used as pigments. Potassium acetate, $CH_3COOK$, is a white powder also used in making crystal glass.

Natural pigments include ochre, umber, ground shale, hematite, and sienna. The red-ochre pigments are the natural red iron oxides of high oxide content. The yellows, or siennas, are the oxides mixed with considerable clay. The browns, or umbers, have manganese present in the clays. Terre verte, or Verona green, of Cyprus, is a fine blue-green earth valued highly in the Middle Ages as a pigment. It contains 53% of silica, 26 ferric oxide, 16 potash, and some magnesia, manganese, and other metals. Manganese green, or Cassel's green, is Barium manganate, $BaMnO_4$, a green poisonous powder of specific gravity 4.85, insoluble in water. Mineral green, or Scheele's green, is Copper arsenite, $CuHAsO_3$. It is a light-green amorphous powder used in paints and in textile printing. It is also used in medicine. Orange pigments, from yellow to brilliant red, with high tinting strength and great fastness, are made with mixtures of Lead chromate, $PbCrO_4$, Lead molybdate, $PbMoO_4$, and Lead sulphate, $PbSO_4$. Gloss white, used as a reduced-color white pigment, and for surface-coating pulp papers and in printing inks, is a coprecipitation product consisting of 75% of blanc fixe and 25 aluminum hydrate.

The most important yellow is Chrome yellow, but it fades easily. Yellow ochre is inferior as a color but is more durable. Cadmium yellow is permanent and brilliant but expensive. It is Cadmium sulphide, CdS, used for either oil or water paints. The yellow pigment called Mosaic gold, or Artificial gold, is Stannic sulphide, $SnS_2$, used in gilding and bronzing paints. Cadmium red and Cadmium orange are produced by calcining selenium with cadmium sulphide. These cadmium sulpho-selenide pigments give brilliant colors. Cadmium pigments are used in Camouflage paints

to give greater reflection of infrared rays. A building painted with a green containing cadmium has the same reflection as grass or leaves, and is indistinguishable in aerial photographs. An ancient lemon-brown pigment is Bistre. It was obtained from the collected chimney soot of wood fires, and was much used by the old masters. It is very durable in water colors. The most important green is Chrome green, which is chrome yellow mixed with Prussian blue. The latter is ferrocyanide of iron, giving a good color but not permanence. Ultramarine is the most important blue. Cobalt blue is a good color but is expensive. Vermilion is mercury sulphide, which gives a fine color and is permanent, but it is expensive. High-grade blacks are usually lampblack, bone black, and ivory black, but may be adulterated with graphite. Spanish black is a name used in old texts for the black pigment made by burning cork. It is light and of soft texture. Mineral black, or Slate black, is made by grinding black slate. Metronite is a white mineral composed of magnesium and calcium carbonates and magnesium silicate, used as a paint filler and extender.

A reactive Fungicidal pigment used in ship paints and antifouling paints is Cupric oxide hydrated, a fine dark-brown powder of the composition $4CuO \cdot H_2O$. A yellow pigment used in anticorrosive and blister-resistant metal primers is Zinc tetroxy chromate, $4Zn(OH)_2 \cdot ZnCrO_4$. The pigment known as Plessy's green is Chromium phosphate, $CrPO_4$, a bluish-green powder insoluble in water. Pigments should be ground fine enough so that all of the powder will pass through a 325-mesh screen. Pearl essence, used in lacquers, in synthetic molding materials, and for making Imitation pearls is a motley-silver substance deposited on the scales of many species of fish. It is extracted and freed of foreign matter. It gives lacquers high luminosity and iridescence.

**Pine.** The wood of coniferous trees of the genus *Pinus,* of which there are 37 species in the United States. The White pine, or Northern white pine, *P. strobus,* grows widely in Canada and in the Northeastern United States. The trees are 80 to 100 ft. high, with trunks 3 to 9 ft. in diameter, reaching full size in 80 years. The wood is soft, straight-grained, and free from rosin. The heartwood is light brown, and the sapwood white. It is the

chief wood for patternmaking and is also extensively used for cabinetwork and general carpentry. Cork pine is a name for the clear, soft, white pieces used for patterns. Yellow pine is a name for the wood of the Longleaf, or Longstraw pine tree, *P. palustris,* of the Southeastern states, and Shortleaf pine, *P. echinata,* of the Southeast and Middle Western states, also called North Carolina pine and Rosemary pine. The leaves, called needles or straws, of the longleaf pine are up to 18 in. in length. The Longleaf pine tree furnishes the best grades of yellow pine and also is the chief source of turpentine. It is also called Georgia pine, Southern pine, Hard pine, and Hill pine.

Slash pine, also known as Cuban pine and Swamp pine, from the tree *P. heterophylla,* or *P. caribaea,* Caribbean pine, growing along the Southern coasts of the United States and the Caribbean countries, is also a yellow pine. It is one of the most rapidly growing forest trees in the United States and produces one of the heaviest, hardest, and strongest of all the conifer or soft woods. In Central America it is called Ocoté. Slash pine is next to longleaf pine as a source of turpentine and rosin. As heartwood does not develop until the tree is 20 or more years old, slash pine forms a valuable source of paper pulp. The term Arkansas pine in the lumber trade includes mixtures of shortleaf, longleaf, slash, loblolly, and pond pines. Lodgepole pine, *P. contorta,* is from a small slow-growing tree of Western United States, Canada, and Alaska. It is also called Knotty pine, Scrub pine, and Jack pine. The wood is moderately lightweight, light yellow to brown in color, with a narrow white sapwood. It is straight-grained with resin ducts, and has large shrinkage. It is used for poles, ties, mine timbers, and rough construction.

Ponderosa pine, also called Western yellow pine, Western white pine, and Oregon white pine, is from the tree *P. ponderosa.* The tree grows to a height of 175 ft. and a diameter of 6 ft. It grows throughout the Mountain states from Mexico to Canada, and is also a source of turpentine and rosin. A similar western pine, Jeffrey pine, *P. jeffreyi,* contains Heptane instead of turpentine in the oleoresin, and is a more economic source of this material than petroleum. The lumber is usually mixed with ponderosa pine and sold as such. It is a moderately soft and lightweight wood with the

heartwood light reddish brown, and quite similar to yellow pine. Loblolly pine, *P. taeda,* is called North Carolina pine, Oldfield pine, and Sap pine. It grows from Virginia to northern Florida and to Texas and is adapted to extensive areas and is easily propagated, receiving the name of Field pine. It is a type of shortleaf pine distinguished by three leaves or straws in each cluster, rough bark, and small prickly burrs. It grows to a diameter of 12 in. in 12 years. Pitch pine is the Pond pine, *P. rigida,* of the Southern states, but all yellow pines are called pitch pine in the export trade. Norway pine, of the North Central states, is *P. resinosa.* The yellow pines are harder and more difficult to work than white pine. They are resinous and more durable. They also take a better polish and show a more figured grain. They are valued for flooring and for general construction. White pine has a specific gravity, kiln-dried, of 0.38, and compressive strength perpendicular to the grain of 780 lb. per sq. in.; Western white pine, *P. monticola,* has a specific gravity of 0.42 and a compressive strength of 750 lb. per sq. in. Deal is a European name for the wood of the tree *P. sylvestris,* also known as Danzig pine, Baltic pine, Scotch fir, Scotch pine, and Northern pine. Paraná pine is a soft, yellowish-white wood with rose veins from the tree *Araucaria brasiliensis* of southern Brazil. In Argentina it competes with American softwoods and is called Brazilian pine and Araucanian pine. The specific gravity is 0.865. The tree is very tall, with branches only at the top. Other species of Araucanian pine, or Antarctic pine, grow in southern Chile and Argentina. Araucaria oil is distilled from the wood. It is a viscous reddish oil of roselike odor containing a high percentage of eudeomol and some geraniol. It has a more durable scent than guaiac wood oil for soaps.

The araucanian pines of New Guinea, *A. khinkii* and *A. cunninghamia,* are called Hoop pine. New Caledonia pine is from the tree *A. cooki,* growing to a height of 200 ft. with no lower branches. White pine of New Zealand is from the very large tree *Podocarpus dacrydioides,* called also Kahikatea. The sapwood is white, and the small heartwood is yellow. The wood is straight-grained, inodorous, easily worked, but not durable. It weighs 29 lb. per cu. ft. It is used for boxes, crates, and packing. Another species, from the tree *P. ferrugineus,* called Miro, is brownish

in color, fine-grained, easily worked, and has high strength. The trees average 65 ft. in height and 20 in. in diameter. The New Zealand species known as Black pine, or Matai, is from the *P. spicatus*. The wood is yellowish brown, straight-grained, and weighs 38 lb. per cu. ft. Red pine, or Rimu, is the chief timber of New Zealand, used for furniture, mill work, and kraft pulp. The tree *Dacrydium cupressinum* averages 100 ft. in height and 30 in. in diameter. The wood is reddish brown with streaks, straight-grained, easily worked, and weighs 37 lb. per cu. ft. Silver pine, Pink pine, and Yellow silver pine of New Zealand are from several other species of *Dacrydium* obtained only in limited amounts. The name silver is applied to the shiny white woods, and the darker and mottled woods are called pink. They are very durable cypress-like woods. Mercus pine is the wood of the tropical pine tree, *Pinus merkusii,* of the East Indies, India, and the Philippines. It is called Tinyu pine in India and Mindoro pine in the Philippines. The wood is used in general construction. The tree yields a superior type of turpentine.

**Pine oil.** An oil obtained from the wood of the *Pinus palustris,* or longleaf pine, in the steam extraction of wood turpentine. It is used as a cold solvent for varnish gums and for nitrocellulose lacquers. In paints and varnishes it aids dispersion of metallic pigments and improves the flow. It is also used in metal polishes and in liquid and powder scrubbing soaps, as the oil is a powerful solvent of dirt and grease. When free from water, pine oil has a yellowish color but is water-white when it contains dissolved water. It has an aromatic characteristic odor, and is distinct from the pine oils distilled from pine leaves and needles and used in medicine. The distillate of the gum of the Jeffrey and Digger pines of California, called Abietine in medicine, contains 96% heptane and is used as a cleaning agent and insecticide, and as a constituent of standard gasolines for measuring detonation of engines. Pine oil is obtained mainly from old trunks and branches, and is a product formed by hydrolysis. Pine-oil disinfectants are made with steam-distilled pine oil. Yarmor is the trade name of the Hercules Powder Co. for highly refined pine oil used in soaps, paper coating, marine paints, and as a wetting agent. Hercosol is a solvent made from

pine oil by the same company. Synthetic pine oil made from gum turpentine by this company has a mild pine odor, a specific gravity of 0.9186, and flash point of 154°F. It is technically the same as the natural and has the same uses. The edible Pine kernels of Europe are the seeds from the large cones of the *P. pinea* of southern Europe and Cyprus. Pine-needle oil is distilled from the Siberian fir tree, *Abies sibirica,* of northeastern Russia. It is also known as Siberian pine oil. It contains a high percentage of Bornyl acetate and is used in soaps and perfumes.

**Plane wood.** The wood of the plane tree, *Platanus orientalis,* native to Europe, and *P. occidentalis,* of North America. The latter species is also called Buttonwood and Buttonball. It is a yellowish, compact wood with a fine, open grain. The weight is about 40 lb. per cu. ft. It resembles maple and gives a beautiful grain when quartered. It is employed in cabinetwork.

**Plastic bronze.** A name applied by makers of bearing bronzes to copper alloys that are sufficiently plastic to assume the shape of the shaft and make a good bearing by running in. These bronzes have a variety of compositions, but the plasticity is always obtained by the addition of lead, which in turn weakens the bearing. In some cases the lead content is so high, and the tin content so low, that the alloy is not a bronze. These copper-lead alloys are referred to as Red metals. The Plastic bronze ingot marketed by one large foundry for journal bearings contains 65 to 75% of copper, 5 to 7 tin, and the balance lead. Semiplastic bronze usually contains above 75% of copper and not more than 15 lead. A.S.T.M. alloy No. 7 has about 10% of lead, 10 tin, 1 zinc, 1 antimony, and 78 copper. The compressive strength is 12,500 lb. per sq. in.

**Plastic wood.** Wood cellulose dissolved in ether or other solvent, used for filling or for building up small sections. It hardens on evaporation of the solvent and can be cut, polished, and painted, but has the disadvantage that it shrinks on setting. It may also consist of cellulose nitrate and a plasticizing agent dissolved in acetone or ethyl acetate and mixed with wood flour. One commercial plastic wood is a mixture of a solution of polyvinyl acetate and wood flour. Plastipaste, of the Duorite Plastic Indus-

tries, has a binder of phenolic resin and an accelerator which cures the material in a short time. The cured material is light in weight, with specific gravity of 1.05, and has a compressive strength of 12,000 lb. per sq. in. and flexural strength of 3,000 lb. per sq. in. It machines like wood, and gives a smooth finish. The fillers with plastic binders do not shrink greatly.

**Plate glass.** Any glass that has been cast or rolled into a sheet, and then ground and polished. But the good grades of plate glass are, next to optical glass, the most carefully prepared and the most perfect of all the commercial glasses. It generally contains slightly less calcium oxide and slightly more sodium oxide than window glass, and small quantities of iron and aluminum oxides may also be present as impurities. The glass is melted in open pots. The melting and refining take about 20 hr., and the glass is then poured on the casting table at 1000°C. The roller is drawn over the plastic glass. After annealing, the sheets are set in plaster of paris on a circular rotating table and ground with iron blocks and sand. Plate glass is now made on a large scale on continuous machines. Herculite is a glass of the Pittsburgh Plate Glass Co. which will withstand temperatures up to 650°F. without cracking. Carrara Structural glass of this company is made like plate glass and ground to true plane surfaces. It is made in many colors in thicknesses from $^{11}/_{32}$ to 1½ in., or laminated to give various color effects. It is used for store fronts, counter tops, bathrooms and kitchen tiling and paneling, shelving, and partitions. The weight of the $^{11}/_{32}$ in. is 4.5 lb. per sq. ft. It does not craze, check, or stain like tile.

**Platinum.** A whitish-gray metal, symbol Pt. It is more ductile than silver, gold, or copper, and is heavier than gold. The melting point is 3190°F., and the specific gravity is 21.40. The hardness of the annealed metal is 47 Brinell and tensile strength 42,000 lb. per sq. in.; when hard-rolled the Brinell hardness is 90 and tensile strength 54,000 lb. per sq. in. It is very ductile and malleable. It resists the action of alkalies and most acids, dissolving only in hot aqua regia. Platinum occurs native in small flat grains or pebbles, usually alloyed with iridium, rhodium, palladium, osmium, and ruthenium. The largest nugget ever found

came from South America and weighed 2 lb. It is also found in the mineral sperrylite. The chief sources are Russia and Colombia, with smaller amounts from Alaska, Canada, and South Africa. The Russian platinum is refined 99.80 to 99.90% pure, with 0.05 to 0.10% of iridium. The rare mineral sperrylite is found in Wyoming and in Ontario, Canada. It is a Platinum arsenide, $PtAs_2$, found in small grains of a tin-white, metallic luster.

Platinum is employed for electric contact points for currents less than 4 amp., for resistance wires, thermocouple wires, standard weights, and for vessels for laboratory use. It is also used in jewelry. It is too soft for use alone, however, and is almost always alloyed with harder metals of the same group, such as iridium and osmium. An important use of the metal is in the form of gauze as a catalyst in chemical reactions, usually alloyed with 10% of rhodium, but for this purpose vanadium and rhodium can be substituted. Platinum is sold by the troy ounce, 1 cu. in. of the metal weighing 11.28 troy oz.

**Platinum-iridium alloys.** The most widely used of the platinum alloys. They are employed for instruments, magneto contacts, and jewelry. The alloys are hard and tough and are noncorrosive. An alloy of 5% of iridium and 95 of platinum, when hard-worked, has a Brinell hardness of 170; an alloy containing 30% of iridium has a hardness of 400. The 5 and 10% alloys are used for jewelry manufacture; the 25 and 30% alloys are employed for making surgical instruments. An alloy of 80% of platinum and 20 iridium is used for magneto contact points, and the 90-10 alloy is widely used for electrical contacts in industrial control devices. The addition of iridium does not alter the color of the platinum. The 5% alloy dissolves readily in aqua regia; the 30% alloy dissolves slowly.

**Plush.** A general name for fabrics woven of cotton, silk, linen, or wool, having a pile deeper than that of velvet. It is used for upholstery. Originally the pile of plush consisted of mohair or worsted yarns, but there is now no distinction except in the length of the pile. Upholstery plush is made in brocade designs by burning the pile with rollers to form a lower background. Plush is also dyed and curled to imitate furs.

**Plywood.** A laminated wood made up of one or more sheets of soft wood with thin sheets of more expensive hardwood glued on the outside. The outside sheets are known as Veneer, but this term is applied also to very thin wood sheets for other purposes. Laminated woods were originally developed to increase artistic appeal of furniture by gluing figured woods to ordinary woods with the veneers matched to give artistic effects. Plywood is always built up in odd numbers of layers, and the grains of successive layers are set at right angles. This arrangement gives tensile and compressive strength in all directions and also symmetrical shrinkage stresses. The strength depends largely on the glue. The cheaper types of plywood are bonded with tapioca paste or with casein glue. A blood-albumin glue gives a strength of 370 lb. per sq. in. Plywood bonded with synthetic plastics is strong and waterproof, and some of these have strength-weights factors higher than alloy steels. They are used for aircraft panels, car siding, portable houses, and general construction. Wherever high strength and water resistance are needed the plastic-bonded plywoods have replaced the glue-bonded materials. The plastic-bonded plywoods, in which the plastic is used only to bond the layers, are not classed with the hard boards and sheets in which the laminations of wood are impregnated with resin and the whole cured into a solid sheet. These latter are classed with the laminated plastics.

Compreg, developed by the Forest Products Laboratory, consists of many layers of $\frac{1}{16}$-in., rotary-cut, yellow-birch plies bonded with about 30% resin under a pressure of 600 to 1,500 lb. per sq. in. The specific gravity is 1.22 to 1.37, and the tensile strength 43,000 to 54,000 lb. per sq. in., depending upon the resin and the molding pressure. Pregwood, of the Formica Insulation Co., is a wood laminate, impregnated with phenolic resin and cured into a hard sheet. But the Impreg weldwood, of the United States Plywood Co., Inc., has the wood plies impregnated only to a short depth before compressing so that it remains a true plywood. It has higher strength and is more resistant than an ordinary resin-bonded plywood. The lightweight plywood Fybr-Tech, of the Technical Plywoods, used for aircraft cabin paneling, consists of $\frac{1}{64}$-in. walnut veneer on a $\frac{1}{4}$-in., balsa-wood core with a 0.005-in.

vulcanized fiber back, bonded with phenolic resin. The weight is 0.2 lb. per sq. ft.

For construction purposes, where plywood is employed because of its unit strength and nonwarping characteristics, the plies may be of a single type of wood without a hardwood face. The Douglas Fir Plywood Association sets up four classes of construction plywood under general trade names. Plywall is plywood in wallboard grade; Plypanel is plywood in three standard grades for general uses; Plyscord is unsanded plywood with defects plugged and patched on one side; Plyform is plywood in a grade for use in concrete forms.

Plywood may have one thick board of cheap wood and two of hardwood, or it may have a large number of thin layers. Basswood, yellow poplar, Spanish cedar, fir, and pine are used for cores. Ash, mahogany, walnut, or any of the expensive woods are used for the outside sheets. The tensile strength of a commercial white ash 3-ply plywood parallel to the grain of the faces is about 6,200 lb. per sq. in., that of a mahogany 6,400 lb., and a walnut plywood 8,200 lb. per sq. in. Mahogany plywood comes in large sheets with thickness of $\frac{1}{16}$ to $\frac{1}{4}$ in. Armorply is a plywood marketed by the United States Plywood Co., Inc. Flexwood, of this company, consists of very thin sheets of veneer glued under heat and pressure to cotton sheeting, used as an ornamental covering for walls. Woven veneer is a paneling made in thin strips of mahogany or other fine wood woven in patterns and pressed between sheets of transparent cellulose acetate. Parkwood, of the Parkwood Corp., is a veneer of this type. Algonite, of the United States Plywood Co., Inc., is Masonite faced with fancy veneers. Randalite, of the same company, is a birch veneer bonded to a kraft liner.

Plywood, or Paneling board, may also be made with metal or fabric plies. Plymax is an English plywood produced by Venesta, Ltd., consisting of thin sheets of aluminum mounted on a plywood backing. Plymetl, of the Haskelite Mfg. Corp., consists of a core of laminated wood with galvanized steel faces cemented to it. Aluminum-Plymetl has aluminum facings on Haskelite plywood. The metal-faced plywoods are strong and can be riveted. Met-L-Wood, of the Met-L-Wood Corp., is made of two layers of light wood separated by sheet metal, with a fabric cemented to one side.

It is used for automobile and truck sides, and has high strength in proportion to weight. Metalite, developed by the United Aircraft Corp., has thin sheets of aluminum alloy bonded to both sides of a balsa-wood core, the grain of the wood being perpendicular to the metal faces. Plywood in block form is sometimes used for making rolls, gears, die blocks, and pulleys. Sprucolite, of the Sprucolite Corp., is such a material made from sheets of western spruce impregnated with a waterproof binder, laminated at right angles, and subjected to hydraulic pressure to make it dense and hard. The coefficient of friction is nearly 50% higher than that of cast iron; the weight is about 35% that of iron. Hydulignum is an English Laminated wood made of thin birch veneers impregnated with vinyl formal resin and compressed into a dense board. It is used for aircraft propellers. The specific gravity is 1.31, tensile strength 45,000 lb. per sq. in., and compressive strength 21,000 lb. per sq. in.

**Poison gases.** Substances employed in chemical warfare for disabling men, and in some cases used industrially as fumigants. They are all popularly called gases, but many are liquids or solids. They are classified according to their main effect on the human system, but one gas may have several effects. They are grouped as follows: Lethal, intended to kill, such as phosgene; lachrymators, which affect the eyes, such as chloropicrin; vesicants, or skin blisterers, such as lewisite and mustard gas; sternutatory, which induce sneezing; and camouflage, which are harmless, but cause soldiers to suffer the inconvenience of wearing gas masks and thus reduce their morale. Gases are also sometimes designated as casualty agents and harassing agents, and further subdivided into persistent and nonpersistent. A Systemic gas is one that interferes with one phase of the system, such as carbon monoxide, which paralyzes the respiratory function of the blood. A Labyrinthic gas is one that affects an organ of the body, such as Dichlormethyl ether, which affects the ears.

Effects of persistent gases, such as mustard, remain over the ground for as long as 7 days, but phosgene is quickly decomposed by dampness. Obscuring agents, such as white phosphorus, and the Toxic smokes, such as Diphenylaminochloroarsine, are also classed as war gases. Dusts of materials having catalytic properties, but not poisonous themselves, may be used to penetrate gas masks

and create poisons, such as carbon monoxide, within the mask. Carbon and oil smokes may be used to choke the filters of gas masks and cause their removal. Absorbents used in gas masks are usually activated charcoal and soda lime. These will absorb or disassociate most of the toxic gases, but will not stop carbon monoxide. A mixture of powdered oxides of copper, manganese, silver, and cobalt, called Hopcalite, is used as a catalyst to oxidize carbon monoxide.

Lethal gases are divided into four classes: actual poisons, which kill with little pain, such as hydrocyanic acid; Asphyxiating gases, which affect the membranes of the lungs, destroying them and allowing blood to fill the air sacs, such as phosgene, diphosgene, and chloropicrin; poisons which destroy the lining of the air passages and block the passages to the lung tissues, as mustard gas and ethyldichloroarsine; and poisons which affect the nose and throat, causing great pain, headache, vomiting, such as diphenylchloroarsine. Mustard gas, $(CH_2ClCH_2)_2S$, known also as Blister gas, Yperite, and Yellow cross, is an oily liquid which boils at 210°C. and vaporizes easily in the air. It destroys the cornea of the eyes, blisters the skin, affects the lungs, and causes discharge from the nose and vomiting. One part in 14 million parts of air is toxic and cannot be detected in dilutions by smell. Another powerful vesicant is Bromlost, which is Dibromethyl sulphide, $(CH_2BrCH_2)_2S$. It is a solid melting at 21°C. Sulvanite is Ethylsulphuryl chloride, $ClSO_3C_2H_5$. It is a colorless liquid boiling at 135°C.

Lewisite, $CHCl:CH \cdot AsCl_2$, is a liquid boiling at 190°C. It is a powerful vesicant causing painful blisters on the skin, pain in the eyes, nose irritation, permanent impairment of eyesight, and arsenic poisoning. It forms a heavy mist and was called Dew of death. Chloropicrin, called Aquinite, Klop, and Nitrochloroform, is Nitrotrichloromethane, $CCl_3NO_2$. It is a persistent lachrymatory and lethal poison. It is a colorless liquid boiling at 112°C. Tonite is Chloroacetone, $CH_3COCH_2Cl$, a clear liquid vaporizing at 119°C. It is a powerful lachrymator and skin blisterer. As it is very reactive, it is also used in the synthesis of pharmaceuticals, dyes, and organic chemicals.

Martonite, a powerful lachrymator, is a mixture of 20% of chloroacetone and 80 bromoacetone. Bretonite is Iodoacetone, $CH_3COCH_2I$, a brownish liquid boiling at 102°C., mixed with

stannic chloride as a lachrymator. Manguinite is Cyanogen chloride, CNCl, which boils at 13°C., and is a lachrymator. Mixed with arsenic trichloride to make it more toxic it was used under the name of Vitrite. Campillit is Cyanogen bromide, CNBr, a white solid melting at 52°C. and vaporizing at 61.3°C. The fumes are highly toxic, paralyzing the nerve centers. Diphenylchloroarsine, or Blue cross $(C_6H_5)_2AsCl$, is a Sneezing gas which penetrates gas masks, forcing their removal. It affects chiefly the nose and throat, but is used with other more violent gases. Adamsite, is a greenish granular solid of the composition $(C_6H_4)_2NHAsCl$, which has a pleasant odor but burns the nose and throat.

**Polonium.** A rare metallic element, symbol PO, belonging to the group of radioactive metals. Unlike radium, however, polonium emits only alpha rays. It is used in meteorological stations for measuring the electrical potential of the air. The melting point of the metal is about 1800°C.

**Polystyrene.** A synthetic resin used for molding, in lacquers, and for coatings, formed by the polymerization of monomeric Styrene, which is a colorless liquid of the composition $C_6H_5CH:CH_2$, specific gravity 0.906, and boiling point 145°C. It is made from ethylene, and is ethylene with one of the hydrogen atoms replaced by a phenyl group. The polymerized resin is a transparent solid very light in weight with a specific gravity of 1.054 to 1.070. The tensile strength is 3,000 to 8,500 lb. per sq. in., compressive strength 12,000 to 17,000 lb. per sq. in., and dielectric strength 450 to 600 volts per mil. Polystyrene is notable for water resistance and high dimensional stability. It is also tougher and stronger at low temperatures than most other plastics. It is valued as an electrical insulating material, and the films are used for cable wrapping. The films are heat-sealing at above 70°C. The molding plastic is used for cosmetic containers, clock crystals, gage dials, and aircraft panels. For coating purposes plasticizers are added to increase pliability, but are not needed for molding. The plastic has good fluidity and is especially suited for injection molding. The polymer used in England for injection molding is called Distrene. Styroflex was a German polystyrene in thin tape form for cable wrapping. Victron, of the Naugatuck Chemical Co., is a clear transparent

polystyrene resin. Lustron is the trade name of Monsanto Plastics for a polystyrene molding plastic. Loalin, of the Catalin Corp., is a polystyrene with a specific gravity of 1.05 to 1.07. It is crystal clear, and will take light pastel colors. In the clear form it transmits 90% of light. It is water-resistant and has a dielectric strength of 500 to 700 volts per mil. It is not affected by alcohol, acids, or alkalies, but is soluble in aromatic hydrocarbons. It is preferably injection-molded. Styron, of the Dow Chemical Co., is polystyrene molding granules, and Styraloy is molding powder. Cellon and Trotlitul are English polystyrene plastics.

**Pontianak.** A gum from the trees *Dyera costulata* and *D. laxifolia* of Borneo and Malaya. The commercial pontianak is a grayish-white mass like burned lime, and contains 60% of water, with only 10 to 25% of rubberlike materials. It is a rubber, but has a high content of resin similar to balata and gutta percha, and is classed with the lower guttas. It is used in the friction compounds employed for coating transmission belting, in insulations and varnishes, for mixing with gutta percha, and also to adulterate or replace chicle for chewing gums. It is also called Jelutong. Pontianak copal is from varieties of *Agathis* trees of Borneo. Its peculiar turpentinelike qualities come from the method of tapping. It is valued for varnishes.

**Poplar.** The wood of several species of the tree *Populus*. The Black poplar, or English poplar, *P. nigra,* of Europe, is a large tree with blackish bark. The wood is yellowish white with a fine, open grain. It is soft and easy to work. The weight is about 35 lb. per cu. ft. It is used for paneling, inlaying, packing cases, carpentry, and paper pulp. Cottonwood is another species of poplar. Gray poplar is from the tree *P. canescens,* of Europe. The color of the wood is light yellow. It has a tough, close texture somewhat resembling that of maple. It is used for carpentry and flooring. The wood of the canary whitewood is called Virginia poplar, or simply poplar, but belongs to a different family of trees. Aspen is also called poplar.

**Potash.** Also called Pearl ash. A white alkaline granular powder, which is a Potassium carbonate, $K_2CO_3$ or $K_2CO_3 \cdot H_2O$,

used in soft soaps, for wool washing, and in glass manufacture. It is produced from natural deposits in Russia and Germany and also produced from wood and plant ashes. The American production is largely from potash salts of New Mexico, from the brines of Searles Lake, Calif., and from solar evaporation in Utah. The specific gravity of potash is 2.33 and melting point 909°C. Hartsalz, mined in the Carpathian Mountains and used for producing potash, is a mixture of sodium chloride, potassium chloride, and magnesium sulphate. It is also a source of magnesium. The extensive potassium mineral deposits at Strassfurt and Müllhausen contain Sylvite, KCl; Carnallite, $KCl \cdot MgCl_2 \cdot 6H_2O$; Kainite, $K_2SO_4 \cdot MgSO_4 \cdot MgCl_2 \cdot 6H_2O$; and Leonite, $K_2SO_4 \cdot MgSO_4 \cdot 4H_2O$. There are at least a billion tons of the potash mineral Wyomingite in the deposits near Green River, Wyo. It is a complex mineral containing leucite, phlogopite, diopside, kataphorite, and apatite. It has 11.4% of $K_2O$, with also sodium oxide, magnesium oxide, phosphorus pentoxide, and other oxides. The potash minerals form the raw material for the production of many chemicals.

**Potassium.** An elementary metal, symbol K, and atomic weight 39.1, also known as Kalium. It is silvery white in color, but oxidizes rapidly in the air and must be kept submerged in ether or kerosene. It has a low melting point, 65.5°C. and a boiling point at 757°C. The specific gravity is 0.859. It is soluble in alcohol and in acids. It decomposes water with great violence. Potassium is obtained by the electrolysis of potassium chloride. It has no commercial applications, but potassium compounds are widely employed. Potassium hydride is used for the photosensitive deposit on the cathode of the photoelectric cell. It is extremely sensitive and will emit electrons under a flash so weak and so rapid as to be imperceptible to the eye. Potassium diphosphate, $KH_2PO_4$, a colorless, crystalline, or white powder soluble in water, is used as a lubricant for wool fibers to replace olive oil in spinning wool. It has the advantages that it does not become rancid like oil and can be removed without scouring.

**Potassium chlorate.** Also known as Chlorate of potash and Potassium oxymuriate. A white crystalline powder, or lustrous crystalline substance of the composition $KClO_3$, employed in ex-

plosives, chiefly as a source of oxygen. It is also used as an oxidizing agent in the chemical industry, in medicine as a cardiac stimulant, and in tooth paste. It melts at 357°C. and decomposes at 400°C. with the rapid evolution of oxygen. It is odorless but has a slightly bitter saline taste. The specific gravity is 2.337. Potassium chlorate is not hygroscopic and does not alter on exposure to the air. It is, however, soluble in water but insoluble in alcohol. It imparts a violet color to the flame when used in pyrotechnic compositions. It is made by the electrolysis of potassium chloride.

Potassium chloride is a colorless or white crystalline substance of the composition KCl, used for molten salt baths for the heat-treatment of steels. It is also used in fertilizers and in explosives. The specific gravity is 1.987. A bath composed of 3 parts of potassium chloride and 2 of barium chloride is used for hardening carbon-steel drills and other tools. Steel tools heated in this bath and quenched in a 3% sulphuric acid solution have a very bright surface. A common bath is made up of potassium chloride and common salt and can be used for temperatures up to 900°C.

**Potassium cyanide.** A white amorphous or crystalline mass of the composition KCN, employed for carbonizing steel for case-hardening and for electroplating. The specific gravity is 1.52, and it melts at about 1550°F. It is soluble in water and is extremely poisonous, giving off the deadly hydrocyanic acid gas. For cyaniding steel the latter is immersed in a bath of molten cyanide and then quenched in water, or the cyanide is rubbed on the red-hot steel. For this use, however, sodium cyanide is usually preferred, because of its lower cost and the higher content of CN in the latter. Commercial potassium cyanide is likely to contain a proportion of sodium cyanide. Potassium ferrocyanide, or Yellow prussiate of potash, can also be used for casehardening steel. It has the composition $K_4Fe(CN)_6$ and comes in yellow crystals or powder. The nitrogen as well as the carbon enters the steel to form the hard case. Potassium ferricyanide, or Red prussiate of potash, is a bright-red granular powder of the composition $K_3Fe(CN)_6$, used in photographic reducing solutions, in etching solutions, in blueprint paper, and in silvering mirrors.

**Potassium nitrate.** Also called Niter, and Saltpeter, although these usually refer to the native mineral. A substance of the composition $KNO_3$, used in explosives and for bluing steel. A mixture of 2 parts of potassium nitrate and 3 of sodium nitrate is used for steel-tempering baths. The mixture melts at 250°C. Potassium nitrate is made by the action of potassium chloride on sodium nitrate, or Chile saltpeter. It occurs in colorless, prismatic crystals, or as a crystalline white powder. It has a sharp saline taste and is soluble in water. The specific gravity is 2.1 and melting point 337°C. It is found in nature in limited quantities in the alkali region of Western United States. Potassium nitrate contains a large percentage of oxygen which is readily given up and is well adapted for pyrotechnic compounds. It gives a beautiful violet flame color in burning. Another use is in smoke-tracer compounds with sulphur and arsenic, and in flares and smoke torches. Its function is to furnish oxygen in concentrated form.

**Precious metals.** A general term for the expensive metals that are used for coinage, jewelry, and ornaments. The name is limited to gold, silver, and platinum, expense or rarity alone not being the determining factor, but rather the setting of a value by law, with the coin having an intrinsic metal value as distinct from a copper coin which is merely a token with little metal value. The term noble metal is not synonymous, although a metal may be both precious and noble, as platinum. Noble metals are highly resistant to acids and to corrosion by themselves unalloyed. The noble metals are gold, platinum, iridium, rhodium, osmium, and ruthenium. Radium and certain other metals are more expensive than platinum but are not classed as precious metals. Because of the expense of the platinum noble metals, they may be alloyed with gold for use in chemical crucibles. Platino is an alloy of 89% of gold and 11 platinum. Palau is the name of an alloy of gold and palladium, and Rhotanium is a Rhodium-gold alloy.

**Prefinished metals.** Sheet metals that have a polished surface of another metal plated on one side, or have the finish metal bonded and rolled on the base metal. In the latter case they are called Bonded metal. The metals are used for stamped parts to save plat-

ing and polishing of the articles after manufacture, or to give the corrosion resistance of the plated metal with the strength of a steel base. They often replace enameled or lithographed metals for making toys and ornamental articles, and when made in strips or patterns are used for making electrical appliance parts. The most usual prefinished metals have a base of copper, zinc, or brass, with nickel- or chromium-plated surfaces. The bonded metals are on the same principle as clad metals, but are in general thin sheets for decorative articles. The highly finished metals are marketed with a thin paper coating on the polished side which is easily stripped off after forming. Brassoid, of the American Nickeloid Co., is a brass bonded to zinc; Chromoloid is chromium bonded to zinc; and Nickeloid is sheet zinc with a polished nickel surface. Chromium, copper, and nickel, in bright or matte finishes, are also bonded to steel in gages of 0.010 to 0.050 in. Tint-Metal is copper-tin, copper-zinc, or copper-steel base metal finished in plain or striped colors. Metal-Bord is prefinished metal bonded to a backing of paper or fiberboard, used for signs, buckles, ornamental articles, or wall facing.

**Primer.** A surfacing material employed in painting or finishing to provide an anchorage or adhesion of the finishing material. A primer may be colorless or it may be with color. In the latter case it is sometimes called an Undercoat. A primer is distinct from the filler coat used on woods to fill the pores and thus economize on the more expensive finish. Primer coats of red lead paint are used on construction steel to give corrosion resistance. Zinc yellow paints may also be used as primer coats on metal. Zinc chromate is used as a primer on steel. It has a tendency to dissolve when moisture penetrates the paint, and this dissolved chromate retards corrosion of the steel. In addition to the pigment, various corrosion inhibitors may be used in primer paints. Ammonium ferrous phosphate, $NH_4FePO_4 \cdot H_2O$, has a platelike structure which gives impermeability to the film as well as adding corrosion resistance. It is greenish in color. A primer is especially required in the finishing of sheet-metal objects that are likely to receive dents or severe service, but they are not usually necessary for castings or roughened surfaces. For sheet-metal work, baked enamels were

formerly much used for the primers for the lacquer finishes, but synthetic resin primers give good adhesion and are less expensive.

**Protein plastics.** Organic plastic molding materials produced by the isolation or precipitation of proteins from animal or vegetable products and hardening or condensing into stable compounds that can be molded into sheets or fiber. Proteins are complex nitrogen organic products of very high molecular weights that occur in animal and vegetable matter. The oldest of the protein plastics is casein plastic which is made into molding plastics or into woollike fibers for textiles. The proteins from soybean meal or other vegetable products are condensed with aldehydes or with various mineral salts or acids to form plastics. These plastics are distinct from those made from the fatty acids of soybean or other oils. Peanut fiber, under the name of Ardil, is made in England by precipitating the protein from peanut meal with an acid, dissolving in caustic soda, and forcing through spinnerets into a hardening bath. The fiber is soft and resilient, moisture-absorbent like wool, moth-resistant, and will dye easily. It is mixed with wool in weaving fabrics. Azlon is a general name for protein fibers.

**Pulpstones.** Large blocks of sandstone cut into wheels and used for grinding, chiefly for the grinding of wood pulp in paper manufacture. The American pulpstones are produced in Ohio and West Virginia. The sandstones for pulpstones must be uniform in texture, have sharp grains, medium hardness, and be composed of even quartz grains of which 85% will be retained on a 150-mesh screen, and 90% on a 200-mesh screen. The cementing material may be siliceous, calcareous, or argillaceous, but must be firm enough to hold the stone together when working under pressure, and soft enough to wear faster than the quartz grains and prevent glazing. The standard diameter of pulpstones is 54 in. and width of face 27 in. The stones are aged or seasoned from 1 to 2 years before use. Aging is quickened by heating the stones to about 180°F. in a closed room and cooling slowly.

**Pumice.** A porous, frothlike volcanic glass which did not crystallize due to rapid cooling, and frothed with the sudden release of dissolved gases. Powdered or ground pumice is used as an

abrasive for fine polishing, in metal polishes, in scouring compounds and soaps, and in plaster and lightweight concrete and pozzuolanic cement. In very fine powder it is called Pounce when used for preparing parchment and tracing cloth. Pouncing paper is paper coated with pumice used for pouncing, or polishing, felt hats. Pumice is grayish white in color, and the fine powder will float on the surface of water. The natural lump pumice contains 65 to 75% of silica, 12 to 15 alumina, and 4 to 5 each of soda and potash. It is produced chiefly in California and New Mexico. Pumicite is a volcanic dust similar in composition to pumice, found in large beds in Nebraska, Kansas, and Colorado. Its chief distinction is that it is fine-grained and has sharp edges suitable for abrasive purposes. The natural material is dried, pulverized, and screened so that 98.8% will pass a 325-mesh screen. Seismotite is a trade name of the Cudahy Co. for pumice used as an abrasive in scouring compounds. Slag pumice, or Artificial pumice, is made in Germany by treating molten slag with less water than is required for granulation. It is used as an aggregate in lightweight concrete and as a heat insulator. Obsidian, or Volcanic glass, will change into pumice when melted. Obsidian was used by the ancients for instruments and by the American Indians for arrowheads and knives. Hawaiian obsidian, or Tachylite, also known as Basalt glass, is a volcanic glass from Oahu, Hawaii. It is jet black, takes a fine polish, and is used for making ornamental articles. The type of obsidian found in Oregon, known as Perlite, is flash roasted to form a bubblelike expanded material. It weighs only 4 to 12 lb. per cu. ft., and is used in light-weight wallboard, acoustical tile, insulation, and as a light-weight aggregate in concrete.

**Purpleheart.** The wood of several species of trees, notably *Peltogyne paniculata* of the Guianas. The color of the wood is brown, the heartwood turning purple on exposure. The grain is open and fine. The wood weighs about 53 lb. per cu. ft., is very hard, strong, and durable. It is used for machine and implement parts, inlays, furniture, and turnery.

**Putty.** A mixture of calcium carbonate with about 18% of linseed oil, with sometimes white lead added. It is used for cementing window glass in place and also as a filler for patterns.

Litharge is often added to putty for steel sash. Another putty for steel contains red lead, calcium carbonate, and linseed oil. The dry pigment for putty, Whiting putty, according to A.S.T.M. specifications contains 95% of calcium carbonate and 5 of tinting pigment. White lead putty contains 10% or more of white lead mixed with the calcium carbonate. Federal specifications call for a minimum of 11% boiled or processed linseed oil with a maximum of 89% pigment in a white lead-whiting putty. Putty powder is a mixture of lead and tin oxides, or a mixture of tin oxide and oxalic acid, or it may be merely an impure form of tin oxide. It is used in enameling and for polishing stone and glass, and as a mild abrasive for dental polishes. Calking putty, used for setting window and door frames, is made of asbestos fibers, pigments, and drying oils, or with rubber or resins.

Pyrargyrite. An ore of silver, known also as dark ruby silver. It is a sulphantimonite of silver, $Ag_3SbS_3$, containing 22.3% of antimony and 59.8 silver. It is found in various parts of Europe, in Mexico, and in Colorado, Nevada, and New Mexico. It occurs in crystals or massive and also in grains. Its hardness is 2.5 and specific gravity 5.85. The color is dark-red to black, showing ruby-red in thin splinters. Proustite is another ore of silver occurring in silver veins associated with other metals. It is found in the mines of Peru, Mexico, Chile, and in Nevada and Colorado. It is also called light Ruby silver and is a sulpharsenite of silver of the composition $Ag_3AsS_3$, containing theoretically 65.4% of silver. It commonly occurs massive, compact, in disseminated grains. The hardness is 2 to 2.5, specific gravity 5.55, and the color is ruby-red with an adamantine luster.

Pyrethrum. The dried flowers of several species of chrysanthemum, of which the *Chrysanthemum cinerariaefolium* of Yugoslavia and Japan is the best known. It is a slender perennial, about 15 in. high, with daisylike flowers. The powder is used as an insecticide chiefly in sprays. It comes from Yugoslavia, Japan, and British East Africa. The crude pyrethrum from Kenya contains 1.3% of Pyrethrin as compared with only 0.9% in the Japanese. Persian powder is pyrethrum from the species *C. coccineum* of southwestern Asia. Lethane, of the Röhm & Haas Co.,

is a synthetic aliphatic diacyanate used as a substitute for pyrethrum. It is 30 to 40% more powerful than pyrethrum in insect sprays. A substitute for pyrethrum for the control of corn worms is Styrene bromide, or Bromo styrene, an oily liquid of the composition $C_6H_5CBr:CH_2$.

**Pyrophyllite.** An aluminum silicate mineral found in North Carolina, used as a substitute for talc. It is similar to talc in structure and appearance, but its composition, $Al_2Si_4O_{10}(OH)_2$, is more nearly like kaolin. It is white, gray, or brown, with a pearly or greasy luster, specific gravity of 2.8, and hardness 1 to 2. Compact varieties of the mineral are made into slate pencils and crayons. A fine-grained compact rock mined in South Africa, composed of about 90% pyrophyllite, with rutile and other minerals, is called Wonderstone, and is used for table tops and switchboard panels. It is resistant to weathering, acids, and heat, and it can be planed, sawed, or turned in the lathe. It then becomes harder on exposure. Wonderstone is an ancient indurated clay resembling fireclay in which the colloidal matter has been destroyed by heat, pressure, and age. Unfired refractory bricks are made of dry-pressed pyrophyllite. They have high spalling resistance and do not shrink. Pyrax, of the R. T. Vanderbilt Co., is pyrophyllite in fine white powder of 100 mesh, with specific gravity of 2.6, used as a filler in rubber. Silical, of Herron Bros. & Meyer, is pyrophyllite from Newfoundland in fine powder form as a dusting talc for rubber.

**Quartz.** The most common variety of silica, $SiO_2$. It occurs mostly in grains or in masses of a white or gray color, but often colored by impurities. Pure crystalline quartz is colorless and is called Rock crystal. Quartz usually crystallizes in hexagonal prisms or pyramids. The hard rigid Beta quartz crystals have a latticelike molecular structure in which each silicon atom is linked to four separate oxygen atoms, each oxygen atom being linked to two different silicon atoms. The formula of quartz crystal, therefore, is $(SiO_2)_x$. The grains in sand are often less than 0.04 in., but crystals up to 20 in. have been found. The specific gravity is 2.65. Quartz will transmit the short waves of ultraviolet light, and fused quartz or Quartz glass is used for bulbs for photoelectric cells and for optical glass. Quartz crystals have the property of

generating an electrical force when placed under pressure and, conversely, of changing dimensions when an electric charge is applied. The best crystals are hexagonal prisms free from twinning, with no bubbles, cracks, or flaws. Brazilian quartz crystals are cut into plates of different sizes to initiate and receive various wave lengths on multiple-message telephone wires, and to obtain selectivity in radio apparatus. Owing to its peculiar refractive powers, quartz crystal is also employed for the plates in polarization instruments and in lenses. Quartz crystals for radio-frequency control are marketed in three forms: Rough-sawed blanks, cut to specified angles; semifinished blanks, machine-lapped to approximate size; and electrically finished blanks, finished by hand and electrically tested.

Quartz is harder than most minerals, being 7 Moh, and is crushed for abrasive use. Finely ground quartz is also used as a filler, and powdered quartz is employed as a flux in melting metals. When quartz is fused, it loses its crystalline structure and becomes a silica glass with a specific gravity of 2.2, compressive strength of 7,000 lb. per sq. in., and hardness of 5. Pure fused quartz is employed for crucibles and for tubes and rods for furnaces, as it will withstand rapid changes of temperature without breaking. Virtreosil, of the Thermal Syndicate, Ltd., is Fused quartz, containing 99.8% silica. It comes opaque, translucent, and transparent. It transmits ultraviolet and short wave lengths, has high electric resistance, and a coefficient of expansion about one-seventeenth that of ordinary glass.

Since quartz crystallizes more slowly than many other minerals, the natural crystals may include other minerals which were crystallized previously. Sagenite is a form of crystalline quartz containing hairlike crystals crossing in a netlike manner. A variety of fibered quartz with a pale amethyst color which shows deep red by transmitted light, found in Russia and Colorado, is called Onegite. Aventurine is a form of quartz crystal containing the inclusions in the form of flakes or spangles. It comes from the Ural Mountains and from India and is prized for gems. For cheap jewelry it is made synthetically in great quantities under the name of Goldstone by melting the inclusions into quartz glass. Amethyst, Topaz, and many other gem stones are quartz. The golden-yellow

topaz of Mexico and Brazil is a type of quartz called Citrine. Inferior-colored amethysts may also be made into yellow or orange-colored citrine by heating. The Rose quartz of South Dakota is prized in the beautiful rose color, but in the large deposits the shades may run from milky white through pale pink to deep rose red. The best stones are used for gems, as are also the translucent pink crystals from Maine. Other grades are cut into vases, ornaments, and architectural facings. The so-called massive topaz used as a refractory instead of kyanite is not true topaz. The massive topaz mined in North Carolina contains about 50% of $Al_2O_3$ and 40 of $SiO_2$ with iron and iron oxide. When calcined for refractory use, it has the same composition as kyanite. The topaz from the wolframite mines of São Paulo, Brazil, used for refractories, has a high alumina content and a high fluorine content. The purer crystals have a melting point of 1880°C. The quartz known as Cristobalite, used as a refractory, differs from ordinary quartz only in the crystal structure. It has a melting point of 3110°F. Jasper is a variety of quartz colored red with iron oxide. It is cut and polished as an ornamental building stone. Egyptian jasper is brown in color with dark zones. In ancient times many of the gem stones were silica stones, and the Athiaenon stone from Cyprus was jasper of bright colors.

**Quartzite.** A rock composed of quartz grains cemented together by silica. It is firm and compact and breaks with uneven, splintery fractures. Most of the quartzites used are made up of angular grains of quartz and are light in color. Quartzite was derived from sandstones by intense metamorphism. Quartzite is employed for making Silica brick used for roofs of open-hearth steel furnaces. It is also used for abrasives, siliceous linings for tube mills, as a structural stone, and as a broken stone for roads. It is found as a widely distributed common rock. Medina quartzite, from Pennsylvania, contains 97.8% of silica. The melting point is about 1700°C.

**Quassia.** Also known as Bitterwood. The wood of the Jamaica quassia tree, *Picroena excelsa*, and of the Surinam quassia, *Quassia amara*, of the West Indies and northern South America. The Jamaica quassia is a large tree, sometimes called Bitter ash because

the leaves resemble those of the common ash. The wood is yellow, light, dense, and tough. It is odorless, but has an intensely bitter taste. The wood is imported mostly as chips for the production of the extract which is used in medicine as a bitter tonic, and also used in insecticides and in flypapers. It is also used as an ingredient in stock feed tonics for cattle. In tropical countries the wood is valued for furniture as it is resistant to insects. The wood of the Surinam quassia is darker in color, heavier, and harder, but has similar properties.

**Quebracho.** The common name for the wood of the Quebracho colorado, or red quebracho tree, *Aspidospera quebracho,* found only along the west bank of the Paraná and Paraguay rivers in Argentina and Paraguay. It contains about 24% of tannin, and is valued chiefly as a source of Quebracho extract. The wood is exceedingly hard and has a brownish-red color often spotted and stained almost black. Quebracho is valued as a firewood in Argentina, and is also used for crossties and posts, but is too brittle for structural work. It takes a fine polish and is very durable, carvings of this wood being in perfect condition after 300 years. The weight is 78 lb. per cu. ft. Quebracho extract is the hard, resinous substance extracted from the wood by boiling. It is brownish black in color and extremely bitter, and the solid extract contains 62% of soluble tannins. One metric ton of wood yields about 250 kilos of solid extract. The liquid extract contains 25 and 35% tannin. It is employed in tanning leather and is rapid acting, but is seldom used alone as it makes a dark leather. It is mixed with alum and salt, or with chestnut extract. Some extract is used in boiler compounds. Aeroseal Q, of the American Cyanamid Co., is powdered quebracho and an organic colloid, used to treat oil well drilling muds.

**Radioactive metals.** Metallic elements which emit radiations that are capable of penetrating matter opaque to ordinary light. They give out light and appear luminous, also having an effect on the photographic plate. The metal radium is the most radioactive of all the elements, and practically its only commercial substitute is mesothorium. It is employed for luminous paints for dials and pointers of instruments and for the hands of watches. Other radio-

active elements are uranium, thorium, ionium, actinum, and polonium. These bodies all have high atomic weight. The radiating power is atomic and is unaffected in combinations. Radium and other radioactive metals are changing substances. Radium gives out three types of rays; some of the other elements give out only one or two. The $\gamma$, or Gamma, rays are wave motion with waves shorter than the X rays below ultraviolet light. The $\beta$, or Beta, rays are believed to be extremely small negatively-charged electrons. The $\alpha$, or Alpha, rays are believed to be the hearts of helium atoms carrying two positive electric charges. The emanations are all emitted at high velocities approaching that of light. The $\alpha$ and $\beta$ rays are deflected by magnetic fields. An aluminum screen completely absorbs the $\alpha$ rays, while lead stops the $\beta$ rays. After breaking up, the rays apparently go into the group of inert gases like argon and helium. By comparison of changing atomic weights, it has been deduced that the metal lead is the ultimate product, and uranium the parent metal under present existing stability conditions. But heavier metals, now no longer stable under present conditions, have been produced synthetically, notably plutonium. Radium has apparently a period of transfer of several thousand years, while mesothorium disintegrates in a little over 5 years, and polonium decays in a short time, losing half its weight in 140 days.

**Radium.** A peculiar radioactive element, symbol Ra, scattered in minute quantities throughout almost all classes of rocks. It was discovered in 1898 by Curie, and the first radium chloride was separated from pitchblende in 1902. Radium is only commercially obtainable from the uranium ores, monazite sand, carnotite, and uraninite, and is believed to be formed from the disintegration of uranium or ionium. In the Sudetenland section of Europe it is obtained from the residue of pitchblende after the extraction of thorium oxide, but most of the present supply comes from carnotite of the Belgian Congo and from the pitchblende of the Great Bear Lake region of Canada. One gram of radium and 7,800 lb. of uranium are obtained from 370 tons of pitchblende. The ratio of radium to uranium in any uranium ore is always about 1 :3,000,000. Radium is marketed in the form of bromides or sulphate in tubes and is extremely radioactive in these forms. In a given interval

of time a definite proportion of the atoms break up with the expulsion of $\alpha$, $\beta$, or $\gamma$ rays. The most powerful ray is the $\gamma$, which it is estimated has a million times the wave frequency of light. Radium is most widely known for its use in therapeutic medicine, but considerable of the production is employed in luminous paints for hands and pointers of watches and instruments, and for luminous signs. It is also used for making inspections of metal castings in place of X rays.

**Ramie.** A fiber used for cordage and for various kinds of coarse fabrics, obtained from the plant *Urtica nivea* of temperate climates, and *U. tenacissima,* of tropical climates. The former plant has leaves white on the underside, and the latter has leaves all green. The name Rhea is used in India to designate the latter species. It is also grown in China, Formosa, Egypt, Brazil, and Florida. The plants grow in tall slender stalks like hemp and belong to the nettle family. The bast fibers underneath the bark are used, but are more difficult to separate than hemp fiber owing to the insolubility of the adhesive gums. The fibers are eight times stronger than cotton, fine and white, and are as silky as jute. They are not very flexible and are not in general suitable for ease of weaving, but their high wet-strength, absorbent qualities, and resistance to mildew, make the fibers suitable for warp yarns in wool and rayon fabrics. The yarn is used also for strong, wear-resistant canvas for such products as fire hose. The fiber is also valued for marine gland packings and for twine. The composition is almost pure cellulose, and the tow and waste are used for making cigarette paper. China grass is the hand-cleaned but not degummed fiber. It is stiff and greenish yellow in color. Grass cloth is a woven fabric made in China from ramie. Swatow grass cloth, imported into the United States, is made of ramie fibers in parallel strands not twisted into yarns.

**Rape oil.** An edible, lubricating, and illuminating oil obtained from the seeds of a species of the turnip, *Brassica campestris,* of which varieties are referred to as *B. rapa, B. napus, B. oleifera,* and *B. glauca.* It is widely used as an edible oil, for making factice, and for mixing with lubricating and cutting oils and for quenching oils. The seeds are very small, an ounce including as many as 40,000 seeds. The seeds contain 40% of oil. The edible oil is

cold-pressed and refined with caustic soda. The burning and lubricating oils are refined with sulphuric acid. The iodine value is about 100, the specific gravity is about 0.915, and the flash point 455°F. The oil contains palmitic, oleic, linoleic, and stearic acids, and 43 to 50% of a characteristic acid, $C_{22}H_{42}O_2$, called Brassidic acid or Erucic acid. Colza oil is a rape oil extracted from French seed, used to mix with mineral oils to make cutting oils. The name Colza now refers to any refined rape oil. Chinese colza oil, from the *B. campestris chinoleifera,* contains the mustard volatile oil. The specific gravity is 0.91, saponification value 174, and iodine number 100.3. From 15 to 20% of blown rapeseed oil is mixed with mineral oil for lubricating marine engines. Cameline oil, called also Dodder oil and German sesame oil, has the same uses as rape oil. It is from the plant *Camelina sativa* grown in Central Europe. The seeds contain 35% of oil which contains oleic and palmitic acids and also erucic acid, the characteristic acid of rape oil. The seed itself is high in mineral and protein content and is used in birdseed mixtures under the name of Gold of pleasure seed.

**Rare metals.** A term given by the U.S. Bureau of Mines to certain metallic elements that are rare in the sense that they are extremely difficult to extract from their ores and are rare commercially. These include the four elements Illinium, Masurium, Alabamine, and Virginium. The last is called Madavium in France. With the rare metals may also be grouped the ultraheavy metallic elements, such as plutonium, that are produced synthetically by bombarding heavy atoms with neutrons which stick to them and make them heavier. They are called Transuranic metals, because they find a place in the periodic table beyond uranium or are heavier than uranium. All of these metals are radioactive. Radium is also classed as a rare metal.

**Ratany.** Also known by the original Inca name of Payta, and in medicine as Krameria. The root of the shrub *Krameria triandria,* which grows in Peru and is used for tanning leather and in medicine as an astringent. The root comes in diameters up to 1 in., and in pieces up to 3 ft. in length. It contains about 40% of tannin which is extracted by hot water. It gives the leather a deep-brown color, and is usually mixed with other tannins.

**Rattan.** The long slender stem of the palm *Calamus rotang* and other species, of Ceylon, Malaya, and Indo China. There are more than 40 varieties. The Malay word is rottan, meaning cane. It is tough, flexible, strong, and durable, and is used for canes, umbrella handles, and furniture. When split it is used for car seats, baskets, baby-carriage bodies, furniture, whips, and heavy cordage. Commercial rattans are in pieces 5 to 20 ft. long. A substitute for rattan is Jacitará, from the plant *Desmoncus macroacanthus,* of Brazil. It is used for seating. Vinylidene chloride plastic is now widely used as a substitute for rattan for seating.

**Rayon.** A general name for artificial-silk textile fibers or yarns made from cellulose nitrate, cellulose acetate, or cellulose derivatives. The general name was adopted after the Federal Trade Commission had ruled against the use of such terms as Art silk, Fiber silk, Chardonnet silk, and Artificial silk. Some of the products are referred to preferably by the manufacturer's trade name such as Celanese, for cellulose-acetate yarns and fabrics. In general, the name rayon is limited to the viscose, cuprammonium, and acetate fibers, or to fibers having a cellulose base, the many other synthetic fibers taking their own or trade names. Viscose rayon is made by treating the cellulose with caustic soda and then with carbon disulphide to form cellulose xanthate, which is dissolved in a weak caustic solution to form the viscose. With the cuprammonium process the cellulose is digested in an ammonia solution of copper sulphate, and the solution forced through the spinnerets into dilute acid for hardening. Rayons manufactured by the different processes vary both chemically and physically. They are resistant to caustic solutions which would destroy natural silk. They are also mildewproof, durable, and easily cleaned. But they do not have the permeability and soft feel of silk. The acetate rayons are more resistant than the viscose or cuprammonium. The lack of permeability of the fibers is partly overcome by having superfine fibers so that the yarns are permeable. The one-denier viscose staple produced by the American Viscose Co. by stretching the fiber after it leaves the spinnerets is finer than Egyptian cotton and can thus be made into yarns that are permeable between the fibers. Fabrics made from the superfine yarns have the appearance of sheer silk. The objec-

tionable high gloss of synthetic fibers is reduced by pigmentation. Glos was an early name for rayon because of this gloss, but the name has now been abandoned. Practically all types of dress fabrics and knitted hosiery and underwear are made from rayons. The material is also used for automotive tire fabrics because of its strength. Staple fiber is fiber cut to length for the spinning system to be used. The Lanese fiber of the Celanese Corp. of America is 3-, 5.5-, 8-, and 12-denier acetate rayon cut to lengths of 1⅛ to 2 in. Seraceta, of the American Viscose Corp., is a continuous-filament acetate rayon. Matesa is the name of continuous-filament cuprammonium rayon of the American Bemberg Corp.

**Red brass.** The standard wrought metal known as Red brass, or Rich low brass, of the brass mills contains 85% of copper and 15 zinc. It is one of the most ductile and malleable of the brasses, and the working stresses can be relieved without softening the metal by heating for a half hour at 275°C. It is also valued for its fine reddish color, ability to take a high polish, and corrosion resistance. It is essentially a drawing and stamping metal and, unless it contains a little lead, will not machine well. The annealed metal has a tensile strength of 35,000 lb. per sq. in., with elongation of 40%, while the hard-rolled metal has a strength of 65,000 lb. per sq. in., with elongation of 5%, and Rockwell B hardness of 75. The melting point is 1875°F., weight 0.316 lb. per cu. in., coefficient of expansion 0.0000104 per deg. F., and electrical conductivity 34.7% that of copper. It is produced regularly in the form of sheets and tubes, and is used for jewelry, name plates, dials, drawn and stamped hardware and mechanical parts, and corrosion-resistant hot-water pipes. Plumrite 85, of the Bridgeport Brass Co., is this alloy in tubes for piping. Revere alloy No. 130, of the Revere Copper & Brass, Inc., is this metal in sheet and tubes. Redalloy, of the Chase Brass & Copper Co., contains 85% of copper, 14 zinc, and 1 tin. The tensile strength is 42,000 lb. per sq. in. and elongation 48%.

The high-copper alloy known in the mills as Commercial bronze contains 90% of copper and 10 zinc. It is widely used for making costume jewelry, weather stripping, stamped hardware, forgings, and screws. It has a bronze color, a weight of 0.318 lb. per cu. in.,

and electrical conductivity 43.6% that of copper. The tensile strength, soft, is 38,000 lb. per sq. in., with elongation of 40%. The tensile strength of the hard-rolled metal is 60,000 lb. per sq. in. and elongation 5%. Revere alloy No. 120 is this metal. Federal specifications for gilding metal call for this alloy, and it is also known as Government gilding metal. But standard Gilding metal employed for making cheap jewelry and small-arms ammunition contains 95 to 97% copper. It has a golden-red color, is stronger and harder than copper, but has only about half the electrical conductivity of copper. The English Cap copper, used for cartridge caps, has 97% of copper and 3 zinc. B.E.S. gilding metal is in three grades, 80, 85, and 90% copper, but the 80-20 alloy has a definite golden-yellow color and is not in the class of red brasses. The 80-20 brass is one of the standard alloys of the brass mills under the name of Low brass. It was early used for jewelry under the name of Dutch metal. It is very ductile and is easily drawn, takes a high polish, and has high strength. It is still much used for cheap jewelry. Chain bronze, used for flat-link jack chains, and also for costume jewelry, contains 87 to 89% of copper, 0.60 to 1.25 tin, and the balance zinc. The tin increases the hardness, and it has good strength and corrosion resistance.

Many old names used in England and the United States for designating the golden or reddish high-copper brasses, especially for cheap jewelry making, are still in occasional use. Pinchbeck metal, originally made by C. Pinchbeck, an English jeweler, contained 88% of copper and 12 zinc. This is the same as the Guinea gold used for traders' jewelry. Manila gold, or Traders' gold, was about the same with some lead to heighten the color. Ormulu gold, a name still used by brass platers, was any composition that would give a golden color. Rich gold metal was the 90-10 alloy, and this alloy is still being used for decorative purposes such as for store fronts, under the name of Copper-rich brass. Mannheim gold, containing 83% of copper, 10 zinc, and 7 tin, was a German alloy for cheap jewelry. It is a considerably harder alloy than ordinary red brasses. Tournay metal was a French alloy widely used for buttons when brass buttons were in vogue. It was essentially the same as the original Tombac metal used by the Chinese for buttons, and was the 85-15 alloy containing considerable arsenic to give

a brilliant grayish tone to the metal. The alloy is quite brittle. The name tombac is the Malay word tombaga used to designate gold-colored jewelry alloys. Chrysochalk is another old name for gilding metal containing enough lead to give a dull gold tone. Japanese low-priced jewelry alloys often contained silver or gold to balance the color and make them resistant to tarnishing. Shadke was a high-copper alloy with some gold, and Shaku-do contained about 4% of gold and 1 silver. The gold color of the red brasses is enhanced by pickling in nitric acid.

Red lead. A common lead pigment, also erroneously called minium. It is a lead tetroxide, $Pb_3O_4$, forming a bright-red or orange-red powder of specific gravity 0.096, insoluble in water. As a pigment it has great covering power and brilliancy, but red lead which has not been completely oxidized and contains litharge must be applied immediately after mixing to avoid combination with the oil. It is used as a heavy protective paint for iron and steel. Red lead is also used in storage-battery plates and in lead glass. With linseed oil it is used as a lute in pipe fitting. Orange mineral is a pure form of red lead made from white lead and has an orange color. Chemically it is the same as red lead, but it has a different structure, giving it a more brilliant color. Red lead is made from lead metal by drossing and then heating in a furnace. Fume red lead is a fine grade made from Fume litharge, which is made by oxidizing molten lead and passed off as a yellow smoke or fume. Fume red lead is notable for the extreme fineness of its particles, and has an apparent bulk much greater than ordinary red lead. Fume red lead is marketed for pigment as Superfine red lead.

Redwood. Also called Sequoia, California redwood, and Humbolt redwood. The wood of the tree *Sequoia sempervirens,* native to the West Coast of the United States. The wood is light, soft, and spongy but has comparatively high strength and is resistant to decay and insect attack. The trees grow in a narrow coastal strip in California, and are of an immense size, reaching a diameter of 20 ft. and a height of 350 ft. in 2,000 years. The so-called Big tree, however, is the S. *gigantea* or S. *washingtoniana.* It grows in the mountains at elevations of 5,000 to 8,500 ft., but is not cut for lumber. Planks of redwood can be readily obtained 6 ft. in

width. The specific gravity is 0.374 to 0.387. It has a tensile strength of from 7,000 to 11,000 lb. per sq. in. The heartwood varies from light-cherry to dark-mahogany color, and the narrow sapwood is almost white. The wood is used in all kinds of common construction. Redwood bark fiber is the shredded fiber of the bark of the redwood. It has excellent felting properties, is water-resistant and fire-resistant, and is an excellent insulator for house walls and refrigerators. It is also used in wool mixtures for blankets and overcoatings. The fiber is short, but has a natural twist that facilitates spinning. The fiber contains a high content of lignin, and makes a good filler for heat-curing plastics. Palco wool, of the Pacific Lumber Co., is redwood bark fiber. Redwood tannin, produced by soaking redwood chips in hot water and dissolving out the tannin with ethyl acetate, is used as an oxidation inhibitor in paraffin hydrocarbons.

**Refractories.** Substances employed where resistance to very high temperature is required, such as for furnace linings and metal-melting pots. They are composed largely of alumina and silica and are employed in the form of powder to be mixed like cement, or are in the form of bricks. They owe their properties largely to silica, magnesia, and alumina. Clay is the oldest and most common of the refractories. The natural refractories are kaolin, chromite, bauxite, zirconia, magnesite, often marketed under trade names. Refractories may be acid, such as silica, or basic, such as magnesite or bauxite, for use in acid- or basic-process steel furnaces. Graphite and chromite are neutral refractories. Magnesia fuses at 3929°F., chromite at 3722°F., and alumina at 3670°F. The fusing point of the refractory, however, is usually dependent on the binder, as all binders or impurities lower the melting point. The Arco refractory brick of the General Refractories Co., with 60 to 80% alumina, will withstand temperatures from 3290 to 3335°F. The melting point of a 99.5% pure alumina is given as 3725°F., and the decomposing point of a 98% pure silicon carbide as 4175°F. Chrome-magnesite bricks are made usually with 75% chrome ore and 25% dead-burned magnesite.

The chief artificial refractories are silicon carbide and aluminum oxide. A refractory cement, marketed by the Carborundum Co.

under the name of Carbofrax, is silicon carbide with a small amount of binder. Grade No. 4 vitrifies at 2460°F. and will not fuse under 3300°F. The tensile strength at 2550°F. is 1,750 lb. per sq. in. Refrax, of the same company, is composed of silicon carbide held together by crystallization. It will withstand temperatures up to 2240°C., at which point it decomposes. The crushing strength of the brick is 12,500 lb. per sq. in. This type of material can be made only in simple shapes. Aluminite is the name of an alumina refractory of the Philip Carey Co. furnished in blocks to withstand temperatures up to 2000°F. Good refractories should be of such a chemical composition that they do not fail below the melting point by great expansion or contraction, or by spalling, that is, by cracking from unequal expansion. A high-grade refractory for melting furnaces should withstand temperatures up to 3300°F. and have high resistance to slag and chemical influences. Fire sand is a sand composed of 98% silica and is very refractory. The natural silica refractories used to replace fireclay for high temperatures should contain at least 97% of silica and not yield too fine a powder on crushing. In order of merit the materials used are chalcedony, old quartzites, and vein quartz. The refractory known in Europe as Klebsand, used for steel furnace linings, has 87% of $SiO_2$, 8.6 of $Al_2O_3$, 0.3 of $TiO_2$, and some ferric oxide. Ganister is a natural refractory mineral used for furnace linings. In compact form it was used for furnace hearths. It contains about 95% of silica, with about 1.5% $Al_2O_3$, and a small amount of lime as a binder. The chief deposits are in the quartzites of Wisconsin, Alabama, and Colorado. An artificial ganister is made with silica and clay. Ganisand, of the Quigley Furnace Specialties Co., Inc., is a ganister having a fusing point at 3250°F. Dinas silica is an English ganister with about 97% silica, having a melting point of 1680°C.

Pinite, from Nevada, is a secondary mineral derived from the alteration of feldspar and other rocks, and is used for kiln linings in cement plants. It is a hydrous silicate of alumina and potash, and the massive material resembles steatite. It will bond alone like clay and has low shrinkage. At 1125°C., the mineral inverts to mullite. Agalmatolite is a massive pinite and can be used in the same way. Bull-dog is an old name for a refractory which is a mixture of ferric oxide and silica made by roasting tap cinder with

free access of air. Tap cinder is a basic silicate of iron, $2FeO \cdot SiO_2$, which on roasting takes up oxygen.

Refractory cement. A large proportion of the commercial refractory cements used for furnace and oven linings and for fillers are fireclay-silica-ganister mixtures with a refractory range of 2600 to 2800°F. Cheaper varieties may be mixtures of fireclay and crushed brick, fireclay and sodium silicate, or fireclay and silica sand. An important class of refractory cements is made of silicon-carbide grains or silicon-carbide fire sand with clay bonds or synthetic mineral bonds. The temperature range of these cements is 2700 to 3400°F. Silicon-carbide cements are acid-resistant and have high thermal and electrical conductivity. For crucible furnaces the silicon-carbide cements are widely used except for molten iron. Alumina and alumina-silica cements are very refractory and have high thermal conductivity. Calcined kaolin, diaspore clay, mullite, sillimanite, and combinations of these, make cements that are neutral to most slags and to metal attacks. They are electrical insulators. Chrome-ore cements are difficult to bond unless mixed with magnesite. Plastic 695, of the Basic Refractories, Inc., is a Chrome-magnesite cement made of treated magnesite and high-grade chrome ore. It sets quickly and forms a hard and dense structure. The melting point is above 3600°F. It is used particularly for hot repairs in open-hearth furnaces. Magnefer is the name of a dead-burned dolomite refractory of the same company, while Basifrit is a magnesia refractory for resurfacing. Zircon-magnesite cement is made with 25% of refined zircon sand, 10 milled zircon, 15 fused magnesia, and 50 low-iron dead-burned magnesite bonded with sodium silicate. A wide range of refractory cements of varying compositions and characteristics is sold under trade names, and these are usually selected by their rated temperature resistance. For example, Hadesite, of the Eagle-Picher Lead Co., is composed of refractory clay and aggregates, mineral wool, and a binder, and is recommended for temperatures up to 1900°F. Vitrobond, of the Johnson Fuller Co., is a powder composed of zirconium silicate and high-melting oxides, which is sprayed or brushed on furnace walls in water solutions. It vitrifies at 2090°F., and will then withstand temperatures up to 3850°F.

**Refrigerants.** Gases, or very low-boiling-point liquids used for the heat-absorbent cycle in refrigerating machines. The ideal refrigerant, besides having a low boiling point, should be noncorrosive, noninflammable, and nontoxic. Ammonia is the most common refrigerant. Ethyl chloride, methyl ether, carbon dioxide, sulphur dioxide, and other chemicals are used as refrigerants. Freon, a colorless, odorless gas of the composition $CF_2Cl_2$, which liquefies at $-21.7°$F., is a refrigerant. The gas is noninflammable. Other chlorofluoro derivatives of ethane and methane are also used as freons, $CCl_3F$, $CHCl_2F$, and others. The freons are also used as carriers for insecticides. Genetron 101, of the General Chemical Co., has the composition $CH_3 \cdot CClF_2$, with boiling point at $-9.2°$C. and freezing point at $-130.8°$C.

**Resins.** An important group of substances obtained as gums from trees, or manufactured synthetically, as the phenol resins. The common resin of the pine tree is called rosin. The natural resins are soluble in most organic solvents and are used in varnishes, adhesives, and various compounds. Oleoresins are natural resins containing essential oils of the plant. The synthetic resins are used chiefly for lacquers, varnishes, coatings, adhesives, and for molding mechanical and electrical parts. Some of the commercial resins are rosin, dammar, mastic, sandarac, frankincense, lac, and anime. Gum resins are natural mixtures of true gums and resins and are not as soluble in alcohol. They include gamboge, myrrh, rubber, guttapercha, and olibanum. Fossil resins are considered especially valuable, and owe their quality to the long formation. These are amber, kauri, and copal.

Galbanum, used in medicine, is a gum resin from the perennial herb *Ferula galbaniflua* of western Asia. It comes in yellowish to brownish tears. Myrrh is a gum resin from species of small trees of India, Arabia, and northeast Africa. There are about 80 species. The Hebrew word Mur means bitter. The gum is called Mulmul and Ogo in East Africa. Sweet myrrh, or Bisabol myrrh, is a very ancient perfume and incense. It comes from the tree *Commiphora erythraea* of Arabia. Herabol myrrh is from the small tree *C. myrrha* of India and is a brown to black solid. It is used in medicine as a stimulant and antiseptic and in perfumes and incense.

Asafetida is a gum resin with a foul odor and acrid taste obtained from the roots of the perennial herb *F. assofoetida* and other species. It is used in Asia for flavoring foods, but in the United States is employed in medicines and perfumes. Creosote bush resin is an amber-colored, soft, sticky resin from the leaves and small twigs of the Greasewood bush, *Larrea tridentata,* of the desert regions of the Southwest and Mexico. It is used in adhesives, insecticides, core binders, insulating compounds, and pharmaceuticals. When distilled, the resin yields Nordihydroguaiaretic acid, $(C_6H_3 \cdot Cl \cdot COOH)_2CH_2$, called NDGA, used as an antioxidant preservative in butter, lard, vegetable oils, and pharmaceuticals. It is a white crystalline solid with a melting point of 184°C., soluble in fats but only slightly soluble in hot water.

**Resistance wire.** The standard alloy for electrical resistance wire for heaters and electrical appliances is nickel-chromium, but nickel-manganese is also used; for high-temperature furnaces molybdenum wire is used. The alloy with 80% of nickel and 20 chromium resists scaling and oxidation up to 2100°F. The alloy containing 60% of nickel, 15 chromium, and 25 iron is resistant up to 1830°F., and the alloy with 30% of nickel, 20 chromium, and 50 iron, is resistant to 1560°F. Resistance wire of these alloys is made to close tolerances. Molybdenum wire is used for temperatures up to 2900°F. For low temperatures, copper-nickel or nickel-iron alloys are used. A resistance alloy developed by the National Bureau of Standards, called Therlo, contains 85% of copper, 9.5 manganese, and 5.5 aluminum. Fecraloy, of the Wilber B. Driver Co., contains 15% chromium, 5 aluminum, and the balance iron. It has high electrical resistance, and will withstand temperatures up to 1400°F. A Silicon-manganese-nickel alloy is marketed by this company under the name of Sparkaloy and is used for spark-plug wire. Manganin, of this company, contains 70 to 85% of copper, 2 to 5 nickel, and 12 to 15 manganese. It has a tensile strength of 70,000 lb. per sq. in. and a resistance of 290 ohms per cir. mil ft. It is used for coils and shunt wires in electrical instruments, and also in sheet form for instrument springs. Tophet A, of this company, is a standard 80-20 nickel-chromium alloy. The tensile strength is 120,000 lb.

per sq. in. and resistance 650 ohms per cir. mil ft. Tophet C, containing 60% of nickel, 16 chromium, and 24 iron, has a resistivity of 675 ohms and is used for temperatures up to 1920°F.

Calorite, of the General Electric Co., has 65% of nickel, 8 manganese, 12 chromium, and 15 iron. Excello metal, of H. Boker & Co., Inc., contains 85% of nickel, 14 chromium, and 0.5 each of manganese and iron. It is used in electric heaters for temperatures up to 2000°F. Alumel, of the Hoskins Mfg. Co., intended for temperatures up to 1250°C., has 94% of nickel, 2.5 manganese, 0.5 iron, and small amounts of other elements. Calido, of the Driver-Harris Co., contains 59% of nickel, 16 chromium, and 25 iron. Nichrome V, of this company, is the 80-20 alloy. Nichrome S contains 25% of nickel, 17 chromium, and 2.5 silicon. It is marketed in sheet form for temperatures up to 1800°F. Comet metal, of the same company, used for rheostats, contains 30% of nickel, 5 chromium, and the balance iron. It has high strength, up to 160,000 lb. per sq. in., and a resistivity of 570 ohms. Hytemco, of this company, is an iron-nickel alloy used for low-temperature wire. The resistance is 120 ohms per cir. mil ft. Magno is a 95% of nickel, 5 manganese alloy of this company; Climax metal has 74% of iron, 25 nickel, and 1 manganese. A Swedish alloy without nickel, used as a substitute for nickel-chromium-iron alloy is Kanthal, containing 23% of chromium, 5 aluminum, 1.8 cobalt, and the remainder iron. Copper-manganese alloys have high resistivity, one with 96 to 98% of manganese having a resistance of more than 1,000 microhms per cu. cm. But when the manganese content is high, they are brittle and difficult to make into wire. Addition of nickel makes them ductile, but lowers the resistivity. A typical alloy contains 35% of manganese, 35 nickel, and 30 copper.

**Resorcinol.** A colorless crystalline material with the composition $C_6H_4(OH)_2$, melting point 110°C., very soluble in water and in alcohol. It is used in the production of plastics, in the manufacture of fluorescein, in the production of xanthane and azo dyes particularly the fast Alsace green, in medicine as an antiseptic, and in making the explosive lead styphnate. Resorcinol polymerizes with formaldehyde to form the Resorcinol-formaldehyde plastics

that will cure at room temperature and with only slight pressure. They are used in strong adhesives for plywood and other products. Resorcinol adhesives remain water-soluble during the working period for 2 to 4 hr. and are then insoluble and chemical-resistant. Pencolite G-1215, of the Pennsylvania Coal Products Co., is a resorcinol-formaldehyde adhesive that cures at 75°F. and gives a bonding strength of 3,000 lb. per sq. in. The resorcinol adhesives may be modified with phenol to reduce cost and still retain the low-temperature setting. Phenac 703, of the American Cyanamid Co., is a phenol-modified resin used for strong plywoods.

**Rhenium.** An elementary metal, symbol Re, present in small quantities in many minerals. Rhenium has a specific gravity of 21.4, and a melting point of 3440°C., or higher than that of tungsten. It has a silvery-white color, is hard but ductile and malleable, and takes a high polish. The metal is obtained from molybdenite, which usually has from 2 to 20 parts per million, but the North Carolina concentrates contain as high as 90 parts per million. It is also found in the Ural platinum ores. The metal is resistant to many acids but is soluble in nitric acid. As a plating metal it gives a hard white deposit, but darker than that of rhodium. Some rhenium is used in radio tubes and as a catalyst.

**Rhodium.** A rare metal, symbol Rh, found in platinum ores. It is very hard and is one of the most infusible of the metals. The melting point is 3542°F. It is insoluble in most acids but is attacked by chlorine and sulphur. The specific gravity is 12.44. Rhodium is used to make the nibs of writing pens, resistance windings in high-temperature furnaces, for the points of thermocouples, as a catalyst in the oxidation of ammonia to nitric acid, for laboratory dishes, and for electroplating jewelry and electric appliances. The plated metal has a pinkish-white luster. The metal is malleable at temperatures above 800°C. It forms a solid-solution alloy with platinum that is easily workable and does not tarnish or oxidize at high temperatures. These alloys are used for thermocouples, and sometimes for chemical apparatus. Rhodium is sold by the troy ounce, 1 cu. in. weighing 6.56 troy oz.

**Rice.** The white seed of the large annual grass *Oryza sativa,* growing to a height of 2 to 4 ft. It is a tropical plant native to Asia, but grows in hot, moist regions well into the temperate zones and is cultivated in many parts of the world. The rice seed grows in an inflorescence composed of a number of fine branches each terminating in a single grain enclosed in a brown husk. There are more than 2,000 listed varieties. Rice forms the staple food of more than half the population of the world. Wild rice was used by the Indians of North America before the first Asiatic rice was brought to South Carolina in 1694. Rice is high in starch and low in proteins. It is used as a direct food, also as flour, cereal, in puddings, and for the manufacture of starch and for alcoholic beverages. Rice hulls are used as stock feed, and Rice straw is used for packing, hats, and other articles. Rice in the husk before hulling is known by the Hindu name of Paddy. Broken grains are sold in the India trade as Coodie or Khood. Patna rice does not refer to the Patna district of India, but to a variety of rice with bold and hard grains especially suited for soups as it holds its shape in boiling. The beverage known in Japan as Saké is Rice wine made by fermenting the rice with a mold, Tané koji. The wine contains 13 to 14% of alcohol. About 62 lb. of cleaned rice, or white rice, are obtained from 100 lb. of paddy. About 91 lb. of white rice are obtained from 100 lb. of Brown rice, or partially cleaned rice.

**Roscoelite.** One of the most important ores of vanadium produced in the United States. It is a muscovite mica in which part of the aluminum has been replaced by vanadium. It occurs in micalike scales varying in color from green to brown. It has a specific gravity of 2.9. The ore mined in Colorado contains about 1.5% of Vanadium oxide, $V_2O_5$, and this oxide is extracted and marketed for making ferrovanadium and vanadium compounds.

**Rosewood.** The wood of several species of *Dalbergia* of northern South America, but chiefly from the Jacaranda tree, *D. nigra.* It is used for fine cabinetwork, pianos, novelties, and expensive furniture. It should not be confused with the wood of the tree *Physocalymma floridum,* which also comes from Brazil and is there called Pao rosa or rose wood. The color of rosewood is dark

brown to purple, and it takes a beautiful polish. It has a characteristic fragrance. It is very hard and has a coarse, even grain. The weight is 54 lb. per cu. ft. Indian rosewood is from the tree *D. sissoo* of India. It is also called Sissoo, and is a beautiful, brown hardwood employed for carvings. In Europe it is also used for parquet floors. Borneo rosewood, also known as Ringas, is the wood of several species of trees of the genus *Melanorrhoea* of Borneo. The wood has a deep-red color with light and dark streaks. It has a close texture suitable for carving. Satinee is a type of rosewood from the tree *Ferolia guianensis* of the order *Rosaceae,* native to tropical America, particularly the Guianas. The wood is reddish brown, weighs 54 lb. per cu. ft., is fairly hard, has a fine grain, and takes a lustrous polish. It is used for cabinetwork. Bois de rose oil, or Rosewood oil, is not from rosewood, but is extracted from the heartwood of the tree *Aniba panurensis* of Brazil and the Guianas. It is also called Cayenne linaloe, or Cayenne oil. It has a delicate rose odor with a suggestion of orange and mignonette valued in perfumes. It contains a high percentage of Linalol, a colorless alcohol with a soft, sweet odor, also found in the rose, lilac, lily, lavender, petitgrain, and other plants. It also contains geraniol. Linaloe oil, or Mexican linaloe, is distilled from the heartwood of the trees *Bursera delpechianum* and *B. aloeoxylon.* It contains less linalol and also terpineol and geraniol. Linalol is closely related to geraniol and nerol. Bois de rose is also made synthetically from geraniol. Oriental linaloe is distilled from selected highly perfumed parts of the wood of the large tree *Aquilaria agollocha* of eastern India, Burma, and Java. The odor of the oil is like rose, ambergris, and sandalwood. Like the linaloes of the American continent the oil is a pathological product and comes only from old trees. It is also called Aloe wood oil and Agar attar, and is a very ancient perfume. True original rosewood oil known as Rhodium oil was distilled from the wood of the plant *Convolvulus scoparius* of the Canary Islands.

**Rosin.** The common resin of several varieties of the pine tree, found widely distributed in North America and Europe. It is obtained by cutting a longitudinal slice in the tree and allowing the exudation to drip into containers. The liquid resin

is then distilled to remove the turpentine, and the residue forms the rosin. It is a reddish-brown translucent solid, inflammable and easily fusible. It consists chiefly of Abietic acid, of the empirical formula $C_{19}H_{29}COOH$, and is one of the cheapest organic acids available. There are two general kinds: Wood rosin and Gum rosin. The specific gravity is 1.08 and the melting point is 100 to 140°C. Rosin is soluble in alcohol, turpentine, and in alkalies. It is used in varnishes, paint driers, soluble oils, paper sizing, belt dressings, and as a filler for other resins. The rubber industry uses 5,000,000 lb. annually, and gum rosin is also used with rubber in nonvulcanizing cements. Wood rosin is used in linoleum manufacture.

Rosin is generally graded commercially by letters according to color. The darkest grade is B, and the lightest is W. Extra grades are A, nearly black, and WW, water white. The dark grades of wood rosin are considered inferior. They have high melting point and low acid number and are used for making rosin oil, for battery wax, thermoplastics, dark varnish, and for linoleum manufacture. The ruby-red wood rosin, obtained by extraction from fat pine wood, has high acid number, 155, and low melting point, 175°F. It is used for printing inks, paper size, and adhesives. Rosin is usually marketed in wooden barrels. A barrel of rosin under Georgia law is 280 lb. Hardened rosin is a weak resinate made by adding 6 to 8% of high-calcium lime to melted rosin. It is used in some varnishes. Rosin ester, or Ester gum, is prepared by heating rosin with glycerin. It is lighter in color than rosin, has a higher softening point, and a much lower acid number, usually 7 to 9. It is used with tung oil in enamels and varnishes and in adhesives. Resin V, of the Advance Solvents & Chemical Corp., is a rosin glycerin ester gum. Naval stores is a name given to rosin and turpentine. Colophony is a chemical name for rosin before the distillation of rosin oil. It was referred to by early writers as Greek pitch, but the so-called Greek fire, used by the ancients as an incendiary material, was described as tow and pine sawdust impregnated with powdered rosin, pitch, and sulphur. Burgundy pitch is a name now used for rosin and mineral oil, used for friction tape and for compounding with rubber. It is amber colored, has a specific gravity of 1.04, and a melting point of

212°F. But the name Burgundy pitch was originally applied to the resin of the Norway spruce, *Picca abies,* used in medicine.

Hydrogenated rosin has greater resistance to oxidation than common rosin, has less odor and taste, and has a pale color that is more stable to light. It is used in protective coatings, paper size, adhesives, in soaps, and as a tackifier and plasticizer in rubber. Because of its saturated nature it cannot be used for rosin-modified plastics. The average acid number is 162, saponification value 167, and softening point 157°F. Stabelite resin, of the Hercules Powder Co., is a hydrogenated rosin. Vinsol resin is a hard, high-melting, dark resin produced from the distillation of wood, or is the black residue left after rosin is extracted with petroleum solvents. It is soluble in alcohols, has a melting point of 115°C., and is used for insulating varnishes where light color is not essential, and for compounding in thermoplastics. Abalyn, of the Hercules Powder Co., is a name for an ester of abietic acid made by treating rosin with methyl alcohol. It is a liquid resin used as a plasticizer. Hercolyn is Abalyn hydrogenated to saturate the double bonds with hydrogen. Flexalyn, of this company, is a pale-colored, very tacky, semisolid resin produced by the esterification of rosin acids with diethylene glycol, and has a complex chemical structure. It is used in adhesives to give added tack and strength. Rosin size is prepared rosin in the form of dry powder or of an emulsion, used for sizing paper. Dresinite is a sodium or potassium salt of rosin, used in sizes, wetting agents, and in adhesives.

Rosin is hardened by polymerization to form a dipolymer of abietic acid. The product is then pale in color, and has a lower acid number and a higher melting point than rosin. Poly-pale resin, of the Hercules Powder Co., is a polymerized rosin with melting point of 208 to 217°F., acid number 152 to 156, and saponification value 157 to 160. It can be substituted for natural copals in paints, and in gloss oil it gives water resistance and high viscosity. In the making of metallic resinates it gives higher melting points, higher viscosity, and better solubility than natural rosin. Pentalyn is another resin derivative of rosin. The melting point is 131°C. It is water-resistant and stable to light and heat, and is used to replace copals in varnishes. Nuroz is a polymerized rosin of New-

port Industries, Inc., with a melting point of 76°C. and acid value 161. It has high resistance to oxidation, and is used in varnishes and soaps.

**Rosin oil.** An oil produced by the dry distillation of rosin at a temperature of 200 to 360°C. There are two qualities of the oil: a light spirit, Pinolin, which forms from 1 to 5% of the rosin, and a bluish, heavy oil, which forms 80 to 84%. It contains abietic acid and has an acid value of about 28. The commercial oil has a specific gravity of 1.020 with a flash point of 160 to 170°C. The refined oil is a yellow liquid with a pleasant odor and may be used for adulterating turpentine. It is also employed as a plasticizer in rubber, as a tack producer in rubber cements, and in synthetic molding resins. When treated with lime, it may be used to mix with lubricating oils. The light distillate is used sometimes in pharmacy under the name of Oil of amber. Blended rosin oil is a mixture with mineral oils.

**Rottenstone.** A soft, friable, earthy stone of light-gray to olive color, used as an abrasive for metal and wood finishing. It resembles Missouri tripoli, and is derived from the weathering of siliceous-argillaceous limestone, with generally from 80 to 85% of alumina, 4 to 15 of silica, and 5 to 10 of iron oxides. Rottenstone was largely imported from England, but a variety is found in Pennsylvania. It is finely ground and is marketed either as a powder or molded into bricks. The latter form is used with oil on rag-wheel polishing. A 250-mesh powder is used as a filler in molding compounds.

**Rouge.** A hydrated iron oxide used for polishing metals. It has a hardness of 5.5 to 6.5 and is made by calcining ferrous sulphate and driving off the sulphur. The color is varying shades of red; the darker the color, the harder the rouge. The grains are rounded, unlike the grains of crocus. The pale-red rouge is used for finishing operations; the other grades are used for various polishing of metal surfaces. Stick rouge is made of finely crushed powder. Although the word rouge means red, materials of other colors are used for buffing and are called rouge. Black rouge, also called Glassite, is magnetic oxide of iron made by precipitating

ferrous sulphate with caustic soda. It is used for buffing but is not popular because it stains the skin. Green chrome rouge is Chromium oxide, CrO, made by the strong heating of chromic hydroxide. It is used for buffing stainless steels. When used as a paint pigment, it is called Guignet's green. Satin rouge is a name applied to lampblack when used as a polishing medium in the form of brick for polishing silverware. Crocus is a name applied to mineral powders of a deep-yellow, brown, or red color made into cakes with grease for polishing. Polishing crocus is usually red ferric oxide. Crocus cloth is a fabric coated with red iron oxide marketed in sheets and used for polishing metals.

**Rubber.** A gum resin exudation of a wide variety of trees and plants, but especially of the tree *Hevea brasiliensis* and several other species of *Hevea* growing in all tropical countries and cultivated on plantations in the East. A hectare grows 400 trees of the species *H. brasiliensis,* yielding 360 kilos of rubber annually. To produce the best yielding trees three species may be grafted together. One species that is a strong producer of roots is used for the seedling; a second high-yielding species for the latex trunk; and a third species resistant to leaf disease for the foliage. The gum resin was formerly referred to as India rubber, and the name given it by Charles Goodyear was Gum elastic. The first highly compounded rubber for insulation, developed in 1867, was called Kerite. Brazilian rubber is sometimes called Para rubber. Caoutchouc is an early name for crude rubber. The milklike juice, or latex, is dried over a fire into a dark, solid mass for shipment, but latex is also shipped. Castilla rubber, sometimes erroneously called Castilloa, is from the very large tree *Castilla elastica.* It was the original rubber of the Mayan and Carib Indians, but was cultivated only in Mexico. The latex and rubber are identical with Hevea rubber after purification. Euphorbia rubber is from vines of the genus *Euphorbia* of which there are 120 species in South Africa.

Crude rubber is usually marketed as crepe or ribbed smoked sheet in various grades. Rubber has the property of being vulcanized with sulphur, making it harder, and more elastic in the low-sulphur compounds. The ordinary Soft rubber contains only

from 3 to 6% of sulphur, and may also contain factice or other softening medium, giving varying degrees of elasticity, flexibility, and resiliency. When 30% of sulphur is added and heated, hard rubber is formed. Vapor-cured rubber is rubber vulcanized by sulphur chloride fumes and neutralized with magnesium carbonate. It is used for thin goods only. Acid-cured rubber is rubber cured in a bath of sulphur chloride in a solvent. About 75% of the rubber consumed in the United States normally goes for automotive tires, but there are innumerable other uses of rubber for molded goods, adhesives, elastic products, and waterproofings. The great value of rubber is its flexibility and elasticity, but it also is valued for its adhesive properties and its water resistance. The tensile strength of rubber of low vulcanization is 800 to 1,200 lb. per sq. in. of the original cross section.

For the rubber used in making automobile tires large percentages of carbon black and zinc oxide are used to reinforce it and give added wearing qualities. Rosin and other resins and gums impart softness to rubber compounds. Carbon black gives wear resistance. Zinc oxide is an accelerator as well as a filler and strengthener. Litharge, lime, and magnesia stiffen rubber and speed up vulcanization. Calcium carbonate increases strength and tear resistance. Red rubber is now simply rubber colored red, but was originally rubber vulcanized with antimony pentasulphide which broke down with the heat of vulcanization yielding sulphur to the rubber and coloring it red with the residual antimony trisulphide. Many trade-named accelerators, fillers, and stiffeners are marketed for rubber compounding. Cycline oil, of the Monsanto Chemical Co., is a mixture of vegetable and mineral oils for softening molding rubbers. Tackol is a mixture of oils and resins used as a rubber plasticizer. Trimene, of the Naugatuck Chemical Div., U.S. Rubber Co., is an aldehyde amine with stearic acid, used to aid the cure and stiffen rubber. Whiting, clay, and barites are used as fillers, but many of the fillers also give added properties to the rubber.

Rubber contains Isoprene, $C_5H_8$, which is the building unit of balata, gutta percha, and many other rubberlike materials. Isoprene can be made from turpentine or from petroleum, and at least small amounts are needed in all synthetic rubbers to increase

elasticity, impart tack, and aid the curing. The exact composition of rubber is not fully determined, but natural rubber contains as many as 4,500 isoprene groups and may have a molecular weight as high as 300,000. The so-called Synthetic rubbers are not rubbers, but are rubberlike products. They do not have the elasticity of rubber, but are more resistant to aging, heat, oils, and chemicals, and are stronger. Some of them, also, have stronger adhesive qualities. They have advantages over rubber for many products where the lesser elasticity is not important, and in mixtures with natural rubber they often form products with the characteristics of both. The original Butadiene rubber was produced in Germany from butane gas by conversion to butadiene. It is not as elastic as natural rubber but has good wear resistance and is resistant to mineral oils and to aging.

Neoprene, formerly called Duprene, of E. I. duPont de Nemours & Co., Inc., is a chloroprene rubber and has various grades, or polymers. It is a rubberlike material but is more resistant to oils and chemicals than rubber. It is also stable to light and aging and is more heat-resistant than rubber, but the elasticity is less. It is not vulcanized with sulphur but is self-curing by polymerization. It is valued for hose, gaskets, belting, molded goods, coated fabrics, and adhesives. The specific gravity is 1.25, but with fillers it ranges from 1.4 to 1.8. The tensile strength is 200 to 4,000 lb. per sq. in., depending upon the polymer and the fillers. This material produced in Russia is called Sovprene.

Thiokol, of the Thiokol Corp., is an olefin polysulphide reaction product, which can be vulcanized like rubber and is used for molded products, wire covering, and coatings. Koroseal, of the B. F. Goodrich Co., is a polymer of vinyl chloride, and is used for gaskets, fabric impregnation, and cable sheathing. The strength is from 1,000 to 7,000 lb. per sq. in., depending upon the amount of plasticizer. The dielectric strength is 250 to 850 volts per 0.001 in. thickness. In solution this material, known as Korolac, is used for lining acid tanks and covering plating racks. It is resistant to acids.

There are at least six general types of Synthetic rubbers: Chloroprene polymers, such as Neoprene; Butadiene polymers, such as Buna; Organic polysulphides, such as Thiokol; Isobutene

polymers, such as Vistanex; Vinyl chloride polymers, such as Koroseal; and Dimethyl butadiene polymers, such as Methyl rubber. In general, these rubbers are made in two steps, by manufacture of the monomer, and then by polymerization or condensation. Chloroprene, a colorless liquid, $CH_2:CHCCl:CH_2$, produced from acetylene, can be polymerized to form a wide variety of products from soft rubberlike plastics to hard, horny, inelastic, and insoluble polymers. The polymerization can be controlled to yield rubberlike materials with some characteristics superior to natural rubber. Thiokol A is made by the reaction of sodium tetrasulphide and ethylene dichloride. Butyl rubber, of the Standard Oil Co., is a variation of Buna rubber made from petroleum. This rubber manufactured from petroleum by the B. F. Goodrich Co. is called Ameripol. It is marketed under the name of Hycar by the Hydrocarbon & Chemical Rubber Co. Methyl rubber is made by Bayer & Co. Perduren is a Buna rubber of I. G. Farbenindustrie. Resenit is a Russian polysulphide, and Vulcaplas is a similar English rubber. Korogel is a highly plasticized Koroseal. Mustone is a Japanese Chloroprene rubber. Perbunan is a butadiene rubber of the Standard Oil Development Co. Chemigum is a rubber derived from petroleum with patents held by the Goodyear Tire & Rubber Co. It is easier to process and cheaper than Buna rubber. The present Buna rubbers differ from the original German products. Buna S, or GRS rubber, is a copolymer of butadiene and styrene.

Agripol, of the Reichhold Chemicals, Inc., is a rubber substitute made from soybean oil-fatty acids polymerized with ethylene glycol. It vulcanizes somewhat like rubber and it is compounded with sulphur, carbon black, zinc oxide, and plasticizers. It is flexible, and is used for mechanical applications. Norepol rubber, developed by the U.S. Department of Agriculture, is made by the polymerization of the linoleic acid from soybean, linseed, or peanut oils. Vistanex, known first in Germany under the name of Oppanol, and further developed by the Standard Oil Co., is a polymer of isobutylene, a petroleum hydrocarbon. It is not elastic like rubber, but has good electrical properties, is resistant to oils and chemicals, and has heat and wear resistance. It is especially valuable when compounded with natural rubber. It is used for insulation, packings, gaskets, and hose.

**Rubber powder.** Also called Granulated rubber. A powder prepared usually by spraying latex containing protective colloids into a current of hot air and drying the particles. The latex is protected or stabilized with an ammonia solution of zinc ammonium sulphate; the final rubber powder contains 8% of zinc ammonium phosphate and 2 of magnesium carbonate. It can also be made by precipitation. Rubber powder is fine, passing through a 200-mesh screen. It is used chiefly in molding and calking compounds. Vulcanizing and compounding materials are sometimes added to the powder for marketing as molding powders. Hard-rubber dust is made from hard-rubber scrap and is used as a filler in rubber.

**Rubidium.** A rare metallic element, symbol Rb, atomic weight 85.45, belonging to the group of alkali metals. The chief occurrence of rubidium is in the mineral lepidolite, although it is found in other minerals, and in tea, coffee, tobacco, and certain other plants. It is a silvery-white metal, with a specific gravity of 1.52, melting point of 39°C., and boiling at 696°C. It takes fire easily in the air, and like potassium it decomposes water. It can be obtained by electrolysis but has few industrial applications as yet, owing to its rarity and instability. Its chief use is for coating photoelectric cells for telephotographic and television instruments. For the photoelectric cell an extremely thin layer of rubidium is applied to the inside of the glass, and it is preferred to cesium.

**Ruby.** A transparent variety of the mineral corundum, having a beautiful red hue. It ranks with the best grades of precious stones as a gem stone, but is also used for pivot bearings in watches and fine instruments. The specific gravity is 4.03 and the hardness is 9, being nearly equal in hardness to the diamond. The color is due to chromic oxide. Most of the best rubies come from Upper Burma. Darker stones come from Siam. The center of ruby cutting is at Cambay, near Bombay. The carmine-red, or pigeon's blood, stones are the most highly prized, and in large sizes are of more value than diamonds. Medium-colored red squares and rounds are highly valuable. Stars are stones of large size. Most rubies range from 0.01 to 0.67 carat. For bearing uses

synthetic rubies are largely substituted for the natural stones. Synthetic ruby, and other Synthetic gems, notably the Aquamarine and Tourmaline, are made for jewelry and for bearings for watches and instruments. They are made from argillaceous earth at high temperatures; the crude product is a pear-shaped crystal 6 mm. in length. They have the same composition and crystal structure as the natural stones. Tourmaline is a complex silicate stone, usually green in color, but sometimes blue or red. The rare colorless variety found in Madagascar is called Achroite. Tourmaline can be used for wave-length control in radio, but is more expensive than quartz crystal.

**Ruthenium.** A rare metallic element, symbol Ru. It is a hard, white metal, having a specific gravity of 12.1 and a melting point of about 4440°F. The Brinell hardness of the annealed metal is 220. It can be obtained in the metallic state by heating Ruthenium oxide, $RuO_2$, obtained from the residue of platinum ores, in hydrogen. It is insoluble in most acids and is not dissolved by aqua regia. Ruthenium is used as a hardener in platinum alloys and has a powerful hardening effect on this metal. It is sold by the troy ounce; 1 cu. in. weighs 6.38 troy oz.

**Rye.** The seed of the plant *Secale cereale* used as a food grain, but in the United States and Great Britain it is valued chiefly for the production of whisky and alcohol and for feeding animals. Only 4% of the world production is in the United States. The grain looks like wheat, and the stalks of the plant are slender and tough, growing to a height of up to 6 ft. But flour made from the grain produces bread that is dark in color, bitter, and soggy. When used for flour in the United States, it is mixed with wheat and other flours. The plant has the advantage that it will grow on poor soil, in arid regions, at high altitudes, and in regions of severe winter. It is thus a grain of poor agricultural countries, and has been called the Grain of poverty. Rye straw is the dried and sun-bleached stalks of the plant. It is very tough and resilient, and is the most valued of all the commercial Straw derived from grains. It is used for packing, bedding, and for the manufacture of strawboard.

**S.A.E. steels.** The common designation for the standard grades of steel approved by the Society of Automotive Engineers. These steels are made regularly by the various mills and are known by their designating numbers. The first number indicates the class of steel, as follows: carbon steel, 1; nickel-carbon, 2; nickel-chromium, 3; molybdenum, 4; chromium, 5; chromium-vanadium, 6; tungsten, 7; and silicon-manganese steel, 9. The second figure indicates the approximate percentage of the predominating alloying element. The last two or three figures indicate the approximate carbon content in hundredths of 1%. Thus, S.A.E. 2350 steel is a nickel steel containing 3% of nickel (2.75 to 3.25) and 0.50 carbon (0.45 to 0.55). The manganese steels, with manganese from 1.60 to 1.90%, are designated by the letter T before the initial 1. Thus, S.A.E. T1350 contains 0.45 to 0.55% of carbon and 1.60 to 1.90 manganese. The S.A.E. steels are made to close specifications of manganese, sulphur, and phosphorus content and, since they are very uniform in quality and usually carried in stock, they have been widely adopted for use in all kinds of products. The silicon range for the basic open-hearth alloy steels is 0.15 to 0.30; for electric and acid open-hearth steels it is 0.15 minimum.

**Sago flour.** A starch extracted from the pith of the sago palm, *Metroxylon sagu,* of the East Indies and Malaya, called locally the Aren palm. Sago is valued industrially for sizing and filling textiles because, like tapioca, it holds mineral fillers better than other starches. It gives a tougher and more flexible feel than tapioca, but its tan color limits its use. From 600 to 800 lb. of crude Sago is obtained from a tree, which is destroyed in the process. Pearl sago, used for food, is the same material made into dough and forced through a sieve.

**Salmon oil.** A pale-yellow oil obtained as a by-product in the salmon-canning industry, and employed as a drying oil for finishes and also used in soaps. There are different classes of the oil, depending upon the type of salmon. The oil contains palmitic and other acids. The specific gravity is 0.926. It has a high iodine value, 168, but it does not form an elastic skin on drying and is therefore inferior for use in most varnishes. The salmon is a valu-

able food fish and is extensively canned. There are five commercial species of North Pacific salmon of the genus *Oncorhynchus,* and the Steelhead trout or Salmon trout, *Salmo gairdneri* of the Atlantic. The Red salmon, or Sockeye salmon, is *O. nerka;* the Pink salmon is *O.gorbuscha;* and the Chinook or King Salmon is *O. tschawytscha.* The catch is in the rivers on both sides of the Alaska Peninsula and in the Columbia River.

**Salt.** The common name for Sodium chloride, known in mineralogy as Halite, but chemically a salt is any compound derived from an acid by replacing the hydrogen atoms of the acid with the atoms of a metal. Common salt, or sodium chloride, is widely used as a preservative, for flavoring foods, in freezing mixtures, for salt-brine quenching baths, and for the manufacture of soda ash and many chemicals. Common salt has such a variety of uses that its curve of consumption practically parallels the curve of industrial expansion. It is a stable compound of the composition NaCl, containing theoretically 60.6% of chlorine, but it usually contains impurities such as calcium sulphate and calcium and magnesium chlorides. The hardness of salt is 2.5, specific gravity 2.1 to 2.6, and melting point 1472°F. It is colorless to white, but when impure may have shades of yellow, red, or blue. It occurs in crystalline granular masses with cubical cleavage, known as Rock salt, or Mineral salt. Vast deposits of salt are found underground in Louisiana, and a large area of Kansas is underlain with a salt deposit reaching 800 ft. in thickness. Salt is produced commercially in 15 states of the United States, with an annual production up to 16 million tons, and is also produced in almost every country of the world. It is easily soluble in water and is found in all waters. It is obtained by evaporation from sea water, which also contains magnesium chloride and other salts. Bay salt is an old name for salt extracted from sea water, now known as Solar salt. Refined California solar salt is 99% pure sodium chloride. From the salt wells of Michigan the bromine, magnesium, and other elements are extracted and the brines form an important source of these products.

Commercial salt is marketed in many grades, depending chiefly on the size of the grain. The term Industrial salt refers rather to the method of packing and shipping than to a grade distinct from

Domestic salt, but most of the industrial salt is rock salt; the bulk of the domestic salt is evaporated salt. Domestic consumption of salt for direct human consumption is large in all countries. It is required in the blood stream up to about 3.5%, and is rapidly exhausted in hot weather. Salt tablets, used in hot weather, or by workers in steel mills, are made up to 70% salt and 30 dextrose. Salt obtained by simple evaporation of sea water contains salt-resistant bacteria which are capable of developing in salted hides or fish and injuring the material. Mineral salt is thus preferred for these purposes. In making brines, 100 parts of water at ordinary temperature will dissolve about 36 parts of salt. Brines used for quenching steel contain from 10 to 15% of salt and have a high cooling rate, but corrode the steel.

Sodium hypochlorite, or Sodium oxychlorite, NaOCl, is a stable, noncorrosive salt used in tanneries. Merclor D is a trade name of the Monsanto Chemical Co. for this material in water solution. Javel water is a name given in the laundry industry to a water solution of sodium hypochlorite used as a bleach. Sodium hypochlorite when used as a bleach in the textile industry is called Chemic. Sodium chlorite, $NaClO_2$, is a white to yellow crystalline water-soluble powder used as a bleaching agent for textiles and paper pulp. It is stable up to 150°C. It yields $ClO_2$ in the solution, and has the property of attacking the coloring matter without injuring the cellulose of the fibers. Textone is a trade name of the Mathieson Alkali Works, Inc., for sodium chlorite as a bleach for textiles.

Sand. An accumulation of grains of mineral matter derived from the disintegration of rocks. It is distinguished from gravel only by the size of the grains or particles, but is distinct from clays which contain organic materials. Sands that have been sorted out and separated from the organic material by the action of currents of water or by winds across arid lands are generally quite uniform in the size of grains. Usually commercial sand is obtained from river beds, or from sand dunes originally formed by the action of winds. Much of the earth's surface is sandy, and these sands are usually quartz and other siliceous material. The

most useful commercial sands are composed chiefly of silica, often above 98%. Other materials in sand are feldspar, garnet, zircon, and tourmaline. Silica sands for making glass must be free from iron. The sand mined at Hot Springs, Ark., called Amosil, is 99.5% pure silica, and comes in transparent rounded grains of 3 microns average size.

Sand is used for making mortar and concrete and for polishing and sandblasting. Sands containing a little clay are used for making molds in foundries. Clear sands are employed for filtering water. Sand is sold by the cubic yard or ton but is always shipped by weight. The weight varies from 2,600 to 3,100 lb. per cu. yd., depending on the composition and size of grain. Standard sand is a silica sand used in making concrete and cement tests. The grains are free of organic matter and will pass through a 20-mesh sieve, but will be retained on a 30-mesh. Engine sand, or Traction sand, is a high-silica sand of 20 to 80 mesh washed free of soft bond and fine particles, used to prevent the driving wheels of locomotives or cars from slipping on wet rails.

Sandalwood. The heartwood of the evergreen tree *Santalum album* and other species of southern Asia. The heartwood is usually equivalent to about one-third of the log. It is sweet scented and is used for chests, boxes, and small carved work. The chips and sawdust are used for incense and for oil production. Sandalwood oil is a yellowish essential oil of specific gravity 0.953 to 0.985, distilled from the wood, which yields 5 to 7% of the oil. It is used in medicine, perfumery, and soaps. The center of the oil production is in Mysore, India.

Sandarac. Known also as White gum, or Australian pine gum. A white, brittle resin obtained as an exudation from various species of the coniferous tree *Callitris,* known as Cyprus pine. The North African sandarac is from the tree *C. quadrivalis* of the Atlas Mountains, and resembles the resin from the Australian tree *C. arenosa.* The trees in Morocco are tapped from May to June, and two months later the small tears of gum are gathered. Sandarac is used in varnishes and is soluble in turpentine and alcohol. It melts at 135 to 140°C. It gives a hard, white spirit varnish used

for coating labels and for paper and leather finishes. Ground sandarac, under the name of Pounce, was formerly used as a pouncing powder and for smoothing parchment and tracing cloth, but is now replaced by pumice for this use.

**Sandblast sand.** Any sand employed in a blast of air for cleaning castings, removal of paint, cleaning of metal articles, or for giving a dull rough finish to glass or metal goods, or for renovating the walls of stone or brick buildings. Sandblast sand is not closely graded, and the grades vary with different producers. The U.S. Bureau of Mines gives the following usual range: No. 1 sand should pass through a 20-mesh and be retained on a 48-mesh screen; No. 2 should pass through a 10-mesh and be retained on a 28-mesh screen; No. 3 through a 6-mesh and be retained on a 14-mesh; No. 4 through a 4-mesh and be retained on an 8-mesh screen. No. 1 sand is used for light work where a smooth finish is desired; No. 4 sand is employed for rough cast-iron and cast-steel work. Sharp grains cut faster, but rounded grains produce smoother surfaces. The sand is usually employed over and over, screening out the dust. In some cases the dust and fine used sand are mixed with clay and blasted wet. This is known as mud blasting and produces a dull finish.

**Sandpaper.** Originally a heavy paper coated with sand grains on one side, used as an abrasive, especially for finishing wood. Sharp grains obtained by crushing quartz replaced ordinary sand, but have now been largely replaced by crushed garnet and aluminum oxide grains, although the papers are still commonly referred to as sandpaper. Quartz grains, however, are still employed. For this purpose the quartz grains are prepared in grades from the 20 mesh, known as No. 3½, through No. 3, 2½, 2, 1½, 0, 00, and 000. All of the No. 000 grains pass a 150-mesh sieve, with 25% retained on a 200-mesh sieve and 80% on a 325-mesh sieve. Good sandpaper quartz will contain at least 98.9% of silica. The paper used is heavy, tough, and flexible, usually 70- or 80-lb. paper, and the grains are bonded with a strong glue. A process is also employed to deposit the grains on end by electrostatic attraction so that the sharp edges of the grains are presented to the work.

**Sandstone.** A consolidated sand rock, consisting of sand grains united with a natural cementing material. The size of the particles and the strength of the cement vary greatly in different natural sandstones. The most common sand in sandstone is quartz, with considerable feldspar, lime, mica, and clayey matter. The cementing material is often fine chalcedony. Silica sandstones are hard and durable but difficult to work. Calcareous sandstone, in which the grains are cemented by calcium carbonate, is called Freestone and is easily worked, but it disintegrates by weathering. Freestone is homogeneous and splits almost equally well in both directions. Chert, formerly used as an abrasive and, when employed in building and paving, known under local names, as Hearthstone, Firestone, and Malmstone, is a siliceous stone of sedimentary origin. It has a radiating structure and splintery fracture and is closely allied to flint. In color it is light gray to black or banded. The colors of sandstones are due to impurities, pure siliceous and calcareous stones being white or cream-colored. The yellow to red colors usually come from iron oxides, black from manganese dioxide, and green from glauconite. Flexible sandstone, which can be bent, is known as Itacolumite, and is found in North Carolina. It derives its flexibility from a content of talc or mica in the bonding material.

Sandstones are employed for grindstones and for building stones. The average compressive strength of sandstone used for building purposes is 12,000 lb. per sq. in., and the average weight is 135 lb. per cu. ft. Sandstones for building purposes are produced under innumerable names, usually referring to the locality. The Blue stone of New York state is noted for its even grain and high crushing strength, up to 19,000 lb. per sq. in. It contains about 70% of silica sand with clay as the binder. Holystone is a block of close-grained sandstone, formerly used for rubbing down the decks of ships and still used for rubbing down furniture and concrete work. Briar Hill stone and Macstone are trade names for building blocks consisting of lightweight concrete faced with a slab of sandstone. Kemrock, of the Kewaunee Mfg. Co., is a sandstone impregnated with a black furfural resin and baked to a hard finish. It is used for table tops and chemical equipment to resist acids and alkalies.

**Sapele.** The figured woods of various species of trees of tropical Africa which are mixed with khaya and exported from West Africa as African mahogany. Sapele woods are harder and heavier than red khaya, but shrink and swell more than khaya with changes in moisture. They are also darker in color with a purplish tinge. Sapele mahogany, also called Scented mahogany, and West African cedar, is from the *Entandrophragma cylindricum,* a very large tree growing in the Ivory Coast, Gold Coast, and Nigeria. On the Ivory Coast it is called Aboudikro. Another species, *E. angolense,* is called Tiama mahogany on the Ivory Coast, and in Nigeria is known as Brown mahogany and Gedunohor. A less heavy wood is from the tree *E. utile,* known on the Ivory Coast as Sipo mahogany, and in the Cameroons as Assie mahogany. It is one of the chief woods exported as mahogany from the Cameroons. The wood known on the Ivory Coast as Heavy mahogany and Omu in Nigeria is from the tree *E. candollei,* and is much heavier than other sapeles. Nigerian pearwood, from species of *Guarea,* notably *G. cedrata* and *G. thompsonii,* is also exported as African mahogany. The woods are more properly called Guarea. The color is pale pink to reddish. The weight is about the same as sapele. The wood is of a finer texture than khaya, but is not figured like sapele or khaya. Another wood marketed as African mahogany is Lingue, from the tree *Afzelia africana* found on the west coast of Africa from Senegal to Nigeria. The wood is light brown, turning to dark brown when seasoned, and is beautifully figured.

**Saponin.** Glucosides of the empirical formula $C_{32}H_{54}O_{18}$ which have the property of frothing with water. They are found in soap bark, soap nut, licorice, and other plants; when separated out, saponin is a white, amorphous powder of a disagreeable odor. It is used in some soap, in soapless shampoos, tooth powders, fire extinguishers, and as a detergent and emulsifying agent. Soap nut is the fruit of the trees *Sapindus mukorossi* and S. *laurifolia* of northern India known locally as Ritha. The soap nut has been used as a detergent in washing fabrics since ancient times. The nut has 56% of pericarp and 44 of seed, and the saponin is found in the pericarp. It is extracted with solvents from the dried

powdered fruit. Saponin is soluble in water but insoluble in petroleum spirits. Soapbark, also called Morillo bark, is the dried inner bark of the tree *Quillaja saponaria* of the west coast of South America. It was used by the Incas and the botanical name comes from the Inca word quillean meaning to wash. The bark produces suds in water, but the powdered bark is highly sternutatory owing to fine crystals of calcium oxalate. It is marketed in brownish white pieces, crushed, or powdered, and used as a source of saponin, and in medicine. It has been used in beverages to produce froth, but is highly toxic, affecting the heart and respiration. In medicine it is called Quillaja and is used as an irritant and expectorant. Soapwort consists of the leaves of the plant *Saponaria officinalis,* growing in North America. The leaves contain saponin which dissolves out in water to produce a lather useful for cleansing silk and fine woolens. Soapberry is the fruit of the tropical tree *Sapindus saponaria,* used in hair and toilet preparations. The Soapberry of the American Southwest consists of the fleshy berries of the small tree, *S. drummondii.* Soaproot is the bulb root of the plant *Chlorogalum pomeridianum* of California. It is used for washing fabrics. Mexican soaproot is the thick rootstock of the *Yucca baccata* and of the Wild date, *Y. glauca,* growing in the dry regions of Mexico and Southwestern United States. Both plants are called Yucca, and in Mexico they are called Amole. The Indians used the roots for washing, and they were called Vegetable soap by the settlers. In the processing of yucca leaves to obtain fiber about 20% of a powder is obtained which contains 3% of saponin. Yucca powder is used in scouring compounds or for the extraction of saponin. The long stout stems of the Soap plant, *Chenopodium californicium,* also yield saponin.

**Sapphire.** A transparent variety of the mineral corundum. When it has the beautiful blue hue for which it is noted, it ranks with the diamond, ruby, and emerald among precious gem stones. The off-color stones are cut for pointers and wearing points of phonographs and instruments. The specific gravity of sapphire is 4.03, and the hardness is 9. The blue color is from titanic oxide and is rarely uniform throughout the stone. The best gem sapphires come from Ceylon and India, but industrial stones are

produced in Montana. Synthetic white sapphire is produced by fusing alumina in an oxyhydrogen flame. The fused material forms a boule as a single crystal. The average boule is 200 carats, but sometimes they are as large as 400 carats, or about ¾ in. in diameter and 2 in. long. This water-white type is used for instrument bearings, but watchmakers prefer the ruby color. The synthetic stone has a melting point above 3700°F. Synthetic sapphires are also marketed in the form of standard ring and plug gages in sizes from 0.004 to 0.350 in. They have a wear life 50 times longer than hard steel gages. Sapphire is also used for thread guides on textile machinery.

**Satin.** A full-silk, heavy fabric with a close twill, or satin, weave. In the satin weave the fine silk warp threads appear on the surface and the weft threads are covered up by the peculiar twill. Common satin is of 8-leaf twill, the weft intersecting and binding down the warp at every eighth pick, but 16 and 20 twills are also made. In the best satins a fine quality of silk is used. The gloss is partly due to hot rolling. Cheaper varieties of imitation satin are made with a cotton weft. Satins are dyed to many colors, and may be sold under trade names. In industry they are used chiefly for linings and trimmings. Sateen is made from mercerized cotton. The wind-resistant sateen used for military garments is a 9-oz. cotton fabric in satin weave with 2-ply yarn in warp and filling. The thread count is 112 ends per in., 68 picks per in. The fabric is singed, mercerized, and given a water-repellent finish.

**Scandium.** A metallic element, symbol Sc, found chiefly in the mineral Thortveitite, $(ScYt)_2Si_2O_7$, and in wolframite. It occurs also in small quantities in a wide variety of minerals but has as yet no commercial application because of the difficulty of extraction.

**Scheelite.** An ore of the metal tungsten, occurring usually with quartz in crystalline rocks associated with wolframite, fluorite, cassiterite, and some other minerals. It is found in various parts of the United States, Asia, and Europe. Scheelite is Calcium tungstate, $CaWO_4$, containing theoretically 80.6% of tungsten trioxide and 19.4 lime. It is called Powellite when it contains some molyb-

denum to replace a part of the tungsten. It occurs massive granular or in crystals, with a specific gravity of 6.0 and a hardness of 4.5 to 5. Its color is white, yellow, brown, or green, with a vitreous luster. High-grade scheelite is used directly for adding tungsten to steel. Tungstic acid is a yellow powder of the composition $H_2WO_4$ made from calcium tungstate ore by treating with hydrochloric acid. It is not soluble in water, but is soluble in alkalies and in hydrofluoric acid, and is used as a mordant in dyeing, in plastics, and for making Tungsten wire by reducing.

**Scouring abrasive.** Natural sand grains or pulverized quartz employed in scouring compounds and soaps, buffing compounds, and metal polishes. The Federal specifications require that the abrasive grains used in grit cake soap and scouring compounds shall all pass a No. 100 screen, that the grains for scouring compounds for marble floors must all pass a No. 100, and 95% pass a No. 200 screen. For ceramic floors 90% must pass a No. 80, and 95% must pass a No. 60 screen. Very fine air-floated quartz is employed in metal polishes, and all grains pass a 325-mesh screen.

**Screw stock.** A common term for soft steel with free-cutting qualities used for screws and small turned parts made in the screw machine. It usually contains a larger percentage of sulphur than ordinary soft steel. Sulphur makes steel hot-short, or brittle, at red heat, and reduces the tensile strength, but it aids machinability and is called for in steel for simple parts where strength is not important. S.A.E. specifications for screw stock call for 0.08 to 0.155% of sulphur, 0.09 to 0.13 of phosphorus, 0.60 to 0.90 manganese, and up to 0.25 of carbon. High-manganese screw stock is an open-hearth, high-sulphur steel in the medium-manganese class having good cutting and casehardening properties and higher strength. A grade of manganese screw stock under the name of Ryco is marketed by Joseph T. Ryerson & Son, Inc., having a tensile strength of 90,000 lb. per sq. in. and elongation of 20%. Silcut steel is a free-cutting steel produced by W. T. Flather, Ltd. Super-cut steel and Freecut steel of the Union Drawn Steel Div., Republic Steel Corp., are high-sulphur, bessemer cold-drawn steels with tensile strengths up to 100,000 lb. per sq. in., elongation 18% and hardness 196 Brinell. Free-cutting steels are produced

by almost all steel mills, containing sulphur, selenium, zirconium, lead, or other elements. These steels include free-cutting stainless steels. The name screw stock also refers to free-cutting brass rod containing a small percentage of lead.

**Seal oil.** An oil obtained by steam extraction from the blubber of the oil seal, *Phoca vitulina*. The industry centers around South Georgia with the whale-oil industry. Seal oil is used in lubricating and cutting oils. It has a saponification value as high as 195 and an iodine value up to 150. It contains palmitic and other acids.

**Selenium.** An elementary metal, symbol Se, found native in cavities in Vesuvian lavas and, in combination with sulphur, in copper and iron pyrites. It is produced as a by-product in copper refining. Like sulphur it exists in various forms, having six allotropic forms. Amorphous selenium is a finely divided brick-red powder with a specific gravity of 4.26. Semicolloidal red amorphous selenium is a blood-red solution. Vitreous selenium forms a brownish-black, brittle, glassy mass with a specific gravity of 4.28. Red and gray crystalline forms are also possible. Metallic selenium is made by fusing the vitreous variety and cooling slowly. The specific gravity of the metal is 4.82, and melting point about 215°C. Selenium is odorless and tasteless, but the vapor has a putrid odor. Selenium is poisonous, and is used in insecticides and in ship-hull paints. It is toxic to some plants, and foods grown on soils containing selenium have toxic effects on animals. The metal boils at 690°C., and burns with a purple flame. Commercial selenium is a blackish powder, 99% pure.

The peculiar photoelectric properties of selenium were discovered in 1873. It changes electrical resistance when exposed to light. Ordinary fused or vitreous selenium is a poor conductor of electricity but, when annealed by heating, it takes a crystalline form and its electrical resistance is reduced, and it also becomes susceptible to changes in light. The change of electric conductivity is instantaneous, even the light of small lamps having a marked effect. It is used for light-measuring instruments and for electric eyes. The change in resistance varies directly as the square of the illumination.

Selenium is also used in steels to make them free-machining. Selenium steels are not as susceptible to corrosion as those with sulphur and are stronger. Small amounts of selenium may be used in glass to neutralize the green tint of iron compounds. Larger amounts produce pink and ruby glass. Selenium ruby glass is used in signal lenses. Selenium gives the only pure red color for ceramics and glass. The pigment may be a combination with cadmium sulphide. Pigment for glass may also be in the form of the black powder, Barium selenide, $BaSeO_3$, or as Sodium selenite, $Na_2SeO_3$. Selenium is also used as an accelerator in rubber and to increase abrasion resistance. Vandex, of R. T. Vanderbilt Co., is a selenium powder used as a rubber vulcanizer. Novac, of Herron Bros. & Meyer, used for curing synthetic rubbers, is selenium dibutyl dithiocarbonate in the form of a liquid easily dispersed in the rubber. In copper alloys selenium improves machinability without hot shortness. Selenium copper is a free-cutting copper containing about 0.50% of selenium. It machines easily, and the electrical conductivity is nearly equal to that of pure copper. The tensile strength of annealed selenium copper is about 30,000 lb. per sq. in. Small amounts of selenium salts are added to lubricating oils to prevent oxidation and gumming.

Senna. The dried small leaves and the pods of the bushy plant *Cassia acutifolia,* the Alexandrian senna, and *C. angustifolia,* the Tinnevelly senna, of India, Arabia and North Africa. The plants are cultivated in India, but the Sudan material comes mostly from wild plants. The sun-dried leaves and pods are shipped in bales. They are used direct as a laxative by steeping in water, or the extract is used in pharmaceuticals. It contains the yellowish non-crystalline Cathartine, a powerful purgative. Another species of the plant, *C. auriculata,* yields Avaram bark which is an important tanning material in India. It is similar to algarobilla in action.

Serpentine. A mineral of the theoretical formula $3MgO \cdot 2SiO_2 \cdot 2H_2O$, containing 43% of magnesium oxide. It is used for building trim and for making ornaments and novelties. The chips are employed in terrazzo and for roofing granules. Actually, the stone only rarely approaches the theoretical formula, and usually contains 2 to 8% of iron oxide with much silica and aluminum.

It has an asbestoslike structure. The attractively colored and veined serpentine of Vermont is marketed under the name of Verde antique marble. The massive verde antique of Pennsylvania is used with dolomite in refractories. Antigorite is a form of serpentine found in California which has a platy rather than a fibrous structure. The serpentine of Columbus County, Georgia, contains 36 to 38% of MgO and 2 to 5 chrome ore. It is used as a source of magnesia and its salts, and the chromium is recoverable.

**Sesame oil.** A pale-yellow, odorless, bland oil obtained from the seeds of the tropical plant *Sesamum orientale* and other species, grown in India, China, Africa, and Latin America, and used for soaps, foodstuffs, and for blending industrial oils. It is distinct from German sesame oil. The seeds from different species and localities vary greatly in size and color, from yellowish white to reddish brown to black. The oil from Nigeria is called Benne oil, and the seed Benniseed. In India it is known as Til oil, and the seed as Til seed. In Madras it is called Gingelly. In Mexico it is called Ajonjoli. The seeds contain 50% of oil of a specific gravity of 0.920 to 0.925, with saponification value 188 to 193.

**Shale.** A rock formed by mud or clay consolidated under pressure. It is fine-grained and has a laminated structure, and is largely composed of silica and alumina with various impurities, often colored by oxides of iron. Unlike sandstones, shales have little porosity, but some shales contain mineral oils and form a future supply of oils. Shale is used with limestone in making portland cement. Slate is another form of shale. Bituminous shale was originally called Boghead coal in England, and Torbane mineral in Scotland. In Germany, Oil shale, after the extraction of the oil, is ground and calcined with limestone to produce cement. Shale oil is obtained from the porous oil-bearing shales found in many parts of the world. They are mined for oil recovery in France, Great Britain, Austria, United States, Serbia, and Australia, and occur in great quantities in Colorado, Argentina, and in other countries. Shale oil in the crude state is dark-green to brown in color, and has a specific gravity of 0.850 to 0.950. The oil is obtained by distillation, the yield varying from almost nothing up to

100 gal. per ton. Scotch shales give an average yield of 24.5 gal. of crude oil and 35.7 lb. of ammonium sulphate per short ton. Colorado shale has yielded 17 to 40 gal. of oil per ton by a continuous method under which the oil is extracted by a stream of hot gases passing through the crushed shale. Shale occurs in strata and is mined like coal. It is a gray to black mineral with a laminated fracture. It is estimated that there are 2,000 sq. mi. of oil shale lands in Colorado alone, with a total of 400 billion tons of oil-bearing shale available in Colorado, Utah, and Wyoming.

**Shark leather.** A durable nonscuffing leather used for book bindings, handbags, and fancy shoes, made from the skin of sharks. The shark is a mammal with a skin unlike fishskin. When tanned, the surface is hard, the epidermis thicker than cowhide, and the long fibers lie in a cross weave. The shark is split on the back instead of the belly as in cowhides, and the skins measure from 3 to 20 sq. ft., averaging 10 sq. ft. The hard denticle, called the shagreen, is usually removed, after which the leather is pliable but firm, the exposed grain not pulling out. Shagreen leather is a hard, strong leather with the grain side covered with globular granules made to imitate the sharkskin. Eastern shark leather has a deep grain with beautiful markings. The eastern shark includes about a dozen species of shark caught off the Florida and Cuban coasts except the Nurse shark and the Sawfish which are graded separately. The nurse shark measures 6 to 10 ft. Olcotrop leather, from a species of shark, has a smooth, fine grain with regular markings. Galuchat leather, or Pearl sharkskin, is from the Japanese ray. It is used for trim on pocketbooks. Boroso sharkskin, Rousette leather, or Morocco leather, is from a small shark of the Mediterranean, but the name is also applied to a vegetable-tanned Spanish goatskin on which a pebbly grain is worked up by hand boarding. It is now made from ordinary goatskin by embossing. Most of the sharkskin is now a by-product of the catch for oil. The shark liver is about one-fourth the total weight of the animal, and Shark-liver oil is 30 times higher in vitamin A than cod-liver oil. The oil is also used for soap, lubricant, and heat-treating oil. The Mexican shark-oil industry centers at Mazatlan, and about 25 species are caught off the west coast.

**Sheepskin.** The skin of numerous varieties of sheep, employed for fine leather for many uses. The best sheepskins come from the sheep yielding the poorest wool. When the hair is short, coarse, and sparse, the nourishment goes into the skin. The merino types having fine wool have the poorest pelts. Wild sheep and the low-wool crossbreds of India, Brazil, and South Africa have close-fibered firm pelts comparable in strength with some kidskin and retain the softness of sheepskin. This type of sheepskin from the hair sheep is termed Cabretta and is used almost entirely for making gloves and for shoe uppers. None are produced in the United States. The lambs grown in the mountains of Wales, Scotland, and Western United States also furnish good skins. The commercial difference between sheepskin and Lambskin is one of weight only. Sheepskins usually run 3 to 3½ lb. per skin without wool, and lambskins are those below 3 lb. Sheepskins are tanned with alum, chrome, or sumac. The large and heavy skins from Argentina and Australia are often split, and the grain side tanned in sumac for bookbinding and other goods; the flesh side is tanned in oil or formaldehyde and marketed as chamois. The fine-grained sheepskins from Egypt, when skived and specially treated, are known as Mocha leather. Uda skins and White Fulani skins, from Nigerian sheep, are used for good quality grain and suède glove leather. Sheepskin shearlings are skins taken from heavy-wooled sheep a few weeks after shearing. The wool is about an inch in length. They are tanned with the wool on, and the leather is used for aviation flying suits and for coats.

**Shellac.** A product of the *Tachardia lacca,* an insect that lives on various trees of southern Asia. The larvae of the lac insect settle on the branches, pierce the bark, and feed on the sap. The lac secretion produced by the insects forms a coating over their bodies and makes a thick incrustation over the twig. Eggs developed in the females are deposited in a space formed in the cell, and the hatched larvae emerge. This swarming continues for 3 weeks and is repeated twice a year. The incrustation formed on the twigs is scraped off, dried in the shade, and is the commercial Stick lac. It contains woody matter, lac resin, lac dye, and bodies of insects. Seed lac is obtained by screening, grinding, and washing stick lac.

The washing removes the Lac dye. Lac dye was once an important dyestuff, giving about the same color as cochineal but not as strong. It gives a fast bright-red tint to silk and to wool, but is now replaced by synthetics. Ari lac is stick lac collected before the young insects have swarmed, and contains living insects. Lac harvested after the swarming is called Phunki lac and contains dead bodies of the insects. Average yield of stick lac from Kusum trees is 12 lb., from the ber tree 3 lb., and from the palas tree 2 lb. About 80% of lac production is in Bihar Province, India, but it is also obtained from Bengal, the Central Provinces, and Assam. The stick lac from Burma and Siam is brought to India for making shellac. Shellac is prepared from seed lac by melting or by extraction with solvents. The molten material is spread over a hot cylinder, stretched, and the cooled sheet broken into flakes of shellac. Button lac is made by dropping molten lac on a flat surface which spreads it into button-shaped cakes 3 to 4 in. in diameter. Kiri is the refuse from the filtering bags. It is marketed in pressed cakes and contains 50 to 60% of lac with resin and dirt. The yield of shellac from stick lac is about 57%. When pure, shellac varies from pale orange to lemon yellow in color, but the color of commercial shellac may be from a high content of common rosin. White shellac is made by bleaching with alkalies. Garnet lac is the material with lac dye left in. Color may also be balanced with pigments. Orange shellac contains up to 1% of powdered orpiment, and the yellow may have smaller quantities. Shellac contains polyhydroxy acids in condensed form as long-chain esters, but it also contains resin and wax. Hard lac is prepared by removing soft constituents by alkali extraction. For electrical use the wax content should be below 3½%. By solvent extraction of the seed lac the wax may be reduced to 1%. Shellac is graded by color and by its freedom from dirt. The first grade contains no rosin, but other grades may contain up to 12%. Most Indian exports of seed lac to the United States are of the special grade which has a high bleach index. Cut shellac is shellac with usually 25 lb. of rosin to 100 lb. of dry shellac, dissolved in alcohol. Shellac is used in adhesives, varnishes, insulating compounds, and in some molding compounds. Shellac plastics, usually for electrical purposes, are sold under trade names such as Electrose, of the Insulation Mfg. Co., and Harvite, of the Siemon Co.

**Shock-resistant steels.** A general name for steels used for tools and parts that are required to withstand much pounding. There are two general types. One type contains chromium, vanadium, and a small amount of molybdenum, with usually fairly high manganese; the other type contains up to 2% of silicon, with usually some molybdenum. The silicon steels are used for pneumatic tools and for such purposes as coining dies. A Chromium-silicon steel marketed by the Timken Steel & Tube Co. under the name of Sicromo steel is a combination of both types, and has high strength and resistance. It contains 2.25 to 2.75% of chromium, 0.5 to 1 silicon, 0.4 to 0.6 molybdenum, and 0.15 carbon. The tensile strength, annealed, is 60,000 lb. per sq. in., elongation 30%, and hardness 170 Brinell. The low-alloy chromium-silicon steels with about 1% of chromium, 1 silicon, 0.60 to 0.70 manganese, and 0.40 to 0.45 carbon have tensile strengths above 200,000 lb. per sq. in. when heat-treated. They have good fatigue resistance and are also used for springs. A steel of the Allegheny Ludlum Steel Corp. called Shoe die steel, for cutting block dies, or Clicker dies, for cutting leather and paper, contains 0.70% of chromium, 0.35 molybdenum, 0.60 manganese, 0.20 silicon, and 0.53 carbon. Shoe die steel is marketed in beveled shapes. MSM steel, of A. Milne & Co., for punches, chisels, and shear blades, has 0.50% of carbon, 2.0 silicon, 0.70 manganese, and 0.25 molybdenum. Ludlum No. 602 steel, for pneumatic tools, has 0.48% of carbon, 0.70 manganese, 1.70 silicon, 0.40 molybdenum, and 0.12 vanadium, while Seminole hard steel of the same company has 1.3% of chromium, 2 tungsten, 0.25 vanadium, and 0.48 carbon. Atsil steel, of the Atlantic Steel Co., for shear blades, punches, and pneumatic tools, contains 0.50% of carbon, 0.60 manganese, 0.50 tungsten, 0.30 molybdenum, and 1.30 silicon.

**Silica.** A mineral of the composition $SiO_2$, Silicon dioxide, which is the most common of all materials, and in the combined and uncombined states is estimated to form 60% of the earth's crust. Many sands, clays, and rocks are largely composed of silica. Silica is the weakest of the inorganic acids, but it forms definite salts with bases. When pure, silica is colorless to white. It is either crystallized or amorphous, and in the crystalline forms it has the

composition $(SiO_2)_x$, with a latticelike structure of the molecule. The varieties of natural silica are Crystalline silica, such as quartz and Tridymite; Cryptocrystalline silica (minute crystals), such as flint, chert, chalcedony, and agate; and Amorphous silica such as opal. Silica is insoluble in water when anhydrous and is also insoluble in all acids except hydrofluoric. Crystallized silica in the form of quartz has a hardness of 7 Moh and a specific gravity of 2.65. Amorphous Silica glass has a density of 2.21. Pure fused silica has a melting point of 1750°C., but softens slightly at 1400°C. In chemical and heat ware it is used up to 1100°C. The coefficient of expansion is very low, 0.00000054 per deg. C. Vitreous silica is a name sometimes used for silica glass of high transparency employed for camera lenses.

Fused silica is used for chemical parts, especially where resistance to sulphuric acid is required or where there is severe thermal shock. The fused silica of the Amersil Co., Inc., known as Amersil, used for tubes, pipe, and parts of chemical equipment, is transparent and will withstand continuous temperatures up to 2700°F. It is resistant to all acids except hydrofluoric and hot phosphoric. Silica is also used as a filler in paints, in ceramics, and for abrasives and building stones.

Silica flour, made by grinding sand, is used in paints and as a facing sand for molds. One large machine-tool foundry uses 50 parts of silica flour to 220 parts of sand and 10 parts of linseed oil. It is also employed for making flooring blocks. An acid-resistant industrial flooring of Johns-Manville contains 50% of silica flour, 32 silica sand, and 18 asphalt. Silver bond silica, of the Tamms Silica Co., is a water-floated silica flour of 98.5% $SiO_2$, ground to 325 mesh. In zinc and lead paints it gives a hard surface. Pulverized silica, made from crushed quartz, is used to replace tripoli as an abrasive. Ultrafine silica flour, with crystals as small as 1 to 1.5 microns, is produced by forcing carbon dioxide through a solution of sodium silicate and methanol, thus precipitating out the fine silica. Silica aerogel is a fine, white, semitransparent silica powder, the grains of which have a honeycomb structure, giving extreme lightness. It weighs 2.5 lb. per cu. ft. and is used as an insulating material in walls of refrigerators, as a filler in molding plastics, and

as a light filler in paints to give a flattening effect. It is produced by treating sandstone or sand with caustic soda to form sodium silicate, and then treating with sulphuric acid to form a jellylike material called Silica gel. This material is then washed with water and alcohol. Santocel is a trade name of the Monsanto Chemical Co. for this material. Silicon monoxide, SiO, does not occur naturally but is made by reducing silica with carbon in the electric furnace and condensing the vapor out of contact with the air. It is lighter than silica, having a specific gravity of 2.24, and is less soluble in acid. It is brown powder valued as a pigment for oil painting as it takes up a higher percentage of oil than ochres or red lead. Monox is a trade name for silicon monoxide. Fumed silica is a fine translucent powder of the simple amorphous silica formula made by calcining ethyl silicate. It is used instead of carbon black in rubber compounding.

**Silicon.** One of the nonmetallic elements, symbol Si. It is used in iron, steel, and in nonferrous metals for deoxidation of the molten metals and to give hardness and other characteristics. Its melting point when pure is about 2615°F., but it readily dissolves in molten metals. It is never found free in nature, but combined with oxygen it forms silica, $SiO_2$, one of the most common substances in the earth. Silicon can be obtained in three modifications. Amorphous silicon is a brown-colored powder with a specific gravity of 2.35. It is fusible and dissolves in molten metals. When heated in the air, it burns to form silica. Graphitoidal silicon consists of black glistening spangles, and is not easily oxidized and not attacked by the common acids, but is soluble in alkalies. Crystalline silicon is obtained in dark, steel-gray globules or six-sided pyramids. It is less reactive than the amorphous form, but is attacked by boiling water. All these forms are obtainable by chemical reduction. Silicon is an important constitutent of commercial metals. Molding sands are largely silica, and silicon carbides are used as abrasives. Commercial silicon is sold in the graphitoidal flake form, or as ferrosilicon, and silicon-copper. The latter forms are employed for adding silicon to iron and steel alloys. Commercial refined silicon contains 97% of pure silicon and less than 1 iron. It is used for adding silicon to aluminum alloys and for fluxing copper alloys.

**Silicon bronze.** A name applied to two classes of copper alloys. One of these is a copper, or nearly pure copper, fluxed with silicon, in which little or no silicon remains in the final metal. This material is used for strong electric wires and has high strength and resistance to corrosion. A standard alloy of this class contains 98.55% of copper, 1.40 tin, and 0.05 silicon. The tensile strength, hard-drawn, is 92,000 lb. per sq. in. The second class of alloy contains a considerable amount of silicon and may have nickel, tin, and other elements. This type of alloy usually depends for hardness on the formation of silicides of nickel or iron. These alloys can be heat-treated and age-hardened.

Phono bronze, or Phono electric alloys, is the trade name of a group of copper alloys of the Bridgeport Brass Co. containing about 1.25% of tin and small amounts of silicon and cadmium. The tensile strength of the wire is up to 100,000 lb. per sq. in., and of the hard-rolled sheet 75,000 lb. per sq. in. It is wear-resistant and corrosion-resistant. The electrical conductivity of the various grades varies from 14 to 80% that of copper. Duronze III, of the same company, contains 91% of copper, 7 aluminum, and 2 silicon. It forges easily and machines readily. The average tensile strength is 90,000 lb. per sq. in. The high strength is inherent in the alloy and is not from cold working. The drawn rod has a tensile strength of 100,000 lb. per sq. in.

An early bearing alloy known as Tetmejer contained 2.75% of silicon, 5 to 10 aluminum, some iron, and the balance copper. Another bearing bronze, called Vulcan bronze, contained 1% of silicon, with iron and nickel. Silicon forms solid $\alpha$ solutions in low brass up to about 2.8% silicon, above which point a $\beta$ phase is formed. Thus, a mixed $\alpha$-$\beta$ structure is present in the high-silicon bronzes. Tombasil, an alloy developed in Germany and marketed by the Ajax Metals Co., is essentially tombac metal with the addition of silicon. It can be die-cast or sand-cast, and is used for bearings. The tensile strength is 65,000 lb. per sq. in., elongation 15%, and Brinell hardness 135. Navy Tombasil contains approximately 90% of copper, with maximums of 5 zinc and 5 silicon. It has good casting qualities, and gives a homogeneous structure. The tensile strength, sand-cast, is up to 58,000 lb. per sq. in. with elongation of 36%. P.M.G. metal, of Vickers-Armstrong, Ltd., has 2% of iron,

3 to 4 silicon, 2 zinc, and the balance copper. The forged metal has a tensile strength of 94,000 lb. per sq. in., elongation of 17%, and Brinell hardness of 153. Cast P.M.G. metal, of the Cramp Brass & Iron Foundries, has a tensile strength of about 50,000 lb. per sq. in. with elongation of 15 to 23%, Brinell hardness of 90 to 125, and specific gravity of 8.44. Castings will withstand high liquid pressures and are corrosion-resistant.

Silicon-copper alloys containing zinc are used also for die castings, bearing metals, and general strong castings. They may be called also Silicon brass, although this name properly refers to the alloys with considerable zinc and small amounts of silicon. The alloys known in Federal specifications as Copper-silicon alloy contain 5% of zinc and 1 to 5 silicon, with some iron, tin, and manganese. They are used for castings or wrought parts. A grade of Olympic bronze, of the Chase Brass & Copper Co., contains 3% of silicon and 1 zinc. The tensile strength is from 56,000 to 110,000 lb. per sq. in. and elongation 5 to 65%. Olympic bronze G contains 22% of zinc and 1 silicon, with the balance copper. It is a strong Silicon brass, and the annealed sheet has a strength of 65,000 lb. per sq. in., with elongation of 50%. Doler brass, of the Doehler Die Casting Co., is a silicon brass for die castings. A group of copper-silicon-manganese alloys is produced by the American Brass Co. under the name of Everdur metal, originally patented by Charles Jacobs and called Jacobs' alloy. Everdur 1000 for castings contains about 94.9% of copper, 4 silicon, and 1.1 manganese. The tensile strength, cast, is 45,000 lb. per sq. in. and elongation 15%. The alloys combine high strength and toughness with acid and corrosion resistance. The wrought alloys have some physical characteristics similar to those of mild steel, but they have the disadvantage as compared with tin bronze that they have no proportionality limit and suffer permanent deformation at a low load and low impact. The hard-drawn rods have a minimum tensile strength of 70,000 lb. per sq. in. The electrical conductivity of the cast metal is 7% that of copper, and of the hard-wrought metal 12% that of copper. A European alloy, under the name of Kuprodur, containing 0.5% of silicon, 0.75 nickel, and the balance copper, has good strength at elevated temperatures and is used for locomotive firebox plates.

**Silicon carbide.** A bluish-black crystalline artificial mineral of the composition SiC, having a hardness of 9.5 on the Moh scale, and used as an abrasive in the form of powder, paper, wheels, and hones. It is also used as a refractory material, being bonded with clays or held together with its own crystals by a method of recrystallization. It is also used as a deoxidizer and graphitizer in melting iron and steel. Silicon carbide is made by fusing sand and coke with sawdust, using salt as a flux. The temperature used is just above 4000°F. It was discovered in 1891 by E. G. Acheson. The specific gravity is 3.12 to 3.20. As a refractory it will withstand temperatures up to about 4200°F., at which point it decomposes. Pure silicon carbide should contain 70% of silicon and 30 of carbon, but the commercial grades contain less silicon and have small amounts of iron oxide. Unlike aluminum oxide, the crystals are large, and it is crushed to make the small grains required for abrasive purposes. It is harder than aluminum oxide, and is used for the hardest types of grinding wheels. The standard grain sizes are the same as those for aluminum oxide. For polishing granite, sizes 70 to 90 are employed. Silicon carbide as an abrasive and refractory is sold under a great variety of trade names. Carborundum is the name of the Carborundum Co. for a silicon carbide. Other silicon carbide abrasives are Carbora, Carborite, Carbolite, Carbolox, Mimico, Carbobrant, Carbicon, Corex, Silexon, Crystolite, Sterbon, Storalon, Natalon, Natrundum, Lotens, Calcinite, Idilon, Electrolon. Carbex is a silicon carbide firebrick made by the General Refractories Co. Crystolon, of the Norton Co., is the name of an abrasive and a refractory. Ferrocarbo is a silicon carbide of the Carborundum Co. in briquettes for adding to the iron cupola charge. It breaks down in the cupola above 2000°F. to form nascent carbon and silicon for adding to the iron and also for deoxidizing. It produces more uniform iron castings.

**Silicon-copper.** An alloy of silicon and copper used for adding silicon to copper, brass, or bronze, and also employed as a deoxidizer of copper and for making hard copper. Silicon alloys in almost any proportion with copper, and is the best commercial hardener of copper. A 50-50 alloy of silicon and copper is hard and extremely brittle and black in color. A 10% silicon, 90% copper alloy is as

brittle as glass; in this proportion silicon-copper is used for making the addition to molten copper to produce hard, sound copper castings of high strength. The resulting copper alloy is easy to run in the foundry and does not dross. Silicon-copper grades in 5, 10, 15, and 20% of silicon are also marketed, being usually sold in slabs notched for breaking into smaller sections for adding to the melt. A 10% silicon-copper melts at 1500°F.; a 20% alloy melts at 1152°F.

**Silicon iron.** An Acid-resistant cast iron containing a high percentage of silicon. When the amount of silicon in cast iron is above 10%, there is a notable increase in corrosion and acid resistance. The acid resistance is obtained from the compound $Fe_3Si$, which contains 14.5% of silicon. The usual amount of silicon in acid-resistant castings is from 12 to 15%. The alloy casts well but is hard and cannot be machined. These castings usually contain 0.75 to 0.85% of carbon; amounts in excess of this decrease the acid resistance. Too much carbon also separates out as graphite in silicon irons, causing faulty castings. Increasing the content of silicon in iron reduces the melting point progressively from 1530°C. for pure iron to 1250°C. for iron containing 23% of silicon. A 14 to 14.5% silicon iron has a silvery-white structure, a compressive strength of about 70,000 lb. per sq. in., Brinell hardness of 290 to 350, and is resistant to hot sulphuric acid, nitric acid, and organic acids. Silicon irons are also very wear-resistant, and are valued for pump parts and for parts for chemical machinery. They are marketed under many trade names. Tantiron, of the Bethlehem Foundry & Machine Co., contains 14 to 15% of silicon, 2 to 2.5 manganese, and 1 carbon. The high manganese aids the machining properties of the metal. Duriron, of the Duriron Co., contains 14.5% of silicon and 1 carbon and manganese. The tensile strength is 16,000 lb. per sq. in. and weight 0.253 lb. per cu. in. Durichlor, of the same company, is a special grade of high-silicon iron resistant to hydrochloric acid. Antaciron is a 14.5% silicon iron of Antaciron, Inc., and Corrosiron is a similar iron of the Pacific Foundry Co. Thermisilid is the original name given by the Krupp Works to high-silicon cast iron. A heat-resistant silicon iron developed by the

British Cast Iron Research Assoc. under the name of Silal contains only 5% of silicon. It is used for stoker and furnace parts.

**Silicon-manganese.** An alloy employed for adding manganese to steel, and also as a deoxidizer and scavenger of steel. It usually contains 65 to 70% of manganese and 12 to 25% of silicon. It is graded according to the amount of carbon, generally 1, 2, and 2.5%. For making steels low in carbon and high in manganese, silico-manganese is more suitable than ferromanganese. A reverse alloy, called Manganese-silicon, contains 73 to 78% of silicon and 20 to 25 manganese, with 1.5 max. iron, and 0.25 max. carbon. It is used for adding manganese and silicon to metals without the addition of iron. Still another alloy is called Ferromanganese-silicon, containing 20 to 25% of manganese, about 50 silicon, and 25 to 30 iron, with only about 0.50 or less carbon. This alloy has a low melting point, giving ready solubility in the metal.

Silicon-spiegel is an alloy of silicon and manganese with iron employed for making additions of silicon and manganese to open-hearth steels, and also for adding manganese to cast iron in the cupola. A typical analysis gives 25 to 30% of manganese, 7 to 8 silicon, and 2 to 3 carbon. Both the silicon and manganese act as strong deoxidizers, forming a thin fusible slag, making clean steel.

**Silicon steel.** All grades of steel contain some silicon and most of them contain from 0.10 to 0.35% as a residual of the silicon used as a deoxidizer. But from 3 to 5% of silicon is sometimes added to increase the magnetic permeability, and larger amounts are added to obtain wear-resisting or acid-resisting properties. Silicon deoxidizes steel, and up to 1.75% the elastic limit and impact resistance are increased without loss of ductility. Silicon steels within this range are used for structural purposes and for springs, giving a tensile strength of about 75,000 lb. per sq. in. and elongation of 25%. A common low-silicon structural steel contains up to 0.35% of silicon and 0.20 to 0.40 carbon, but the Structural silicon steels are ordinarily Silicon-manganese steel, with the manganese above 0.50%. European silicon structural steels contain 0.80% or more of silicon, with manganese above 0.50%, and very low carbon. The silicon alone is a graphitizer and to be most effective needs the assistance of manganese or other carbide-forming elements. It is

useful in high-strength low-alloy steels, and has a wide range of utility when used with expert technique in alloy steels. Considerable addition of silicon above 1.75% increases the hardness and the corrosion resistance, but reduces the ductility and makes the steel brittle. The lower grades can be rolled, however, and silicon-steel sheet is used for electric transformer laminations. Silicon forms a chemical combination with the metal, forming an iron silicide. The value of silicon steel as a Transformer steel was discovered by Hadfield in 1883. Silicon increases the electrical resistivity and also decreases the hysteresis loss, making silicon steel valuable for magnetic circuits where alternating current is used. Tran-Cor is a high-silicon steel produced by the American Rolling Mill Co. for cores for electrical transformers. Electrical steel, or Electric sheet, is sheet steel for armatures and transformers, in various grades from 1 to 4.5% of silicon. Hipersil is a high-permeability silicon steel of the Westinghouse Electric Corp. The Relay steel of the Allegheny Ludlum Steel Corp., used for relays and magnets, contains 0.5 to 2.75% of silicon.

A very tough and strong tool steel for forming tools, pneumatic tools, and long punches is made with the addition of silicon and some molybdenum. Solar steel, of the Carpenter Steel Co., has 1% of silicon, 0.50 molybdenum, 0.40 manganese, and 0.50 carbon. It is water-hardening, and has a breaking strength of 323,000 lb. per sq. in., with elongation of 4.5%. Silman steel, of the Vanadium Alloys Steel Co., has 2.1% of silicon, 0.25 chromium, 0.30 vanadium, 0.85 manganese, and 0.55 carbon. The silicon gives it wear-resistant properties, making it suitable for shear blades and punches; the other alloying elements give toughness and resistance to fatigue. These steels are often referred to as Shock-resistant steel. Black giant steel, of the Bethlehem Steel Co., for bending, drawing, and stamping dies, has 1.4% of carbon, 2.2 silicon, 0.90 manganese, 0.45 chromium, and 0.5 tungsten. The high silicon precipitates some of the carbon in graphitic form, giving the steel a low coefficient of friction and high resistance to wear.

As a casting metal, steel or iron containing considerable amounts of silicon makes sound castings without blow holes, as the silicon aids in the deoxidation of the molten metal. The silicon-manganese steels with silicon up to 2% and up to about 1% of manganese

are tough, strong, and wear-resistant, and are useful for gears, cams, and rolls. A steel with 1.5% of silicon, 0.50 manganese, and 0.40 carbon has a tensile strength of 110,000 lb. per sq. in. and elongation 18%. S.A.E. steel 9255 has 2% of silicon and 0.75 manganese. Silicon, up to 1%, is used in nickel and chromium steels to increase hardness and to resist oxidation at high temperatures. Larger amounts of silicon are used to give acid resistance.

**Silicones.** A group of resinlike materials in which silicon takes the place of the carbon of the organic synthetic resins. Silicon is quadrivalent like carbon, and is thus capable of forming long molecular chains like those present in the carbon compounds. The molecular structure, however, is somewhat different. In the long-chain organic synthetic resins the carbon atoms repeat themselves, attaching themselves on two sides to other carbon atoms, while in the silicones the silicon atom alternates with an oxygen atom so that the silicon atoms are not tied to each other. The polymerization of the silicone monomer may be carried out in the same manner as with organic synthetic resin monomers to produce resinlike materials from liquids or soft rubbery masses to hard and tough solids. They are classed as Inorganic plastics as distinct from the older Organic plastics. They are more heat-resistant than the organic resins, and have higher dielectric strength. They are also highly water-resistant. They can be compounded with plasticizers, fillers, and pigments. For varnishes and insulating coatings they are applied in solvent solution and cured at 450 to 500°F. Silicone insulating varnishes will withstand continuous operating temperatures at 350°F. or higher. For lubricants the liquid silicones are compounded with graphite or metallic soaps and will operate between −50 and 500°F. The silicone liquids are stable at their boiling points, between 750 and 800°F., and have low vapor pressures, so that they are also used for hydraulic fluids and heat-transfer media.

Silicone rubber is a polymer that remains elastic between −70 and 500°F., has good dielectric strength, and can be molded by compression or extrusion. It is cured by heat. Silastic, of the Dow Corning Corp., is a silicone rubber. It is resistant to oils and many chemicals, has a dielectric strength of 500 volts per mil, tensile

strength of 200 to 330 lb. per sq. in. with elongation of 70 to 115%, and has good adhesion to various materials. It is used for electric insulation, for coating fabrics, and for gaskets and other parts. The Silicone rubber of the General Electric Co. has a monomer with alternate silicon and oxygen atoms with two methyl groups, —$CH_3$, attached to each silicon atom. The silicon rubbers are not resistant to strong acids and alkalies. The Silicone oils of this company, used for lubrication and as insulating and hydraulic fluids, are methyl silicone polymers. They retain a stable viscosity at both high and low temperatures. As hydraulic fluids they permit smaller systems to operate at higher temperatures. A phenyl ethyl silicone is used for impregnating glass-fiber cloth for electrical insulation and it has about double the insulating value of ordinary varnished cloth. A great variety of molecular combinations are obtainable in the silicon polymers, giving resins of varying characteristics. Those having one or more carbon-silicon bonds are termed Organosilicon polymers. Silicon tetramethyl, $Si(CH_3)_4$, is a liquid that boils at 26°C. Methyl chloro silane, $(CH_3)_2SiCl_2$, is a liquid used for waterproofing steatite and other ceramic electrical insulators. The ceramic is treated with the vapor from the silane which reacts with the moisture particle in the ceramic, forming a thin water-repellent coating of methyl silicone and hydrochloric acid, the latter then being washed off.

Silk. The fibrous material in which the silkworm, or larva of the moth *Bombyx mori,* envelops itself before passing into the chrysalis state. Silk is closely allied to cellulose and resembles wool in structure, but unlike wool it contains no sulphur. The natural silk is covered with a wax or silk glue which is removed by scouring in manufacture, leaving the glossy Fibroin, or raw-silk fiber. The fiber is unwound from the cocoon and spun into threads. Each cocoon has from 2,000 to 3,000 yd. of thread. One pound of raw silk is obtained from 2½ lb. of cocoons. The chief silk-producing countries are China, Japan, India, Italy, and France. Japanese raw silk is shipped in bales of 100 kin, 133⅓ lb. European silk bales weigh 220.5 lb., and Canton bales 106⅔ lb. The conditioned weight in shipping is the dry weight plus 11% of moisture. A book is a bundle of Asiatic silk containing 50 to 60 skeins, about

4 to 4.5 lb. Floss silk is a soft silk yarn practically without twist, or is the loose waste silk produced by the worm when beginning to spin its cocoon. Hard silk is thrown silk from which the gum has not been discharged. Soft silk is thrown silk yarn, degummed, dyed or undyed. Souple silk is dyed skein silk from which little gum has been discharged. It is firmer but is less lustrous. Organizine silks is from the best grade of cocoons. Marabout silk, used for making imitation feathers, is a white silk, twisted, and dyed without discharging the gum. Silk waste is a term used to designate all silk other than that reeled from the cocoon. It includes cocoons not fit for reeling, partly unwound cocoons, broken filaments, mill waste, and discarded noils. It is used in the spun-silk yarn industry. Noils consist of the short, staple knotty combings.

In China the cultivation of the silkworm is claimed to date back to 2640 B.C. Silk was first woven in Rome about 50 B.C. The eggs of the silkworm were smuggled into Europe in the year 552. Sericulture, or silkworm culture, is a highly developed industry. The larvae, which have voracious appetites, are fed on mulberry leaves for 24 days, after which they complete their cocoon in 3 to 4 days. In from 7 to 10 days these are heated to kill the chrysalis to prevent bursting of the shell. The reeling is done by hand and by machine. Wild silk is from a night peacock moth which does not feed on the mulberry. It is coarser and stronger, but darker in color and less lustrous. Tussah silk is a variety of wild silk from South China and India. Byssus silk is a long fiber from a mussel of Sardinia and Corsica which spins the thread to attach itself to rocks. The fiber is golden brown, soft, lustrous, and elastic, and not dissolved by acids or alkalies. It was formerly used for fine garments but is no longer obtained commercially. Canton silk is soft and fluffy, but is greenish in color and lacks firmness. It is from the *B. textor,* and is used for weft yarns and in crepes. This silk when grown in India and known as Indian silk is the finest of all silks with fibers 0.0004 in. compared with 0.001 in. for Japanese silk. Before the war Japan produced most of the silk of the world from a cultivated moth of the tussah variety, *Antheria yama mai.* Shantung silk is from a tussah moth, *A. pernyi,* which feeds on oak leaves.

The fabric called Shantung is a rough-textured plain-woven silk with irregular fillings, heavier and more bumpy than pongee.

Grosgrain is a heavy close-woven corded fabric of silk. It is used for tapestry, and in narrow widths for ribbons. China silk, or Habutai, is an unweighted all-silk fabric of close, firm, but uneven texture woven of low quality, unthrown raw silk in the gum, but it is also imitated with textiles with a silk warp and a rayon filling. The lightweight grades of 3, 3½, and 4 momme (42, 36, and 31 sq. yd. per lb.) are classed as sheer fabrics, and are used for impregnated fabrics for umbrellas, raincoats, hospital sheetings. Unimpregnated habutai is used for curtains, lamp shades, handkerchiefs, and caps. Heavyweight habutai of 12 momme, or 10 yd. per lb., is used for parachutes. Pongee is a rough-textured plain-woven silk fabric with irregular filling yarns. It is made in natural color or dyed, and like China silk has a gummy feel.

**Silver.** A white metal, symbol Ag, very malleable and ductile, and classed with the precious metals. It occurs in the native state, and also combined with sulphur and chlorine. Copper, lead, and zinc ores frequently contain silver; about 70% of the production of silver is a by-product of the refining of these metals. Mexico and the United States produce more than half of the silver of the world. Canada, Peru, and Bolivia are also important producers. Although nearly 90% of the silver produced in Arizona comes from copper ores, most of that produced in California is a by-product of gold quartz mining. It is profitable to extract the silver from lead ores having only 3 oz. per ton. Silver is the whitest of all the metals and takes a high polish, but easily tarnishes in the air because of the formation of a silver sulphide. It does not corrode. It has the highest electrical and heat conductivity. The specific gravity is 10.7, and the melting point is 1762°F. When heated above the boiling point, it passes off as a green vapor. It is soluble in nitric acid and in hot sulphuric acid. The tensile strength of cast silver is 41,000 lb. per sq. in. and Brinell hardness 59. The metal is marketed on a troy-ounce value.

The standard grades of commercial silver are Fine silver, Sterling silver, and Coin silver. Fine silver is 99.9% pure. Coin silver is usually an alloy of 90% silver and 10 copper. The ratio of value of silver to gold has remained for nearly 2,500 years as 15.5 and 16 to 1. It is used for coinage, silverware, ornaments, silver plating,

for alloying with gold, and in the form of its salts for photography and other uses. About 20 million ounces are used annually for photographic and motion-picture film. Electrical contacts are made frequently of fine silver and also of sterling silver, but mostly of coin silver since the higher proportion of copper hardens the metal and gives greater wear resistance. Doré metal, used for jewelry, is silver containing some gold. Silver plating is sometimes done with a Silver-tin alloy containing 20 to 40 parts silver and the remainder tin. It gives a plate having the appearance of silver but with better wear resistance. Silver-clad sheet, made of a cheaper nonferrous sheet with a coating of silver rolled on, is used for food-processing equipment. It is resistant to organic acids but not to products containing sulphur. Silver-clad steel, used for machinery bearings, shims, and reflectors, is made with pure silver bonded to the billet of steel and then rolled. For bearings, the silver is 0.010 to 0.35 in. thick, but for reflectors the silver is only 0.001 to 0.003 in. thick.

**Silver nitrate.** Formerly known as Lunar caustic. A colorless, crystalline, poisonous, and corrosive material of the composition $AgNO_3$ made by dissolving silver in nitric acid. It is used for silvering mirrors, for silver plating, and in indelible inks. It is an active oxidizing agent. Silver chloride, AgCl, is a white granular powder used in silver-plating solutions. This salt of silver and other halogen compounds of silver, especially Silver bromide, AgBr, are used for photographic plates and films. The image cast on the plate by the lens breaks down the compound in proportion to the intensity of the light. Silver sulphide, $Ag_2S$, is a gray-black, heavy powder used for inlaying in metal work. Silver potassium cyanide, $KAg(CN)_2$, is a white, crystalline, poisonous solid used for silver-plating solutions.

**Silver solder.** High-melting-point solder employed for soldering joints where more than ordinary strength is required. Most silver solders are copper-zinc brazing alloys with the addition of silver, and the soldering is done with a blowtorch. They may contain from 9 to 80% of silver, and the color varies from brass yellow to silver white. Cadmium may also be added to lower the melting point. Silver solders do not necessarily contain zinc, how-

ever, and may be alloys of silver and copper in proportions arranged to obtain the desired melting point and strength. A silver solder with a relatively low melting point contains 65% of silver, 20 copper, and 15 zinc. It melts at 1280°F., has a tensile strength of 64,800 lb. per sq. in., and elongation of 34%. The electrical conductivity is only 21% that of pure copper. A solder melting at 1400°F. contains 20% of silver, 45 copper, and 35 zinc. Any tin present in silver solders makes them brittle; lead and iron make the solders difficult to work. Silver solders are malleable and ductile and have high strength. They are also corrosion-resistant and are especially valuable on food machinery and apparatus where lead is objectionable. They can be employed to braze stainless steels. Sil-Fos is the trade name of Handy & Harman, for a phosphor-silver brazing solder with a melting point of 1300°F. It contains 15% of silver, 80 copper, and 5 phosphorus. Lap joints brazed with Sil-Fos have a tensile strength of 30,000 lb. per sq. in. The phosphorus in the alloy acts as a deoxidizer, and the solder requires little or no flux. It is used for brazing brass, bronze, and nickel alloys. The grade made by this company under the name of Easy solder contains 65% silver, melts at 1325°F., and is a color match for sterling silver. TL silver solder of the same company has only 9% silver and melts at 1600°F. It is brass yellow in color, and is used for brazing nonferrous metals. A Lead-silver solder recommended by the Indium Corp. of America, to replace tin solder, contains 96% of lead, 3 silver, and 1 indium. It melts at 310°C., spreads better than ordinary lead-silver solders, and gives a strength of 4,970 lb. per sq. in. in the joint.

**Sisal.** The hard, strong, light-yellow to reddish fibers from the large leaves of the sisal plant, *Agave sisalana,* and the henequen plant, *A. fourcroydes,* employed for making rope, cordage, and sacking. About 80% of all binder twine is normally made from sisal, but sisal ropes have only 75% of the strength of Manila rope and are not as resistant to moisture. Sisal is a tropical plant, and grows best in semiarid regions. The agave plant is native to Mexico, but much of the sisal hemp comes from East Africa and the East Indies. The retting, separation, and washing of the fiber are done by machine, and less than 5% of the weight of the leaf results in

good fiber. The plant is cut for fiber after 3 years and produces for 5 years after. Mexican sisal is classed in seven grades from the Superior white fiber 105 cm. in length to the grade C-1, short-spotted fiber 60 cm. in length. Yucatan sisal, or Henequen, is from the henequen plant and is reddish in color, stiffer and coarser, and is used for binder twine. The Indian word henequen means knife, from the knifelike leaves. Henequen also comes from the East Indies as the spotted or reddish grades of sisal. Sisal is usually shipped in 400-lb. bales. Maguey, or Cantala, is from the leaves of the *Agave cantala* of India, Philippines, and the Dutch East Indies. It is used for binder twine. The fibers are white, brilliant, stiff, and light in weight. The fibers are not as strong as sisal, but have a better appearance and greater suppleness. Zapupe fiber, of Mexico, is from the *A. zapupe*. The fiber is similar to sisal, finer and softer than henequen. Salvador sisal, of El Salvador, is from the *A. letonae*. The leaves are more slender than Mexican sisal, and the fiber is softer and finer. It is used for cordage and fabrics.

The fibers of sisal are not as long or as strong as those of Manila hemp and swell when wet, but they are soft and are preferred for binder twine either alone or mixed with Manila hemp. Sisal fiber is also used instead of hair in cement plasters for walls and in laminated plastics. Corolite is a molded plastic of the Columbia Rope Co. made with a mat of sisal fibers so as to give equal strength in all directions. Agave fibers from other varieties of the plant are used for various purposes, notably Tampico, from the *A. rigida,* which yields a stiff, hard, but pliant fiber employed for circular power brushes, and Istle, a similar stiff brush fiber from several plants. Jaumave istle is from the *A. funkiana* of Mexico. It yields long, uniform fibers finer than tampico. Lechuguilla is a type of istle from the *A. lechuguilla.*

There are at least 50 species of agave in Mexico and Southwestern United States, which yield valuable by-products in addition to fiber. From some varieties saponin is obtained as a by-product. From a number of thick-leaved species the buds are cut off, leaving a cavity from which juice exudes. This juice is fermented to produce Pulque, a liquor with a ciderlike taste containing about 7% alcohol. The juice contains a sugar, Agavose, $C_{12}H_{22}O_{11}$, which is used in medicine as a laxative and diuretic.

**Slag.** The molten material that is drawn from the surface of iron in the blast furnace. Slag is formed from the earthy materials in the ore and from the flux. Slags are produced in the melting of other metals, but iron blast-furnace slag is usually meant by the term. Slag is used in cements and concrete, for roofing, and as a ballast for roads. Blast-furnace slag is one of the lightest concrete aggregates available. It has a porous structure and, when crushed, is angular. About 1,300 lb. of slag is produced for every long ton of metallic iron. It is also crushed and used for making Pozzuolan and other cements. Slag contains about 32% of silica, 14 alumina, 47 lime, 2 magnesia, and small amounts of other elements. It is crushed, screened, and graded for marketing. Crushed slag weighs 1,900 to 2,100 lb. per cu. yd., or about 30% lighter than gravel. Honeycomb slag weighs only about 30 lb. per cu. ft. The finest grade of commercial slag is from $\frac{3}{16}$ in. to dust; the run-of-crusher slag is from 4 in. to dust. Basic phosphate slag, a by-product in the manufacture of steel from phosphatic ores, is finely ground and sold for fertilizer. It contains not less than 12% of phosphoric acid, $P_2O_5$, and is known in Europe as Thomas slag. Foamed slag is a name used in England for honeycomb slag used for making lightweight, heat-insulating blocks. A superphosphate cement is made in Belgium from a mixture of basic slag, slaked lime, and gypsum.

**Slate.** A shale possessing a straight cleavage. Most shales are of sedimentary origin, and their cleavage was the result of heavy or long-continued pressure. In some cases slates have been formed by the consolidation of volcanic ashes. The slaty cleavage does not usually coincide with the original stratification. Slate is of various colors, black, gray, green, and reddish. It is used for electric panels, blackboards, slate pencils, table tops, roofing shingles, floor tiles, and treads. The terms Flagstone and Cleftstone are given to large flat sections of slate used for paving, but the names are also applied to blue sandstones cut for this purpose. Slate is quarried in large blocks, and then slabbed and split. The chief slate-producing states are Pennsylvania, Vermont, Virginia, New York, and Maine. Roofing slates vary in size from 12 by 6 in. to 24 by 14 in., and from $\frac{1}{8}$ to $\frac{3}{4}$ in. in thickness, and are usually of the harder varieties.

The roofing slate from coal beds is black, fine-grained, and breaks into brittle thin sheets. It does not have the hardness or weather resistance of true slate. Ribbon slate, with streaks of hard material, is inferior for all purposes. Lime impurities can be detected by the application of dilute hydrochloric acid to the edges and noting if rapid effervescence occurs. Iron is a detriment to slates for electric purposes. The average compressive strength of slate is 15,000 lb. per sq. in. and the weight 175 lb. per cu. ft. Slate flour is ground slate used as a filler in linoleum and in calking compounds. Slate lime is an intimate mixture of finely divided calcined slate and lime, about 60% by weight of lime to 40 of slate. It is employed for making porous concrete for insulating partition walls. The process consists in adding a mixture of slate-lime and powdered aluminum, zinc, or magnesium to the cement. The gas generated on the addition of water makes the cement porous.

**Smoke agents.** Chemicals used in warfare to produce an obscuring cloud or fog to hide movements. Smokes may be harmless and are then called Screening smokes, or Smoke screens, or they may be toxic and called Blanketing clouds. There are two general types of smokes: those forming solid or liquid particles, and those forming fogs or mists by chemical reaction. The first naval smoke screens were made by limiting the admission of air to the fuel in the boilers, and the first Army Smoke pots contained mixtures of pitch, tallow, saltpeter, and gunpowder. The British Smoke candles contained 40% of potassium nitrate, 29 pitch, 14 sulphur, 8 borax, and 9 coal dust. They gave a brown smoke, but one that lifted too easily.

The fog used by the American Army on the Rhine in 1945 was an oil mixture sprayed at high velocity into the air. The microscopic droplets were calculated to be so small that there were 70,000 billion per cubic inch. The spray made an impenetrable fog which remained for a long period. White phosphorus gives a dense white smoke by burning to the pentoxide and changing to phosphoric acid in the moisture of the air. Its vapor is toxic. Sulphuric trioxide, $SO_3$, is an effective smoke producer in humid air. It is a mobile, colorless liquid vaporizing at 45°C. to form dense white clouds with an irritating effect. The French Opacite is Tin tetrachloride,

$SnCl_4$, a liquid that fumes in the air. The smoke is not as dense, but it penetrates gas masks and is corrosive. Sulphuryl chloride, $SO_2Cl_2$, is a liquid that decomposes on contact with the air into sulphuric and hydrochloric acids. F. S. smoke is made with a mixture of chlorosulphonic acid and sulphur trioxide. Silicon tetrachloride, $SiCl_4$, is a colorless liquid that boils at 60°C. and fumes in the air forming a dense cloud. Mixed with ammonia vapor it resembles a natural fog. The heavy mineral known as Amang, separated from tin ore, containing ilmenite and zircon, is used in smoke screens. Titanium tetrachloride, $TiCl_4$, is a colorless to reddish liquid boiling at 136°C. It is used for smoke screens and for sky writing from airplanes. In moist air it forms dense, white fumes of Titanic acid, $H_2TiO_3$, and hydrogen chloride. The commercial liquid contains about 25% of titanium by weight.

A common smoke for airplanes is Oleum. It is a solution of sulphur trioxide in sulphuric acid. The dense liquid is squirted into the exhaust manifold. Zinc smoke is made with mixtures of zinc dust or zinc oxide with various chemicals to form clouds. H. C. smoke is zinc chloride with an oxidizing agent to burn up residual carbon so that the smoke will be gray and not black. Signal smoke is colored smoke used for signaling in war, aviation and ship distress signals, and for aviation marking signals. They are mixtures of a fuel, an oxidizing agent, a dye, and sometimes a cooling agent to regulate the rate of burning and to prevent decomposition of the dye. Only definite, unmistakable colors are used so that the signals may be distinguished from fires, and the dyes are mainly anthraquinone derivatives. Sugar is one of the best combustible materials with potassium chloride as the oxidizing agent, and either potassium or sodium bicarbonate as the cooling agent.

**Snakeskins.** The snakeskins employed for fancy leathers are in general the skins of large tropical snakes which are notable for the beauty or oddity of their markings. Snakeskins for shoe upper leathers, belts, and handbags are glazed like kid and calfskin after tanning. Small cuttings are used for inlaying on novelties. The leather is very thin, but is remarkably durable and is vegetable-tanned and finished in natural colors, or is dyed. Python skins are

widely used for ladies' shoes. Regal python skins from Borneo, the Philippines, and the Malay Peninsula sometimes measure 30 ft. in length and have characteristic checked markings. Diamond-backed rattlesnakes are raised on snake farms in the United States. The meat is canned as food, and the skins tanned into leather. Only the back is used for leather as the belly is colorless.

**Soap.** A cleansing compound produced by saponifying oils, fats, or greases with an alkali. When caustic soda is added to fat, glycerin separates out, leaving Sodium oleate, $Na(C_{18}H_{33}O_2)$, which is soap. If an excess of alkali is used, the soap will contain free alkali, and the greater the proportion of the free alkali the coarser is the action of the soap. A.S.T.M. standards for milled toilet soap permit only 0.17% of free alkali. Sodium soaps are always harder than potassium soaps with the same fat or oil. Hard sodium soaps are used for chips, powders, and toilet soaps. Soft caustic potash soaps are the liquid, soft, and semisoft pastes. Mixtures of the two are also used. Soaps are made by either the boiled process or the cold process. Chip soap is made by pouring the hot soap onto a cooled revolving cylinder from which the soap is scraped in the form of chips or ribbons which are then dried to reduce the moisture content from 30 to 10%. Soap flakes are made by passing chips through milling rollers to make thin, polished, easily soluble flakes.

Powdered soap is made from chips by further reducing the moisture and grinding. Milled soaps are made from chips by adding color and perfumes to the dried chips and then passing through milling rollers and finally pressing in molds. Toilet soaps are made in this way. Nearly half of the American production of soaps consists of granulated, powdered, chips, flakes, and scouring powders. Only about 10% is toilet soap. Soap is used widely in industrial processing in the textile and other industries, and is one of the indicators of industrialization. The American consumption increased from 21.6 lb. per capita in 1920 to 25.4 lb. in 1930, and 28.1 lb. in 1940. About half of all soap is made with tallow, 25% with coconut oil, and the remainder with palm oil, greases, fish oils, olive oil, soybean oil, or mixtures. A typical American soap contains 80% of mixed oils and 20 coconut oil, with not over 0.2 free alkali. The wartime soap used in Germany called Rif had only 40% fat content,

with the remainder sodium silicate, kaolin, or clays. Auxiliary ingredients are used in soap to improve the color, for perfuming, as an astringent, or for abrasive or harsh cleansing purposes. Phenol or other antiseptics are used in Antiseptic soap. The Disinfectant soap used by the Army contained 2% of "G-11" which was dihydroxy-hexachloro diphenyl methane. Solvents are added to industrial soaps for scouring textiles or when used in soluble oils in the metal industry. Zinc oxide, benzoic acid, and other materials are used in facial soaps with the idea of aiding complexion. Excessive alkalinity in soaps dries and irritates the skin, but Hand grit soap usually has 2 to 5% of alkaline salts such as borax or soda ash and 10 to 25% of abrasive minerals. Softer Hand soap may contain marble flour. Silicate of soda, used as a filler, also irritates the skin. Transparency usually varies with the content of coconut, palm, or olive oil. Castile soap is a semitransparent soap made with olive oil. Marseilles soap and Venetian soap are names for castile soap with olive oil and soda. Ordinary soft soaps used as bases for toilet soap are made with linseed and olive-oil mixtures. Linseed oil, however, gives a disagreeable odor. Soybean oil, corn oil, and peanut oil are also used, although peanut oil, unless the arachidic acid is removed, makes a hard soap.

Saddle soap is any soap used for cleaning leather goods which has the property of filling and smoothing the leather as well as cleaning. The original saddle soaps were made of palm oil, rosin, and lye, with glycerin and beeswax added. Oil for the best soaps are of the non-drying type. Soft soap of U.S.P. grade always has a therapeutic value. High-grade soft soap for industrial use is made with coconut or palm kernel oil with caustic potash. But soft soap in paste form is generally made of "low titer" oils with caustic soda, usually linseed, soybean, or corn oil. The lauric acid of coconut oil gives the coconut oil soaps their characteristic of profuse lathering, but lauric acid affects some skins by causing itching. Palm-kernel oil develops free acids, and upon aging the soap acquires the odor of the oil. Palm oil produces a crumbly soap. It does not lather freely, but is mild to the skin. Olive oil is slow lathering, but has good cleansing powers. It is often used in textile soaps. Cottonseed oil is used in some laundry soaps, but develops yellow spots in the soap. Corn oil with potash makes a mild soft soap. Soybean oil also makes

a soft soap. Rosin is used to make yellow laundry soaps. A.S.T.M. standards for bar soap permit up to 25% of rosin. Sulphonated oils do not give as good cleansing action as straight oils, but are used in shampoos where it is desirable to have some oil or greasiness. Blending of various oils is necessary to obtain a balance of desired characteristics in a soap. Hand soaps may be made with trisodium phosphate, or with disodium phosphate, or Sodium perborate, $NaBO_3 \cdot H_2O$, known as Perborin, all of which are crystalline substances which are dissolved in water solution. Soap powder is Granular soap made in a vacuum chamber or by other special processes. It usually contains 15 to 20% of soap and the balance sodium carbonate. Scouring powder is an intimate mixture of soap powder and an insoluble abrasive such as pumice. Floating soaps are made light by blowing air through them while in the vats. Soapless shampoos and tooth powders contain saponin or chemical detergents.

**Soapstone.** A massive variety of impure talc employed for electric panels, gas-jet tips, stove linings, tank linings, and as an abrasive. It can be cut easily and becomes very hard when heated because of the loss of its combined water. The waste product from the cutting of soapstone is ground and used for the same purposes as talc powder. Steatite is a massive stone rich in talc that can be cut readily, while soapstone may be low in talc. Alberene stone, quarried in Virginia, is blue-gray in color. The medium-hard varieties are used for building trim and for chemical laboratory tables and sinks, and the hard varieties are employed for stair treads and flooring. Alberene stone marketed by the Alberene Stone Corp. as a basic refractory substitute for chrome or magnesite for medium temperatures has a fusion point of 2400°F. Virginia greenstone is a gray-green soapstone resistant to weathering, used as a building stone.

**Soda ash.** The common name for anhydrous Sodium carbonate, $Na_2CO_3$, which is the most important industrial alkali. It is a grayish-white lumpy material, which loses water of crystallization when heated. For household use in hydrous crystallized form, $Na_2CO_3 \cdot 10H_2O$, it is called Washing soda, Soda crystals, or Sal soda, as distinct from Baking soda, which is Sodium hydrogen carbonate, or Sodium bicarbonate, $NaHCO_3$. Sal soda contains more than 60%

water. Another grade, with one molecule of water, $Na_2CO_3 \cdot H_2O$, is the standard product for scouring solutions. Federal specifications call for this product with a total alkalinity not less than 49.7% of $Na_2O$. Commercial high-quality soda ash contains 99% min. $Na_2CO_3$, or 58% min. $Na_2O$. Laundry soda is this material mixed with sodium bicarbonate, with 39 to 43% $Na_2O$. Modified sodas, used for cleansing where a mild detergent is required, are mixtures of sodium carbonate and sodium bicarbonate. They are used in both industrial and household cleaners. Tanners' alkali, used in processing fine leathers, and Textile soda, used in fine wool and cotton textiles, are modified sodas. Flour bland, used by the milling industry in making free-flowing, self-raising food flours, is a mixture of sodium bicarbonate and tricalcium phosphate.

Soda ash is less expensive than caustic soda and is used for cleansing, for softening water, in glass as a flux, and to prevent fogging, in the wood-pulp industry, for refining oils, in soapmaking, and for other applications. Caustic ash, a strong cleaner for metal scouring and for paint removal, is a mixture of about 70% of caustic soda and 30 soda ash. Flake alkali, of the Columbia Chemical Div., Pittsburgh Plate Glass Co., contains 71% of caustic soda and 29 soda ash. Soda ash is also used as a flux in melting iron to increase the fluxing action of the limestone, as it will carry off 11% of sulphur in the slag. Soda briquettes, used for desulphurizing iron, are made of soda ash formed into pellets with a hydrocarbon bond. Hennig purifier is soda ash combined with other steel-purifying agents made into pellets. The natural hydrous sodium carbonate of Egypt and Libya is called Nitron. It is used in glass- and soapmaking. Soda ash is made from sodium bicarbonate, which in turn is made by treating salt brine with ammonia and carbon dioxide, called the Solvay process. It is usually sold in two grades, 48, and 58% $Na_2O$. The 58% grade is marketed as dense or light, the dense consistency being used where bulk is needed, as for glass. Purite is the trade name for sodium carbonate marketed by the Mathieson Alkali Works, Inc., for use as a fluxing agent with lime.

**Sodium.** A metallic element, symbol Na, and atomic weight 23, occurring only in the form of its salts. The most important mineral containing sodium is the chloride, NaCl, which is common salt. It

also occurs as the nitrate, Chile saltpeter, as a borate in borax, and as a fluoride and a sulphate. When pure, sodium is silvery white, ductile, melts at 97.6°C., and boils at 877°C. The specific gravity is 0.972. It can be obtained in metallic form by the electrolysis of salt. When exposed to the air, it oxidizes rapidly and must be kept in airtight containers. Sodium is a powerful desulphurizer for iron and steel. It is used in the form of soda-ash pellets. Desulphurizing alloys for brasses and bronzes are Sodium-tin, with 95% of tin and 5 sodium, or Sodium-copper. Sodium is widely used in industry in the form of its salts, particularly sodium chloride and soda ash. Sodium dichromate, $Na_2Cr_2O_7 \cdot 2H_2O$, a red powder, is used in hot-water solution with sulphuric acid to give a golden-brown brass finish to zinc parts. Cronak, of the New Jersey Zinc Co., is this material.

Sodium aluminate. A white powder of the composition $Na_2Al_2O_4$, used as a water-softening agent with lime and soda in steam boilers. It has a melting point of 1800°C. and is soluble in water. It is made by the reaction of alumina with some source of sodium oxide such as caustic soda or soda ash, or by heating bauxite with sodium carbonate and extracting with water.

Sodium cyanide. A salt of hydrocyanic acid of the composition NaCN, used for carbonizing steel for casehardening, for heat-treating baths, for electroplating, and for the extraction of gold and silver from their ores. For carburizing steel it is preferred to potassium cyanide because of its lower cost and its higher content of available carbon. It contains 53% of CN, as compared with 40% in potassium cyanide. The nitrogen also aids in forming the hard case on the steel. The 30% grade of sodium cyanide, melting at 1156°F., is used for heat-treating baths instead of lead, but it forms a slight case on the steel. Sodium cyanide is very unstable, and on exposure to moist air liberates the highly poisonous Hydrocyanic acid gas, HCN. For gold and silver extraction it easily combines with the metals, forming soluble double salts, $NaAu(CN)_2$. Sodium cyanide is made by passing a stream of nitrogen gas over a hot mixture of sodium carbonate and carbon in the presence of a catalyst. It is a white crystalline powder, sol-

uble in water. It is usually packed in 100- and 200-lb. containers, made up in 1-oz. briquettes, 4-oz. eggs, or fused and broken. Cyanegg is the name of the E. I. duPont de Nemours & Co., Inc., for 96 to 98% sodium cyanide in egg shape for casehardening steel. The melting point is 1040°F. The white Copper cyanide used in electroplating, has the composition $Cu_2(CN)_2$, containing 70% copper. It melts at 474.5°C., is insoluble in water, but is soluble in sodium cyanide solution. Sodium ferrocyanide, or Yellow prussiate of soda, is a lemon-yellow crystallline solid of the composition $Na_4Fe(CN)_6 \cdot 10H_2O$, used for carbonizing steel for casehardening. It is also employed in paints and printing inks and for the purification of organic acids. It is soluble in water. Cyanogas is Calcium cyanide. It liberates hydrocyanic acid gas, and is used chiefly as an insecticide.

Sodium hydroxide. Known commonly as Caustic soda, and also as Sodium hydrate. Lye is an old name used in some industries and in household uses. A white, massive crystalline solid of the composition NaOH, used for scouring and cleaning baths, for etching aluminum, in quenching baths for heat-treating steel, in cutting and soluble oils, and in a wide variety of other commercial uses. Sodium hydroxide is made by the causticization of soda ash or by the electrolysis of salt. The specific gravity is 2.13 and melting point 318°C. It is soluble in water, alcohol, and in glycerin. Sodium hydroxide is sold in liquid and in solid or powder forms on the basis of its $Na_2O$ content. A high-grade commercial caustic soda contains 98% min. NaOH equivalent to 76% min. $Na_2O$. The liquid contains 50% min. NaOH. Phosflake, of the Columbia Chemical Div., Pittsburgh Plate Glass Co., used in washing machines, is a mixture of caustic soda and trisodium phosphate. Caustic potash is Potassium hydroxide, KOH, which has the same uses but is more expensive. Caustic potash is a white, lumpy solid. It is soluble in water and makes a powerful cleansing bath for scouring metals. It is marketed as solid, flake, granular, or broken, and also in 40 and 50% liquid solutions. It is also used in soaps and for bleaching textiles. When used in steel-quenching baths, it gives a higher quenching rate than water alone and does not corrode the steel like a salt solution.

**Sodium nitrate.** Also called Soda niter and Chile saltpeter. A mineral found in large quantities in the arid regions of Chile, Argentina, and Bolivia, where the crude nitrate with iodine and other impurities is called Caliche. It is used for making nitric and sulphuric acids, for explosives, as a flux in welding, and as a fertilizer. The composition is $NaNO_3$. It is usually of massive granular crystalline structure with a hardness of 1.5 to 2 and specific gravity of 2.29. It is colorless to white, but sometimes colored by impurities. It is readily soluble in water. In other parts of the world it occurs in beds with common salt, borax, and gypsum. Synthetic Chile saltpeter is made by nitrogen fixation and is marketed granulated, in crystals, or in sticks. It is colorless, odorless, has a specific gravity of 2.267 and a melting point of 316°C. It has a bitter, saline taste. Norway saltpeter, used in fertilizers and explosives, is Calcium nitrate $Ca(NO_3)_2$, in colorless crystals soluble in water.

**Solder.** An alloy of two or more metals used for joining other metals together by surface adhesion. A requirement is that it have a lower melting point than the metals being joined, and also have an affinity for, or be capable of uniting with, the metals to be joined. The most common solder is called Half-and-half, or Plumbers' solder, and is composed of equal parts of lead and tin. It melts at 360°F. The weight of this solder is 0.318 lb. per cu. in., tensile strength 55,000 lb. per sq. in., and the electrical conductivity 11% that of copper. S.A.E. Solder No. 1 has 49.5 to 50.5% of tin, 50 lead, and 0.12 max. antimony and 0.08 max. copper. It melts at 357.8°F. Much commercial half-and-half, however, usually contains larger proportions of lead and some antimony, with less tin. These mixtures have higher melting points, and solders with less than 50% of tin have a wide melting range and do not freeze quickly. Sometimes a wide melting range is desired, in which case a Wiping solder with 38 to 45% of tin is used. Solder No. 4663, of the Westinghouse Electric Corp., is a narrow-melting-range solder, melting from 183 to 185°C., while Solder No. 1580 is a wiping solder with a melting range from 183 to 231°C. The first contains 60% of tin and 40 lead, and the second has 42% of tin and 58 lead. Slicker solder is the best quality of plumbers' solder, containing 63 to 66% of tin and the balance lead. The earliest solders were

the Roman solder called Argentarium, containing equal parts of tin and lead, and Tertiarium, containing one part of tin and two of lead. Both alloys are still in use, and throughout early industrial times Tertiarium was known as Tinman's solder.

Good-quality solders for electrical joints should have at least 40% of tin as the electrical conductivity of lead is only about half that of tin, but conductivity is frequently sacrificed for better wiping ability, and the wiping solders are usually employed for electrical work. Soft solders should not contain zinc because of poor adhesion from the formation of oxides. Various melting points to suit the work are obtained with solders by varying the proportions of the metals. The low-melting-point solders are those that have a melting point at 230°C. or lower, and the high-melting-point solders melt at 705°C. and higher. The flow point, at which the solder is entirely liquid, is often considerably above the melting point. Tin added to lead lowers the melting point of the lead until at 356°F., or 68% tin, the melting point rises with increase in tin content until the melting point of pure tin is reached. A standard solder with 48% of tin and 52 lead melts at 360°F. A 45-55 solder melts at 465°F. Cheap solders may contain as low as 25% tin, but they do not adhere well. S.A.E. solder No. 4 contains 22.5 to 23.5% of tin, 75 lead, and 2 max. antimony. It melts at 370.4°F.

Solders with low melting points are obtained from mixtures of lead, tin, and bismuth. Bismuth solder is also more fluid, as the bismuth lowers the surface tension. Bismuth, however, hardens the alloy, although to a lesser extent than antimony. A bismuth solder containing equal parts of lead, tin, and bismuth melts at 284°F. Cadmium solders have low melting points, are hard, and are usually cheaper than tin solders, but they have the disadvantage of blackening and corroding. In Germany Cadmium zinc solders were used because of the scarcity of tin. A solder containing 80% of lead, 10 tin, and 10 cadmium has about the same strength as a 50-50 tin-lead solder and has greater ductility, but is darker in color. Cadmium-tin solder, with high cadmium, is used to solder magnesium alloys. Soft solders for soldering brass and copper, especially for electrical connections, may be of tin hardened with antimony. Solder wire, marketed by the American Brass Co. for this pur-

pose, contains 95% of tin and 5 antimony. Thallium may be used in high-lead solders to increase strength and adhesion.

Hard solders may be any solder with a melting point above that of the tin-lead solders; more specifically they are the brazing solders, silver solders, or aluminum solders applied with a brazing torch. Aluminum solders may contain up to 15% of aluminum. Soluminium, an early German solder, contained 55% of tin, 33 zinc, 11 aluminum, and 1 copper. Mouray's solder contained 80 to 90% of zinc, 3 to 8 copper, and 6 to 12 aluminum. A solder prepared by the National Bureau of Standards contains 78% of tin, 8 zinc, and 5 aluminum. It has good strength and ductility. The solder known as Richard's solder is a yellow brass with 3% of aluminum and 3 phosphor tin. Solders with nickel content are used for soldering nickel silver, and silver and gold solders are used for jewelry work. Silver solder in varying proportions is also used as a high-melting-point solder for general work, and small amounts of silver are sometimes used in lead-tin solders to conserve tin, but the melting point is high. Lead-silver solders with more than 90% lead and some silver, in use during the war emergency, had high melting points and poor spreading qualities. Indium improves these solders, and a solder with 96% of lead, 3 silver, and 1 indium has a melting point at 310°C. and a tensile strength of 4,970 lb. per sq. in. Adding 0.85% of silver to a 40% tin soft solder gives equivalent wetting on copper alloys to a 63% tin solder, but the addition is not effective on low-tin solders.

Solvents. Liquids having the power of dissolving various materials. The usual commercial solvents for organic substances are the alcohols, ether, benzene, and turpentine, the latter two being common solvents for paints and varnishes containing gums and resins. The so-called Coal-tar solvents are light oils from coal tar, distilling off between 150 and 270°C., the Hi-flash solvent being a water-white liquid of specific gravity 0.855 to 0.890, distilling between 150 and 185°C., with a flash point above 100°F. Carbon bisulphide and dichlorethylene are good solvents for rubber. Ethyl acetate, $CH_3COOC_2H_5$, made from ethyl alcohol and acetic acid, is an important solvent for nitrocellulose and lacquers. It is a liquid boiling at 77°C. One of the best solvents for cellulose is cupram-

monium hydroxide. Amyl and other alcohols, amyl acetate, and other volatile liquids are used for quick-drying lacquers, but many synthetic chemicals are available for such use. Dioxan, a water-white liquid of specific gravity of 1.035 and composition $CH_2CH_2$-$OCH_2CH_2O$, is a good solvent for cellulose compounds, resins, and varnishes, and is used also in Paint removers, which owe their action to their solvent power. Ethyl lactate, used as a solvent for cellulose nitrate, is a liquid with boiling point of 150°C. and specific gravity of 1.03. Octyl alcohol, a stable liquid of the composition $CH_3$-$(CH_2)_6CH_2OH$, sp. gr. of 1.429, and boiling point of 195°C., has a high solvent power for nitrocellulose and resins. Diafoam, of the Resinous Products & Chemical Co., is a secondary octyl alcohol used as a defoaming agent in plastics and lacquers. Methyl hexyl ketone, $CH_3(CH_2)_5COCH_3$, is a powerful high-boiling solvent which also acts as a dispersing agent in inks, dyestuffs, and perfumes. It is a water-white liquid boiling at 173°C.

The chlorinated hydrocarbons have powerful solvent action on fats, waxes, and oils and are used in degreasing. Water is a solvent for most acids and alkalies and for many organic and inorganic materials. Acids or alkalies that decompose the material are not solvents for the material. Solvents are used to produce a solution that can be applied, as in the case of paints, and the evaporation of the solvent then leaves the material chemically unchanged. They may also be employed to separate one substance from another, by the selection of a solvent that dissolves one substance but not the other. They are also used in scouring solutions. Dichlorethyl ether, a yellowish liquid with a chloroformlike odor, of the composition $ClCH_2CH_2OCH_2CH_2Cl$, is a good solvent for fats and greases and is used in scouring solutions and in soaps. Dichlorethylene is a liquid of the composition $C_2H_2Cl_2$, specific gravity 1.278, and boiling point of about 52°C. It is used as a solvent for the extraction of fats and for rubber. Isocrotyl chloride, of the Shell Development Co., is a liquid of the composition $CH_3 \cdot C(CH_3)$:-$CHCl$, with specific gravity of 0.919, boiling point of 68°C., used for cleaning and degreasing. Cyclohexane, $C_6H_{12}$, made by the hydrogenation of benzene, is a good solvent for rubbers, resins, fats, and waxes. It is a water-white highly inflammable liquid of specific gravity 0.777, boiling point 80.8°C., and flash point 10°F. Cyclo-

hexanol, also called Hexalin and Hexahydrophenol, $C_6H_{11}OH$, is a solvent for oils, gums, waxes, rubber, and resins. It is made by the hydrogenation of phenol, and is a liquid boiling at 158°C.

Dichlorethyl formal, $CH_2(OCH_2 \cdot CH_2 \cdot Cl)_2$, is a water-insoluble high-boiling solvent for cellulose and for fats, oils, and resins. The boiling point is 218.1°C., and specific gravity 1.234. The Nitroparaffins constitute a group of powerful solvents for oil, fats, waxes, gums, and resins. Blended with alcohols they are solvents for cellulose acetate, producing good flow and hardening properties for nonblushing lacquers. Nitromethane, $CH_3NO_2$, is a water-white liquid, specific gravity 1.139, boiling point 101°C., and freezing point −29°C. Nitroethane, $CH_3CH_2NO_2$, has a specific gravity of 1.052, boiling point 114°C., and freezing point −90°C. A Plasticizer is a liquid or solid that dissolves in or is compatible with a resin, gum, or other material and renders it plastic, flexible, or easy to work. Dibutyl phthalate, a water-white oily liquid of specific gravity 1.048, boiling point 340°C., and composition $C_{16}H_{22}O_4$, is a plasticizer for Buna N rubber and polyvinyl chloride plastics. Thickening agents for sizes, coatings, and paints not only increase the viscosity but also add other properties such as giving better adhesion or toughening the film. They must be compatible with the other components.

Sound insulators. Materials employed, chiefly in walls, for reducing the transmission of noise. Insulators are used to impede the passage of sound waves, as distinct from Isolators used under machines to absorb the vibrations that cause the sound. For factory use the walls, partitions, and ceilings offer the only mediums for the installation of sound insulators. All material substances offer resistance to the passage of sound waves, and even the glass windows may be considered as insulators. But the term refers to the special materials placed in the walls for this specific purpose. Insulators may consist of mineral wool, hair felt, fiber sheathing boards, or simple sheathing papers. Sound insulators are marketed under a variety of trade names, such as Celotex, made from bagasse, and Fibrofelt, made from flax or rye fiber. Wheat straw is also used for making insulating board. Sound insulators are often also heat insulators. Linofelt, of the Union Fiber Co., Inc., is a sound- and

heat-insulating material used for walls. It consists of a quilt of flax fiber between tough waterproof paper. It comes in sheets 5/16 to 3/4 in. thick. Torfoleum is a German sound- and heat-insulating material made from peat moss treated with a waterproofing agent. It will withstand temperatures up to 230°F., is finely porous, and weighs less than 1 lb. per bd. ft. Vibration insulators, or Isolators, to reduce vibrations that produce noises, are usually felt or fiber boards placed between the machine base and the foundation. Keldur, of the International Products Corp., is a fibrous insulating material made up in sheets 3/4 in. thick, with a resilient binder. Korfund isolator, of the Korfund Co., Inc., is a resilient mat of cork treated with oil and bound in a steel frame. It will take loadings up to 4,000 lb. per sq. ft. Vibro-Insulator, of the B. F. Goodrich Co., is an isolator of Ameripol synthetic rubber.

**Soybean oil.** Also known as Soya bean oil. A pale-yellow oil obtained by expression from the seeds of the plant *Glycine soya,* native to Manchukuo, but grown also in the United States. It is primarily a food oil, but is also used as a drying oil for linoleum, paints, and varnishes, or for mixing with linseed oil, although the untreated oil has only half the drying power of linseed oil. It is also used in core oils and in soaps. The bean contains up to 20% of oil. The average yield factor is 15%. The oil content decreases in warm climates. Southern-grown soybeans contain 2 to 5% less oil than those grown in Illinois. The usual conversion factor is 8.5 lb. of oil and 48 lb. of meal per bushel of beans. There are 280 varieties of the bean grown in the United States and 2,500 varieties listed. The pods contain two or three beans which range in color from light straw through gray and brown to nearly black. Most varieties are straw colored or greenish yellow.

The specific gravity of the oil is about 0.925, iodine value 134, and it should have a maximum of not more than 1.5% of free fatty acids and not more than 0.3% of moisture and volatile matter. The fractionated oil yields: 15% of Cut soybean oil of an iodine value of 70 to 90, used for soaps, lubricants, and rubber compounding; 72% of Neo-fat oil of an iodine value of 145 to 155, used for varnish and paint oils alone or in blends with other oils, or for glycerin making; 13% of Bottoms, used for soaps, lubricants, and giving a

by-product pitch used in insulation and mastic flooring. Much soybean oil is used in butter substitutes. Soybean meal is the product obtained by grinding the soybean chips obtained from the expeller process, or the Soybean oil cake obtained from the Hydraulic process. The meal is marketed as cattle feed or fertilizer, but the ground meal is also used to make a strong glue. Soybean meal hardened with formaldehyde is used as a filler with wood flour in plastics. It gives plastic flow during molding. The stalks and leaves of the plant contain much nitrogen, and about half of the crop is usually plowed under for fertilizer.

Soybean flour for bakery food products for the American market is made from treated beans which have the bitter taste removed. The food flour is made in three types: that with about 23% oil left in, low fat with only 6%, and solvent type, with practically all the oil removed. Soybean flour has a yellow color which in cakes gives the appearance of the use of eggs. Up to 25% is used in blends with wheat flour. It is also used in dehydrated soup mixes and in meat products. It has high protein content and also contains lecithin.

**Spanish moss.** The fiber from the plant *Tillandsia usneoides,* which grows throughout tropical and subtropical America, and along the Southeastern Coast of the United States, hanging from branches of trees. Spanish moss is used for cheap upholstery and for packing glass and fragile articles. A fiber produced in Argentina for the same purpose and for stuffing mattresses is Caranday fiber from the leaves of the palm *Copernica cerifera.* The tree grows in marshy ground in Corrientes Province.

**Speculum metal.** An alloy formerly used for mirrors, and also in optical instruments. It contains 65 to 67% of copper and the remainder tin. It takes a beautiful polish and is hard and tough. Speculum metal should have a maximum of crystals of $Cu_4Sn$, containing 66.6% of copper. An old Roman mirror contained about 64% of copper, 19 tin, and 17 lead, and an Egyptian mirror contained 85% of copper, 14 tin, and 1 iron. The old Greek mirrors were carefully worked out with 32% of tin and 68 copper. They had 70% of the reflecting power of silver, with a slight red excess of reflection that gave a warm glow, without the blue of

nickel or antimony. This alloy is now plated on metals for reflectors. A modern telescope mirror contains 70% of copper and 30 tin. Chinese speculum contains about 8% of antimony and 10 tin. The Speculum metal advocated by the Tin Research Institute for electroplating to give a hard, white, corrosion-resistant plate for food-processing equipment, has 55% of copper and 45 tin.

Spelter. An old name for slab zinc. Metallic zinc was first introduced into Europe from China and was called by the Dutch traders spialter, which was Anglicized to spelter. The first spelter, or metallic zinc, to be produced in the United States was made in 1838 at Washington, D. C., from zincite ore from Franklin, N. J. Sterling spelter was a grade 99.5% pure.

Sperm oil. The waxy oil extracted from the head cavity of the sperm whale, *Physeter breviceps,* and the Bottlenose whale, *P. macrocephalus.* The spermaceti is first separated out, leaving a clear yellow oil. It is purified by being pressed in bags at a low temperature. It is graded according to the temperature of pressing. A good grade of sperm oil has a specific gravity of 0.875 to 0.885, and a flash point above 440°F. Inferior grades of sperm oil may be from sperm-whale blubber. Commercial sperm oil is likely to be one-third head oil and two-thirds body oil. Sperm oil differs from fish oil and whale oil in consisting chiefly of liquid waxes and not fats. The fatty acids are in combination with alcohol instead of glycerin. Sperm oil absorbs very little oxygen from the atmosphere and is not influenced by variations in temperature. It is therefore valuable as a lubricating oil. It burns with a white shining flame, and was formerly used as a high-grade lamp oil. It is also an excellent soap oil. Sulphonated sperm oil is used as a wetting agent in textile manufacture. Sperm oil from the head has an iodine value of 76, and saponification value of 140.

Spermaceti is the white, crystalline flakes of fatty substance, or wax, that separate out from sperm oil on cooling after boiling. It is a true wax and does not yield glycerin when saponified. It is purified by pressing. It is also separated out from dolphin head oil. Spermaceti is odorless and tasteless, has a melting point of 43°C., is insoluble in water, but soluble in hot alcohol. It burns with a bright flame. It was formerly used for candles but now is

employed chiefly as a fine wax for ointments and compounds. Sperm oil and spermaceti are inedible and indigestible.

**Spice.** An aromatic vegetable substance, generally a solid used in powdered form, employed for flavoring foods. There is no sharp dividing line between Flavors and spices, but in general a spice is a material that is used to stimulate the appetite and increase the flow of gastric juices. They are not classed as foods in themselves, having little food value, but as food accessories. Pepper is distinctly a spice, while vanilla is merely a flavor, though often grouped with the spices. Some spices are also used widely as flavors and in perfumes, and also in medicine either for antiseptic or other value or to disguise the unpleasant taste of drugs. A condiment is a strong spice, or a spice of sharp taste, although the word is often erroneously applied to any spice. A Savory is a fragrant herb or seed used for flavor in cooking. Spices are obtained from the stalks, bark, fruits, flowers, seeds, or roots of plants.

Allspice, also known as Pimento and Jamaica pepper, is the dried unripe fruit of the small evergreen tree *Pimenta officinalis* of the myrtle family growing in the West Indies and tropical America. The fruit is a small berry which when dried is wrinkled and reddish brown. It has a flavor much like a combination of clove, nutmeg, and cinnamon. Pimento oil is a fragrant essential oil distilled from the berries, which contain 4%. It contains eugenol and cineol and is used in flavors, in bay rum, and in carnation perfumes. Coriander is the dried fruit of the perennial plant *Coriandrum sativum* grown in the Mediterranean countries and in India. It is one of the oldest of spices and has a pleasant aromatic taste. Oil of coriander, extracted from the dried seed, is used in medicine, in beverages, and in flavoring extracts. It has a higher aromatic flavor than the fruit. Savory is a fragrant herb of the mint family, *Satureia hortensis*, used in cooking, and in medicine as a carminative. It contains Carvacrol, a complex phenol also occurring in caraway and camphor. The word savory also designates other herbs that are used directly in foods as flavors.

Celery seed, used as a savory, is the seed of the plant *Apium graveolens*. The leafstalks of this plant, known as Celery, are bleached white and eaten raw or cooked. The plant is widely

grown for seed in France and Spain. Celery-seed oil is a pale-yellow oil extracted from the seeds and used as a flavor and in perfumery. Dill seed, from the herb *Aenethum graveolens,* of the parsley family, is used as a condiment for pickles. Dill leaves are used as seasoning for soups, sauces, and pickles. Dill oil, extracted from the whole herb, is used as a flavor in the food industry. It resembles caraway oil and has a finer flavor than Dill-seed oil which is more plentiful. Dill is grown in the central United States and in Central Europe. Cardamon is the highly aromatic and delicately flavored seeds of the large perennial herb *Elettaria cardamomum,* of India, Ceylon, and Central America. The seeds are used in pickles, curries, and cakes, and the oil is employed as a flavor. Garlic is the root bulb of the lily *Allium sativum,* used as a condiment, and in medicine as an expectorant under the name of Allium. It contains allyl sulphide which gives it a pungent odor and taste.

Cumin is the seed of the *Cuminum cyminum,* the true Cumin, and *Nigella sativa,* the Black cumin, both of India. The seed is used in confectionery and in curries. A kind of black cumin known as Shiah zira, from the plant *Carum indicum* of India is superior in taste and fragrance to ordinary cumin. The Japanese condiment, Adjinimoto, with a meatlike flavor, used in sauces, is made from wheat gluten and is largely Sodium glutamate, a salt of Glutamic acid, $C_5H_9O_4N$, which occurs in seeds and in beets. Caraway is the spicy seed of the biennial herb *C. carvi* of Europe and North Africa. The seeds are used on cookies. Caraway oil, distilled from the seeds, contains carvone and limonene, and in combination with cassia gives a pleasant odor. It is used in soap, perfumes, and mouth washes. Sage is the grayish-green hairy leaves of the shrublike plant *Salvia officinalis* used as a spice. It is cultivated extensively in the Mediterranean region. Oil of sage is used in perfumery. Clary sage oil is distilled from the flowers of the S. *sclarea* of France, Italy, and North Africa. It has the odor of a mixture of ambergris, neroli, and lavender, and is used in flavoring vermouth liquor and muscated wines, and also in eau de cologne. Sassafras is sometimes classed as a spice but is a flavor. It is the aromatic spicy bark of the root of the tree *Sassafras officinale* which grows wild in Eastern United

States. It is used mostly for making root beer, but also for flavoring tobacco, and in patent medicines. Sassafras oil is an oil extracted from the whole roots and is used in medicine and in perfumery and soaps. It produces artificial heliotrope. The oil contains Safrol, $C_{10}H_{10}O_2$, also produced from brown camphor oil. Wintergreen oil is from the leaves of the small evergreen plant *Gaultheria procumbens* of the Middle Atlantic states. The oil does not exist in the plant but is formed by the reaction between a glucoside and an enzyme when the chopped leaves are steeped in water. It is largely Methyl salicylate, $C_8H_8O_3$. It is used in flavoring candies and soft drinks and in medicine. Hop oil, used to give hop flavor to cereal beverages, and also in perfumes, is obtained from Lupulin, a glandular powder found in the female inflorescence of the hop plant, *Humulus lupulus*. Hops are used directly in making beer, and the oil is produced from the discard hops which contain 0.75% oil.

Spodumene. A mineral of the composition $Li_2O \cdot Al_2O_3 \cdot 4SiO_2$, with some potassium and sodium oxides. It is the chief ore of the metal lithium. It is found in South Dakota and in the Carolinas, and has an average content of 4% $Li_2O$, ranging from 2.9 to 7.6%. Crystals of spodumene in South Dakota are 8 to 10 ft. long and a foot in thickness, appearing like logs of wood, with as high as 6.5% lithium. The specific gravity is 3.13 to 3.20, and the melting point is 1395 to 1425°C. Spodumene is three times more active than feldspar as a flux in ceramics, giving fluidity, increasing surface tension, and eliminating pinholes. A mixture of 25% spodumene with 75% feldspar is an active vitrifying agent in ceramics. The melting point of the mixture is 1110°C., which is below the usual minimum temperature used for chinaware; it thus forms a glaze. Lithospar is a name for feldspar and spodumene from the pegmatites of King's Mountain, North Carolina. In Germany lithium is obtained from the lithium mica Zinnwaldite, which is a mixture of potassium-aluminum orthosilicate and lithium orthosilicate with some iron, and contains less than 3% of $Li_2O$. Kryolithionite, a mineral found in Greenland, has the composition $Na_3Li_3(AlF_6)_2$ and contains up to 11.5% of $Li_2O$. It has a crystal structure resembling garnet. A transparent emerald-green spodu-

mene in small crystals, known as Hiddenite, is found in North Carolina, and is cut into gem stones.

Sponge. The cellular body of a marine animal, of the genus *Spongia,* of which there are various species. It is employed for wiping and cleaning as it will absorb and hold a great quantity of water in proportion to its weight. Sponges grow like plants, attached to the sea bottom. They are prepared for use by maceration in water, and are then beaten and treated with acids to remove concretions. They may also be bleached chemically. The best sponges come from the Mediterranean and Red seas, and from the Caribbean Sea. Tarpon Springs, Fla., is the center of the American sponge fisheries. The sponge skeleton, after the retting and beating off of the soft membranes, is an elastic fibrous structure chemically allied to silk. It has sievelike membranes with small pores leading into small pear-shaped chambers. The best sponges are spheroidal, regular, and soft. Most of the Florida sponges are the Sheepswool sponge used for cleaning and industrial sponging. The fine Honeycomb sponge of the Mediterranean is used as a bath sponge. Central American sponges are now almost extinct.

Sponge iron. Iron made from ferrous sand and pressed into briquettes, which can be charged directly into steel furnaces instead of pig iron. It was originally made on a larger scale in Japan where only low-grade sandy ores were available. Sponge iron is made by charging the sand continuously into a rotary furnace to drive off the light volatile products and reduce the iron oxide to metallic iron, which is passed through magnetic separators, and the finely divided iron briquetted. Unbriquetted sponge iron, with a specific gravity of 2, is difficult to melt because of the oxidation, but the briquetted material, with a specific gravity of 6, can be melted in the electric furnace. Sponge iron to replace scrap in steelmaking is also made from low-grade ores by reducing the ore with coke-oven gas or natural gas. It is not melted, but the oxygen is driven off, leaving a spongy granular product. As it is very low in carbon, it is also valuable for making high-grade alloy steels.

A form of sponge iron employed as a substitute for lead for coupling packings is made in Germany under the name of Sinterit.

The reduction is carried out in a reducing atmosphere at a temperature of 1200 to 1350°C., instead of heating the iron oxide with carbon. Since the porous iron corrodes easily, it is coated with asphalt for packing use. Iron powder, as originally produced in Sweden, is made by reducing solid iron ore by the action of carbon monoxide at a temperature below the melting point of the iron and below the reduction point of the other metallic oxides in the ore. It is used for bearings, gears, and other machine parts by compressing and sintering to exact size; the resulting product is porous enough to permit impregnation with oil. Porous iron bearings, of the Keystone Carbon Co., Inc., are molded from powdered iron to the shape desired and sintered. They have a porosity of 25 to 35% and are saturated with oil to make self-lubricating bearings. Powdiron, of the Bound Brook Oil-Less Bearing Co., is a porous iron sintered bearing that will hold up to 25% of lubricant. Iron sponge, employed as a purifier for removing sulphur and carbonic acid from illuminating gas, is a sesquioxide of iron obtained by heating together iron ore and carbon. It has a spongy texture filled with small cells.

**Sponge rubber.** Rubber expanded with a cellular structure and cut or molded into blocks or forms for use as a substitute for sponges or for resilient upholstery padding or insulation. Ordinary chemically blown sponge rubber is made up of interconnecting cells in a labyrinthlike formation. When made by beating latex, it may show spherical cells with the porous walls perforated by the evaporation of moisture. It is also called Foam rubber. Special processes are used to produce celltight and gastight Cellular rubber which is nonabsorbent. Rubatex, of Rubatex Products, Inc., is a cellular rubber made in molds under high pressure and sufficient heat for partial vulcanization. After removal from the tight mold the rubber expands and is then vulcanized. Airtex, of the Firestone Co., is a sponge rubber used for upholstery. Cellular rubber, of the U.S. Rubber Co., has somewhat the appearance of sponge rubber enclosing a structure of cells filled with nitrogen gas. In the form of insulation board for heat and cold it has a thermal conductivity of 0.237 B.t.u. per hr. per deg. F. temperature difference per inch of thickness. It weighs 4.5 and 5.5 lb. per

cu. ft. The 5.5-lb. board has a crushing strength of 33 lb. per sq. in. Under the name of Royal insulation board it is marketed in thicknesses from ¾ to 1½ in. Cellular rubber is also used for floats. Bubblfil, of E. I. duPont de Nemours & Co., Inc., is an expanded cellulose used to replace sponge rubber and kapok as an insulating and buoyancy material. It is expanded into a material with air-filled beads, light, tough, and resilient. Foamex, of the Firestone Tire & Rubber Co., is a foam rubber made from synthetic latex in several density grades. It is stronger than that made from natural rubber and is flexible at very low temperatures. Styrofoam is polystyrene plastic expanded into a nonpermeable multicellular mass 42 times the original size. It is lighter than cork, but will not withstand hot water or temperatures above 170°F. as the material is thermoplastic. Ipoka was a German foam rubber made of urea-formaldehyde plastic blown and molded into blocks for cold-storage insulation.

**Sprengle explosives.** Chlorate compounds that have been rendered reasonably safe from violent explosion by separating the chlorate from the combustible matter. The potassium chlorate is made up into porous cartridges and dipped, just before use, in liquid combustible such as nitrobenzene or dead oil. Potassium chlorate so treated is called Rack-a-rock. Sprengle explosives were formerly used as military explosives, but are very sensitive to friction and heat and are now valued only when it is desired to economize on nitrates. Cheddite is a French explosive consisting of a chlorate with an oily material, such as castor oil thickened by having a nitro-hydro-carbon dissolved in it. A typical cheddite has 80% of potassium chlorate, 8 castor oil, and 12 mono-nitro-naphthalene. With sodium chlorate it is less sensitive to detonation and more powerful but is hygroscopic. Potassium chlorate cheddite is a soft, yellowish, fine-grained material, and is a slow, mild explosive which will split rocks rather than shatter them. Minelite is a chlorate with paraffin wax. Steelite is a chlorate explosive with rosin. Prométhée is another French chlorate explosive. In this explosive the oxygen carrier consists of 95% of potassium chlorate and 5 manganese dioxide, and the combustible contains 50% of nitrobenzene, with turpentine and naphtha. It is

extremely sensitive and will explode by friction. Silesia is a German high explosive used for blasting. It is potassium chlorate with rosin, with some sodium chlorate to make it less sensitive.

**Spring steel.** A term applied to any steel used for making springs. About 99% of all springs are made of steel, but brass, bronze, nickel silver, and phosphor bronze are used where corrosion resistance or electrical conductivity is desired. Carbon steels, with from 0.50 to 1.0% of carbon, are much used, but vanadium and chrome-vanadium steels are also employed, especially for heavy car and locomotive springs. Special requirements for springs are that the steel be low in sulphur and phosphorus, and the analysis be kept uniform. For flat or spiral springs that are not heat-treated after manufacture, hard-drawn or rolled steels are used. These may be tempered in the mill shape. Music wire is widely employed for making small spiral springs. A much used straight-carbon spring steel has 1% of carbon and 0.30 to 0.40 manganese, but becomes brittle when overstressed. A.S.S.T. carbon steel for flat springs has 0.70 to 0.80% carbon and 0.50 to 0.80 manganese, with 0.04 max. each of sulphur and phosphorus. Motor springs are made of this steel rolled hard to a tensile strength of 250,000 lb. per sq. in. Watch spring steel, for mainsprings, has high carbon, 1.15%, and low manganese, 0.15 to 0.25, rolled hard and giving an elastic limit above 300,000 lb. per sq. in.

Silicon steels are used for springs. They have high strength and impact resistance. These steels average about 0.40% of carbon, 0.75 silicon, and 0.95 manganese, with or without copper, but the silicon may be as high as 2%. Flexo steel, of the Carpenter Steel Co., used for automobile leaf springs and for recoil springs, contains 2% of silicon, 0.75 manganese, and 0.60 carbon. The elastic limit is 100,000 to 300,000 lb. per sq. in., depending on the drawing temperature, with hardness 250 to 600 Brinell.

Manganese steels for automotive springs contain about 1.25% of manganese and 0.40 carbon, or about 2% of manganese and 0.45 carbon. When heat-treated, the latter has a tensile strength of 200,000 lb. per sq. in. and elongation of 10%. Part of the manganese may be replaced by silicon and the Silicon-manganese steels have tensile strengths as high as 270,000 lb. per sq. in. The

addition of chromium or other elements increases the elongation and improves the physical properties. Uma spring steel, of the Republic Steel Corp., is a chromium-manganese steel with 1 to 1.2% of chromium, 0.80 to 1 manganese, and about 0.50 carbon. In the rolled condition it has an ultimate strength of 135,000 lb. per sq. in. and Brinell hardness up to 332. Manganese steels are deep-hardening but are sensitive to overheating. The addition of chromium, vanadium, or molybdenum widens the hardening range.

Wire for coil springs ranges in carbon from 0.50 to 1.20%, and in sulphur from 0.028 to 0.029. Bessemer wire contains too much sulphur for spring use. Cold working is the method for hardening the wire and for raising the tensile strength. An 0.85% carbon rod, with an ultimate strength of 140,000 lb. per sq. in., when drawn with four or five passes through dies will have a strength of 235,000 lb. per sq. in. Wire drawn down to a diameter of 0.015 in. may have an ultimate strength of 400,000 lb. per sq. in. The highest grades of wire are referred to as music wire. The second grade is called Hard-drawn spring wire. The latter is a less expensive basic open-hearth steel with manganese content of 0.80 to 1.10%, and an ultimate strength up to 300,000 lb. per sq. in. Specially treated carbon steels for springs are sold under trade names such as Enduria of the Bethlehem Steel Co. Resilla is a silicon-manganese spring steel of this company.

**Spruce.** The wood of various coniferous trees of northern Europe and North America. Spruce is a leading commercial wood of north Europe and is exported from the Baltic region as White fir and White deal. It is also called Norway spruce and Spruce fir. The wood is white, and has a straight, even grain. It is tough and elastic, and is more difficult to work than pine. The weight is 36 lb. per cu. ft. Norway spruce is *Picea abies,* and this tree yields the Jura turpentine of Europe. Spruce is used for making paper pulp, for packing boxes, and as a general utility lumber. White spruce is from the tree *P. canadensis,* of the United States and Canada. It has quite similar characteristics. Red spruce, *P. rubra,* is the chief lumber spruce in the Eastern United States. It is also called Yellow spruce, West Virginia spruce, and Canadian spruce. Black spruce, *P. mariana,* of New England, eastern

Canada, and Newfoundland, is used for making paper pulp. It is also called Blue spruce, Bog spruce, and Spruce pine. White spruce, or Shingle spruce, is from *P. glauca.* It is also called Skunk spruce because of the peculiar odor of the foliage. All of these three species are called Eastern spruce, and they grow from Nova Scotia to Tennessee and westward to Wisconsin except that red spruce does not grow in the Lake states. All are mountain trees and are slow growing. Silver spruce, Yellow spruce, Sitka spruce, or Western spruce, is from the enormous tree, *P. sitchensis,* of the West Coast of the United States and Canada. It is soft and light in weight, but strong, close-grained, and very free from knots. The wide sapwood is creamy white and the heartwood pinkish to brownish. The weight is less than eastern spruce, but it has high strength in proportion to weight. The trees reach a height of 280 ft. and a diameter of 10 ft. in 600 years, but the growth is rapid in early life. The wood is used for boxes, crates, millwork, and paper pulp. The various species of commercial spruce have an average specific gravity, when kiln-dried, of 0.40, a compressive strength of 840 lb. per sq. in. perpendicular to the grain, and a shearing strength of 750 parallel to the grain. It combines stiffness and strength per unit weight and has a uniform texture free from pitch. Japanese spruce is from *Abies mariesii,* and Himalayan spruce is from *P. morinda.* The latter resembles Norway spruce.

**Spruce extract.** The waste sulphite liquor from paper-pulp mills purified for use in tanning leather. The tanning agent in the liquor is Ligno-sulphonic acid. Spruce extract is not used alone in tanning but is mixed with quebracho or other tanning material, or the leather may first be tanned with spruce and then with syntans. Spruce gum is the gum exudation of the *Picea rubra, P. mariana,* and *P. canadensia* of the Northeastern United States and Canada. It exudes from cuts in the trees as a transparent viscous liquid which hardens when it loses the volatile oil and is broken off in the wintertime. The gum is brown or reddish black in color, has a turpentinelike odor and a bitter pungent taste. It is used in cough medicines and in chewing gum.

**Squill.** Also known as Red squill and Sea onion. A reddish powder used chiefly for the control of rats in warehouses and

docks. It is obtained from the onionlike bulb of the perennial plant *Urginea maritima* growing on the beaches of Italy and other Mediterranean countries. The bulb is pear-shaped, from 1 to 6 lb. in weight and 6 to 12 in. in diameter. The outer scales are dry, brittle, and reddish brown, and the inner scales are cream color to deep purple. Red squill powder is a powerful emetic to man or animals other than rats or mice. As rats and mice do not vomit, they are poisoned by it while it is harmless to poultry and domestic animals. It is also used in medicine. It contains Calcium oxalate and in contact with the skin it gives a sensation like nettle poisoning. White squill is another variety used in medicine as an emetic, heart tonic, and expectorant. The substitute for red squill known as Antu, of E. I. duPont de Nemours & Co., Inc., is Naphthyl thiourea, a gray powder of little odor or taste about 100 times more poisonous to rats than squill and not normally injurious to domestic animals. Another poison more toxic to rats than squill is Ratbane 1080 which is Sodium fluoracetic acid made synthetically. The poison occurs as natural fluoracetic acid in the Gifblaar plant, *Dichapetalum cymosum,* of South Africa, which has been used locally for killing rodents. The poison, however, also kills domestic animals, and can thus be employed only in restricted places.

**Stainless iron.** A chromium-iron alloy usually containing from 12 to 20% of chromium, but it may contain as low as 9%. The chromium gives to the alloy the property of being highly resistant to oxidation and corrosion even at elevated temperatures. The resistance to nitric acid increases with the chromium content, and the grades with 16 to 20% of chromium are used for nitric acid equipment. The Brinell hardness is as high at 325, and the tensile strength is up to 150,000 lb. per sq. in. It differs from stainless steel in having low carbon and it is sometimes referred to as Rustless iron. Stainless iron is employed for tank plates, and for parts where corrosion- or acid-resisting qualities are valuable, but where the higher strength and hardness of the stainless steels are not required. Stainless iron No. 12, of the Crucible Steel Co. of America, contains 11 to 13% of chromium, 0.35 to 0.60 manganese, and 0.12 max. carbon. The tensile strength is 164,000 lb.

per sq. in., elongation 11%, and Brinell hardness 321. It forges easily and can be machined readily when annealed. It is used for turbine blades, pump rods, and parts for food machines. Grade No. 18 of the same company contains 17 to 19% of chromium and 0.07 to 0.12 carbon, and has a tensile strength of 100,000 lb. per sq. in., elongation 25%, and Brinell hardness of 200. It is more resistant to acids and corrosion than the No. 12. Uniloy 1409, of the Cyclops Steel Co., has 12% of chromium, 0.50 nickel, and 0.10 carbon. The heat-treated rolled alloy has a tensile strength of 105,000 lb. per sq. in., elongation of 25%, and Brinell hardness of 240. Uniloy 1409M is this alloy with a small amount of molybdenum sulphide to make it free-machining. Circle L12M, of the Lebanon Steel Foundry Co., is a 13% chromium cast steel with 0.10 carbon and 0.25 selenium to give it good machinability. The tensile strength is 85,000 lb. per sq. in., elongation 20%, and Brinell hardness 170.

Turbine blade steel, which is Lesco L of the Latrobe Electric Steel Co., is a stainless iron having 11 to 13% of chromium, 0.50 max. each of silicon and manganese, and 0.10 max. carbon. Lesco LM has 13 to 15% chromium and has higher corrosion resistance; Lesco M and Lesco H, with 15 to 18, and 18 to 20% chromium, have still higher resistance. These stainless irons are furnished also with 0.20 to 0.30% of sulphur to give free-machining qualities. Rustless RR-11, of the Rustless Iron & Steel Corp., is a structural stainless iron containing 11 to 12% of chromium and 0.07 carbon. The ultimate strength is 75,000 lb. per sq. in., elongation 25%, Brinell hardness 170, and coefficient of expansion 0.0000125 per deg. C. Defirust of this company contains 12 to 15% of chromium and 0.10 carbon, with some nickel. It resists temperatures to 1250°F. Defiheat iron contains 26 to 29% of chromium and 0.20 carbon, with a small amount of nickel. The tensile strength is 70,000 to 95,000 lb. per sq. in., and scaling point 2100°F.

Stainless iron does not require heat-treatment, but its physical properties are often improved by such treatment, and it can be hardened, although ordinary steel of the same carbon content will not harden. Columbium or titanium may be added to the 10 to 20% chromium irons to give a softening effect, shorten the time

of annealing, and to minimize intergranular corrosion. In Germany a 17% chromium iron with 0.10% of carbon and a small amount of titanium has been used to replace chromium-nickel stainless steels. Nitrogen in very small proportions produces a fine-grain structure. From 1 to 2% nickel in these irons hardens and strengthens the alloy when heat-treated. A small amount of silver in the alloys modifies the grain structure and prevents pitting.

**Stainless steels.** A group of steels containing high chromium which gives them great corrosion resistance. They were first produced in America in 1914 under English and German patents and contained 12 to 18% of chromium. The original composition was 13.5% of chromium and 0.35 carbon. This steel is machinable, has a tensile strength of 150,000 lb. per sq. in., and Brinell hardness of 325. It is hardened by air cooling or by quenching in oil. With high carbon the steels are not stainless unless the amount of chromium is increased. With very low carbon the steels are more malleable, but they then do not possess air-hardening properties nor do they keep a keen edge in cutting tools. Hardness is necessary to bring out the stainless qualities, and the scale must be polished off. Because of the difficulty of polishing after hardening, the steels are always brought to a high finish before hardening. The higher carbon steels, with carbon up to 0.90%, are used for cutlery and retain a keen cutting edge. Sterling stainless steel, Type A, of the Firth-Sterling Steel Co., is a typical stainless steel used for automobile parts and for cutlery. It contains 13.5% of chromium and 0.35 carbon. The tensile strength is from 100,000 to 240,000 lb. per sq. in., elongation 4 to 27%, specific gravity 7.77, and Brinell hardness 185 to 500. Steels of this type are also used for making pen nibs to replace gold pens tipped with osmi-iridium. Staybrite, of this company, has 10% of chromium, 3 to 4 silicon, and 0.45 carbon. It is used for cutlery. Colonial stainless F.M.S., of the Colonial Steel Co., with a maximum of 0.12% of carbon and up to 0.35 sulphur, is easily machined, and is used for valve parts, screws, and gun barrels.

A group of stainless steels is produced by the United States Steel Corp. under the name of U.S.S. steels. Duraloy is the name of a group marketed by the Duraloy Co., and Heiloy is the name of

stainless steels used by the Heil Co., for dairy equipment. Radianite, of the Latrobe Electric Steel Co., contains 16.5 to 18% of chromium, 0.70 to 0.80 carbon, and not over 0.50 each of silicon and manganese. It keeps a fine cutting edge, and retains a high polish. Lusterite is another grade with higher carbon, and is a Keen-edge steel for surgical instruments and knives. Hy-Glo steel, of this company, has 17% of chromium and 0.60 carbon. It has a tensile strength up to 250,000 lb. per sq. in., hardness up to 600 Brinell, and is used for cutlery and tools.

Columbium is added to stainless steels of various grades to minimize intergranular corrosion and to shorten the time of annealing. Columbium stainless steel is used in tank cars. A free-cutting stainless steel is made by adding about 0.40% of zirconium sulphide. The latter makes the steel easy to machine and does not impair the resistance to corrosion, but it decreases the ductility. Carpenter stainless No. 5 contains 14% of chromium, 0.40 zirconium sulphide, and 0.10 carbon. E-Z stainless steel, of the Latrobe Electric Steel Co., is stainless steel with 13.5% of chromium and 0.34 carbon, having in addition 0.20 to 0.30% of sulphur to make it easy to machine. Ni-Stainless steel, of the same company, is regular stainless with the addition of 1.5 to 2% of nickel. It gives added abrasion resistance and is used for pump rods, pistons, and valves. Sterling stainless FC, of the Firth-Sterling Steel Co., contains 0.40% of molybdenum, and 0.25 sulphur for free-cutting qualities. Circle L25M, of the Lebanon Steel Foundry, is a 21-10 chromium-nickel steel with 0.25% of selenium to give free machining. None of the plain chromium steels are austenitic, but additions of nickel produce the austenitic condition. The 18-8 chromium-nickel steels were called Super stainless steels in England, and they have become designated as stainless steels in America, but they do not belong to the original class of stainless steels. The steels with low nickel are called ferritic and are harder than the plain stainless steels. Colonial 410 has 12.5 to 14.5% of chromium, 1 nickel, and 0.12 carbon. Stainless steels are used for turbine blades, pump rods, parts for chemical equipment, dairy equipment, restaurant fixtures, and where corrosion resistance and heat resistance are needed. They are used in wrought and cast forms.

**Starch.** A large group of substances with the empirical formula $(C_6H_{10}O_5)x$, occurring widely in grains, tubers, and fruits. They are used industrially for pastes, adhesives, fillers, explosives, and stiffening materials. The common cereal grains contain from 55 to 75% of starch. Potatoes have about 18% of starch and 78 of water. Most of the commercial starch is made from corn. The starches from different plants have similar chemical reactions, but all have different granular structure, and the differences in size and shape of the grain have much to do with the variations in adhesive properties in glues and sizings. Cornstarch has a polygonal grain of simple structure. It is the chief food starch, although Sweet potato starch is used in confections where gelatinization is valued. Cornstarch is also used for textiles and for laundry use.

Tapioca starch has rounded grains truncated on one side and of lamellar structure. It gives quick tack and high adhesion in glues. Tapioca is from the root of the *Manihot utilissima* now grown in many parts of the world. It is called Cassava in the East Indies, Manioc in Brazil, Mandioca in Paraguay, and Yuca in Cuba. It is used in enormous quantities for food in some countries, the Dutch East Indies alone producing 8 to 10 million tons annually. But in the United States it is used mainly for making adhesives and paper and textile coatings. Pearl tapioca, which is the material in globules and flakes, is used for foodstuffs. Gaplek is dried cassava root, usually sliced, used for fodder. Rice starch is polygonal and is lamellar. Potato starch has conchoidal or ellipsoidal grains of lamellar structure. White potato starch is used for sizing textiles, nitrostarch, soluble starch, and dextrins. The starch molecule is a chain of glucose units, and the waxy starches valued for glues are those with branch chains. These starches do not crystallize easily. Amioca starch, developed during the war to replace tapioca, is from cross-bred waxy corns. The starch contains only amylpectin molecules which give stability in solution, clarity, and adhesiveness. While ordinary starch gelatinizes slowly over a range of 30 deg. from 64 to 94°C., the waxy starch gelatinizes sharply at 70°C. over a range of only 8 deg., thus resembling the root starches.

Prolonged grinding of grain starches destroys the microstructure and makes the starch soluble in cold water. In general, starch is a white, amorphous powder having a specific gravity

from 0.499 to 0.513. It is insoluble in cold water. When boiled with water, starch produces a paste. Soluble starch is made by allowing starch to stand in contact with cold, dilute acid for some days. Dextrin is a starch with a smaller value of $x$ in the molecule, and is made by heating starch in a dry condition. Starch gives a blue color with iodine, and the dextrins give violet and red. Dextrins have a sweet taste. Dextrin has adhesive properties and is used on envelope flaps and postage stamps. Animal starch is glycogen, the reserve food of animals, stored in the muscles and internal organs. Green fruits, especially bananas, often contain much starch until the ripening process has changed the starch to sugar. Potato starch, produced from the common white potato, *Solanum tuberosum,* is the most important commercial starch in Europe. Sweet-potato starch, from *Ipomoca batata,* gelatinizes completely at 165°F. and has excellent colloidal and pasting qualities. An average of 10 lb. of starch is produced per bushel. It is used as a foodstuff stabilizer and for textile finishing. Arrowroot starch is from the tubers of the *Maranta arundinacea* of the West Indies. It is very easily digested, and is valued for food products. Florida arrowroot is from the *Zamia floridana.* Other types of arrowroot are grown in the East. East Indian arrowroot is from the plant *Curcuma angustifolia* which belongs to the ginger family. Starch acetates are used as textile sizing and to replace dextrin in adhesives, and also for greaseproofing paper.

Allyl starch is a resinous material made by treating sweet-potato or grain starches with allyl chloride or allyl bromide. It is soluble in varnish solvents and is a substitute for shellac as a varnishing agent, forming an adherent, resistant film on paper, fabric, wood, or metal. It will withstand temperatures to 400°F. Starch sponge is an edible starch in the form of a coarse-textured, porous, crispy, spongelike material, used for confections by impregnating with chocolate or sweets. In crushed form it is added to candy or cookies. It is produced by freezing starch paste, thawing, and pressing. The freezing insolubilizes the starch so that no soluble starch goes off when the water is pressed out. Nitrostarch, or Starch nitrate, $C_{12}H_{12}O_{10}(NO_2)_3$, is a fine white powder made by treating starch with mixed acid. It is highly explosive and is used for blasting, as a military explosive, and in signal lights. Grenite is nitrostarch

mixed with an oil binder for use in grenades. Trojan explosive is a mixture of 40% nitrostarch with ammonium and sodium nitrates and some inert material to reduce the sensitiveness.

**Statuary bronze.** Copper alloys used for casting statues, plaques, and ornamental objects that require fine detail and a smooth, reddish surface. Most of the famous large bronze statues of Europe contain from 87 to 90% of copper, with varying amounts of tin, zinc, and lead. Early Greek statues contained from 9 to 11% of tin with as much as 5% of lead added apparently to give greater fluidity for sharper casting. A general average bronze will contain 90% of copper, 6 tin, 3 zinc, and 1 lead. Statuary bronze for cast plaques used in building construction contains 86% of copper, 2 tin, 2 lead, 8 zinc, and 2 nickel. The nickel improves fluidity and hardens and strengthens the alloy, and the lead promotes an oxidized finish on exposure. The statuary bronze used for hardware has 83.5% of copper, 4 lead, 2 tin, and 10 zinc.

**Stearic acid.** A hard, white, waxlike substance used for making paint driers, soaps, candles, lubricating greases, and in buffing compounds, cosmetics, and waterproofing compounds. It is the common constituent of hard fats, and is a white mass of the composition $CH_3(CH_2)_{16}COOH$, soluble in alcohol but insoluble in water. The specific gravity is 0.922 to 0.935, and melting point 129 to 130°F. It is obtained from fats and oils by splitting and distilling, or it can be made from oleic acid by hydrogenation. Pearl stearic acid is the material in free-flowing powdered bead form for compounding purposes. Stearic acid is also marketed in cakes, powder, or flake form, as single-pressed, double-pressed, or triple-pressed. The successive pressings remove more of the liquid oils, thus raising the melting point and giving a whiter, harder product with lower iodine value. Stearic acid is also used for making candles, usually mixed with palmitic acid or paraffin. Oleostearin, used for filling and finishing leather, is the stearin remaining after extraction of the edible Oleo oil from cattle fats. Oleo oil is the yellow oil obtained by cold-pressing the first-run tallow; Tallow oil is a grade following the first two grades of oleo oil. Stearite is a trade name for Synthetic stearic acid made by the hydrogenation of

unsaturated animal and fish oils. It is used in rubber compounding as it is more uniform than natural stearic acid.

**Stearin pitch.** The brown to black by-product residue produced in the distillation of animal and vegetable oils and fats. It is used in varnishes, insulating compounds, floor coverings, and cold-molding compositions. It produces a low-cost paint that surface-skins and dries with a smooth enamel-like finish. Stearin pitch is obtained as the residue from the oil splitting for the manufacture of candles, soaps, or fatty acids. It may also be called Candle tar, Candle pitch, or take its name from a specific oil such as Linseed pitch or Palm pitch. The pitch obtained from nondrying oils such as corn or palm is usually softer and more pliable than that from semidrying oils such as linseed or cottonseed.

**Steel.** Iron with carbon chemically dissolved in it, with no carbon in the free graphitic state. When raised to a red heat and cooled suddenly, it becomes exceedingly hard by the formation of carbides. This hardness can be modified by subsequent heat-treatment. Steels with less than 0.15% of carbon harden only slightly, and these are technically classed as irons, although the name steel is used even when the carbon is quite low, especially if there are other carbide-forming elements in the material. Steel is graded according to the percentage of carbon in it, and is roughly divided into four groups: Low-carbon steel, with 0.15 to 0.30% of carbon; Medium-carbon steel, with 0.30 to 0.60% of carbon; High-carbon steel, with 0.60 to 0.90% of carbon; and Very high-carbon steel, with 0.90 to 1.5% of carbon. Steel with more than 1.25% of carbon is very brittle unless there are some other balancing elements. The low-carbon steels machine easily and can be forged readily. Those containing above 0.90% of carbon are difficult to forge and machine. In general, the low-carbon steels are used for construction parts and the high-carbon steels for tools and high-strength parts. All steels contain some manganese, usually at least 0.30%, left after deoxidizing and desulphurizing with ferromanganese. The latter forms MnS and MnO which passes off in the slag, but sometimes an excess of manganese is used for hard steels as the manganese is a carbide-forming element. Sulphur in steel forms the weak and soft sulphide FeS which weakens

the steel and promotes hot shortness or brittleness at red heat. But sometimes a very small amount of sulphur is left in the steel to aid machinability. Oxygen in the steel forms the embrittling compound FeO and is undesirable in any quantity. Normally, phosphorus is considered detrimental in steels, but small amounts, up to 0.20%, in low-carbon steels increase the hardness, strength, and also increase corrosion resistance. Dirty steel is steel with inclusions of iron oxide from scrap used in the converter or of aluminum oxide from the aluminum used in deoxidizing. The melting point of steel varies with the carbon, but is always higher than that of cast iron with the same amount of combined carbon. The average weight of carbon steel is 0.283 lb. per cu. in.

Ordinary steel has only carbon as the influencing element, except that there is usually residual manganese, sulphur, and some other elements in very small amounts. The carbon forms the hard carbide $Fe_3C$ when the steel is cooled suddenly, and the strength of the steel is greater with the increase in amount of carbon up to 0.85% which is the saturation point of the carbon in the iron. Above this point the metal becomes increasingly brittle unless there are other carbide-forming elements to take up the carbon that is thrown out. In modern practice a very large proportion of steels contain chromium, manganese, vanadium, or other carbide-forming elements. Open-hearth steel is made by fusing cast iron with steel scrap or wrought iron in a regenerative furnace. Cementation consists in heating bars of wrought iron in contact with carbon. The product is known as Blister steel as the surface of the bars is covered with blisters. Blister steel has a crystalline fracture decreasing toward the center of the bar where there is less carbon. Shear steel is produced from this blister steel by cutting and piling together, heating to a high temperature, and rolling or hammering into bars. Shear steel was originally the only form of commercial steel.

Bessemer steel is made by decarbonizing cast iron by forcing a powerful blast of air through the molten iron. Crucible steel is made by melting wrought iron in a crucible with charcoal and ferromanganese, or special steel mixes in a crucible furnace. The slag separates by gravity from the molten metal in the crucibles, and the oxides combine with carbon and manganese or aluminum,

and boil off. The metal is poured into ingots which are reheated and rolled into bars or other forms. The crucible process permits a high degree of control and reduces sulphur and phosphorus.

Electric steel is made in either the induction or the arc-type furnace, and is of a uniform quality and of a higher strength and ductility than open-hearth steel of the same carbon content. In general, rolled and forged steel is stronger, tougher, and more ductile than cast steel. The ordinary wrought steel used for wrought-steel pipe has a tensile strength of 52,000 lb. per sq. in., yield point 30,000 lb. per sq. in., and elongation 20%. The tensile strength of a typical open-hearth steel varies from about 50,000 lb. per sq. in. for a 0.12% carbon steel to 110,000 lb. per sq in. for a 0.55% carbon steel, with elongations of 29 and 12%, respectively. Ordinary forgings are made from steels of 0.15 to 0.30% carbon, and strong forgings from steel with 0.35 to 0.40% carbon, but most strong forgings are now made with alloy steels. Raising the carbon content from 0.40 to 0.45% will increase the possible hardness of the steel about 10%, but greater variations in strength and hardness of a steel may come from heat-treatment.

**Steel powder.** Finely divided steel powder used for molding under hydraulic pressure into various parts which are then sintered at a temperature of 1075°C. The tensile strength of the molded and sintered products is about the same as that of cast steel of the same composition. It has the advantage that there is no metal loss in machining, and accurate gears, cams, and other parts can be made without machining labor. Sinterloy is the name of a steel powder marketed by Charles Hardy, Inc., in compositions of 0.05, 0.40, and 0.80% carbon. Some grades also contain nickel and chromium. Durex iron, of the Moraine Products Div., General Motors Corp., is iron or steel made by compressing iron powder containing a small percentage of carbon and sintering in special furnaces with controlled atmospheres. It can be controlled by pressure to form 70 to 95% of the density of pure iron; or with a porosity range from 5 to 30% by volume when it is desired to impregnate with oil. The final compressed and sintered product has a structure similar to that of carbon steel, and intricate shapes can be made to close tolerances that require no machining. It is used for me-

chanical parts or the porous variety for bearings. By the compression and sintering of powders, or Powder metallurgy, compositions can be obtained that are not easily obtainable by alloying. P.M.P. iron, of the Powdered Metals Corp., used for bearings, contains 90% of iron and 10 copper. With a density of 5.5 lb. per cu. in. it has a tensile strength of 30,000 lb. per sq. in. and will absorb 30% of oil by volume. When compressed to a higher density it has greater strength, and is used for cams and machine parts.

**Steel wool.** Long, fine fibers of steel used for abrasive purposes, chiefly for cleaning utensils and for polishing. It is made from low-carbon Bessemer wire of high-tensile strength, usually having 0.10 to 0.20% of carbon and 0.50 to 1 manganese. The wire is drawn over a track and shaved by a stationary knife bearing down on it. A special machine also is made for shaving off the wool in a continuous piece and winding it around wheels. Fibers of a length of 100,000 ft. have been made. Steel wool usually has three edges but may have four or five, and strands of various types are found together. There are nine standard grades of steel wool, the finest of which has no fibers greater than 0.0005 in. thick, the most commonly used grade having fibers that vary between 0.002 and 0.004 in. Steel wool comes in batts, or in flat ribbon form on spools usually 4 in. wide.

**Sterling silver.** Since silver is a very soft metal, it is not used industrially in its pure state, but is alloyed with a hardener, usually copper. Sterling silver is the name given to a standard high-grade alloy containing a minimum of 925 parts in 1,000 of silver. It is used for the best tableware, for jewelry, and for electrical contacts. Sterling silver is made by melting the silver and copper together in a crucible using a cover of charcoal. The 7.5% of copper makes the alloy so hard that it requires annealing between rollings. When quenched from a temperature of 1400°F., sterling silver is as soft as 18 Rockwell, but when quenched from 700°F. it is hard, 47 Rockwell. Silver may sometimes be hardened with other elements besides copper. Silanca is a silver hardened with small amounts of zinc and antimony, but the name sterling is applied only to the Silver-copper alloy.

**Stillingia oil.** A drying oil obtained from the kernels of the seeds of the tree *Stillingia sebifera,* cultivated in China. The seeds contain about 23% of a light-yellow oil resembling linseed oil but of somewhat inferior drying power. The oil has a specific gravity of 0.943 to 0.946 and iodine value of 160. It has the peculiar property of expanding with great force at the congealing point. Stillingia oil is edible, but deteriorates rapidly, becoming bitter in taste and disagreeable in odor. Stillingia tallow, also known as Chinese vegetable tallow, is obtained by pressing from the coating, or mesocarp, of the seeds. Sometimes the whole seed is crushed, producing a softer fat than the true tallow. The tallow contains palmitic and oleic acids and is used in soaps and for mixing with other waxes. Some stillingia trees are grown in Texas.

**Strontium.** A metallic element of the alkaline earth group, symbol Sr. It occurs in the minerals Strontianite, $SrCO_3$ and Celestite, $SrSO_4$, and resembles barium in its properties and combinations. It has a pale-yellow color, specific gravity of 2.54, melting point about 900°C., and it decomposes water. It is obtained by electrolysis of the fused chloride. Strontium compounds are used as deoxidizers in nonferrous alloys, and in fireworks to furnish oxygen and give a colored flame. Strontianite is used in Germany as a desulphurizer for steel.

**Strontium nitrate.** A yellowish-white, crystalline powder of the composition $Sr(NO_3)_2$. It is the strontium salt of nitric acid and is prepared by roasting Celestite, leaching out the strontium sulphide, and dissolving the strontium carbonate in dilute nitric acid. The yellowish commercial product is 99.5% pure. It is soluble in water but insoluble in alcohol. The specific gravity is 2.96 and melting point is 645°C. Strontium nitrate gives a beautiful crimson flame and is used in red lights, railway-signal flares, and signal stars. It also furnishes the oxygen necessary for the combustion of the compounds. A typical flare compound contains 50% of strontium nitrate, 37½ potassium chlorate, and 12½ shellac, the last serving as a binder and to furnish heat of combustion. The Strontium sulphate used as a brightening agent in paints, and as a filler in rubber and in sealing wax, is powdered celestite. Strontium carbonate, used in pyrotechnics and in glass and ceramics,

is $SrCO_3$, marketed 99.5% pure. Strontium sulphide, SrS, used for luminous paint, gives a persistent blue-green glow, but it deteriorates rapidly unless placed between glass plates and sealed in.

**Styrax.** A grayish-brown, viscous, sticky, aromatic balsam obtained from the small tree *Liquidambar orientalis* of Asia Minor. It is also called Levant styrax. It is used in cough medicines and for skin diseases, as a fixative for heavy perfumes, and for flavoring tobacco. American styrax is from the sweet gum *L. styraciflua* of North America. It is a brownish semisolid and has the same uses as Levant styrax. It is shipped from Central America under the name of Liquidambar, and in the Southern United States is called Sweet gum and Storax. The gum is not present in large amounts in the wood, but its formation is induced by cuts. The red gum of Louisiana yields 2.5 oz. per tree per year. Benzoin is another balsam obtained from several species of *Styrax* trees. It is a highly aromatic solid with an odor like vanilla, and is used in medicine and in perfumes and incense. Sumatra benzoin is from the tree S. *benzoin* and comes in reddish-brown lumps or tears. In medicine it was originally called Gum Benjamin. Siam benzoin, from southern Asia, is from the trees S. *tonkinense* and S. *benzoides*. It is in yellowish or brownish tears. The Sumatra benzoin contains cinnamic acid, while the Siamese gum contains benzoic acid. Benzoic acid, $C_6H_5COOH$, formerly produced from benzoin, is now made synthetically from benzol or toluol. It is a white crystalline solid melting at 122°C., soluble in water and in alcohol, used as a food preservative, antiseptic in medicine, for flavoring tobacco, as a weak acid mordant in printing textiles, and in the manufacture of dyestuffs and pharmaceuticals. It is poisonous, and not more than 0.1% is used in food preserving in the form of its salt, Sodium benzoate, $C_6H_5COONa$, a white crystalline powder.

**Suède.** Also called Napped leather. A soft-finished, chrome-tanned leather made from calf, kid, or cowhide splits, or from sheepskin. It is worked on a staking machine until it is soft and supple, and then buffed or polished on an abrasive wheel. It has a soft nap on the polished side and may be dyed in any color. Suède is used for shoe uppers, coats, hats, and pocketbooks. Artificial suède, or Izarine, of the Atlas Powder Co., has a base of rubber-

ized fabric. A thin coating of rubber cement is applied to one side which is sprinkled with fine cotton fibers dyed in colors. The sheet is beaten from the bottom to make the fibers stand out until the cement hardens. It is then vulcanized. The fabric looks and feels like fine suède.

Sugar. A colorless to white or brownish crystalline, sweet material produced by evaporating and crystallizing the extracted juice of the Sugar cane or the Sugar beet. Refined sugar is practically pure Sucrose, $C_{12}H_{22}O_{11}$, and in addition to being a sweetening agent for many foods it is a valuable carbohydrate food, and also a food preservative. When used with cooked fruits to make jams and jellies, it is both a preservative and an added food material. Lack of sugar in the diet develops ketosis, the disease of diabetics, and results in the wasting away of muscles, using up of the reserve fats, and the production of poisonous ketones. The natural brown sugar contains about 2% of the minerals found in the plant, calcium, iron, phosphorus, magnesium, and potassium and, although these are valuable as foods, they are lost in the refining process to make white sugar. Sugar is also one of the most economical raw materials for the production of ethyl alcohol, being used for this purpose in the form of molasses or invert sugar.

Sugar cane, *Saccharum officinarum,* is a tropical plant, originating in Asia and first brought to the Canary Islands in 1503 and thence to the West Indies. The plant will not withstand frost, but can be grown in a few favored regions outside of the tropics such as Louisiana. It is now grown on plantations in Cuba, Hawaii, Brazil, Philippines, East Indies, Puerto Rico, Peru, and many other countries. The cane or stalks of the plant are crushed to extract the juice, which is then concentrated by boiling, crystallized, and clarified with activated carbon or other material. The sugar beet is a white-rooted variety of the common beet, *Beta vulgaris,* and grows in temperate climates. It is cut up and boiled to extract the juice, and the production and refining of the sugar are essentially the same as for cane sugar. There is no difference in the final product.

Refined commercial sugar contains 99.98% of sucrose, and is graded by screening to crystal size. The best qualities are the larger

crystals from the first and second runs. The soft sugars are from further crystallizing, until the noncrystallizing brown sugars are reached. Raw sugar testing 96° by the polariscope is the grade used as a basis for raw-sugar quotations. About 107 lb. of this grade of sugar are required to produce 100 lb. of refined sugar.

Cane sirup is the high-grade sirup or liquid sugar, while Molasses is the heavy residual sirup left after the crystallization. Edible molasses is the yellow to brownish, light purified residue sirup. Blackstrap molasses is the final, inedible, unpurified residue heavy sirup, used for the production of ethyl alcohol. It contains 50 to 60% of sugar by weight, mostly sucrose but some glucose. Cuban sugar mills average 48 gal. of blackstrap molasses per ton of sugar. Papelon is a name used in northern South America for solidified edible molasses. Gur is the crude unrefined brown sugar of India. It polarizes between 50 and 60°. The Pilancillo used in Mexico is unrefined brown sugar. Treacle is an English term for edible molasses. The Beet pulp after extraction of the juice is marketed as cattle feed. The refuse from sugar cane is used as fuel and for making insulating board. Liquid sugar is cane sugar in various liquid densities and various degrees of invert, used in large-scale food manufacturing as it saves handling costs. For food manufacturing it may be obtained with calcium and other mineral contents and is then golden in color. Flo-Sweet, of the Refined Syrups & Sugar, Inc., is such a liquid sugar. A type of edible sugar sirup is also obtained from the juice of a variety of Sorghum grass, *Sorghum vulgare,* native to South Africa, but now grown in Southern United States. The juice or sirup, called Sorghum sirup, or Sorgo sirup, is light in color, has a characteristic mild flavor, and contains gummy materials and starch, which prevent crystallization. It also contains other sugars besides sucrose, and considerable mineral salts of value as foods. The total sugar in the juice is from 9 to 17%, varying with the age of the plant. Apple sirup, or Apple honey, used as a sweetening agent in the food industry, for curing hams, and as a substitute moistening agent for tobacco, is made from cull apples. The reduced sirup is treated to remove the bitter calcium malate. The sirup contains 75% solids of which 65% consists of the sugars levulose, dextrose, and sucrose. Saccharin, sometimes used as a substitute sweetening agent for sugar,

is Benzoic sulphinide, $C_6H_4SO_2NHCO$, a coal-tar product. It is 450 times sweeter than sugar, but has a disagreeable flavor and no food value.

**Sugar pine.** The common name of the wood of the *Pinus lambertiana,* a coniferous tree growing in California and Oregon. The tree grows ordinarily to a height from 150 to 175 ft. with a diameter of 4 to 5 ft. Occasional trees are more than 200 ft. in height and 12 ft. in diameter, and are often free of limbs up to 75 ft. from the ground. It is the largest of the pines. The stand is estimated to be 35 billion bd. ft. and is cut at the rate of 300 million ft. annually. Sugar pine is durable, has moderate strength, fairly even grain, and is not subject to excessive shrinkage or warping. Because of the latter quality it has come into use to replace the scarcer eastern pines for patterns. It does not darken on exposure like western pine. It is widely employed for construction work and for Factory lumber for doors, frames, boxes, and wooden articles. Sugar pine is classified into three standard classes of grades according to freedom from knots and faults as: select, commons, and factory, or shop. The selects are designated as No. 1, and 2 clear, C select, and D select. The commons are graded as No. 1, 2, 3, and 4; the factory as No. 3 clear, No. 1 shop, No. 2 shop, and No. 3 shop. The shops are judged with the idea that they will be cut up into small pieces, and are consequently classified by the area of clear cuttings that can be obtained.

**Sulfamic acid.** A white crystalline odorless solid of the composition $HSO_3 \cdot NH_2$. It is very soluble in water, but only slightly soluble in alcohol or ether. The melting point is 205°C., and the molecular weight 97.1. Sulfamic acid is used for bating, pickling, and tanning leather. It makes a silky and tight grain in leather. It is also used in the form of Ammonium sulfamate for making textiles and paper fire-resistant, for the manufacture of dyes, and as a weed killer. Lead sulfamate, $Pb(SO_3NH_2)_2$, is very soluble in water and is used in lead plating. The solution has high throwing power and gives rapid plates.

**Sulphonated oil.** A fatty oil that has been treated with sulphuric acid, the excess acid being washed out, and only the chemi-

cally combined acid remaining. The oil is then neutralized with an alkali. Sulphonated oils are water-soluble and are used in cutting oils and in fat liquors for leather finishing. Sulphonated castor oil is called Turkey red oil. Leatherlubric is the trade name of E. F. Houghton & Co. for sulphonated sperm oil used for leather. Solcod is the sulphonated cod oil of the same company. Sulphonated stearin and Sulphonated tallow are also used in leather dressing. They are cream-colored pastes readily soluble in hot water. Mahogany soap is a name for oil-soluble petroleum sulphonates used as dispersing and wetting agents, corrosion inhibitors, emulsifiers, and to increase the oil absorption of mineral pigments in paints. Petronate, of L. Sonneborn Sons, Inc., is a petroleum sulphonate containing 62% of sulphonates, 35 mineral oil, and 3 water. Phosphorated oils, or their sulphonates, may be used instead of the sulphonates as emulsifying agents or in treating textiles and leathers. They are more stable to alkalies. Phosoils, of the Beacon Co., are phosphorated vegetable oils. Aquasol, of the American Cyanamid Co., is a sulphonated castor oil used as an emulsifying agent. Cream softener is a name used in the textile industry for sulphonated tallow.

Sulphur. An element, symbol S, which occurs abundantly in its uncombined state. It is obtained from the gypsum deposits of Texas and Louisiana, and from volcanic deposits in Sicily, Mexico, Chile, and Argentina. It is purified by distillation. It can also be obtained by distillation from iron pyrites and as a by-product from copper and zinc smelting. Sulphur forms a crystalline mass of a pale-yellow color. Its hardness is 1.5 to 2.5 and specific gravity 2.05 to 2.09. It melts at 232°F. At about 780°F. it is converted into a ruby-colored vapor. The amorphous sulphur has a specific gravity of 1.955. When melted and cast into sticks, it is known as Brimstone. Sulphur also condenses in light flakes, in which form it is known as Flowers of sulphur. Flotation sulphur is a fine, free-flowing dust containing a minimum of 95% sulphur. It has particles of extreme fineness, 80% of which are less than 4 microns in diameter. It is recovered in gas production from coal. Also, the sour natural gas of Arkansas contains a large proportion of the

offensive smelling, colorless Hydrogen sulphide gas, $H_2S$, which yields sulphur powder.

Sulphur has a great affinity for most metals and combines with great energy when heated together with them. Sulphur, even in very small quantities, makes metal alloys brittle and must ordinarily be kept out of commercial metals. Sulphur has many uses in the formation of sulphur compounds and sulphuric acid, for making gunpowder, for vulcanizing rubber, for bleaching cloth, as a fumigant, and in medicine. It is also used as a cement for anchoring iron in stone and for lining iron pipes for brine waters. Commercial crude Sicilian sulphur contains from 2 to 11% of impurities and is sold in three grades. Refined sulphur is marketed in crystals, roll, or various grades of powder, and the Sicilian superior grade is 99.5% pure. This is the grade used in rubber manufacture. The sulphur of the Texas Gulf Sulphur Co. is 99.5% pure and is free of arsenic, selenium, and tellurium.

Vegetable sulphur is not sulphur, but the name is a colloquial term for Lycopodium, also known as Club moss. It is a fine yellow powder derived from the spores of a fernlike plant, *Lycopodium clavatum,* a perennial growing in North America, Europe, and Asia. Its chief use is in medicine, but it is also employed in fireworks and flashlight powder and as a dusting powder for sand molds for fine castings.

**Sulphur dioxide.** Also known as Sulphurous acid anhydride. It is colorless gas of the composition $SO_2$, employed for industrial bleaching, as a preservative, and in refrigeration. It is used extensively for domestic refrigerating machines. The gas is poisonous, but has a pungent, suffocating odor and is thus detected easily. It is also easy to locate small leaks by cloud test with ammonia. It is corrosive to organic materials but does not attack copper or brass. Sulphur dioxide in refrigerating machines has a condensing pressure of 51.7 lb. gage at 86°F., and a pressure of vaporization of 2.9 lb. gage at 5°F. It boils at −10°C. It is soluble in water, forming Sulphurous acid. Sulphur dioxide is produced by roasting pyrites in a furnace. It is also obtained from metallurgical waste gases. Sulphurous acid is a colorless liquid of the composition $H_2SO_3$, with suffocating fumes. It is made commercially by absorbing the sul-

phur dioxide gas in water. The U.S.P. grade has a strength of 6%. Sulphurous acid is used in industrial bleaching.

Sulphuric acid. Also called Oil of vitriol and Vitriol. An oily, highly corrosive liquid of the composition $H_2SO_4$, used for pickling and cleaning metals, plating baths, making explosives, rayon, electric batteries, production of fertilizers, and for many other purposes. In weak solutions sulphuric acid is sometimes known in the metal industries as Dipping acid, and in the automotive trade as Battery acid. Concentrated acid, or Fuming sulphuric acid, was known as Nordhauser acid. The specific gravity is 1.834 and boiling point 210°C. It is miscible in water in all proportions. The color is yellowish to brownish according to the purity. It disintegrates wood, rubber, and most organic materials and many metals, but the weak acid does not dissolve lead or mercury. Sulphuric acid is made from sulphur or from pyrites, or by oxidizing the sulphur dioxide from the waste gases of copper and zinc smelters and absorbing the gas in water. In Germany it is made from gypsum by breaking down and treating the $SO_2$ gas. The common commercial grade of sulphuric acid known as oil of vitriol is 66°Bé., which is 93.2% of acid. Other grades are 50 and 60°Bé.

Niter cake, which is Sodium acid sulphate, $NaHSO_4$, or Sodium bisulphate, contains 30 to 35% of available sulphuric acid and is used in hot solutions for pickling and cleaning metal articles. It comes in colorless crystals or white lumps, of a specific gravity of 2.435 and melting point 300°C. Sodium sulphate, or Glauber's salt, is a white crystalline material of the composition $Na_2SO_4 \cdot 10H_2O$, used in making kraft paper, rayon, and in glass. It was first produced from Hungarian spring water by Johann Glauber, and when obtained from mineral springs is called Crazy water crystals. The Burkeite, sodium sulphate-sodium carbonate double salt, which separates out of Searles Lake brine, is used to produce sodium sulphate and other chemicals as by-products. Salt cake, $NaSO_4$, is impure sodium sulphate used in the cooking liquor in making paper pulp from wood. It is also used in freezing mixtures. Synthetic salt cake, used for making kraft pulp, is produced by sintering soda ash and sulphur. Chrome cake is a greenish by-product salt cake which contains some chromium as an impurity.

It is used in papermaking. Kaiseroda is a German name for salt cake of high purity obtained as a by-product from the production of magnesium chloride from potash minerals. Sodium sulphite, $Na_2SO_3$, or $Na_2SO_3 \cdot 7H_2O$, is a white to tan crystalline powder very soluble in water but nonhygroscopic. Santosite, of the Monsanto Chemical Co., is a grade of sodium sulphite containing 93% of sodium sulphite with the balance chiefly sodium sulphate. Sodium sulphide, $Na_2S$, is a pink flaky solid, used in tanneries for dehairing, and in the manufacture of dyes and pigments. Sodium sulphhydrate, NaSH, is in lemon-yellow flakes. It has much less alkalinity than sodium sulphide, and is used in tanneries in unhairing solutions.

Sumac. The dried ground leaves of the bush *Rhus coriaria* of Sicily, or *R. typhina* of Eastern United States, used for tanning leather. The Sicilian leaves contain up to 30% of tannin, and the American leaves up to 38%. It contains gallotannin and ellagitannin and gives a rapid tan. Sumac produces a light strong leather of fine soft grain and has a bleaching action which can produce a white leather. It is used for book and hatband leathers.

Sunflower oil. A pale-yellow drying oil with a pleasant odor and taste obtained from the large seeds of the common sunflower plant, *Helianthus annuus*, of which there are many varieties. The plant is native to Peru but is now grown in many parts of the world particularly in California, Argentina, Chile, Uruguay, and Russia. It requires boron in the soil. The specific gravity of the oil is 0.925. Sunflower oil is used in varnish and soap manufacture or as a food oil. The by-product cake is used chiefly for cattle feed, but Sunflower meal is also blended with wheat flour or cornmeal in foods. It is higher in vitamin B than soybean flour. Sunflower seeds are also used as poultry feed. Madia-seed oil is quite similar to sunflower oil and has the same uses. It is obtained from the seeds of the plant *Madia sativa*, native to California. The seeds contain 35% of oil, and the cold-pressed oil has a pleasant taste.

The leaves of selected varieties of some species of sunflower contain from 1 to 6% of Sunflower rubber and up to 8% of resin. The *H. occidentalis, H. giganteus, H. maximiliani,* and *H. strumosus,* are cultivated in Russia both for the oil seed and for the

rubber in the leaves. These perennials yield leaves up to 10 years. A stand of 50,000 plants per hectare yields about 150 kilos of rubber and 325 kilos of resin. Another similar rubber-bearing plant of southern Russia is the *Asclepias cornuti,* known as Vatochnik. It is a perennial, producing leaves for 10 to 15 years. The leaves yield 1 to 6.5% of rubber and large percentages of resin.

**Sunn hemp.** The bast fiber of the plant *Crotalaria juncea.* It is used for cordage and rope in place of jute, but is lighter in color and is more flexible, stronger, and more durable than jute. It resembles true hemp but it is not as strong. It is more properly called Sann hemp from the Hindu word Sann. It is also known as Sunn fiber, Indian hemp, and Bombay hemp. The plant, which is a shrub, is cultivated extensively in India. It grows to a height of about 8 ft., with slender branches yielding the fiber. The method of extraction is the same as for true hemp. The best fibers are retained locally for making into cloth. It is also used in the United States for making cigarette paper, and for oakum. Madras hemp is from another species of the same plant. Sunnee, also called Brown Indian hemp, is a fiber from the plant, *Hibiscus cannabinus,* of India. It is used as a substitute for hemp, and in mixtures with jute in making burlap.

**Superbronze.** A name applied to brasses containing both aluminum and manganese. They are ordinarily high brasses modified with 2 to 3% of manganese and 1 to 6 aluminum, with sometimes also some iron. They have greatly increased strength and hardness over the original brasses, but the ductility is reduced and they are difficult to work and machine. The early superbronze was known as Heusler alloy. Muntz metal is also frequently modified with manganese, iron, and aluminum. The alloys are used where high strength and corrosion resistance are required, and they are often marketed under trade names. Tensilite, of the American Manganese Bronze Co., is a bronze of this type. A grade containing about 64% of copper, 30 zinc, 2.5 manganese, 3 aluminum, and 1 iron has a tensile strength, cast, up to 100,000 lb. per sq. in. and elongation of 16%. Mallory metal is a superbronze of the P. R. Mallory Co.

**Sycamore.** The wood of the tree *Acer pseudo-platanus,* which is also classed as a kind of maple, especially in England. The species cut as sycamore in the United States is largely *Platanus occidentalis.* The wood has a close, firm, tough texture and is yellowish in color, with a reddish-brown heartwood. The light-colored sapwood is up to 3 in. thick in commercial trees. When quartered, the wood resembles quartered oak. The weight is about 38 lb. per cu. ft. The surface is lustrous and takes a fine polish. It is used for veneers, flooring, furniture, cooperage, and for handles and rollers. Two other species grown in the Southwest are California sycamore, *P. racemosa,* and Arizona sycamore, *P. wrightii.*

**Synthetic resins.** A large group of resinlike materials, properly called Resinoids, produced synthetically by either polymerization or condensation of various chemicals. The resins, or Plastics, are complex chemical compounds. The physical characteristics and high molecular weights depend upon the number of repeating molecular groups that make up the resins. The basic molecule of a synthetic resin is called a Monomer, and the recurring additions of monomers is called a Polymer. Polymerization is the chemical union of many simple molecules, and the chemical formula of the final product is identical with that of the structural unit or monomer. The process of polymerization is achieved through the action of light, heat, pressure, or a chemical catalyst. Thus, in the polymerization of styrene, the basic formula $C_6H_5CH:CH_2$ is repeated over and over to form polymers, or polystyrene, with constantly increasing molecular weights until the process is stopped when the desired characteristics are reached. Condensation plastics are made by the action between two different molecules. In this fusion of two molecules, a simple molecule, such as water or ammonia, may be eliminated in the process. For example, when a dibasic acid, $R(COOH)_2$, is reacted with a diamine $R'(NH_2)_2$, as in the production of the the nylons, water is eliminated and the nature of the molecule is changed and it is increased in size. Where certain terminal groups are present, in this case —COOH and —$NH_2$, polycondensation produces plastics with increasing molecular weights, but the molecular formula is different from that of either of the two original materials condensed. Styrene and butadiene can be poly-

merized separately to form polymerization plastics, but when both together are condensed, as in making Buna S rubber, the copolymer is a different product from either product formed by separate polymerization.

The chief groups of synthetic resins are Phenolaldehyde, Aminoaldehyde, and the Hydroxycarboxylic, or alkyd, vinyl, acrylic, styrene, and indene. Cellulose nitrate, cellulose acetate, and the proteins such as casein are classed with the others as plastics, but they are not synthetic resins like the others. Molding plastics consist of the partly polymerized resin either alone or mixed with pigment and filler, usually in powder form, for molding to the final set by heat and pressure. The filler may be wood flour, fibers, or mineral powders, but it should have the characteristic of being wet by the resin. For use in adhesives and lacquers the resins are mixed with plasticizers and sometimes with other gums and resins to give flexibility or other characteristics. Albertol resins was a name of the original German resins mixed with natural resins for greater pliancy. The molded resins are marketed under a great variety of trade names such as Durium and Insurox.

Nypene is a terpene polymer resin of the composition $(C_{10}H_{16})n$, produced from turpentine by The Neville Company. It is stable, alcohol-resistant, light in color, and permanently thermoplastic. The specific gravity is 0.98, and melting point 145°C. It is used to soften and plasticize rubber, to add adhesive qualities to rubber and latex in making rubber cements, and in compounding wax protective coatings. Vandiset resin, of the Wilson Carbon Co., is a thermoplastic black synthetic resin produced by regrouping the hydrocarbons from Venezuelan crude oil. It has quick-setting and rapid oxidation characteristics ascribed to the presence of vanadium oxide. It is used in molding plastics and in varnishes and printing inks. A group of resins is made from Fumaric acid, which is a free-flowing powder of the composition $HOOC \cdot (CH)_2 \cdot COOH$ made by the fermentation of carbohydrates. Its esters are polymerized to form liquid or solid resins which are clear and stable. Acetone-formaldehyde resins made by reacting acetone and formaldehyde with an alkaline catalyst are used in lacquers, adhesives, and printing inks. They are rapid drying, insoluble, and give high gloss,

**Talc.** A soft, friable mineral, usually oily and yielding to the touch. The very white colloidal talc, such as that from the Alpine cliffs of northern Italy, with a soapy feel, is used for cosmetics; the massive form is cut into electrical and chemical particles and kiln-fired, or ground for use as a filler for paper, paints, and rubber, as a filtering agent, and for molding into ceramic insulators, heater parts, and chemical ware. Talc is a hydrated magnesium silicate of the theoretic composition $4SiO_2 \cdot 3MgO \cdot H_2O$, occurring in white, gray, green, brown, or red colors, with a hardness of 1 and a specific gravity of 2.8. It is a secondary material formed from magnesium silicates. The gritty varieties contain carbonate minerals. The lime talcs are preferred for porcelains. The lime-free talcs are desired for electric heater plates where minimum thermal expansion and resistance to heat shock are needed. These talcs are also used as fire-box lining for boilers, and will withstand a temperature of 1700°C.

Talc is usually sold under trade names for filler purposes. Asbestine, of C. K. Williams & Co., is a talc powder of 325 mesh. French chalk is a high-grade talc in massive block form used for marking. The mineral occurs in the United States in the Appalachian region from Vermont to Georgia. The Georgia talc for making Crayons is mined in blocks, and the yield of talc suitable for sawing into crayons is about 1 ton for every 8 tons of crude talc. The crayons are made ¼ in. diameter rounds, ¼ in. square, and 3/16 by ½ in. The residue is made into ground talc. The purer grades of Steatite talc, or massive talc, are valued for making high-frequency electrical insulators. The steatite talc, or Lava talc, of British Columbia, is used for this purpose.

Agalite is a mineral having the same composition as talc but with a less soapy feel. It is used as a filler in cheap writing papers, but is more wearing on the paper rolls than talc. The talc of northern New York, known as Rensselaerite, does not have the usual talc slip, and has a fibrous nature. The hydrous aluminum silicate Pyrophyllite, found in California, is similar to talc but with the magnesium replaced by aluminum. In mixtures with talc for wall tile it eliminates crazing. It is also substituted for talc as a filler for paints and paper.

**Tall oil.** An oily resinous liquid obtained as a by-product of the sulphite paper-pulp mills. The name comes from the Swedish Talloel, meaning pine oil. The crude oil is brown, but the refined oil is reddish yellow and nearly odorless. It is a blend of crude pine fatty acids. It has a specific gravity of 0.97 to 0.99, flash point of 350° to 370°F., and acid number 160 to 170. About 50 lb. of tall oil is obtained per ton of kraft paper produced. It contains 45 to 50% of fatty acids of which more than 70% is linoleic acid, 20% oleic, and 5% linolenic, with some palmitic. The rosin acids in the oil are composed mainly of abeitic acid. Tall oil is used in scouring soaps, asphalt emulsions, cutting oils, insecticides, rust preventatives, animal dips, in the production of factice, and in plastics. It is also used to produce a glossy drying oil for varnishes by reacting the crude tall oil with maleic anhydride and then esterifying with pentaerythritol. Sulphonated tall oil is used to replace sulphonated castor oil in coating mixes for paper to increase folding strength. Opoil is a crude tall oil of the National Southern Products Co., and Facoil is the refined oil with 60% fatty acid content and low-rosin acid content.

**Tallow.** A general name for the heavy fats obtained from all parts of the bodies of sheep and cattle. The best grades of internal fats, or Suet, are used for edible purposes, but the external fats are employed for lubricants, for mixing with waxes and vegetable fats, for soaps and candles, and for treating leather. About half of the fatty materials used in the United States for soaps are grades of tallow. The tallows consist largely of stearic, palmitic, and oleic acids. The edible grades known as Premier jus, Prime, and Edible, are white to pale yellow, almost tasteless, and free from disagreeable odor, but the nonedible or industrial tallows are yellow to brown unless bleached. The best grade of industrial tallow is Packers No. 1. Beef tallow is a white to yellow solid containing about two-thirds Stearin and palmitin with also olein. Stearin is the glyceryl ester of stearic acid. Beef tallow is used to produce stearic acid, for leather dressing, lubricating greases, and for making soap. Mutton tallow contains less liquid fat and is harder, but it becomes rancid more easily.

**Tanning agents.** Materials, known as Tannins, used for the treatment of skins and hides to preserve the hide substance and make it resistant to decay. The tanned leather is then treated with fats or greases to make it soft and pliable. Tannins may be natural or artificial. The natural tannins are chiefly vegetable, but some mineral tanning agents are used. The vegetable tannins are divided into two color classes: the Catechol and the Pyrogallol. The catechol tannins are Cutch, quebracho, hemlock, larch, gambier, oak, and willow. The pyrogallol tannins are Gallnuts, sumac, myrobalans, chestnut, valonia, divi-divi, and algarobilla. Catechol tannin is distinguished by giving a greenish-black precipitate with ferric salts; the pyrogallol tannins give a bluish-black precipitate. The catechol tannins, in general, produce leathers that are more resistant to heat and decay than the pryogallols. Some tannins contain considerable coloring or dye matter, but the color that a tannin imparts to leather may be lightened or darkened by raising or lowering the acidity of the tanning bath. In the ink industry the catechol tannins are known as iron-greening, and the pyrogallol tannins as iron-bluing, and the latter are used for making writing inks.

Alum tanning is an ancient process but was introduced into Europe only about the year 1100, and the alum- and salt-tanned leather was called Hungary leather. Formaldehyde is also used as a tanning agent. Formaldehyde was patented as a tanning agent in 1898. A later patent covered a rapid process of tanning sheepskins with alcohol and formalin and then neutralizing in a solution of soda ash. Unlike vegetable agents, formaldehyde does not add weight to the skin. It is often used as a pretanning agent to lessen the astringency of the vegetable tannin and increase its rate of diffusion. Leather may also be tanned with chromic acid or chrome salts, which make the fibers insoluble and produce a soft, strong leather. Chrome alum, sodium or potassium dichromates, or products in which chromic acid has been used as an oxidizing agent may be used. Chrome tanning is rapid and is used chiefly for light leathers. Tanolin is a name for basic Chromium chloride marketed in crystal form for use in the chrome tanning of leather. Santotan KR is a trade name of the Monsanto Chemical Co. for basic Chromium sulphate, $Cr_2(SO_4)_2(OH)_2$, used as a one-bath chrome-tanning agent. This material is also used for treating mag-

nesium alloy parts to give a gray to black surface color. Panchrome, an English tanning agent, is a sulphur dioxide dichromate. Chromalin is a glycerin-reduced dichromate. Chrome-tanned leather is more resistant to heat than vegetable-tanned leathers, withstanding temperatures to 200°F. Chrome tanning is used for shoe upper leathers and for gloves, belting, and packings.

In tanning processes various supplementary materials may be used to give special properties to the leathers. Glucose or starch may be used to make the leather more plump. Hydrochloric acid is used in two-bath chrome tanning to enhance the feel and appearance of the leather. Synthetic tannins, or Syntans, are largely condensation products made by condensing sulphonic acid with formaldehyde. Neradol D is such a syntan. Tansyn is the trade name of an English syntan of this kind. Permanol, of the Monsanto Chemical Co., is a sulphonic acid condensation syntan in liquid form used to produce light-fast white leathers. The free sulphuric acid is completely neutralized. Syntans do not add weight to leather and are seldom used alone. They are marketed under trade names. Leukanol, of the Rohm & Haas Co., has a bleaching action and is used in combination with vegetable tannins to speed up the tanning and to give a light-colored leather. The German Tanigan is a complex sulphonated condensation product produced from waste pulp-mill liquor and formaldehyde or diphenyl methane.

**Tantalum.** A white, lustrous metal resembling platinum. It is one of the most acid-resistant of the metals and is classed as a noble metal. The specific gravity is 16.6, or about twice that of steel, and the melting point is very high, 2850°C. It is very ductile and can be rolled down from 0.300 to 0.0015 without annealing, or drawn into extremely fine wire. The tensile strength of the sheet metal is 50,000 lb. per sq. in., and of the drawn wire 130,000 lb. per sq. in. The annealed metal has a hardness of 75 Brinell. It is resistant to all acids except hydrofluoric, and is not dissolved by aqua regia. It will dissolve, however, in a mixture of nitric and hydrofluoric acids, and also reacts with chlorine above 175°C. When heated in the air to about 400°C., it becomes blue; at a higher temperature, it becomes black. At very high temperatures it absorbs oxygen, hydrogen, or nitrogen, and becomes very brittle. It

will absorb 740 times its own volume of hydrogen, producing a coarse, brittle substance. Tantalum can be tempered or hardened to about 600 Brinell by heating in the air to absorb gases, and will hold a fine cutting edge on tools. It can also be hardened by the addition of silicon to a hardness close to that of the diamond, but any alloying is difficult because of the high melting point.

Tantalum is used as a filament in electric-light bulbs. The metal becomes incandescent at 1700°C., or 400° below that of tungsten, so that a tantalum lamp is cooler. It is also used in radio tubes, and in vacuum tubes to absorb gases. It is lower in cost than platinum, and is used for surgical instruments, pens, instruments, and acid-resistant chemical equipment. It is also used in alloy special steels to give increased resistance to scaling at high temperatures. Tantalum coils are used to heat acid baths. A tube with a wall thickness of 0.020 in. will withstand operating steam pressure up to 150 lb. per sq. in. The metal has the property of passing an alternating electric current in one direction only, and is thus used for current rectifiers. As an anode, tantalum reacts instantly with oxygen in acid solutions forming a stable oxide film which is current blocking; this property is used in rectifiers and electrolytic condensers.

Tantalum carbide. An extremely hard, heavy, brownish, crystalline material of high melting point, 3875°C., used for the same purposes as tungsten carbide, as an abrasive and cutting material. It has the composition TaC, and in hardness it ranks close to the diamond. For use in cutting tools the carbide is ground to 325 mesh, mixed with a binder of powdered cobalt, iron, or nickel, molded to shape, and sintered at high heat. Ramet is the trade name of the Fansteel Metallurgical Corp. for tantalum-carbide cutting materials, and Tantaloy is a name for a sintered alloy in bar form for flowing on faces of tools with a welding torch. Vascoloy-Ramet is a name given by the Vascoloy-Ramet Corp. to tantalum-carbide cutting and wear-resistant materials in various grades. They have a hardness range from Rockwell A 88.4 to 92.5. Tantung G, of the same company, is a nonferrous cutting alloy containing tantalum carbide. It is not as brittle as the cemented carbides and can be operated at higher cutting speeds than high-speed steel or ordinary nonferrous cutting alloys.

**Tantalum ores.** The most important ore of the metal tantalum is Tantalite. When pure, its composition is $FeO \cdot Ta_2O_5$, but the American ore may contain only from 10 to 40% of Tantalic oxide, $Ta_2O_5$, and the Australian ore may contain as high as 70%. The ore is marketed on the basis of 60% tantalic oxide content. Tantalite occurs usually as a black crystalline mineral with a specific gravity up to 7.3. It often contains manganese, tin, titanium, and sometimes tungsten; the tantalum may be replaced by columbium, which is similar to it. When the columbium content in the ore predominates, the mineral is called Columbite. Tantalite also contains small amounts of germanium. Tantalum metal is produced from tantalite by dissolving in acid and separating the tantalum salts from the columbium by precipitation. The tantalum salts are reduced to powdered metal, which is then compressed into rods and sintered and rolled. One pound of tantalum is produced from about 2½ tons of American ore. Australia is the most important source of tantalite.

A tantalum ore that is abundant at Wodgina, Western Australia, is Manganotantalite which contains about 69% of Tantalum oxide, $Ta_2O_5$, 15 of Columbium pentoxide, $Cb_2O_5$, and 14 manganese protoxide, with a little tin oxide. The specific gravity of the ore is 6.34. Microlite, an ore found at Wodgina and in the McPhee Range of Western Australia, contains 76% of $Ta_2O_5$ and 4 to 7 of $Cb_2O_5$. Tanteuxenite, another Western Australian ore, contains 24 to 47% of $Ta_2O_5$ and 4 to 14 of $Nb_2O_5$. Tapiolite, from Western Australia, contains 82% of $Ta_2O_5$ and 2 of $Nb_2O_5$.

**Tar.** A black solid mass obtained in the destructive distillation of coal, peat, wood, petroleum, or other organic material. When coal is heated to redness in an enclosed oven, it yields volatile products and the residue coke. Upon cooling the volatile matter, tar and water are deposited, leaving the coal gases free. Various types of coal yield tars of different qualities and quantities. Anthracite gives little tar, and cannel coal yields large quantities of low-gravity tar. In the manufacture of gas the tar produced from bituminous coal is a viscous black liquid containing 20 to 30% of free carbon, and is rich in benzene, toluene, naphthalene, and other aromatic compounds. In the dry state this tar has a specific gravity of

about 1.20. Tar is also produced from coke ovens and as a by-product of blast furnaces using coal as a fuel.

Coal tars are usually distilled to obtain the aromatic substances, and the residue tar, known as Treated tar, or Pitch, is used for making roofing, for road making, and for bituminous paints and waterproofing compounds. Coal-tar pitch is the most stable bituminous material for covering underground pipes. The Fiber pipe used as conduits in chemical plants is molded of vegetable fibers impregnated with coal-tar pitch. Pitch-On metal, of the Cheney Co., is a very soft 26- and 24-gage sheet steel hot-dipped with coal-tar pitch so that the coating is firmly embedded into the pores. It is used to replace galvanized iron and copper for roofing and flashings. Crysolite paint, of the Semet-Solvay Co., is a corrosion-resistant and acid-resistant paint with a base of refined coke-oven pitch, which is mixed with vegetable drying oils. The color is black. It is used for painting tanks, smokestacks, and structural steel. Tarvia is the trade name of a refined coal tar, marketed by the Barrett Co. in various grades. Tarmac is practically the same material marketed by the Koppers Co., Tar & Chemical Div. Bituvia is a road tar, produced in various grades by the Reilly Tar & Chemical Corp. Coal-tar carbon amounts to about 32% of the original tar. It is marketed in lump form for chemical use. The fixed carbon content is 92.5 to 95.6%, sulphur about 0.30, and volatile matter 3 to 6. Calcined carbon, of the Reilly Tar & Chemical Corp., contains less than 0.5% of sulphur, and 0.5 volatile matter.

The lightest distillate of coal tar, benzol, is used as an automotive fuel. Coal-tar oils are used as solvents and plasticizers. They consist of various distillates or fractions up to semisolids. Bardol B, of the Barrett Div., Allied Chemical & Dye Corp., is a clear yellow coal-tar fraction of specific gravity 1.0 to 1.04, used as a plasticizer for synthetic rubber, while Carbonex is a solid black tar hydrocarbon in flake form used as a rubber plasticizer. The softening point is between 205 and 220°F. Xylol is a water-white liquid of specific gravity 0.860 to 0.870, distilling between 135 and 185°C.

Naphthalene and Anthracene are among the distillates. Anthracene is a colorless crystalline product of the composition $C_6H_4$:-$(C_2H_2)$:$C_6H_4$ and melting point 217°C. used for the production of dyes, resins, plasticizers, tanning agents, and inhibitors. Quino-

line is a liquid with a tar odor having the empirical formula $C_9H_7N$ and boiling point 237°C. used for the manufacture of antiseptics, pharmaceuticals, insecticides, vitamins, and rubber accelerators.

Pine tar is a by-product in the distillation of pine wood. It is a viscous black mass and is much used for roofing. It is also sometimes called pitch, but pitch is the tar with the pine-tar oil removed and known as Pine pitch. Navy pitch and Ship pitch are names that refer to specification pine pitch of the Navy. The Navy grade is medium hard to solid, of a specific gravity of 1.08 to 1.10, melting point not less than 148°F., completely soluble in benzol, and of a uniform black color, or red brown in thin layers. Wood tar from the destructive distillation of other woods is a dark-brown viscous liquid used as a preservative, deriving this property from its content of creosote. Stockholm tar, a name now out of commercial use, was a term employed in shipbuilding for the tar obtained from the crude distillation of pine stumps and roots.

**Taylor process wire.** Very fine wire made by the process of drawing in a glass tube. The process is used chiefly for obtaining fine wire from a material lacking ductility, such as antimony, or extremely fine wire from a ductile metal. The procedure is to melt the metal or alloy into a glass or quartz tube, and then draw down this tube with its contained material. Wire as fine as 0.00004 in. in diameter is made commercially by this process. Wires of this kind can be obtained only in short lengths but, since they are used only for electrical instrument and laboratory work, this is not ordinarily an objection.

**Tea.** The dried leaves of the shrubs *Camellia sinensis* and *Thea sinensis*, grown chiefly in southern Asia, Japan, Ceylon, Russian Transcaucasia, and the East Indies but also in Peru and in East Africa. The plant requires a warm subtropical humid climate. Tea leaves are valued for making the beverage tea which contains the alkaloid Caffeine and is stimulating. The leaves contain more caffeine than coffee berries but the flavor is different. Like coffee, also, it contains tannin, which dissolves out when the leaves are steeped too long, and is an astringent. In well-prepared tea the tannins have been oxidized to the brown and red tannin which is not easily soluble and does not enter the properly steeped beverage

to any great extent although it gives the color to the beverage. The flavor and aroma of tea depend largely upon the age of the leaves when picked and the method of drying. Green tea is made by drying the fresh leaves in the sun or artificially, while Black tea is made by first fermenting the leaves and then drying. Rolling is done to break the leaves and release the juices. In Great Britain green tea is preferred, while the consumption in the United States is mostly black tea. The Oolong tea of Formosa is partly fermented and is intermediate between green and black. Pouchong tea is graded by mixing oolong with aromatic flowers such as jasmine. Tea is also graded by the size and age of the leaf. Flowery orange pekoe is the smallest leaf, orange pekoe the second, then pekoe, pekoe souchong, and souchong. Tea also varies with varieties grown in different climates so that Japan tea, China tea, and Ceylon will have different flavors.

Commercial tea is usually a blend of different varieties to give uniformity under one trade name. The blending of tea is considered an art. Brick tea, made in China for the Russian trade, is produced from coarse leaves and twigs which have been fermented. They are mixed with tea dust, treated with rice water, and pressed into bricks 11 by 14 in. Cake tea, or Puerh tea, is produced in Yunnan. The leaves are panned, sundried, and steamed, and then pressed into circular cakes about 8 in. in diameter. Tablet tea is selected tea dust pressed into small tablets. Tea waste is the final dust from the tea siftings, and is used for the production of caffeine. Teaseed oil, or Sasanqua oil, is from the seeds of another species of the tea plant, *Thea sasanqua,* of Asia. The seeds contain 58% of a pale-yellow oil with a specific gravity of 0.916 used for lubrication, hair oil, soap, and pharmaceutical preparations. Paraguayan tea, or Yerba maté, used in immense quantities as a beverage in Argentina, Paraguay, Brazil, and some other South American countries, consists of the dried smoked leaves of the small evergreen tree *Ilex paraguayensis,* native to Paraguay and southern Brazil. It was an ancient beverage of the Indians and cultivation began on a large scale under the early missionaries. It contains a higher percentage of caffeine than tea or coffee, 3.88%, and is also used as a source of caffeine. It has less tannin than tea or coffee. The flavor of the steeped beverage is different from that of China tea and is

preferred by many. In the Brazilian state of Paraná near the coffee-growing district it is preferred to coffee and the annual consumption is 40 lb. per inhabitant. There are many varieties. The center of the growing region is about the Upper Paraná River.

**Teak.** The wood of the tree *Tectona grandis,* of southern Asia. It resembles oak in appearance, is strong and firm, and in England is called Indian oak. It contains an essential oil that gives it a pleasant odor and makes it immune to the attacks of insects. It is used for boxes, chests, and for decking and interior woodwork on ships. The color is golden-yellow, the grain is coarse and open, and the surface is greasy to the touch. It is one of the most durable of woods, and also has small shrinkage. The weight is 40 lb. per cu. ft. In Burma large plantations grow teak for export. Trees grow to a height of 100 ft. with a diameter of 3 ft. The growth is slow, a 2-ft. tree averaging 150 years of age. The wood marketed as African teak, known also as Iroko, is from the tree *Chlorophora excelsa,* of West Africa, and is unlike true teak. It is a firm, strong wood with a brownish color and a coarse, open grain. The weight is somewhat less than teak, and it is harder to work, but it is resistant to decay and to termite attack, and is used in ship construction. Surinam teak is the wood of the tree *Hymenea courbaril* of the Guianas and the West Indies. It is also called West Indian locust. The wood is dark brown in color, hard, heavy, and difficult to work. It is not very similar to teak and not as durable. Seacoast teak, or Bua bua, is a hard, yellow, durable wood from species of the tree *Guettarda* of Malaya. Australian teak, from New South Wales, is from the tree *Flindersia australis.* It is yellowish red in color, close-grained, and hard with an oily feel resembling teak, but more difficult to work. In wood, of Burma, also called Eng teak, is from the In tree, *Dipterocarpus tuberculatus* from which gurjun balsam is obtained. The wood is reddish brown; it is not as durable as teak.

**Tear gases.** An important group of lachrymatory poisons used in chemical warfare and for police work. They have a powerful irritating effect on the eyes, causing temporary blindness and swelling of the eyes. They cause a copious flow of tears. Some of the gases also have a sour, irritating odor and are also classed as Haras-

sing agents. Some of the gases are also irritating to the throat. Most of the gases, except acrolein, are poisonous in any considerable quantity, having after effects, and some, like chloropicrin, are highly toxic. Acrolein, one of the original tear gases, is Acrylic aldehyde, $CH_2:CH\cdot CHO$, made by heating glycerin with a dehydrating agent. The unpleasant effect of scorching fat is due to the acrolein formed. The material is a volatile liquid boiling at 52°C. and is extremely irritating to the eyes and nose. Bromoacetone is a colorless liquid of the composition $CH_2BrCOCH_3$, with a specific gravity of 1.631 and boiling point 126°C. It is thrown in bombs or shells and disseminated as a mist. Bromoacetone attacks the eyes, causing a copious flow of tears. Bromobenzyl cyanide is a solid of the composition $BrC_6H_4CH_2CN$, with a melting point of 25°C; when impure it is a liquid, but it is not purified as it is easily decomposed. It is very persistent and has a sour, irritating odor, being classed as a harassing agent. It was called Camite by the French. Another tear gas, Chloroacetophenone, $C_6H_5COCH_2Cl$, is a white, crystalline solid, specific gravity 1.321, and melting point 59°C., which, when thrown as a vapor, has a sweet, locustlike odor but produces pains in the eyes and temporary blindness. Other tear gases include chloropicrin, benzyl chloride, benzyl bromide, cyanogen chloride, martonite, xylyl bromide. The French gas Fraissite is Benzyl iodide, $C_6H_5CH_2I$, a liquid boiling at 226°C. The gas Papite is acrolein with stannic chloride. Caderite is benzyl bromide with stannic chloride. Xylyl bromide, $CH_3\cdot C_6H_4\cdot CH_2Br$, is a colorless liquid boiling at 216°C. When disseminated as a mist from explosive bombs, it causes a copious flow of tears.

**Tellurium.** An elementary metal, symbol Te, obtained as a steel-gray powder of 99% purity by the reduction of Tellurium oxide recovered from the residues of lead and copper refineries. It is also marketed in slabs and sticks. It occurs also with gold in Washington and Colorado as Gold telluride, $AuTe_2$. The specific gravity is about 6.2 and melting point 450°C. The chief uses are in lead to harden and toughen the metal, and in rubber as an accelerator and toughener. Less than 0.1% of tellurium in lead makes the metal more resistant to corrosion and acids, and gives a finer grain structure and higher endurance limit. Tellurium-lead

pipe, with less than 0.1% of tellurium, has a 75% greater resistance to hydraulic pressure than plain lead. A Tellurium lead, patented in England, contains 0.05% of tellurium and 6 antimony. Tellurium copper is a free-machining copper containing about 1.0% of tellurium. It machines 25% easier than free-cutting brass. The tensile strength, annealed, is 30,000 lb. per sq. in., and the electrical conductivity is 98% that of copper. A Tellurium bronze containing 1% of tellurium and 1.5 tin has a tensile strength, annealed, of 40,000 lb. per sq. in., and is free-machining. Tellurium is used in small amounts in some steels to make them free-machining. It forms a sulphide in the steel which aids machinability without making the steel hot-short as do increased amounts of sulphur. As a secondary vulcanizing agent with sulphur in rubber, tellurium in very small proportions, 0.5 to 1.0%, increases the tensile strength and aging qualities of the rubber. It is not as strong an accelerator as selenium, but gives greater heat resistance to the rubber. Telloy is the trade name of the R. T. Vanderbilt Co. for tellurium powder ground very fine for rubber compounding.

**Terne plate.** Bessemer or open-hearth steel plate containing on each side a thin coating of an alloy of 20% tin and 80 lead, although other proportions may also be used. Terne is an old name meaning dull and refers to the color as compared with bright tin plate. Terne plate is made by the dip process and is used for roofing, construction work, and to replace the more expensive tin plate for uses not in contact with foodstuffs. The coating is measured by the pounds per double base box containing approximately 436 sq. ft., or 112 sheets, 20 by 28 in. Long ternes are those with coatings of 8, 12, and 15 lb., not heavier than No. 14 gage or lighter than No. 30 gage. Short ternes are those with coatings of 8 lb. or lighter, or in very heavy coatings from 15 to 40 lb. for roofing use. The name long terne is used to designate flat sheets of the heavier weights used for manufacturing purposes. The usual roofing material is 40 lb., and the coating is 25% of tin and 75 lead. Industrial terne plate usually comes in base boxes of 112 sheets, 14 by 20 in., furnished as standard, deep-drawing, and extra deep-drawing. When copper steel is specified, it has at least 0.18% of copper.

Lead-coated steel is now much used instead of terne plate for building use and for stamped and formed parts. Lead alone does not adhere well to steel, but the lead dip used contains small amounts of other elements. Weiralead, of the Weirton Steel Co., is a lead-coated steel in gages 16 to 28. The lead coating contains small amounts of tin, silver, and antimony, and it will not peel when bent or deep-drawn. Amaloy, of the American Machine & Foundry Co., is a lead alloy with 1% tin, used for hot-dipping iron and steel parts. Plate-Loy, of the American Smelting & Refining Co., is a hot-dip plate, and the coating contains 2 to 4% of tin, 1 antimony, 1.5 to 2 zinc, and the balance lead. It adheres well to the steel, and the plate can be seamed and soldered.

**Terra-cotta.** A general English term applied to fired, unglazed, yellow, and red clay wares; in the United States it refers particularly to the red and brown square and hexagonal tiles made from common brick clay, always containing iron. Some special terra-cottas are nearly white, while for special architectural work other shades are obtained. The clays are washed, and only very fine sands are mixed with them in order to secure a fine open texture and smooth surface. Terra-cotta is used for roofing and for tile floors, for hollow building blocks, and in decorative construction work. Good, well-burned terra-cotta is less than 1½ in. thick. Terra-cotta is very light, 120 lb. per cu. ft., and will withstand fire and frost.

**Tetrachlorethane.** A colorless liquid of the chemical formula $CHCl_2 \cdot CHCl_2$, employed as a solvent for organic compounds such as oils, resins, and tarry substances. It is an excellent solvent for sulphur, phosphorus, iodine, and various other elements. It is used as a paint remover and bleacher, as an insecticide, and in the production of other chlorine compounds. It is also called Acetylene tetrachloride, and is made by the combination of chlorine with acetylene. Tetrachlorethane boils at 144°C., freezes at −36°C., is noninflammable, and has a specific gravity of 1.601. It is narcotic and toxic, and the breathing of the vapors is injurious. Mixed with dilute alkalies, it forms explosive compounds. In the presence of moisture it is very corrosive to metals. Mixed with zinc dust and sawdust, it is employed as a smoke screen.

**Tetraethyl lead.** A liquid of the composition $Pb(C_2H_5)_4$, used to mix with gasoline to lower the rate of explosion to prevent knocking in the engine from the hammerlike blows of sudden explosions. It is volatile, and the fumes are poisonous. Only minute quantities are dissolved in the gasoline; the latter, called Ethyl gasoline, is then always colored with dyes for identification. Ethyl fluid, for adding tetraethyl lead to gasoline, is marketed by the Ethyl Gasoline Corp. Ethyl fluid is usually added to high-test gasolines. Tetraethyl lead is also used as an antioxidant to reduce the sludging of lubricating oils that are used at high temperatures.

**Thallium.** A rare metallic element, symbol Tl. The metal resembles lead, is soft and malleable, with specific gravity of 11.85, and melts at 570°F. At about 600°F. it ignites and burns with a green light. It tarnishes in the air and forms an oxide coating. It is resistant to acids but is acted on by nitric and by sulphuric acids. It is a poor electric conductor. Thallium is capable of forming alloys with many other metals. It has a crystalline structure, and in white bearing alloys increases the strength and resistance to deformation. Alloys of lead and thallium, containing from 20 to 65% of thallium, are corrosion-resistant and are used for depositing as a plate on parts for chemical machinery. A patented Lead-thallium alloy of the Westinghouse Electric & Mfg. Co., containing up to 20% of thallium, is used for soldering. The metal occurs in copper and iron pyrites and zinc ores, and the chief source is the flue dust of smelters from spalerite ores. Four rare minerals are ores of thallium: Vrbaite, $Tl_2S \cdot 3(AsSb)_2S_3$, is found in Macedonia; Lorandite, $Tl_2S \cdot 2As_2S_3$, is found in Macedonia and in Wyoming; Hutchinsonite, $PbS \cdot (TlAg)_2S \cdot 2As_2S_3$, occurs in Switzerland and in Sweden; Crooksite, $(CuTlAg)_2Se$, is found in Sweden. The salts of thallium are highly poisonous, the sulphide being used as a rat poison. Thallium oxysulfide is used in light-sensitive cells. It is also sensitive to infrared rays, and is used for dark signaling. Thallium sulphate, $Tl_2(SO_4)_3$, is a crystalline powder used as an insecticide. It is more toxic than lead compounds. Thallium also gives high refraction to optical glass.

**Thermit.** The name of a mixture of finely divided aluminum and pure iron oxide, which when ignited reacts to produce a super-

heated steel at a temperature of about 4600°F. The process was originally patented by the Goldschmitt Thermit Co. The reaction, which depends upon the affinity of oxygen for aluminum at high temperatures, is started with a gas torch or with an ignition powder, usually barium peroxide with other chemicals. The ignition powder will produce a temperature of about 2800°F. At this temperature the aluminum will ignite and the reaction then increases the temperature, setting free the iron in molten form. It is used for the welding of heavy pipes and large sections of iron or steel. Red thermit is the mixture with red oxide of iron, and Black thermit is with the black oxide. Railroad thermit is plain thermit with the addition of 17% of nickel, manganese, and mild-steel punchings, used for all steel welds. Forging thermit is plain thermit with additions of manganese steel and mild steel punchings. Cast-iron thermit is plain thermit with 3% of ferrosilicon and 20 of mild steel punchings, used for welding cast-iron parts.

**Thermoelectric metals.** Also called Thermostatic metals, or Thermocouple metals. Metals or alloys used in thermocouples for measuring high temperatures. When two wires of different metals are joined, any application of heat to the coupled end will set up an electric current in the metallic circuit. Such a couple is connected by wires to a sensitive galvanometer. The electromotive force is proportional to the temperature at the junction; a reading of the indicator thus gives the temperature. Accuracy within a range of 2°F. in temperature readings can be obtained for high-temperature readings. Metals for thermocouples must be refractory, and must be selected to give the greatest possible electromotive force since the electric voltage generated is extremely small, about 50 millivolts. These bimetals are usually made in thicknesses from 0.008 to 0.250 in. One maker produces the metals in grades up to 650 ohms per sq. mil ft. Thermoelectric metals in use are platinum, rhodium, iridium, nickel, iron, copper. Usually they are special alloys of these metals such as Chromel, Nichrome, and Alumel. A copper-constantan couple is used for temperatures up to 800°F., and iron-constantan or nickel-constantan up to 1650°F., a Chromel-Alumel up to 2200°F., and a platinum-platinum rhodium up to 2600°F.

Thermometals, used for indicating temperatures from about −40 to 1000°F., consists of two metals or alloys with different rates of thermal expansion bonded together so that with a change of temperature the bimetal bends or deflects. In heat-control or indicating devices the deflection is measured to indicate the temperature, or the deflection is utilized for mechanical or electrical action. A wide variety of metals is used for thermometals. The requirements are corrosion resistance, heat resistance, and uniform pull proportional to the temperature change. Thermometals welded at the contact surfaces are sold under trade names, such as Highflex of the H. A. Wilson Co.

**Thorium.** A rare metal which, in the form of Thorium nitrate, $Th(NO_3)_4$, is used for incandescent gas mantles, and in the form of other compounds is used in luminous paints and in flashlight powders. The metal is not used in a pure state owing to its high melting point and the ease with which it combines with oxygen, but it can be used with uranium for the production of plutonium. The impure metal is a gray powder with a specific gravity of 11.3. It burns easily in the air with great brilliance. The melting point is placed at 3090°F. The chief source of thorium nitrate is in the mineral monazite found in Brazil, India, East Africa, and to some extent in the United States. Ceylon monazite usually contains about 10% of thoria, or double that of Brazil. Monazite is a sand varying in color from yellow to dark brown. The thorium is separated from the cerium, yttrium, lanthanum, and other elements in the monazite by a complicated process. The incandescent mantle, invented by Welsbach in 1893, used a mixture containing 98 to 99% of thorium oxide and 1 to 2 cerium oxide. The thorium nitrate is converted to the oxide by ignition, with an increase of 10 times its volume. Thorium oxide, or Thoria, $ThO_2$, is produced from Monazite sand, the Brazilian beach sand containing up to 8% of thoria. It has a high melting point, 3000°C. and is used for crucibles, but its use as a refractory is limited because of its cost and its sensitiveness to sudden temperature changes. Small amounts of thorium in nickel-chromium heat-resisting alloys increase the life of the alloys. The rare mineral Thorite, found in Norway, is also a source of thorium. Thorite is a Thorium silicate,

$ThSiO_4$, sometimes also containing uranium. It occurs in crystals or massive, with a resinous luster and color orange, brown, or black. The specific gravity is 4.8 to 5.2, and hardness 5 Moh.

**Thuya.** The wood of the tree *Thuya plicata,* also known as Western red cedar, Giant arbor vitae, Shinglewood, and Pacific red cedar. The tree grows in cool, humid coast regions from Alaska to northern California, and the wood is widely used for shingles, poles, and tanks. It is light in weight, soft, and weak, with a straight coarse grain, but is durable. The sapwood is white and the heartwood reddish. The tree grows to great size, reaching to 200 ft. in height and 16 ft. in diameter at the age of 1,000 years. The stand is estimated at 53 billion bd. ft. Northern white cedar is the wood of the tree *T. occidentalis,* of Northeastern United States. It is also called White cedar, Arbor vitae, Swamp cedar, or simply Cedar. The wood is soft, knotty, brittle, weak, but very durable. It is used for shingles, poles, posts, and lumber for small boats. The sapwood is white and the heartwood light brown. The trees have a diameter of 1 to 3 ft., and a height of 25 to 75 ft. Thuya leaf oil, used as a fixative in perfumery, is a colorless oil with a bornyl acetate odor, distilled from the leaves.

**Tin.** A silvery-white lustrous metal with a bluish tinge. The chemical symbol is Sn. It has been employed from the earliest times. Tin is soft and very malleable. It is rolled into sheets of foil as thin as 0.0002 in. It melts at 232°C., and has a specific gravity of 7.298. It is dissolved by mineral acids. When rubbed it gives a peculiar odor; when bent it gives a peculiar cracking or crying sound. Tin pest is the breaking up of the metal into a gray powder. This action occurs below 18°C. Tin is used as a protective coating for other metals against corrosion, for tin foil, as a solder, and in bronze alloys and babbitts. Electroplated tin gives a fine white color which is corrosion-resistant. It also gives a lubricating effect on wearing surfaces, and is thus used for plating on airplane engine pistons and rings. The chief source of tin is cassiterite, but Nigerian columbite contains about 6% of tin oxide. The principal tin-producing countries are the East Indies, Malay Peninsula, and Bolivia. The Standard tin of the London Metal Exchange must contain over 99.75% of tin. Chempur tin

is 99.997% pure. Federal specifications for Pig tin call for two grades, 98 and 99.75%. Block tin is virgin tin cast in stone molds. Even small traces of impurities have an influence on tin. Lead softens the metal; arsenic and zinc harden it. An addition of 0.3% of nickel doubles the tensile strength of tin; 2% of copper increases the strength 150%. Pure tin melts sharply, but small amounts of impurities broaden the melting period. Tin powder, for use in making sintered alloys, is 99.8% pure, and is furnished in finenesses of 100, 200, and 300 mesh.

**Tin oxide.** Also called Stannic oxide. A fine white crystalline powder of the composition SnO, used as an opacifier in ceramic enamels, as a ceramic color, and also as an abrasive. It is made by oxidizing tin powder in a flame. The specific gravity is 6.9 and refractive index 2.04. When mixed and fired with magnesium and cobalt oxides, it gives a sky-blue color called Cerulean blue. It gives rose-red and reds with other materials. Tin oxide is permanent to light and is acid-resistant in ceramics.

**Tin plate.** Soft-steel plate containing a thin coating of pure tin on both sides. A large proportion of the tin plate used goes into the manufacture of food containers because of its resistance to the action of vegetable acids and its nonpoisonous character. It solders easily, and also is easier to work in dies than terne plate, so that it also is preferred over terne plate for making toys and other cheap articles in spite of a higher cost. Commercial tin plate comes in boxes of 112 sheets, 14 by 20 in., and is designated by the net weight per box when below 100 lb. Heavy tin plate above 100 lb. goes by number as with sheet steel, or by letter symbols. The weight of tin is usually 1.5 to 1.7% of the total weight of the plate. Coke plates carry as little tin as is necessary to protect and brighten the plates for temporary use. The tin of the coat forms compounds of $FeSn_2$, $Fe_2Sn$, and FeSn with the iron of the plate, and on a coke plate this compound is 0.00006 to 0.00015 in. thick. Best cokes carry more tin than do the standard cokes. Charcoal plates have heavier coats of tin designated by the letter A. The AAAAAA, or 6A, has the heaviest coating. Tin plate is made by the hot-dip process using palm oil as a flux, or by a continuous electroplating process. Taggers was originally

a name for tin plate that is undersized, or below the gage of the plate in the package, but the name Taggers tin is also applied to light-gage plate. These sizes are No. 38 gage, 55 lb.; No. 37, 60 lb.; and No. 36 gage, 65 lb. Ductilite, of the Wheeling Steel Corp., is a tin plate that is not made by hot rolling in packs, but is cold-rolled from single hot-rolled strip steel. It is of uniform gage and does not have the thin edges of pack-rolled plate. It also has a uniform grain structure. Weirite, of the Weirton Steel Co., is cold-reduced coke tin plate. Electrotinning gives coatings of any desired thickness, and an electrolytic tin plate may have a usable coat as thin as 0.00003 in. or about one-third that of the thinnest possible dipped plate. Cold-rolling electrolytic tin plate after plating between high-pressure rolls that only slightly elongate the plate gives a bright and smooth finish. Black plate, used for cans in place of tin plate where the tin protection is not necessary, is not black, but is any sheet steel other than tin plate or terne plate in tin-plate sizes. It may be chemically treated to resist rust or corrosion.

Titanium. A metallic element, symbol Ti, occurring in a great variety of minerals. It was first discovered as an element in 1791 in a black magnetic sand at Menachin, Cornwall, England, and called Menachite, from the name of the sand, Menachanite. Its chief commercial ores are rutile and ilmenite. In rutile it occurs as an oxide. It is an abundant element, but is often considered as a rare metal, owing to the difficulty of separating it. It has a strong affinity for oxygen, hydrogen, and carbon. The pure metal has a silvery-white color and is extremely hard, cutting glass with ease. It can be forged when red hot, but when heated to 600°C. in oxygen it burns to titanic oxide. At about 800°C. it burns in nitrogen. Its melting point is very high, 3272°F., but it dissolves easily in molten copper. The specific gravity is 4.5. The ore is reduced by calcium shavings or calcium hydride to produce metallic titanium in powder form, which is sintered and rolled into sheets. The pure metal, free from oxides, is ductile, but the metal normally contains oxides and is brittle. Metallic titanium, 98% pure, is marketed in lump or in small cakes for alloying. It is also used in the form of ferrotitanium for deoxidizing and denitro-

genizing steel. It is a more powerful deoxidizer than silicon or manganese, but not as strong as aluminum. An alloy used in Germany under the name of Badin metal for deoxidizing steel contained 8 to 10% of aluminum, 18 to 20 silicon, 4 to 6 titanium, and the balance iron.

Titanium is used in alloy steels to increase the tensile strength, toughness, and hardness. It is a hard carbide-forming element. In chromium nickel steels it minimizes intergranular corrosion. It may also be used instead of vanadium in high-speed steels. One of the earliest titanium steels was the French Titanor metal used for tools. The metal is also used in some heat-resistant steels to prevent the combination of molybdenum with the carbon. When added to cast iron in quantities greater than 1%, it toughens the iron remarkably, but is expensive for use in iron alloys. Small quantities of titanium in cast iron close the grain and act as a graphitizer. Titanium is alloyed with copper in strong bronzes. Its salts are used in arc-lamp electrodes, as mordants in dyeing, for yellow coloring of ceramics, and for pigments. It is also used as a gas getter in radio tubes, and as a corrosion inhibitor in mercury boilers. Titanium carbide is used for mixing with tungsten carbide in sintered carbide cutting alloys. It is nearly as hard as the diamond, is lighter and less costly than tungsten carbide.

**Titanium ores.** The most common titanium ores are ilmenite and rutile. Ilmenite is an iron-black mineral having a specific gravity of about 4.5, and containing about 52% of Titanic oxide, $TiO_2$. The ore of India is sold on the basis of 58 to 60% titanium dioxide. A white pigment is made from ilmenite by removing the iron oxide. Ilmenite has the composition $FeO \cdot TiO_2$, but much of the material called ilmenite is Arizonite, $Fe_2O_3 \cdot 3TiO_2$, or mixtures, or both mixed with magnetite. The ilmenite for white pigment comes chiefly from the sea beaches of southwestern India and from northern New York, but some is obtained from the sands of Albemarle Sound, North Carolina. The mineral is also employed for making ferrotitanium used for adding titanium to steel. Titanium copper, used for deoxidizing nonferrous metals, is made directly from titanium metal by adding the metal to molten copper. It cannot be poured, but the congealed alloy is broken

into lumps. Rutile is a titanium dioxide, $TiO_2$, containing theoretically 60% of titanium. Its usual occurrence is crystalline or compact massive, with a specific gravity of 4.18 and 4.25 and a hardness of 6 to 6.5. The color is red to black. Rutile is found in granite, gneiss, limestone, or dolomite. It is obtained from beach sand of northern Florida, and Espirito Santo, Brazil, and is also produced in Nelson County, Virginia, and in Australia and India. Rutile and also Brookite containing titanium oxide are produced in Arkansas. The best Virginia concentrates are 92.5 to 98% of $TiO_2$, but some are 42% from rock originally showing 18.5% of $TiO_2$ in a body of feldspar. Rutile is marketed in the form of concentrates on the basis of 79 to 98.5% of titanium oxide. It is used extensively in the ceramic industry as a coloring agent for enamels and glazes. It is also employed for welding rod coatings. On welding rods it aids stabilization of the arc and frees the metal of slag.

**Titanium oxide.** The white Titanium dioxide of the composition $TiO_2$, which is an important paint pigment. It is produced from ilmenite, and is higher in price than many white pigments but has great hiding power and durability. It is also substituted for zinc oxide and lithopone in the manufacture of white rubber goods, and for paper filler. The specific gravity is about 4. Mixed with blanc fixe it is also marketed under the name of Titanox. Zopaque, of the Chemical & Pigment Co., is a pure titanium oxide for rubber compounding. Titanox L, of the Titanium Pigment Corp., is a Lead titanate, $PbTiO_3$, used as a less costly substitute for titanium oxide. It is yellowish in color and has only 60% of the hiding power, but is very durable and is rust-resistant for steel. The Ti-Pure of E. I. duPont de Nemours & Co., Inc., is commercially pure titanium dioxide for pigment use. Duolith, of this company, is titanated lithopone pigment containing 15% of titanium dioxide, 25 zinc sulphide, and 60 barium sulphate.

**Tolu balsam.** A yellowish-brown semisolid gum with a pleasant aromatic odor and taste, obtained from the tree *Myroxylon balsamum,* or *Toluifera balsamum,* of Venezuela, Colombia, and Peru. It is used in medicine, chiefly in cough sirups, and also as a fixative in perfumes. Balsam of Peru, or Black balsam, is a

reddish-brown viscous aromatic liquid from bark of the tall tree *M. pereirae* of El Salvador. It is used in cough medicines and skin ointments, as an extender for vanilla, and as a fixative in perfumes. Some white-colored balsam is also obtained from the fruit of the tree. Peru balsam contains benzyl benzoate, benzyl cinnamate, and some vanillin.

**Toluol.** Also called Toluene and Methyl benzene. A liquid of the composition $C_6H_5CH_3$, resembling benzene but with a distinctive odor. It is obtained as a by-product from coke ovens and from coal tar. It occurs also in petroleum, with from 0.20 to 0.70% in Texas crude oil, which is not sufficient to extract. But toluol is produced from petroleum by dehydrogenation of the Methyl cyclohexane, $C_6H_{11}CH_3$, with heat and a catalyzer to yield toluol and free hydrogen. Industrially pure toluol from coal tar distills off between 108.6 and 112.6°C., and is a water-white liquid with specific gravity of 0.864 to 0.874, flash point 35 to 40°F., and freezing point about −95°C. The fumes are poisonous. Toluol is used as a solvent, and is also employed for making dyestuffs, explosives, and many chemical compounds. T oil is a sulphur toluene condensation product made under a British patent and used as a plasticizer for chlorinated rubber. Notol No. 1, of the Neville Co., is a coal-tar hydrocarbon high in aromatics used as a substitute for toluol as a lacquer solvent. The specific gravity is 0.825, and a boiling point between 177 and 280°F. Tollac, of the same company, is another hydrocarbon substitute for toluol.

**Tomato seed oil.** A food oil from the seeds of the Tomato, *Lycopersicon esculentum,* the seeds being by-products of the manufacture of the tomato-canning industry. The tomato plant is a perennial herb native to Central and South America, and was grown by the Aztecs under the name of Tomatl. There are many varieties, and the fruits are true berries. The common red varieties are 2 to 3 in. in diameter and contain a large number of seeds in the pulp. The seeds yield 17% of oil by cold pressing, or 33% with ether extraction. The cold-pressed oil with a single filtering is a clear liquid of 0.9206 specific gravity, with an agreeable odor and bland taste. It is used in salad oils and margarine, as a semi-

drying oil in paints, and in soaps. The iodine number is 113, and saponification value 192.

**Tonka bean.** Called in northeastern Brazil Cumarú bean. The kernel of the pit of the fruit of the Sarrapia tree, *Dipteryx odorata* or *Coumarouna odorata,* of northern South America, used for the production of Coumarin for flavoring and scenting. It has an aroma resembling vanilla. The trees often reach a height of 100 ft., and begin to bear in 3 years. The fruit is like a mahogany-colored plum, but with a fibrous pulp. The pits, or nuts, contain a single shiny black seed 1 in. or longer. The chief production is in Venezuela, Brazil, Colombia, Trinidad, and the Guianas. The tonka bean from the tree *D. oleifera* of Central America has an unpleasant odor. Before shipping, the beans are soaked in rum or alcohol to crystallize the coumarin. The ground beans are again soaked in rum, and the aromatic liquid is used to spray on cigarette tobacco. The coumarin extract is also used as a perfume or flavor in soaps, liqueurs, and confectionery. The essential oil produced from the seed is called Cumaru oil. A substitute for tonka bean is Deer's-tongue leaf, which is the long leaves of the herb *Trilisa* odoratissima growing wild on the edges of swamps from Carolina to Florida. The leaf has a strong odor of coumarin when dry, and contains coumarin. It is used in cigarette manufacture, in flavoring, and to produce synthetic vanilla.

**Tool steel.** A high-carbon steel used for making tools. It has the property of becoming extremely hard by quenching from a temperature of 1400 to 1800°F. It can then be drawn to any degree of hardness by heating at lower temperatures. The original tool steels were accidental combinations produced by uniform expert processes rather than by alloying. One of the earliest recorded tool steels was the ancient Chalybeate steel, originally referring to steel from the Chalybes in Pontus. The unqualified term tool steel does not usually include special alloy steels containing nickel, manganese, and other metals, nor high-speed steels. However, tool steels for special purposes may contain many other elements besides carbon. The possibilities of percentage combinations of vanadium, nickel, manganese, chromium, silicon, tungsten, and other elements in alloy tool steels are infinite; and as there are

hundreds of trade-named steels on the market, the name Carbon tool steel is used to designate tool steel containing only carbon, and with other elements below perceptible amounts.

Tool steel may contain from 0.65 to 1.50% of carbon, the lower-carbon grades, up to 0.90 carbon, being used for punches, hammers, chisels, and other tools requiring some degree of elasticity, and the high-carbon grades are used for dies, drills, and edge tools. Files, saws, and engraving tools may contain up to 1.60% of carbon. The manganese content is 0.20 to 0.30. Razor steel was steel with 1.5% carbon, but razors are now usually made of alloy steels. Beyond 1% of carbon, there is an excess of carbon and the steels become very brittle when hardened. Theoretically, the maximum point of solution of the $Fe_3C$ in a plain carbon steel is at 0.85% of carbon. When other elements are present, other carbides are formed giving greater hardness and strength above this point. The ideal maximums of phosphorus and sulphur in a tool steel are 0.025%, with silicon at 0.20 and manganese at 0.25, but in special steels the silicon and manganese are increased. Some water-hardening carbon tool steels have higher content of silicon to give wear resistance for dies, liners, and bushings. The silicon also adds fatigue resistance. Graph-Sil steel, of the Timken Steel & Tube Co., has 1.5% of carbon, 0.85 to 0.95 silicon, and 0.40 max. manganese.

The lower temperature ranges are used for hardening high-carbon steels and thin pieces. Some steelmakers grade carbon steels by divisions as low as 5 points of carbon. Pompton tool steel, of the Allegheny Ludlum Steel Co., has 19 grades from 0.50 to 1.45% of carbon. Modern carbon tool steels for ordinary water hardening, with or without residual vanadium, develop remarkable physical properties. Ryerson VD die steel, as quenched, has a hardness of 725 Brinell, or 96 Scleroscope.

Oil-hardening tool steels usually contain about 1% of manganese, but mild-alloy tool steels may contain less, with other elements. CM and CMM tap steels, of the Colonial Steel Co., are oil-hardening, keen-edge steels; CM contains 0.50% of chromium, 0.60 manganese, and 1.20 carbon; CMM contains 0.50% of chromium, 0.85 manganese, 0.60 molybdenum, and 1.20 carbon. These

steels have high torsional strength. Small amounts of molybdenum with higher silicon give oil-hardening steels that are wear resistant and quite nondeforming. Graph-Mo, of the Timken Steel & Tube Co., used for gages and dies, has 1.5% of carbon, 0.25 to 0.30 molybdenum, 0.75 to 0.85 silicon, and 0.40 max. manganese.

Tool steel comes regularly in round, square, and octagon bars, and in flats, but drawn shapes are also available. Tool steels require more care in forging than low-carbon machinery steels and they are more difficult to machine. The quality of the steel is dependent upon the method of melting, rolling, and forging as well as upon the composition. The smallest possible grain size, and freedom from nonmetallic inclusions, are the qualities sought. A.S.V. steel, of the Firth-Sterling Steel Co., is made by a patented winged ingot form of casting in order to eliminate any porosity in the center. Carbon-vanadium tool steels are produced in all carbon contents with about 0.20% of vanadium. They have a uniform fine grain, and constitute a class of "super" carbon tool steels. Some steels for special purposes contain more vanadium. Colhead steel, of the Vanadium Alloys Steel Co., for cold-heading dies, has 0.45% of vanadium and 1 carbon. Vatool, of the Henry Disston & Sons, Inc., is a vanadium tool steel for taps.

**Toon.** The wood of the tree *Cedrela toona* of India, Burma, Java, and Australia. It is called Moulmein cedar in England and is also known as Indian mahogany. The wood is almost indistinguishable from the Spanish cedar of tropical America. If seasoned well, the wood does not warp and is durable. It is easily worked and takes a fine polish. The weight is about 35 lb. per cu. ft. The color is a deep red, and the grain has a beautiful appearance. It is used for boxes, furniture, and construction.

**Tracing cloth.** A thin, fine cotton or linen fabric, of plain weave, heavily sized and glazed on one side. It is used for making tracings in ink and is quite transparent. It can also be obtained with the glaze on both sides. Tracing cloth is usually marketed in rolls of 24 yd. The sizing of ordinary tracing cloth is easily soluble in water, and will therefore not withstand wetting, but special grades are made with impervious resin coatings.

**Tragacanth gum.** An exudation of the shrub *Astragalus gummifer* of Asia Minor and Persia, used in adhesives or for mucilage, for leather dressing, for textile printing, and as an emulsifying agent. To obtain the gum a small incision is made at the base of the shrub, from which the juice exudes and solidifies into an alteration product, not merely the dried juice. The gum derived from the first day's incision, known as Fiori, is the best quality, and is in clear fine ribbons or white flakes. The second incision produces a yellow gum known as Biondo. The third incision produces the poorest quality, a dark gum known as Sari. Rainy weather during the incision period may cause a still inferior product. Tragacanth is insoluble in alcohol but is soluble in alkalies and swells in water. The Indian gum from India and southern Asia is from various species of *Astragalus*. It is also known as Indian hog gum, or Hog tragacanth, and as Karaya gum. It is marketed as a white odorless powder or in flakes, and there are about a dozen grades shipped from India varying chiefly in color and acidity. In general, the gum is more acid than the tragacanth from the Near East and is not as soluble in water. It is used in textile finishing, in inks, adhesives, for thickening rubber latex, and in foods and cosmetics as a thickening agent.

**Trichlorethylene.** A heavy colorless liquid of pleasant odor of the composition $CHCl:CCl_2$, also known as Westrosol. Its boiling point is 87°C. and specific gravity 1.471. It is insoluble in water and is unattacked by dilute acids and alkalies. It is not inflammable and is less toxic than tetrachlorethane. Trichlorethylene is a powerful solvent for fats, waxes, resins, rubber, and other organic substances, and is employed for the extraction of oils and fats, for cleaning fabrics, and for degreasing metals preparatory to plating. The freezing point is −88°C., and it is also used as a refrigerant. It is also used in soaps employed in the textile industry for degreasing. Tri-Clene is a trade name of E. I. duPont de Nemours & Co., Inc., for trichlorethylene, marketed for dry cleaning. Triad and Perm-A-Clor are trade names of the Detroit Rex Products Co. for trichlorethylene stabilized with a basic organic stabilizer that prevents breakdown of the solvent in degreasing metals.

**Tripoli.** A name given to finely granulated, white, porous, siliceous rock, used as an abrasive and as a filler. True tripoli is an infusorial diatomaceous earth known as Tripolite, and is a variety of opal, or Opaline silica. In the abrasive industry it is called Soft silica. It is quarried in Missouri, Illinois, eastern Tennessee, and Georgia. Pennsylvania rottenstone is not tripoli, although it is often classed with it. The material marketed for oil-well drilling mud by the Corona Products, Inc., under the name of Opalite, is an amorphous silica. The Missouri tripoli ranges in color from white to reddish, and the crude rock has a porosity of 45%, and contains 30% or more of moisture. It is air-dried and then crushed and furnace-dried. Tripoli is used in massive form for the manufacture of filter stones for filtering small supplies of water. Missouri tripoli is also used for the manufacture of foundry parting. Tripoli finely ground, free from iron oxide, is used as a paint filler and in rubber. The grade of tripoli known as O. G. (once ground) is used for buffing composition, D. G. (double ground) for foundry partings, and the air-float product for metal polishes. Tripoli grains are soft, porous, and free from sharp cutting faces, and thus give a fine polishing effect. It is the most commonly used polishing agent. The word Silex, which is an old name for silica, and is also used to designate the pulverized flint from Belgium, is sometimes applied to finely ground white tripoli employed as an inert filler for paints. Much Illinois fine-grained tripoli is used for paint filler, and for this purpose should be free from iron oxide.

**Trisodium phosphate.** A white crystalline substance of the composition $Na_3PO_4 \cdot 12H_2O$, also known as Phosphate cleaner, used in soaps, cleaning compounds, plating, textile processing, and in boiler compounds. The commercial grade is not less than 97% pure, with total alkalinity of 16 to 19% calculated as $Na_2O$. The anhydrous trisodium phosphate is 2.3 times as effective as the crystalline form, but requires a longer time to dissolve. Disodium phosphate is a white crystalline product of the composition $Na_2HPO_4 \cdot 12H_2O$ used for weighting silk, boiler treatment, cheese making, and in cattle feeds. The medicinal, or U.S.P. grade, has only 7 molecules of water and has a different crystal structure.

The commercial grade is 99.4% pure, and is readily soluble in water. Sodium tetraphosphate, $Na_6P_4O_{13}$, contains 39.6% of $Na_2O$ and 60.4 of $P_2O_5$. It is the sodium salt of Tetraphosphoric acid, and is marketed in beads that are mildly alkaline and highly soluble in water. The specific gravity is 2.55, and melting point 600°C. It is used in the textile industry as a water softener and to accelerate cleansing operations. It removes lime precipitation and sludge and saves soap. Sodium pyrophosphate, $Na_4P_2O_7$, is added to soap powders to increase the detergent effect and the lathering. It is also used in oil-drilling mud to control the viscosity. The crystalline form, $Na_4P_2O_7 \cdot 10H_2O$, is very soluble in water and is noncaking, and is used in household cleaning compounds. Quadrafos, of the American Cyanamid Co., used for reducing the viscosity of oil-well drilling mud, is sodium tetraphosphate.

**Tulipwood.** Also called Yellow poplar, Whitewood, and Canary whitewood. The wood of the tree *Liriodendron tulipifera* of Canada and the Eastern United States. The tree grows to a height of 250 ft. and to diameters of more than 10 ft. It is used for furniture, veneer, millwork, toys, woodenware, boxes, crates, and pulpwood. Owing to its close texture and even coefficient of expansion it has been used for expansion blocks in humidity regulators. The wood is yellowish, soft, and durable. It weighs about 30 lb. per cu. ft. The lumber may be mixed with Cucumber magnolia, *Magnolia acuminata,* and Evergreen magnolia, *M. Grandifolia,* but Magnolia woods are lighter in color.

**Tung oil.** A drying oil which has almost double the rapidity of linseed oil. It is used for enamels and varnishes, in brake linings, plastic compounds, and linoleum, and for making pigment for India ink. Tung oil is pressed from the seeds of the *Aleurites montana,* and *A. fordii.* The names Wood oil or China wood oil are loosely and erroneously used to designate tung oils, but true wood oil is an oleoresin from the Keruing tree of Malaya used for waterproofing and calking boats, while tung oil is never from the wood. The oil has a powerful purgative action, and the Chinese word tung means stomach. The Chinese tung oil is from the nuts of the tree *A. montana,* the China wood oil tree, and from the

*A. fordii.* The latter tree is more hardy than the *A. montana* which requires a hot climate. The American tung oil is from the nuts of the tree *A. fordii* of the Gulf states which gives an annual production of about 30 lb. of oil per tree. The tree grows to a height of 25 ft., and bears for 5 years. The seeds, or nuts, contain 50 to 55% of oil. The color varies from golden yellow to dark brown according to the degree of heat used in extraction. It has a pungent odor resembling that of bacon fat. A good grade of raw tung oil should have a specific gravity between 0.943 and 0.940, a saponification value of 190, and an iodine value of 163. The oil contains about 72% of Eleostearic acid, which has a very high iodine value, 274, and gives to the oil a greater drying power than is indicated by the iodine value of the oil itself. The oil has the property of drying throughout at a uniform rate instead of forming a skin as does linseed oil, but it dries flat instead of glossy like linseed oil and is inclined to produce a wrinkled surface. It is mixed with rosin since rosin has great affinity for it, and the two together are suitable for gloss varnishes. The oil from *A. montana,* or Mu oil, has a higher percentage of eleostearic acid than that from *A. fordii.* The Japanese wood oil is from the nuts of the larger tree *A. cordata.* The oil is superior to Chinese tung oil and is seldom exported. It does not gelatinize like Chinese tung oil when heated. It is used in Japan for varnishes, for waterproofing paper, and for soaps. The saponification value is 193 to 195, iodine No. 149 to 159, and specific gravity 0.934 to 0.940. The kernels of the nuts yield about 40% of oil. The tree is grown also in Brazil and thrives in hot climates. Candlenut oil is from the seed nuts of the *A. moluccana* of Oceania and Southern Asia. It received its name from the fact that the Polynesians used the nuts as candles to light their houses. The oil is variously known as Kukui, Kekune, and Lumbang, and as an artist's paint oil is called Walnut oil or Artist's oil. The nut resembles the walnut but has a thicker shell. The oil has a specific gravity of 0.923, iodine value 165, and is between linseed and soybean oil in properties. It is high in linoleic and linolenic acids. The variety known as soft lumbang oil, or Bagilumbang oil, from the tree *A. trisperma* of the Philippines, resembles tung oil and is high in eleostearic acid.

**Tungsten.** An elementary metal, symbol W, never found free in nature. Its commercial ores are wolframite, ferberite, scheelite, and Hübnerite. The important sources of tungsten ores are India, Argentina, China, Australia, Europe, and the United States, half of the world's production coming from China, but the ores are very widely distributed in small quantities. The metal was produced first in metallic form in 1783, but was not used alone until developed as a filament for incandescent lamps in 1904. For this purpose the filaments were made from Tungsten paste, or Colloidal tungsten. The paste was made by treating tungsten oxide with ammonia, and boiling in water. Tungsten is a heavy white metal with specific gravity of 19.6 and melting point 6100°F. The Brinell hardness is 290. It is obtained in powder form by reduction of the oxide $WO_3$ in a stream of hydrogen. The powder is pressed into rods, which are worked until ductile. In ordinary tungsten metal the grains are large, not over 1,500 per sq. mm., but for special purposes, such as for electric contacts, tungsten is produced with as high as 80,000 per sq. mm. The tensile strength of rolled sheets is as high as 500,000 lb. per sq. in. Wire drawn to a diameter of 0.0014 in. has a strength of 590,000 lb. per sq. in., the greatest tensile strength of all the metals. Sheets are available in thicknesses from 0.001 to 0.062 in. and the rod in diameters from 0.040 to 0.375 in. It is not attacked by nitric, hydrofluoric, or sulphuric acid solutions. Tungsten wire, 99.9% pure, is used for filaments and contact points, but the chief use of tungsten is in high-speed steels and special-alloy steels. Tungsten is usually added to iron alloys in the form of ferrotungsten, but also in the form of Tungsten powder, which is the commercially pure metal in powder form of 200 to 325 mesh, melting at about 6000°F., and being 95 to 98% pure tungsten. Tungsten salts are used for bronze powders, and also as mordants in dyeing. Ferrotungsten, used for adding tungsten to iron and steel, is one of the oldest of the ferro alloys. It is made in the electric furnace by reduction of the oxide with iron, or by reducing tungsten ores with carbon and silicon. The standard grade contains 75 to 85% tungsten and has a melting point of 3200 to 3450°F. The minimum melting point of the iron-tungsten series is 2770°F., and because of the

high melting point the alloy is not tapped, but the solid mass is taken from the cold furnace and broken into lumps.

**Tungsten carbide.** An iron-gray powder of minute cubical crystals, having the composition WC. The specific gravity is about 16 and the hardness is 9.8 to 9.9, or nearly that of the diamond. The melting point is about 5400°F., but if strongly heated it may decompose into $W_2C$ and carbon, and the commercial carbide may be a mixture of WC and $W_2C$, with a hardness of about 9.5. Tungsten carbide is produced by carbonizing incandescent tungsten in a methane or hydrocarbon vapor, and other forms may be produced, $W_2C$, $W_3C$, and $W_3C_4$. Another method of production is by heating tungsten powder and carbon in a furnace. Tungsten carbide is used as an abrasive, or is briquetted with cobalt or nickel binders into tools for the high-speed cutting of metal or for cutting hard materials.

The briquetted and sintered product is harder than any commercial steel and will scratch sapphire. Briquetting of tungsten carbide into usable form was first patented in Germany and produced by the Krupp Works under the name of Widia metal. It is made by diffusing powdered cobalt through the finely divided carbide under hydraulic pressure, and then sintering in an inert atmosphere at about 1500°C. The briquetted material is then ground to shape, and the pieces are brazed to tools. They will withstand cutting speeds from three to ten times those of high-speed steel, and will turn manganese steel with a hardness of 550 Brinell, but will not withstand shocks. However, they are used to replace diamonds in oil-well boring tools. Tungsten carbide sintered materials are sold under many trade names such as Camite, of the Cleveland Automatic Machine Co.; Dimondite, of the Firth-Sterling Steel Co.; Armide, of the Armstrong Bros. Tool Co.; Strauss metal, of the Allegheny Ludlum Steel Co. Perdurum and Hartmetall are European tungsten carbides. Haystellite tungsten carbide, of the Haynes Stellite Co., is in the form of welding rods, cast inserts, and crushed particles.

Wilcoloy is a tungsten-carbide material of the H. A. Wilson Co. used for telegraph relay contact points. Talide, of the Metal Carbides Corp., is a tungsten-carbide wear-resistant metal used

for bushings, lathe centers, and gage surfaces. Borium, of the Stoody Co., is used for facing oil-well drills. Borod, of the same company, is the material encased in a metallic tube used as a welding rod for facing wearing parts. Firthite, of the Firth-Sterling Steel Co., is a mixture of tungsten and other carbides for cutting tools. Firthaloy is a special grade for wire-drawing dies. The Firthite carbides contain from 3 to 20% of cobalt binder. The low cobalt is used for the hardest cutting tools, and the high cobalt for tough tools resistant to shock. Carboloy, of the Carboloy Co., Inc., is a material for cutting tools, drawing dies, and facing blocks, made in several grades of tungsten carbide, tantalum carbide, titanium carbide, or combinations. It has a compressive strength of 700,000 lb. per sq. in. and transverse rupture stength up to 295,000 lb. per sq. in. Kennametal, of the McKenna Metals Co., is Tungsten-titanium carbide, $WTiC_2$, compressed with a binder metal and sintered. It is harder than tungsten carbide. Small amounts of titanium carbide are also added to tungsten carbide to give greater cutting efficiency in the tool material. Cutanit, of the Firth-Sterling Steel Co., is a mixed material of this kind.

**Tungsten steel.** Any steel containing tungsten as the alloying element imparting the chief characteristics to the steel. It is one of the oldest of the alloying elements in steel, the celebrated ancient Eastern sword steels having had tungsten in them. Tungsten increases the hardness of steel, gives it the property of red hardness, stabilizing the hard carbides at high temperatures. It also widens the hardening range of steel, and gives deep hardening. Very small quantities serve to produce a fine grain and raise the yield point. The tungsten forms a very hard carbide and an iron tungstite, and the strength of the steel is also increased, but it is brittle when the tungsten content is high. When large percentages of tungsten are used in steel, they must be supplemented by other carbide-forming elements. Tungsten steels, except the low-tungsten chromium-tungsten steels, are not suitable for construction, but tungsten steels are widely used for cutting tools as the tungsten forms hard abrasion-resistant particles in high-carbon steels. Tungsten also increases the acid resistance and

corrosion resistance of steels. The alloys are difficult to forge, and cannot be readily welded when the tungsten exceeds 2%. Standard S.A.E. tungsten steels, S.A.E. 71360, and S.A.E. 71660, contain 12 to 15 and 15 to 18% of tungsten, respectively, with 3 to 4 chromium and 0.50 to 0.70 carbon. S.A.E. 7260 contains 1.5 to 2% of tungsten and 0.50 to 1 chromium.

When the tungsten content is high, particularly when the steel contains manganese also, the steel can be hardened by air cooling. These alloy steels have a close, uniform texture, and tools made from them will keep an edge when hot; for cutting tools tungsten steels with other alloying elements are used. In annealing tungsten steels the hard stable carbide WC may be formed; to prevent this, chromium is used as an inhibitor. A low tungsten steel for taps and cutters contains 1.5 to 2% of tungsten, 1 to 1.3 carbon, with a small amount of chromium and vanadium. Maxtack steel, of A. Milne & Co., for tack and nail dies, has 10% of tungsten, 2 chromium, 2.5 manganese, 1 silicon, and 2.25 carbon. It is self-hardening. Steels with 2 to 3% tungsten have high wear resistance and impact resistance. They are used for cold-drawing dies, air hammers and general tools. Graph-Tung, of the Timken Steel & Tube Co., has 2.6 to 3% of tungsten, 0.50 molybdenum, 0.70 silicon, and 1.5 carbon. O. K. steel of William Jessop & Sons, used for chisels and punches, has 2% of tungsten with only 0.40 carbon. It is hard but very shock resisting. A Firth-Sterling Steel Co. chisel steel, sold under the name of J-S steel, has 2.25% of tungsten, 1.4 chromium, 0.50 carbon, and a trace of vanadium. It is also used for cutters, punches, and shear blades for hot and cold work. It will retain a good cutting edge. Buster steel, of the Columbia Steel Co., is a similar steel, but has less chromium with more vanadium. Wizard steel, of the Ziv Steel and Wire Co., used for pneumatic tools, riveter dies, and swaging dies, has 1% of tungsten, 1 chromium, 0.35 carbon, and a small amount of molybdenum. At a hardness of 55 Rockwell it has great toughness and resistance to shock. A wear-resistant tool steel for finishing tools and gages, but not in the class of die steels, contains about 1.6% of tungsten, 0.42 chromium, 0.20 vanadium, and varying amounts of carbon up to 1.25%. Chimo steel, of the Firth-Sterling Steel Co., used for pneumatic chisels, is an air-hardening, fatigue-resistant steel.

Steels with from 4 to 6% of tungsten, 2 to 6 chromium, 0.40 to 1.80 manganese, and 0.40 carbon are used for dies for die casting, and give long life in contact with the molten casting metals. Steels with as high as 10% of tungsten and 3.5 chromium are used for die blocks for hot forging. High-carbon tungsten steels retain a high magnetism and give great coercive force, and are used for magnets.

**Turpentine.** Also called in the paint industry Oil of turpentine. An oil obtained by steam distillation of the oleoresin which exudes when various conifer trees are cut. Longleaf pine and slash pine are the main sources. It also includes oils obtained by distillation and solvent extraction from stumpwood and waste wood. Longleaf sapwood contains about 2% of oleoresin, heartwood 7 to 10%, and stumpwood 25%. Most oleoresin is obtained from the sapwood of living trees, but it is not the sap of the tree. Heartwood resin is obtained only when the cut wood is treated with solvents. The oleoresin yields about 20% of oil of turpentine and 80 of rosin; both together are known as Naval stores.

Wood turpentine, called in the paint industry Spirits of turpentine, is obtained from waste wood, chips, or sawdust by steam extraction or by destructive distillation. Wood turpentine forms more than 10% of all American commercial turpentines. A percentage of pine oil and rosin is also obtained in the process. Wood turpentine has a peculiar characteristic sawmill odor, and the residue of distillation has a camphorlike odor different from gum turpentine. It differs very little in composition, however, from the true turpentine. Some wood turpentine is also produced as a by-product in the manufacture of cellulose. Sulphite turpentine is a black oil obtained as a by-product in the making of sulphite wood pulp from spruce. It collects on the surface of the liquor in the sulphur dioxide separator. It is purified with soda, and is used only for making toluol and thymol.

Turpentine varies in composition according to the species of pine from which it is obtained. It is produced chiefly in the United States, France, and Spain. The turpentine of India comes from the Chir pine, *Pinus longifolia,* of the southern slopes of the Himalayas, also valued for lumber, and the Khasia pine, *P. khasya.*

The gum of the chir pine is different from American gum, and the turpentine, unless carefully distilled, is slower drying and greasy. French and Spanish turpentine, or Bordeaux turpentine, is from the Maritime pine, *P. pinaster,* which is the chief source, and from Aleppo pine, *P. halepensis,* and Corsican pine, *P. laricia.* In Portugal, the Stone pine, *P. pinea,* is the source. Venetian turpentine, or Venice turpentine, is from the Corsican pine or European larch. It produces a harder film than American turpentine. The pinene in European turpentine is laevo-rotary while that in the American turpentine is dextro. Artificial Venice turpentine is made by mixing rosin with turpentine. The French maritime pine is also grown on plantations in Australia. Aleppo pine of Greece was the source of the naval stores of the ancients. European pines do not give as high a yield as American longleaf and slash pines. American turpentine oil boils at 154°C., and the specific gravity is 0.860. It is a valuable drying oil for paints and varnishes, owing to its property of rapid absorption of oxygen from the atmosphere and transferring it to the linseed or other drying oil, leaving a tough and durable film of paint. Turpentine is also used in the manufacture of artificial camphor and rubber, and in linoleum, soap, and ink. It is often adulterated with other oils of the pine or with petroleum products, and the various states have laws regulating its adulteration for paint use. Gum thus, used in artists' oil paints, is thickened turpentine, although Gum thus was originally made from the gum resin of the tree *Boswellia carterii* of the Sudan and Somaliland, known in medicine as Olibanum; when used in incense and perfumes, it is known as Frankincense. This gum resin comes in hard yellow grains. Kiou-nouk, used as a fixative in perfumes, is a clear yellowish semiliquid obtained from olibanum resin. Piccolyte resin is a terpene thermoplastic nonyellowing varnish resin of the Pennsylvania Industrial Chemical Corp. made from turpentine. The grades have melting points from 10 to 125°C.

**Type metal.** Any metal used for making printing type, but the name generally refers to lead-antimony-tin alloys. The antimony has the property of expanding on cooling, and thus fills the mold and produces sharp, accurate type. The properties required in a type metal are ability to make sharp, uniform castings, strength

and hardness, fairly low melting point, narrow freezing range to facilitate rapid manufacture in type-making machines, and resistance to drossing. A common type metal is composed of 9 parts of lead to 1 of antimony, but many varieties of other mixtures are also used. The antimony content may be as high as 30%, 15 to 20% being frequent. A common monotype metal has 72% of lead, 18 antimony, and 10 tin. Larger and softer types are made of other alloys, sometimes containing bismuth; the hardest small type contains 3 parts of lead to 1 of antimony. A low-melting-point, soft-type metal contains 22% of bismuth, 50 lead, and 28 antimony. It will melt at about 310°F. Copper, up to 2%, is sometimes added to type metal to increase the hardness, but is not ordinarily used in metals employed in rapid-acting type machines. Since zinc causes drossing, it is avoided in all type metals. German and English practice employs fairly large amounts of bismuth. Standard linotype-machine metal for pressure casting has 79% of lead, 16 antimony, and 5 tin. Monotype metal has 10 to 13% of antimony and 2 to 5 tin. Stereotype metal, for sharp casting and hard wearing qualities, is given as 83.75% lead, 11.75 antimony, 4 tin, and 0.50 copper. Intertype metal has 11 to 14% of antimony and 3 to 5 tin. The Brinell hardness of machine-molded type ranges from 17 to 23, and that of stereotype metal is up to 30. As constant remelting causes the separation of the tin and lead, and also the loss of tin, or impoverishment of the metal, new metal must be constantly added to prevent deterioration of a standard metal into an inferior alloy.

**Ultramarine.** An important blue pigment, used in printing and paints. It is also used as a blue for whitening the yellow of paper, starch, sugar, and fabrics. Ultramarine was formerly obtained by grinding lapis lazuli, but is now made by calcining a mixture of aluminum silicate and sodium sulphide. Ultramarine blue is ground and is sold as a deep-blue crystalline powder of 325 mesh, insoluble in water. It may also come mixed with oil, and such a paste should contain 70% of pigment and 30 of linseed oil. It is a double silicate of sodium and aluminum, $Na_2Al_2SiO_8 \cdot Na_2S$. Green ultramarine is obtained as an intermediate product. White, red, yellow, and violet ultramarines are obtained by various methods. Cheaper grades of

ultramarine are adulterated with gypsum or other materials. Another blue pigment is Egyptian blue, composed of a double silicate of calcium and copper, $CaO \cdot CuO \cdot 4SiO_2$. It resists the action of most chemical reagents. It was originally made by fusing sand, soda, and copper. It was employed by the Romans, and paintings 1,900 years old have retained the color. It is now made by fusing finely powdered quartz, chalk, copper oxide, and sodium carbonate, and washing with hydrochloric acid.

**Upholstery leather.** Very thin, finely finished leather used for upholstery, seats, and coverings for various articles. It consists of split hides, tanned to a soft, even texture, and usually dyed in colors. Chrome-tanned leather is softer and stronger than ordinary leather tanned with barks or quebracho. In splitting, the full hide thickness of about ¼ in. can be split into three or four thicknesses. After splitting, the leather is retanned and "nourished" with cod oil. Hand buffs are top grains with the top of the grain snuffed off. The second split of $\frac{3}{64}$ in. is called deep buff, and has an artificial grain put on. The third split is called No. 2 split. What remains is called a slab and is unsuited for upholstery leather. Splitting with four cuts give Buffing, Machine buff, No. 1 split, No. 2 split, and Slab. Upholstery leather is finished by japanning, by coating with lacquer, by dyeing with aniline, or by combinations of the last with either of the first two methods. Spanish leather, used for upholstery, is made by tanning in strong quebracho liquor which draws the grain and gives a slightly wrinkled appearance.

**Uraninite.** Also called Pitchblende. It is the chief source of the elements radium and uranium. The mineral is a combination of the oxides of uranium $UO_2$ and $UO_3$, together with small amounts of lead, thorium, yttrium, cerium, nitrogen, helium, argon, and radium. The process of separation of radium is chemically complicated. The structure of uraninite is usually massive or in grains. The color is black, with pitchlike luster. The specific gravity is 9 to 9.7 and the hardness is 5.5. Uraninite is found with the ores of silver and lead in Saxony, Bohemia, and Hungary, and with tin ores in Cornwall, England. In the United States it occurs in pegmatite veins, and in the mica mines in North Carolina, and in

Utah and Colorado. The richest ores come from the Belgian Congo and from near Great Bear Lake, Northwest Territory, Canada. Autunite, or Uranite, is a secondary mineral from the decomposition of pitchblende. The composition is approximately $P_2O_5 \cdot 2UO_3 \cdot CaO \cdot 8H_2O$. It is produced in Utah. Torbernite, or Copper uranite, $Cu(UO_2)_2P_2O_8 \cdot 12H_2O$, is a radioactive mineral of specific gravity 3.22 to 3.6 and hardness 2 to 2.5.

**Uranium.** An elementary metal, symbol U. It never occurs free in nature but is found chiefly as an oxide in the minerals pitchblende and carnotite where it is associated with radium. The metal has a specific gravity of 18.68 and atomic weight 238.2. The melting point is about 1860°C. It is hard but malleable, resembling nickel in color, but related to chromium, tungsten, and molybdenum. It is soluble in mineral acids. The metal is alloyed with iron to make Ferrouranium, used to impart special properties to steel. It increases the elastic limit and the tensile strength of steels, and is also a more powerful deoxidizer than vanadium. It is also used to denitrogenize steel and has also carbide-forming qualities. It is used in high-speed steels in amounts of 0.05 to 5% to increase the strength and toughness. Uranium is more expensive than vanadium, and the losses from oxidation in adding to steel are greater. In cast iron small quantities of uranium, up to 1%, increase the strength, toughness, and fluidity of the iron. Metallic uranium is used as a cathode in photoelectric tubes responsive to ultraviolet radiation. Uranium compounds, especially the uranium oxides, are used for making glazes in the ceramic industry and also for paint pigments. Chemically, uranium has a number of isotopes, and its atomic weight varies from 234 to 239. It has the highest atomic weight of any of the materials occurring normally in nature, being 92 on the periodic scale. The transuranic elements Neptunium, symbol Np, and Plutonium, symbol Pu, elements 93 and 94, have been made from uranium of atomic weight 235, called U-235, by means of cyclotron electronic bombardment. They are highly unstable, and can be made to disintegrate with tremendous explosive violence. Plutonium was the material in the first atomic bombs. The transuranic elements numbers 95 to 96 are named Americium

and Curium. They were first made at the University of California by bombarding U-238 and Pu-239 with 40 million electron volt helium ions.

**Uranium yellow.** Also called Yellow oxide and Sodium uranate. A sodium diuranate of the composition $Na_2U_2O_7 \cdot 6H_2O$, obtained by reduction and treatment of the mineral pitchblende. It is used for yellow and greenish glazing enamels and for imparting an opalescent yellow to glass, which is green in reflected light. Uranium oxide is an olive-green powder of the composition $U_3O_8$, used as a pigment. Uranium trioxide, $UO_3$, is a yellow powder also used for ceramics and pigments. It is also called Uranic oxide. As a pigment in glass it produces a beautiful greenish-yellow Uranium glass; Uranous oxide, $UO_2$, gives glass a fine black. Sodium uranate, $Na_2UO_4$, is a yellow to orange powder used to produce ivory to yellow shades in pottery glazes. The uranium oxide colors give luster and iridescence.

**Urea.** Also called Carbamide. A colorless to white crystalline powder, $NH_2 \cdot CO \cdot NH_2$, made by combining ammonia and carbon dioxide under high pressure and temperature. It is the chief nitrogen constituent of urine, and was the first organic chemical ever synthesized. Its chief use is in the production of plastics, but it is also used in fertilizer mixtures, in cattle feeds, and for the chemical seasoning of lumber. The specific gravity is 1.323, melting point 132°C., and it is soluble in water and in alcohol. Thiourea, called also Thiocarbamide, Sulphourea, and Sulphocarbamide, $NH_2 \cdot CS \cdot NH_2$, is a white crystalline material of bitter taste, soluble in water, and having a specific gravity of 1.405. It changes on prolonged heating below the melting point, 182°C., to ammonium thiocyanate. Solutions of thiourea are neutral and are mildly reducing. It is used in the manufacture of plastics, in the textile and glass industries, and in medicine. Related to these materials also is Urethane, a white powder of the composition $NH_2COO\text{-}C_2H_5$, used in the production of Polyurethane plastics. During the war the Germans used polyurethane for textile fibers under the name of Igamide. The fiber has good strength.

**Urea-formaldehyde resins.** Synthetic resins used for plastic molding and for adhesives and lacquers, which belong to the group known as Amino-aldehyde resins made by the interaction of an aldehyde and an amine. The urea resins are made by the condensation of urea or thiourea with formaldehyde. An initial condensation product is obtained which is soluble in water, and is valuable for coatings and adhesives. The final condensation product is insoluble in water, alcohol, oils, or in weak acids or alkalies, and will withstand temperatures higher than the phenol plastics. Molding is done at a pressure of 2,000 lb. per sq. in. and a temperature of 300°F., in the same manner as for other synthetic resins. The urea resins are also noted for their transparency and ability to take translucent colors. The use of thiourea improves the water resistance of the molded products. The refractive index is about the same as that of quartz, and the original Austrian urea plastic known as Pollopas was called Organic glass. It transmits ultraviolet light, but has a double refraction and is not suitable for lenses. The specific gravity of the resin is 1.44, and hardness about 3 Moh. The resins are also noted for their good adhesion, and they are used as adhesives for plywood. Small amounts of urea-formaldehyde resins are used in sizing paper to give it wet strength. Uformite 449, of the Resinous Products & Chemical Co., is a 50% water solution of urea-formaldehyde used for paper sizing. Uformite 412-A is a urea resin for laminating plywood. Uformite 580 is a urea resin in powder form for adding to foundry ore mixtures to give strength to the core. Urac 185, of the American Cyanamid Co., is a urea-formaldehyde resin used for bonding plywood.

Cascamite, of the Casein Co. of America, is a dry, powdered, water-soluble urea-formaldehyde resin used for making adhesives. The molding powders marketed under the name of Beetle by the American Cyanamid Co. are made from thiourea and formaldehyde. The specific gravity of the molded material is 1.49, tensile strength 5,000 to 7,000 lb. per sq. in., and compressive strength up to 26,000 lb. per sq. in. Other urea plastics are Aldur, of the Aldur Corp.; Unite, of the Unite Corp.; Plaskon, of the Plaskon Co., Inc.; Coltrock, of the Colt's Patent Fire Arms Co. Carboloid and Marboloid are Japanese urea plastics.

**Vanadium.** An elementary metal, symbol V, found widely distributed, but in commercial quantities in only a few places, chiefly Peru, Rhodesia, and Colorado. The common ores of vanadium are carnotite, patronite, roscoelite, and vanadinite. Much of the commercial vanadium comes from Peruvian patronite and shales. Some Russian vanadium comes from the mineral Tyuyamunite, a vanadate of lime and uranium, mined in Turkmen. Colorado and Utah vanadium comes from carnotite, and the Arizona ore is vanadinite. The metal is also recovered from phosphate rock in Idaho by dissolving the rock in sulphuric acid and then precipitating with nitric acid to vanadium pentoxide powder for use in making alloy steels. Vanadium is a pale-gray metal with a silvery luster. It is brittle and has a crystalline structure. Its specific gravity is 6.02, and it melts at 3236°F. It does not oxidize in the air and is not attacked by hydrochloric or dilute sulphuric acid. It dissolves with a blue color in solutions of nitric acid. It is marketed in lump forms in grades from 80 to 95% pure. Vanadium readily alloys with iron. When added to steel in small quantities, it toughens and strengthens it. It forms hard carbides which are retained at high temperatures. When chromium is present, it forms double carbides, giving hard keen-edge quality to the steel. It also refines the grain, reduces grain growth, widens the hardening range, and increases the fatigue resistance and shock resistance of the steel. It is a powerful deoxidizer, but is too expensive for this purpose alone. It is used largely in special alloy steels, being added in the form of ferrovanadium. Ferrovanadium is made by reducing ferrous vanadate, calcium vanadate, or the oxides in the electric furnace. The standard grade contains 30 to 40% of vanadium, with 3 to 6 carbon and 8 to 15 silicon, and the balance iron, but the alloy is also marketed with carbon not over 0.20% and silicon not over 1.5%.

Vanadium salts are used to color pottery and glass and as mordants in dyeing. Red cake, or crystalline Vanadium oxide, is a reddish-brown material, containing about 85% of Vanadium pentoxide, $V_2O_5$, and 9% of $Na_2O$, used as a catalyst and for making vanadium compounds. Vanadium oxide is also used to produce yellow glass; the pigment known as Vanadium-tin yellow is a mixture of vanadium pentoxide and tin oxide.

**Vanadium steel.** Vanadium was originally used in steel as a cleanser, but is now employed in small amounts, 0.15 to 0.25%, especially with a small quantity of chromium, as an alloying element to make strong, tough, and hard steels. It increases the tensile strength without lowering the ductility, reduces grain growth, and increases the fatigue-resisting qualities of steels. The steels, with 0.45 to 0.55% of carbon, are used for locomotive forgings. In tool steels vanadium widens the hardening range, and by the formation of double carbides with chromium makes hard and keen-edge die and cutter steels. Vasco vanadium steel, of the Vanadium-Alloys Steel Co., contains 0.20% of vanadium with 0.80 chromium in the various carbon grades from 0.50 to 1%. The higher carbon steels, for gages and rollers, have somewhat more chromium. All of these steels are classed as chromium-vanadium steel. The carbon-vanadium steels for forgings and castings, without chromium, have slightly higher manganese. Plain carbon-vanadium steel is regularly marketed in all standard carbon grades. It is finer grained, tougher, and keener edged than plain carbon steel. Colonial No. 7, Red star, and Elvandi, of the Vanadium Alloys Steel Co., are steels of this type. Python steel, a shock-resistant steel of the Allegheny Ludlum Steel Corp. has 0.25% of vanadium, 0.90 carbon, 0.30 manganese, and 0.25 silicon.

Vanadium steels require higher quenching temperatures than ordinary steels or nickel steels. S.A.E. 6145 steel, with 0.18 vanadium and 1 chromium, has a fine grain structure and is used for gears. It has a tensile strength of 116,000 to 292,000 lb. per sq. in., when heat-treated, with a Brinell hardness of 248 to 566 depending on the temperature of drawing, and an elongation of 26 to 7%. In cast vanadium steels it is usual to have from 0.18 to 0.25% of vanadium with 0.35 to 0.45 carbon. Such castings have a tensile strength of about 80,000 lb. per sq. in. and an elongation of 22%. A nickel-vanadium cast steel, marketed by the Los Angeles Steel Casting Co. under the name of Nickeladium, has a tensile strength of 100,000 lb. per sq. in. with elongation of 20%.

**Vanilla beans.** The seed pods of a climbing plant of the orchid family of which there are more than 50 known species. It is native to Mexico, but now also grown commercially in Madagascar, Ré-

union, Mauritius, and Brazil. It is used for the production of the flavor Vanilla. The species grown for commercial vanilla is *Vanilla planifolia,* a tall climbing herb with yellow flowers. It grows in humid tropic climates. The flowers are pollinated by hand to produce 30 to 40 beans per plant. The green beans are cured immediately in ovens to prevent spoilage after a sweating process. During the curing the glucoside is changed by enzyme action into Vanillin which crystallizes on the surface and possesses the characteristic odor and flavor. The pods turn dark brown. The cured beans are put up in small packs in tin containers. The species *V. pompana* is more widely distributed, but is not as fragrant. The vanilla grown in Tahiti has an odor of heliotrope which must be removed. At least 15 species of vanilla grow in the Amazon and Orinoco valleys. Vanilla was used by the Aztecs for flavoring chocolate. It is now used for the same purpose, and as a flavor for ice cream, puddings, cakes, and other foodstuffs. Vanillin is also produced synthetically from eugenol derived from clove oil. It is also made from Coniferin, $C_{16}H_{22}O_8 \cdot 2H_2O$, a white crystalline material of melting point 185°C. obtained from the sapwood of the northern pine. It is produced in Wisconsin from waste liquors from pulpmaking by hydrating into sugar and another crystalline substance which is oxidized to vanillin. Ethyl vanillate, $C_6H_3$-$(OH)(OCH_3)(COOC_2H_5)$, is made from Wisconsin sulphite liquor. It is used in cheese to prevent mold, and as a preservative in tomato and apple juice.

**Varnish.** A solution of a resin in drying oil, which when spread out in a thin film dries and hardens by evaporation of the volatile solvent, or by the oxidation of the oil, or both. A smooth, glossy coating is left on the surface. Varnishes do not contain pigments; when mixed with pigments, they become enamels. The most commonly used resin is ordinary rosin, and the most common drying oils are linseed and tung oils. Spirit varnishes are those in which a volatile liquid, such as alcohol or ether, is used as a solvent for the resin or oil. They dry by the evaporation of the solvent. Oleoresinous varnishes are those in which the resin is compounded with an oxidizable oil, such as linseed oil. The gums used in varnish, such as copal, dammar, and kauri, produce hardness and gloss to the

film, and the Fossil resins, such as kauri, give greater hardness and luster to varnishes than do the natural resins. The oils, such as tung and linseed, make it elastic and durable.

Other important ingredients of varnishes are driers, such as manganese oxide, to hasten the action of the drying oil, and thinning agents, or reducers, such as turpentine, naphtha, and benzol. Hydrated lime is added to varnishes to neutralize the acid in the resin, and to clarify and harden the varnish to prevent it from becoming sticky in warm weather. Spar varnishes are those made to withstand weather conditions. Gloss oil is a solution of hardened rosin in benzine or in turpentine with sometimes a small amount of tung oil to give a tougher film. It gives a high gloss but is not durable. Long varnishes are those containing 20 to 100 gal. of oil to 100 lb. of resin; a Short varnish is one with less oil. The short varnishes are hard, more glossy, but not as flexible or durable.

Ordinarily, quick-drying varnish made with a natural resin is less durable than slow-drying; hardness and gloss are not guarantees of good varnish. The quick-drying varnishes, made with a synthetic resin of the phenol type and tung oil, are very durable and are waterproof. Marine varnish is of this type. Opaque varnish, for signs, consists of synthetic resin varnish with graphite. Varnodag, of the Acheson Colloids Corp., is such a varnish, consisting of phenol-formaldehyde resin with colloidal graphite. Varnish is employed usually as a finish for fancy wood surfaces, but is also used as a protection against moisture on wood, paper, fiber, and other materials.

**Vegetable fats.** When specifically used, the term refers particularly to semisolid vegetable oils that are used locally for food. Vegetable oils and fats usually contain only small quantities of the fat-soluble vitamins A, D, and E, and after refining, they are usually devoid of vitamins. Thus, they are a better food in the producing countries. Climate in which the plant is grown has an effect on the nature of the oils. Warm climates favor the development of oleic acid while colder climates favor the less palatable linolenic acid. The low-melting-point oils are more easily assimilated in the body, but when these are hydrogenated to a melting point above 45°C. they become difficult to assimilate. Most of the more

edible vegetable fats are tropical products. Suari fat is a hard white fat with a pleasant taste obtained from the kernels of the seeds of the *Caryocar brasiliense* and other species of tropical America. The kernels yield 60 to 70% of fat of a specific gravity of 0.898, melting point 30 to 37°C., and iodine value 41 to 50. Ucuhuba tallow, used in soaps and for candles, is a fat from the seeds of the trees *Virola surinamensis* and *V. sebifera* of Brazil. Mahuba fat is a hard edible fat from the fruit of the tree *Acrodiclidium mahuba* of Brazil. Gamboge butter, known locally as Gurgi and Murga, is from the seeds of the fruit of the tree *Garcinia morella, G. hanburii,* and other species of Ceylon and India. The melting point is 34 to 37°C., specific gravity 0.90 to 0.913, and saponification value 196. It is used as a soap and food oil, and locally as an illuminant and as an ointment. From these trees also comes the gum resin Gamboge used in medicine as a cathartic, and also used as a dyestuff. It is alcohol-soluble and gives a brown color.

Sierra Leone butter, also called Kanga or Lamy, is a pale-yellow fat from the seeds of the fruit of the tree *Pentadeama butyracea* of West Africa. The melting point is about 40°C., specific gravity 0.857 to 0.860, and saponification value 186 to 198. It is a soap oil. Mafura tallow is a bitter-tasting heavy fat from the nuts of the tree *Trichilia emitica* of East Africa. It is used for soap, candles, and ointments. The specific gravity is 0.902, melting point about 40°C., and saponification value 201. Shea nut oil, also known as Shea butter, Bambuk butter, Galam butter, and by various local names as Karité, Kade, and Kedempó, is a fat obtained from the kernels of the fruit of the large tree *Bassia butyrospermum* of tropical West Africa. The kernels contain 45 to 55% of fat, which when refined is white, stiffer than lard, with little odor or taste. The melting point is 33 to 42°C. It contains oleic and stearic acids and 3 to 4% of lauric acid. It is used in Europe in butter substitutes, and as a substitute for cocoa butter, and also in candles. Malabar tallow, also called Dhupa fat and Pinay tallow, used in Europe for soap and candles, and in India for food, is from the kernels of the seed of the evergreen Pinne tree *Vateria indica* of south India. The tree also yields White damar or Indian copal. The seeds give about 25% of a greenish-yellow, odorless, and tasteless fat of specific gravity 0.890, melting point 40°C., and saponi-

fication value 190. The fat is extracted by grinding the roasted seed, boiling in water, and skimming off. It is bleached by exposure to the air.

Vegetable tallow, also called Bayberry tallow and Myrtle wax, used extensively in Europe for soapmaking, and in the United States for blending in candles and with waxes, is a waxy fat obtained from the outside coating of the berries of species of *Myrica* bushes of America, Europe, and Africa, by boiling the berries in water. The berries yield 15 to 25% of tallow. The species *M. cerifera* and *M. carolinensis* grow in the Eastern coastal states, and the *M. mexicana* grows in Central America. The melting point of the tallow is 40 to 46°C., specific gravity 0.995, and saponification value 205 to 212. The Central American product contains about 58% of myristic acid, 36 palmitic, and 1.3 oleic acid. Ocuba wax is a waxy fat, but not chemically a wax, obtained from the seeds of the fruit of the shrub *Myristica ocuba* of Brazil. The seeds yield about 20% of fat with a specific gravity of 0.920 and melting point of 40°C., used in candles. The fruit nut is surrounded by a thick skin which yields a water-soluble pink dye known as Ocuba red.

Mahubarana fat is a pale-yellow solid oil of melting point 40 to 44°C. obtained from the kernels of the fruit of trees of the genus *Boldoa.* The kernels contain 65% of oil. It is used for soaps and candles. Mocaya butter is a fat from the kernels of the nuts of the Paraguayan palm, *Acrocomia sclerocarpa,* of tropical South America. The tree resembles a coconut palm, but the nuts grow in bunches. The pulp of the fruit contains 60% of a yellow oil similar to palm oil. The kernels yield 53 to 65% of the mocaya fat which is softer than palm kernel oil. The specific gravity is 0.865, and saponification value 240. It has the same uses as palm kernel oil.

**Vegetable oils.** An important class of oils obtained from plants, used industrially as drying oils, for lubricants, in cutting oils, for dressing leather, and for many other purposes. Many of the oils find wide usage in food products. Large tracts of land are under cultivation in all parts of the world for the production of the seeds and fruits from which the oils are obtained. Linseed,

cottonseed, palm, olive, and castor beans are examples of these, and the oils are obtained by crushing. In some cases the oil-bearing material, copra or soybean, may be dehydrated before crushing, making it simpler to extract the oil, and giving a better residue meal for animal feed. The only distinction between vegetable oils and fats is a physical one, oils being fluid at ordinary temperatures. Vegetable oils can be thickened for various uses by oxidation, by blowing air through them, or they can be hydrogenated by passing hydrogen through them in the presence of a catalyst. Considerable oil is extracted from the kernels of the stones or pits of cherries, apricots, and other fruits as a by-product of the canning and drying of fruits. Cherry kernel oil is from cherry pits which contain 30 to 38% oil. The cold-pressed oil is yellow and has a pleasant flavor. It is used in salad oils and in cosmetics. The hot-pressed oil is used in soaps. The oil contains 47% of oleic acid, 40 linoleic, 4 palmitic, 3 stearic, and some arachidic and myristic acids.

**Velvet.** A closely woven silk fabric with a short pile on one side formed by carrying the warp threads over wires and then cutting open the loops. Velvet is made in a great variety of qualities and weights, and may have a cotton back in the cheaper grades, or be made in wool. True velvet is all silk, but because of the number of imitations in other materials this variety is usually designated as Silk velvet. Velvet is dyed in various colors, the depth of color shown by the pile giving it an air of richness. Its largest use is in dress goods and hangings, but it is used industrially for upholstery, fancy linings, and trim.

**Velveteen.** A variety of imitation velvet, woven of cotton. In the best grades the pile is of mercerized yarns. Velveteen is woven into two systems of filling yarns and one system of warp yarns, the pile being made with the cut filling yarns instead of the warp yarns as in velvet. It belongs to the class of Fustians which includes also Moleskin and Corduroy. The latter is a sturdy pile fabric with heavy warp rib, dyed in the piece. It is also made in wool. The ribs run lengthwise, while Whipcord, a hard-woven worsted fabric, has fine ribs running diagonally on the face. Velveteen is used for apparel, linings for jewelry and silverware boxes, shoe uppers, artificial flowers, and covering material. It is made

either plain back or twill back, the plain back having a tendency to loosen and drop the pile when subjected to abrasion.

**Vermiculite.** A foliated mineral employed in making plasters and boards for heat, cold, and sound insulation, as a filler in calking compounds, and for plastic mortars and refractory concrete. The mineral is an alteration product of biotite and other micas, and is found in Colorado, Wyoming, and Montana, and in the Transvaal. It occurs in crystalline plates, specific gravity 2.3, and hardness 1.5, measuring sometimes as much as 9 in. across and 6 in. in thickness. The color is yellowish to brown. Upon calcination at 1750°F. vermiculite expands at right angles to the cleavage into threads with a vermicular motion like a mass of small worms, hence its name. The volume increases as much as 16 times, and the color changes to a silvery or golden hue. It is ground into pellet form. Plaster made with 60% of vermiculite, 30 plaster of paris, and 10 asbestos will withstand red heat without disintegrating. Therm-O-Flake brick, of the Illinois Clay Products Co., is made of granules of Exfoliated vermiculite bonded with a chemical. It is lightweight, tough, and will withstand temperatures up to 2000°F. The cork-like pellets of vermiculite used for insulating fill in house walls are called Mica pellets. Zonolite, of the Zonolite Co., is an exfoliated vermiculite. A sound-absorbing building tile marketed by Johns-Manville under the name of Rockoustile is made of exfoliated mica. An expanded vermiculite of extremely fine mesh, under the name of Mikolite, of the Mikolite Co., is used as an extender in aluminum paint and in lubricating oils.

**Vermilion red.** One of the oldest paint pigments. It is a brilliant red powder of the composition HgS, known chemically as Red mercury sulphide. The specific gravity is about 8.1. It is insoluble in water. Vermilion red is expensive, more than 85% of its weight being mercury, and is consequently often mixed with red lead, red ochre, or red iron oxide, or is replaced by Antimony red. It is made by heating mercury and sulphur together and grinding the product.

**Vine black.** The charred remains of partly burned vines or twigs, ground very fine and used as a pigment, especially for inks.

The original vine black, or Frankfort black, was made from grapevine twigs, but the so-called Vegetable black is made from wood pulp and is a by-product of the paper pulp industry. The name is now also applied to the black made from fruit pits and nut shells.

**Vinyl resins.** A group of products varying from liquid to hard solids, made by the polymerization of ethylene derivatives, employed for finishes, coatings, and molding resins. The simplest are the poly esters of vinyl alcohol, one of the most common being made by the reaction of vinyl chloride and vinyl acetate. Polyvinyl alcohol is a white, odorless, tasteless powder which on drying from solutions forms a colorless and tough film. It is used for adhesives, as a thickener for latex, emulsifying agent, in chewing gum, and for paper and fabric coatings. It is easily mixed with plasticizers and molded or extruded under moderate pressures and temperatures to form elastic, tough, heat-resistant products or sheets and tubing. They are also acid- and alkali-resistant. The polyvinyl alcohols are called Solvars, and the polyvinyl acetates are called Gelvas. The Polyvinyl formals, Formvars, are used in molding compounds, wire coatings, and impregnating compounds. The Polyvinyl acetals, Alvars, are used in lacquers, adhesives, and phonograph records. The Polyvinyl butyrals, Butvars, are used as an interlayer in laminated glass. They are transparent and completely light-stable. Polyvinyl carbazole, under the name of Luvican, was used in Germany as a mica substitute for high-frequency insulation. It is a brown resin, softening at 150°C.

Vinyl acetate is a water-white mobile liquid with boiling point 70°C., usually shipped with a copper salt to prevent polymerization in transit. The composition is $CH_3 \cdot COO \cdot CH : CH_2$. It may be polymerized in benzene and marketed in solution, or in water solution for use as an extender for rubber, and for adhesives and coatings. The higher the polymerization of the resin, the higher the softening point of the resin. The formula for Polyvinyl acetate resin is given as $(CH_2 : CHOOCCH_3)_x$. It is a colorless, odorless, thermoplastic with density of 1.189, unaffected by water, gasoline, or oils, but soluble in the lower alcohols, benzene, and chlorinated hydrocarbons. Polyvinyl acetate resins are stable to light, transparent to ultraviolet light, have high dielectric strength, and are

hard and tough. They are valued for lacquers because of their high adhesion, durability, and ease of compounding with gums and resins. Saflex is the name of vinyl acetal resins of Monsanto Chemical Co.

Vinylite and Vinyloid are trade names of the Carbide & Carbon Chemicals Corp. for vinyl-acetate resins. They are molded with heat and pressure like other synthetic resins, and are compounded with wood flour, asbestos, mica, and other fillers. The clear resins are light in color. Vinyon, of the same company, is a polyvinyl chloride acetate fiber which is produced in various grades as fine as natural silk. It is waterproof, more elastic than natural silk, and nearly as strong. Since it is resistant to strong acids and alkalies, Vinyon fiber is made into filter cloth for temperatures not above 160°C. It is also used in wool mixtures for hat felts. It is produced by the copolymerization of vinyl chloride and vinyl acetate. Advagum, of the Advance Solvents & Chemical Corp., is a highly plasticized vinyl copolymer used as an extender in synthetic rubber. Victron, of the Naugatuck Chemical Co., is a vinylite resin. Mowilith is a German vinylite resin. Gelva, of the Shawinigan Products Corp., is a polyvinyl acetate resin used for lacquers. Formvar, of the Carbide & Carbon Chemicals Corp., and Formex, of the General Electric Co., are vinyl-formaldehyde resins used for such purposes as coating insulated wire. Butacite, of E. I. duPont de Nemours & Co., Inc., is a polyvinyl acetal resin for laminated safety glass. It is clear and stable. Vinal is a general trade name used by the plastics industry for vinyl-butyral resins for laminated glass and other uses. Mipolam is the name of a vinyl polymer plastic used in Germany for floor coverings to replace rubber flooring. Korogel is a plasticized polyvinyl chloride for molding. Igerin was a German polyvinyl plastic made by the polymerization of vinyl ether with a catalyst. Cosal was polymerized vinyl isobutyl ether used in adhesives and lacquers. Resistoflex is the trade name of the Resistoflex Corp. for polyvinyl alcohol plastics.

Vinylidene chloride plastics are derived from ethylene and chlorine polymerized to produce a thermoplastic with softening point of 240 to 280°F. The resins are noted for their toughness and resistance to water and chemicals. The molded resins have a specific gravity of 1.68 to 1.75, tensile strength of 4,000 to 7,000 lb. per sq. in., and flexural strength of 15,000 to 17,000 lb. per sq. in.

Saran is the name of a Vinylidene chloride plastic of the Dow Chemical Co., extruded in the form of tubes for handling chemicals, brines, and solvents as it is acid- and alkali-resistant and also resistant to temperatures as high as 275°F. It is also extruded into strands and woven into a box-weave material as a substitute for rattan for seating. Velon, of the Firestone Tire & Rubber Co., is this material for screens and fabrics. Saran latex is used for coating, sizing, and impregnating fabrics.

**Vitamins.** Organic chemical compounds which are vital building units, coenzymes, or catalyzing agents in the growth and maintenance of animal bodies. They are produced by extraction from vegetable or animal products or made synthetically, and marketed in solid or extract form for use in foodstuffs and pharmaceuticals. Vitamin A, called Carotene because of its abundance in carrots, is an orange-yellow needle-shaped crystalline substance with a complex molecular structure having the empirical formula $C_{40}H_{56}$. It is soluble in fats, but poorly soluble in water. Yellow and leafy green vegetables are rich sources of carotene-bearing pigments, and carotene accompanies the green chlorophyll coloring of all plants. The more intense the green or yellow coloring, the greater the carotene content. Cryptozanthin, one of the four yellow carotene-carrying pigments, occurs in yellow corn, egg yolk, and green grasses. Animals convert carotene of green plants into vitamin A which is then obtained commercially from the tissues especially from the liver. Deficiency of vitamin A in the human body causes night blindness, muscular weakness, and defective tooth structure.

Vitamin B is a complex of several vitamins, including Vitamin $B_1$ and Vitamin G. The former cannot be formed in the normal processes of the human body and must be supplied in the diet. Plants manufacture and store it in the seed. Lack of vitamin $B_1$ causes beriberi, fatigue, stiffness, headache, nervousness, and loss of appetite and, when chronic, causes enlargement of the heart, polyneuritis, and loss of coordination of the muscular movements. The crystalline vitamin $B_1$ is called Thiamin chloride, and in Europe is called Aneurin. It is water-soluble, insoluble in most fats, and is destroyed by heat in the presence of moisture. In alkaline solutions

the destruction is rapid. It is essential to the health of every living cell. Greater amounts are needed when starches or carbohydrate foods are eaten in order to prevent the formation of Pyruvic acid. Riboflavin is the generally accepted name for Vitamin $B_2$, or vitamin G. The orange-yellow needle-shaped crystals have a green fluorescence. Riboflavin, $C_{27}H_{20}N_4O_6$, is water-soluble. It is gradually destroyed by exposure to light, and is destroyed by many chemicals, or by high temperatures in the presence of alkalies. It is present in meats, eggs, barley malt, yeast, milk, green leafy vegetables, and in grasses. Deficiency of riboflavin results in ill health, loss of hair, and dermatosis. Nicotinic acid, or Niacin, is the pellagra-preventing member of the vitamin B complex. It can be made from the nicotine of the variety of tobacco *Nicotina rustica.* Coffee contains some niacin, and meat extracts are rich in both niacin, and riboflavin. Biotin is also a member of the B group, and has an enzyme action on starches and sugars. Vitamin $B_6$, called Pyriodoxine, is required to enable the body to assimilate proteins. A deficiency causes nausea, muscular weakness, and anemia.

Vitamin C, $C_6H_8O_6$, known also as Ascorbic acid, or Ceritamic acid, is unstable and is easily oxidized, especially in the presence of alkalies or in iron or copper vessels, so that in foods that have been long exposed to the air it loses its value. It is found in milk, fruit juices, tomato, and in green vegetables.

Vitamin D regulates the metabolism of calcium and phosphorus in the human body. Without it the body is subject to rickets, soft bones, or ill-formed bones and teeth. It is also effective against the germ of tuberculosis. It is found in fish and fish-liver oils and in some fruits. The vitamin D concentrate of General Mills, Inc., is made by the activation of crystalline ergosterol with low-velocity electrons, in vegetable oil. Calciferol, or Vitamin $D_2$, of the Winthrop Chemical Co., is a synthetic antirachitic marketed in crystalline form or in solution in corn oil. Its melting point is 116°C. Vitamin D is formed in the body from Cholesterol by the action of sunlight on the skin. Vitamin E is so widely distributed in foods taken by man that the effect is not well known. It is known that in certain animals deficiency causes failure of the female to give birth to living young, and that abortion is cured by it. It is found in wheat germ oil. Vitamin P is found in capsicum and in lemon

peel, and is a preventative of rheumatic fever. Although proper quantities of vitamins are necessary in the human body, overdoses are often toxic and poisonous.

**Vulcanized fiber.** A wood, paper, or other cellulose fiberboard impregnated with a gelatinizing medium. It is not vulcanized in the same sense that rubber is vulcanized. It is made by various processes, and the medium may be sulphuric acid, zinc chloride solution, or cuproammonium solution. It may also be made by impregnating the cellulose fiber with a phenol-furfural resin dissolved in alcohol or other solvent. After dipping in the solution, the fiber is washed to remove excess alcohol, and then dipped in a zinc chloride solution which hydrolizes it, and it is then washed free of the chloride, dried, and rolled. The original vulcanized fiber, patented in 1899, and called Cellulith, was sulphite wood pulp molded into sheets or formed parts. The modern fiber in the hard grades is a tough, resilient, hornlike material in standard gray, red, and black colors. Soft flexible grades are made for washers and gaskets.

Another type of material, called Maizolith, developed by the National Bureau of Standards, is a hard, dense product made by cooking cornstalks or corncobs with caustic soda, washing out the residue, beating, and compressing. It has a tensile strength of 8,000 lb. per sq. in., hardness of 15 to 30 Brinell, is resistant to oils, is a good insulator, and resembles vulcanized fiber.

The Hard vulcanized fiber, produced by the Spaulding Fibre Co., Inc., is made from cotton rags softened and gelatinized in a zinc chloride solution and built up in layers. The specific gravity is from 1.1 to 1.4, the heavier thicknesses being the lightest and the softest. The shearing strength is 10,000 to 15,000 lb. per sq. in. and compressive strength 30,000 lb. per sq. in. The dielectric strength is from 275 to 375 volts per mil. Sheets as thin as 0.004 in. are produced. The Diamond fiber, marketed by the Continental-Diamond Fibre Co., is made in various grades with compressive strengths up to 40,000 lb. per sq. in. Bone quality is a dense material with a specific gravity of 1.40, made in thicknesses from ⅛ to ½ in., with high machining properties. The Commercial quality is made in thicknesses from 0.004 to 2 in. The thin paper sheets are used for armature insulation. Codite is the trade

name of this company for a hard, tough, vulcanized fiber tubing with dielectric strength up to 710 volts per mil. Cellulak is another tubing of the same company made of kraft paper coated with resin and laminated under heat and pressure. Flexible fiber is a grade of vulcanized fiber made to retain sufficient moisture to keep it soft. Vulcanized fibers are used for electrical insulation, gaskets, gears, rollers, handles, and for such articles as trunks, boxes, and novelties. For electrical insulation it has the disadvantage that it absorbs moisture in damp places unless impregnated with insoluble resins. The higher grades of vulcanized fibers, and those for electrical work, are all now of the insoluble type. Victorite, of the Victor Mfg. & Gasket Co., is an impregnated Manila-rope paper, used for gaskets. Fish paper, for electrical use, may be vulcanized fiber in thicknesses from 0.005 to $\frac{1}{16}$ in. The 0.005-in. paper will withstand 1,500 volts. Protectite, of the National Vulcanized Fibre Co., is a thin, white, vulcanized fiber sheet used for backing rubber shoe soles. Shoe fiber is sheet material in leather color used for reinforcements in shoes. It is very resilient, but can be cut with dies and nailed.

**Vulcanized oils.** Vegetable oils vulcanized with sulphur and used for compounding with rubber for rubber goods, or as a rubber substitute in erasers. Castor oil, corn oil, rapeseed oil, and soybean oil are used. Vulcanized oil is a white to brown, spongy, and odorless cake, or sticky plastic, with specific gravity of 1.04. The material was invented in France in 1847, and was known as Factice. Factice cake is solidified vulcanized oils, cut in slab form for compounding with rubber. Factice is not a mere adulterant of rubber, but may be used to give certain desirable characteristics such as softness or plasticity. It also has some elasticity. Brown factice is made by treating the oil with sulphur or sulphur chloride at 160 to 200°C. The softer grades are made with blown oils and low sulphur. The harder grades contain up to 20% of sulphur. White factice is made from rapeseed oil, which is high in a characteristic acid, erucic acid, by slow addition of sulphur chloride up to 25% of sulphur content. Erasing rubbers are rubber compounded with white factice or the factice alone. Black factice has mineral bitumin added to brown factice. Neophax is the trade name of the

Stamford Rubber Supply Co. for brown factice, and Amberex is the name for light-tan colored factice. Factex of this company is partly vulcanized oil dispersed in water. It produces a nontacky elastic film. When mixed with rubber latex to the extent of 30% it gives a velvety feel to the vulcanized product and does not decrease the strength greatly. Factice sheet is made from specially processed factice made by treating warm oil with sulphur and then with sulphur chloride. The strength and elasticity are higher. Mineral rubber is a name sometimes applied to vulcanized oils mixed with bitumens, especially gilsonite, but this term is also applied to petroleum asphalt when used in rubber compounding for such uses as shoe soles.

Vulcanized rubber. Crude rubber, as obtained by precipitation or coagulation from the latex of the rubber tree, does not have the elastic or other properties of commercial rubber. To obtain these it is purified, and vulcanized by heating it together with sulphur at a temperature of about 140°C. From 3 to 50% of sulphur is used, depending upon the class of rubber desired. A part of the sulphur is actually taken up by the molecule of the rubber, forming a chemical combination and not acting as a filler. The process was invented in 1839 by Charles Goodyear. The ordinary soft, elastic rubbers contain from 3 to 6% of sulphur. All rubber is vulcanized, but when vulcanized rubber is designated it refers usually to the hard rubbers made with more than 20% of sulphur. These are hard and brittle, and are used for molded parts. It is also marketed in sheets, rods, and tubes, but is now largely replaced by synthetic plastics. The amount of sulphur determines the hardness, which varies from 45 to 70 Scleroscope. Sometimes factice is added to reduce brittleness. Vulcanite and Ebonite are old names for hard rubber. The specific gravity is 1.1 to 1.15, dielectric strength 1,000 to 1,200 volts per mil and tensile strength from 1,500 to 9,000 lb. per sq. in. It is not as resistant to water absorption as the plastics, and it is softened by mineral oils. Some synthetic rubbers can also be made into hard rubber, notably Buna S and Buna N. The GR-S ebonite, containing 15 to 44% of sulphur and made from Buna S, has a tensile strength of 8,800 to 9,900 lb. per sq. in., elongation 4.2 to 8.5%, Rockwell hardness 100 to 110,

and softening point 144°F. Vultex is a prevulcanized natural rubber in liquid or paste form used for coatings and adhesives. It hardens on evaporation of the water.

**Walnut.** A hardwood from the tree *Juglans regia,* native to Europe and Asia Minor, but now growing in many other places. The wood is firm, with a fine to coarse, open grain, and a lustrous surface. The weight is about 45 lb. per cu. ft. The color is dark brown to black, and it takes a beautiful polish. Walnut has great strength, toughness, and elasticity. It also has great uniformity of texture and does not split easily. It is particularly adapted for carving. Walnut is valued as a cabinet wood, for fine furniture, and for gunstocks. The wood from this tree is called English walnut, and the beautifully figured wood from Persia is known as Circassian walnut. Black walnut, or American walnut, is from the tree *J. nigra,* of Eastern United States. The color is darker, and it has a more uniform color than European walnut. It is handsomely grained and has the same general characteristics and uses as European walnut. It has a specific gravity, kiln-dried, of 0.56, a shearing strength parallel to the grain of 1,000 lb. per sq. in., and a compressive strength perpendicular to the grain of 1,730 lb. per sq. in. Butternut, from the tree *J. cinerea,* resembles closely the wood of the black walnut except for its color, which is yellowish gray. The supply of this wood is limited. East India walnut is the wood of the tree *Albizzia lebbek* of tropical Asia and Africa, used for furniture, paneling, and interior decorative work. It is hard, dense, close-grained, and has a weight of about 50 lb. per cu. ft. The color is dark brown with gray streaks. The logs come as large as 30 in. square and 20 ft. long. The shipments may be mixed with the wood of the *A. procera,* the White siris wood of India. This wood has a brown walnut color, is lustrous, and resembles true walnut more than does the East India walnut. Mahoe, also called Blue mahoe and Majagua, is the wood of the tree *Hibiscus elatus,* of tropical America. It has been used to replace true walnut for gunstocks and in cabinetwork. The wood has a gray-blue color, an aromatic odor, and is hard with a coarse, open grain. Walnut oil is yellowish oil obtained by pressing the nut kernels of the common walnut. It is a good drying oil and is used especially for artists'

paints. The specific gravity is 0.919 to 0.929 and iodine value 148. It is soluble in alcohol. The oil from the candlenut is also called walnut oil. Walnut-shell flour, made from the refuse shells of the walnut industry of California, is used as a filler in molded plastics and in synthetic adhesives to increase bonding strength. It contains cellulose with about 27% of lignin, 5 furfural, 9 pentosans, and 6 methyl hydroxylamine. In colonial times walnut bark was used as a cathartic. It contains a Juglone, or Nucin, a complex naphthoquinone, $C_{10}H_6O_2$. In Russia vitamin C is extracted from the Zakatalsk nuts, which are bitter "pignut" walnuts.

**Walrus hide.** The skin of the walrus, a marine mammal, *Odontobaenus rosmarus,* and *O. abesus,* native to the North Atlantic and Pacific oceans. The animals sometimes have a length of 16 ft., and a weight up to 2,000 lb., and the hide is obtainable in large pieces. They congregate in herds on the icebergs of the North. The skin is tanned and makes a leather with a beautiful natural grain. It is also very tough and was formerly much used for coach traces. It is now employed where a tough and ornamental leather is required. Walrus leather is imitated with embossed heavy sheepskin, and the leather is used for such things as bags and coverings.

**Water glass.** Also called Soluble glass. A soluble silicate of sodium known chemically as Sodium metasilicate or Sodium silicate, and having the composition $Na_2SiO_3$ or $NaSiO_3 \cdot 9H_2O$. Two other forms of the silicate are also available, Sodium sesquisilicate, $3Na_2O \cdot 2SiO_2$, and Sodium orthosilicate, $2Na_2O \cdot SiO_2$. All of these are noted for their powerful detergent and emulsifying properties, and for their suspending power. When solid, sodium silicate is glassy in appearance and dissolves in hot water. It melts at 1018°C. It is obtained by melting sodium carbonate with silica, or by melting sand, charcoal, and soda. The fused product is ground and dissolved in water by long boiling. Potassium silicate is made in the same way, or a double soluble glass is made by using both sodium and potassium carbonates. Potassium silicate is more soluble than sodium silicate. Kasil, of the Philadelphia Quartz Co., is a potassium silicate, a colorless sirupy liquid with 19.5% of $SiO_2$ and 7.8 of $K_2O$, used for welding rods.

Water glass is marketed as a viscous liquid or in powder form. It is used as a detergent, as a protection for wood and porous stone, as a fixing agent for pigments, for cementing stoneware, for lute cements for such uses as sealing electric-light bulbs, for waterproofing walls, greaseproofing paper containers, for coating welding rods, as a filler for soaps, and as a catalyst for high-octane gasoline. It increases the cleansing power of soaps but irritates the skin. However, it is used in cleaning compounds because it is a powerful detergent. Sodium silicate is also used for insulating electric wire. It is applied in solution and the coated wire is then heated, leaving a flexible coating. Mixed with whiting it is used as a strong cement for grinding wheels. Sodium metasilicate marketed by the Philadelphia Quartz Co. as a cleaner of metals is a crystalline powder. Hot solutions of this salt in water are caustic and will clean grease readily from metals. Drymet, of the Cowles Detergent Co., is the anhydrous sodium metasilicate. It is a fine white powder with total alkalinity of 51% $Na_2O$. It is easily soluble in water, and is used as a detergent and in soap powders to give free-flowing, noncaking properties. The anhydrous material for a given detergent strength weighs little more than half the weight of the hydrous powder. Dryorth is the anhydrous material of 60% alkalinity. It is a powerful detergent and grease remover. Crystamet, of the same company, is the material with 42% water of crystallization. It is a free-flowing white powder. Penchlor, of the Pennsylvania Salt Mfg. Co., is an Acidproof cement made by mixing cement powder with a sodium silicate solution. It is used for lining chemical tanks and drains. Aquagel, of the Silica Products Co., is a hydrous silicate of alumina, used in the same manner for waterproofing concrete.

**Water repellents.** Chemicals used for treating textiles, leather, and paper such as washable wallpaper, to make them resistant to wetting by water. They are different from waterproofing materials in that they are used where it is not desirable to make the material completely waterproof, but to permit the leather or fabric to "breathe." Water repellents must not form acids that would destroy the material, and they must set the dyes rather than cause them to bleed on washing. They usually consist of a mineral salt over which a wax emulsion is placed; the treatment may be a one-

bath process, or be by two separate treatments. Aluminum acetate is one of the most common materials for this purpose. Basic aluminum acetate is a white, amorphous powder of the composition $Al(OH)(OOC \cdot CH_3)$. It is only slightly soluble in water but is soluble in mineral acids. Zirconium acetate, a white crystalline material of the composition $ZrOH(C_2H_3O_2)_3$, and also its sodium salt, are used in water-repellent compounds.

**Water softeners.** Chemical compounds used for converting the soluble scale-forming solids in boiler feed water into insoluble forms. In the latter condition they are then removed by setting or filtration. The hardness of water is due chiefly to the presence of carbonates, bicarbonates, and sulphates of calcium and magnesium. Temporary hard waters are those that can be softened by boiling; permanent hard waters are those that require chemicals to change their condition. Sodium hydroxide is used to precipitate magnesium sulphate. Caustic lime is employed to precipitate bicarbonate of magnesium, and sodium aluminate is used as an accelerator. Alum is used to precipitate mud and other impurities. Water softeners may consist of mixtures of lime, soda ash, and sodium aluminate, the three acting together. Barium carbonate may also be used as a softener. The water is treated with the chemicals before it is run into the boiler. Water is also softened and purified by the ion-exchange method, using specially prepared melamine synthetic resins. By treating the water with a hydrogen derivative of a resin the salts in the water are converted to the corresponding acids and the total solids thus reduced. The carbonates are converted to carbonic acid which goes off in the air. The water is again treated with a sodium salt of a resin which reduces the acids. Water receiving this double treatment is equal to distilled water. Zeo-Karb and D-acidite, of the Permutit Co., are Ion exchangers of this type.

**Wax.** A general name for a variety of substances of animal and vegetable origin, which are fatty acids in combination with alcohols instead of with glycerin as in fats and oils. They are usually harder than fats, less greasy, and more brittle, but when used alone do not mold as well. Chemically, the waxes differ from fats and oils in being composed of high-molecular-weight fatty acids with high-

molecular-weight alcohols. The most familiar wax is beeswax from the honeybee, but commercial beeswax is usually greatly mixed or adulterated. Another animal wax is spermaceti from the sperm whale. Vegetable waxes include Japan wax, jojoba oil, candelilla, and carnauba wax. Mineral waxes include paraffin wax from petroleum, ozokerite, ceresin, montan wax. The mineral waxes differ from the true waxes in chemical composition and are mixtures of saturated hydrocarbons.

The animal and vegetable waxes are not plentiful materials, and are often blended with or replaced by hydrocarbon waxes. Santowax, of the Monsanto Chemical Co., is a synthetic high-melting-point microcrystalline hydrocarbon wax derived from coal tar. The specific gravity is 1.097. It is used in polishes and coatings, and as a plasticizer in synthetic resins. Opalwax, of E. I. duPont de Nemours & Co., Inc., is a synthetic wax produced by the hydrogenation of castor oil. It has about the same hardness as carnauba, specific gravity of 0.98, melting point of 86 to 88°C., is odorless, and of a pearl-white color, but it lacks the luster of carnauba. It is very resistant to most solvents, and is used for insulation, coatings, candles, and carbon paper. Acrawax, of the Glyco Products Co., Inc., is a somewhat similar substitute for carnauba with higher melting point. Stroba wax of this company is a synthetic wax with a base of stearic acid and lime. The melting point is 103 to 106°C. It is used in polishes, insulation, and as a flatting agent. Synthetic wax under the name of Pentawax 286, of the Heyden Chemical Corp., is a true wax in that it is a combination of fatty acids with an alcohol. It is made from the long-chain acids of vegetable oils with pentaerythritol. It has a higher melting point than carnauba, 110°F., but does not form a self-polishing liquid wax like carnauba. Waxes are employed in polishes, phonograph records, leather dressings, sizings, waterproofing for paper, candles, and in varnishes. They are softer and have lower melting points than resins, are soluble in mineral spirits and in alcohol, and insoluble in water.

**Wear-resistant steel.** Many types of steel have wear-resistant properties, but the term usually refers to high-carbon, high-alloy steels used for press dies subject to abrasion and for wear-resistant

castings. They are generally cast and ground to shape. They are mostly sold under trade names for specific purposes. Adamite is the trade name of the Mackintosh-Hemphill Co. for a high-carbon, nickel-chromium-iron alloy used for drawing and forming dies. The Brinell hardness ranges from 186 to 477 as cast, with tensile strengths up to 125,000 lb. per sq. in. The various grades contain from 0.50 to 1.50 chromium, with half this amount of nickel in each case, carbon from 1.25 to 3.50%, and silicon from 0.50 to 2%. The softest grades can be machined and then hardened, but the hard grades are finished by grinding. Castaloy, of the Detroit Alloy Steel Co., is a high-carbon, high-chromium steel for automobile-fender dies and wear-resistant castings. Martin steel, of this company, is an air-hardening steel containing 12 to 14% of chromium, 0.85 to 1.25 molybdenum, 0.35 vanadium, 0.80 cobalt, and 1.4 to 1.6 carbon. It is highly resistant to abrasion. Dasco is a general trade name for steels of this company. Carbomang is another cast-to-shape steel of the same company containing 1 to 1.25% of manganese, 0.45 chromium, 0.50 tungsten, 1 carbon. It can be cast to intricate shapes and is oil-hardening. Cobaltchrom is a nondeforming, wear-resistant cast steel for cutting and stamping dies. It contains 12 to 14% of chromium, 0.80 cobalt, and 1.5 carbon. Krokoloy is a die steel of the 14% chromium type containing higher cobalt, and is air-hardening. Kinite, of the Kinite Corp., for blanking and forming dies, and for cams and cutters, contains 12.5 to 14.5% of chromium, 1.5 carbon, 1.10 molybdenum, 0.70 cobalt, 0.55 silicon, 0.50 manganese, and 0.40 nickel. It has high compressive strength. Cristite, of the Commercial Alloys Co., contains 10% of chromium, 17 tungsten, 3.5 carbon, 2.5 molybdenum, and is notable for corrosion and acid resistance. Circle L4 steel, of the Lebanon Steel Foundry, used for cams and rolls, contains 1.25 to 2% of chromium, 1 to 1.5 manganese, 1 molybdenum, 0.12 vanadium, and 0.8 carbon.

**Welding rods.** A name applied to metal rods and wire used for either electric or gas welding, or for building up surfaces, or hard-facing surfaces. Nonferrous rods used for welding bronzes are usually referred to as Brazing rods as the metal to be welded is not fused when using them. Welding rods may be standard metals or

special alloys, coated with a fluxing material or uncoated, and are normally in diameters from 3/32 to 1/4 in. Compositions of standard welding rods follow the specifications of the American Welding Society. Molded carbon, in sizes from 1/8 to 1 in. in diameter, is also used for arc welding. Intensarc is the trade name of the National Carbon Co., Inc., for carbon rods. Low-carbon steel rods for welding cast iron and steel contain less than 0.18% of carbon. High-carbon rods produce a hard deposit that requires annealing, but these are also used for producing a hard filler. High-carbon rods, with 0.85 to 1.10% of carbon, will give deposits with initial hardness of 575 Brinell, whereas high-manganese rod deposits will be below 200 Brinell but will work-harden to above 500 Brinell. Stainless-steel rods are marketed in various compositions. Stainless C, of the Lincoln Electric Co., is an 18-8 type of stainless steel having also 3.5% of molybdenum. Aluminweld, of this company, is a 5% silicon aluminum rod for welding silicon-aluminum alloys. Chromang, of the Arcos Co., used for welding armor plate and high-alloy steels, is an 18-8 stainless steel modified with 2.5 to 4% of manganese. In the welded condition it has a tensile strength of 80,000 to 90,000 lb. per sq. in. with elongation of 35 to 45%. Amsco welding rod, for pointing dipper teeth and for hard-facing tools, is a high-manganese steel of the American Manganese Steel Co. It is marketed in grades giving hardnesses from 500 to 700 Brinell. Toolface, of this company, is a high-speed steel rod for facing worn cutting tools. Superloy, of the Resisto-Loy Co., used for facing surfaces where extreme hardness is required, has the alloy granules in a soft-steel tube. The welded deposit has a composition of 30% chromium, 8 cobalt, 8 molybdenum, 5 tungsten, 0.05 boron, and 0.20 carbon. Tung-Alloy, Resisto-Loy, and Isorod are other hard-facing rods of the same company.

Stoodite is a high-manganese steel in the form of rods marketed by the Stoody Co. for hard facing. Chromend 9M, of the Arcos Corp., is a rod for arc-welding hard deposits. It contains 8 to 10% of chromium and 1.5 molybdenum, giving a weld with a hardness of 400 Brinell. Elkonite, of the P. R. Mallory Co., is the name of a group of welding alloys made especially for welding machines. They are, in general, sintered tungsten or molybdenum carbides combined with copper or silver, and are electrodes for spot welding

rather than welding rods. They are durable and wear resistant in service. Stellite hard-facing rods, of the Haynes Stellite Co., are cobalt-base alloys that retain their hardness at red heat and are very corrosion-resistant. The grades have tensile strengths from 47,000 to 105,000 lb. per sq. in. and Rockwell C. hardness from 40 to 52. Cor-ten is a chrome copper steel rod for welding stainless steels. Murex is a 13% manganese steel rod with 1% of carbon and 0.85 nickel. Racolloy is the name of Reid-Avery Co., Inc., for stainless and air-hardening welding rods.

**Wetting agents.** Chemicals used in making solutions, emulsions, or compounded mixtures, such as paints, inks, cosmetics, starch pastes, oil emulsions, dentifrices, detergents, to reduce the surface tension and give greater ease of mixing and stability to the solution. In the food industries chemical wetting agents are added to the solutions for washing fruits and vegetables to produce a cleaner and bacteria-free product. Wetting agents are described in general as chemicals having a large hydrophilic group associated with a smaller hydrophilic group. Some liquids naturally wet the pigments, oils, or waxes, but others require a proportion of a wetting agent to give mordant or wetting properties. Pine oil is a common wetting agent, but many wetting agents are complex chemicals. They should be powerful enough not to be precipitated out of solutions in the form of salts, and they should be free of odor or any characteristic that would affect the solution. Aerosol wetting agents, of the American Cyanamid & Chemical Corp., are in the form of liquids, waxy pellets, or free-flowing powders. Aerosol OS is a sodium salt of an alkyl naphthalene sulphonic acid. It is a yellowish-brown powder soluble in most organic solvents.

**Whale oil.** An oil extracted by boiling and steaming the blubber of several species of whale that are found chiefly in the cold waters of the extreme North and South. Whales are mammals, and are predaceous, living on animal food. The blubber blanket of fat protects the body, and the tissues and organs also contain deposits of fat. Most whale oil is true fat, namely the glycerides of fatty acids, but the head contains a waxy fat. In the larger animals the meat and bones yield more fat than the blubber. Both the whalebone whales and the toothed whales produce whale oil.

The Bluehead whales of the south, *Silbaldus musculus,* are the largest and also yield most oil per weight. The Greenland whale of the north, *Balaena mysticetus,* and the Finback whale of the south, *Balaenoptera physalus,* produce much oil. The Beluga or White whale, *Delphinapterus leucas,* and the Narwhal, *Monodon monoceros,* of the North Polar seas, produce Porpoise oil. Both species of porpoise measure up to 20 ft. in length. A 100-ft. whale will weigh about 150 tons and will yield about 27 tons of oil.

Whale oil is sold according to grade, which depends upon its color and keeping qualities. The latter in turn depend largely upon its proper cooking at extraction. No. 0 and No. 1 grades are fine pale-yellow oils, No. 2 is amber, No. 3 is pale brown, and No. 4 is the darkest oil. The oils contain oleic, stearic, palmitic, and other acids. Grade 1 has less than 1% of free fatty acids, while grade 4 has from 15 to 60% with a strong fishy odor. The specific gravity is 0.920 to 0.927, saponification value 180 to 197, and iodine value 105 to 135. The oil of the sperm whale has high content of spermaceti, and the iodine and saponification values are lower than whale oil. Whale oils of the lower grades are used for quenching baths for heat-treating steels, and also in lubricating oils. The best oils are used in soaps and candles, or for preparing textile fibers for spinning, or for treating leather. In Europe whale oil is also used in making margarine. Sod oil is oil recovered from the treatment of leather in which whale or other marine mammal oil was used. It contains some of the tannins and nitrogenous matter which makes it more emulsifiable and more penetrant than the original oil. Sperm oils are used for lubricating.

**Whalebone.** The elastic, hornlike strips in the upper jaw of the Greenland whale, *Balaena mysticetus,* and some other species. The strips are generally from 8 to 10 ft. long and number up to 600. Those from the Bowhead whale of the Arctic Ocean are the longest slabs, measuring up to 13 ft. in length and 10 to 12 in. wide at the bottom. Finback whalebone is less than 4 ft. in length. Whalebone is light in weight, very flexible, elastic, tough, and durable. It consists of a conglomeration of hairy fibers covered with an enamel-like fibrous tissue. It is easily split and is carved easily when softened in hot water. Whalebone has a variety of

uses in making whips, helmet frames, ribs, and brush fibers. Baleen is a trade name for strips of whalebone used for whips, and for products where great flexibility and elasticity are required.

**Wheat.** The edible seed grains of an annual grass of the genus *Triticum* of which there are many species and thousands of varieties. It was the basic food grain of the early civilizations of the Near East, and has remained the chief grain of the white races except in cold climates where rye grows better. The plains of the United States and Canada, Argentina, Australia, southern Russia, the Danube Valley, and northern India are the great wheat areas. The United States normally produces 15% of the wheat of the world and Canada about 10%. The types grown commercially are chiefly limited to common wheat and durum wheat. Common wheat, *Triticum vulgare,* is the chief source of Wheat flour. It has a stout head from which the grains can be separated easily. The hundreds of varieties are divided roughly into hard wheats and soft wheats, and red wheats and white wheats. The hard wheats usually have smaller grains, but are richer in proteins. Spring wheat is wheat that is sown in the spring and harvested in the late summer. Winter wheat is sown in the fall to develop a root system before winter, and is then harvested in the early summer. It is more resistant and gives a higher yield. Durum wheat, *T. durum,* has a thick head with long beards, and large hard grains rich in gluten. The plant is hardy and drought-resistant, but the flour is too glutenous for American bread, and is much used for macaroni and in mixtures. Seven classes of wheat are designated in the official grain standards of the U.S. Department of Agriculture: Hard red spring wheat; Durum wheat; Red durum wheat; Hard red winter wheat; Soft red winter wheat; White winter wheat; and Mixed wheat. Each class permits mixtures of varieties. The minimum test weight of wheat is required to be 60 lb. per bu. Most of the wheat production is used for making edible flour, and 4.5 bu. of wheat produces a barrel of flour. Wheat is also used for making beer, and at times is employed for producing starch and alcohol. Some wheat is used for stock feed, but most of the wheat for this purpose is of lower and condemned grades. Buckwheat consists of the seed grains of the

*Fagopyrum esculentum,* a plant of the same family as the rhubarb and dock. It is native to Asia and is one of the chief foods in Russia, but is used only in mixed flours in the United States. The flour is more starchy and has less protein than wheat. It is also darker in color and has a different flavor.

**Whetstone.** Stones of regular fine grains composed largely of chalcedony silica, often with minute garnet and rutile crystals. They are used as fine abrasive stones for the final sharpening of edge tools. Whetstones are also sometimes selected, fine sandstones from the grindstone quarries. The chocolate whetstone from New Hampshire is mica schist. The finest whetstones are called oilstones. A fine-grained Honestone, known as Coticule, comes from Belgium, and is used for sharpening fine-edged tools. It is compact, yellow in color, and contains minute crystals of yellow manganese garnet, with also potash mica and tourmaline. Coticule is often cut double with the blue-gray Phyllite rock adhering to and supporting it. Scythestones are made from Ohio and Indiana sandstones, and from the schist of Vermont. Rubbing stones are fine-grained Indiana sandstones.

**White brass.** A bearing metal which is actually outside of the range of the brasses, bronzes, or babbitt metals. It is used in various grades, the specification adopted by S.A.E. being tin, 65%; zinc, 28 to 30; and copper, 3 to 6. It is used for automobile bearings, and is close-grained, hard, and tough. It also casts well. A different alloy is known under the name of white brass in the cheap jewelry and novelty trade. It has no tin, small proportions of copper, and the remainder zinc. It is a high-zinc brass, and varies in color from silvery white to yellow depending upon the copper content. An old alloy formerly used for casting buttons, known as Birmingham platina, or Platina, contained 75% of zinc and 25 copper. It has a white color but is very brittle. A yellowish metal, known as Bath metal, once widely used for casting buttons, candlesticks, and other articles, was a brass containing 55% of copper and 45 zinc. White nickel brass is a grade of nickel silver. The White brass used for castings where a white color is desired may contain up to 30% of nickel. The 60-20-20 alloy is used for white plaque castings for buildings. The high-

nickel brasses do not cast well unless they also contain lead. Those with 15 to 20% of nickel and 2 lead are used for casting hardware and valves. White nickel alloy is a cupro-nickel containing some aluminum. White copper is a name sometimes used for cupro-nickel or nickel brass.

**White gold.** The name of a class of jewelers' white alloys used as substitutes for platinum. The name gives no idea of the relative value of the different grades, which vary widely. Gold and platinum may be alloyed together to make a white gold, but the usual alloys consist of from 20 to 50% of nickel, with the balance gold. Nickel and zinc with gold may also be used for white golds. The best commercial grades of white gold are made by melting the gold with a white alloy prepared for the purpose. This alloy contains nickel, silver, palladium, and zinc. The 14-carat white gold contains 14 parts of pure gold and 10 white alloy. A superior class of white gold is made of 90% of gold and 10 palladium. High-strength white gold contains copper, nickel, and zinc, with the gold. Such an alloy, containing 37.5% of gold, 28 copper, 17.5 nickel, and 17 zinc, when aged by heat-treatment, has a tensile strength of about 100,000 lb. per sq. in. and an elongation of 35%. It is used for making jewelry, has a fine, white color, and is easily worked into intricate shapes. White-gold solder is made in many grades containing up to 12% of nickel, up to 15 zinc, with usually also copper and silver, and from 30 to 80% of gold. The melting points of eight grades marketed by Handy & Harman are from 695 to 845°C.

**White metals.** Although a great variety of combinations can be made with numerous metals to produce white, or silvery, alloys, the name usually refers to the lead-antimony-tin alloys employed for machine bearings, packings, and linings, to the low-melting-point alloys used for toys, ornaments, and fusible metals, and to the type metals. A number of white metals are specified by the A.S.T.M. for bearing use. These vary in a wide range from 2 to 91% of tin, 4.5 to 15 antimony, up to 90 of lead, and up to 8 of copper. The alloy containing 75% of tin, 12 antimony, 10 lead, and 3 copper, melts at 184°C., is poured at about 375°C., has an ultimate compressive strength of 16,150 lb.

per sq. in. and a Brinell hardness of 24. The alloy containing 10% of tin, 15 antimony, and 75 lead melts at 240°C., has a compressive strength of 15,650 lb. per sq. in. and a Brinell hardness of 22. The first of these two alloys contains copper-tin crystals; the second contains tin-antimony crystals. A white bearing metal produced by the American Smelting & Refining Co., under the name of Asarcoloy, is composed of cadmium with 1.3% nickel. It contains $NiCd_7$ crystals, and is harder and has higher compressive strength than babbitt, and a low coefficient of friction. It melts at 604°F. Thermit metal is a lead-base metal containing 0.7 to 1.5% of nickel and cadmium to hold up the lead in solution. The lead content is as high as 78%. The compressive strength is 25,000 lb. per sq. in. and the hardness 29 Brinell. One of the oldest of the American antifriction lead-base bearing metals is Magnolia metal, marketed by the Magnolia Metal Co. It contains as high as 80% of lead, with considerable antimony, but this trade name now covers a full line of bearing metals. A Bismuth-lead alloy containing 58% of bismuth and 42 lead melts at 123.5°C. It casts to exact size without shrinkage or expansion, and is used for master patterns and for sealing.

Various high-tin or reverse bronzes have been used as corrosion-resistant metals, especially before the advent of the chromium, nickel, and aluminum alloys for this purpose. Trabuk was a corrosion-resistant, high-tin bronze with about 5% of nickel. Fahry's alloy was a Reverse bronze containing 90% of tin and 10 copper, used as a bearing metal. The bearing alloy known in England as Motor bronze is a babbitt with about double the amount of copper of a standard babbitt. One analysis gives tin, 84%; antimony, 7.5; copper, 7.5; and bismuth, 1. An old alloy, used in India for utensils, and known as Bidery metal, contained 31 parts of zinc, 2 lead, and 2 copper, fluxed with resins. It was finished with a velvety-black color by treating with a solution of copper sulphate. An alloy used for dies for casting plastics contains 48% of bismuth, 28.5 lead, 14.5 tin, and 9 antimony. It is nonshrinking and has good resistance to compression.

**Willow.** The wood of the trees *Salix coerulea* and S. *alba*, native to Europe, but grown in many other places. It is best

known as a material for cricket bats made in England. The American willows are known as Black willow, from the tree S. *nigra,* and Western black willow from the tree S. *lasiandra.* The wood is also employed for making artificial limbs, and for articles where toughness and nonshrinking qualities are valued. The wood is brownish yellow in color, has a fine, open grain, and weighs about 30 lb. per cu. ft. It is of the approximate hardness of cherry and birch. Japanese willow is from the tree S. *urbaniana.* It has a closer and finer texture, and has a browner color. Black willow has a maximum crushing strength parallel to the grain of about 1,500 lb. per sq. in. Salicin, also called Salicoside and Saligenin, is a glucoside extracted from several species of willow bark of England and also from the American aspen. It is a colorless, crystalline material of the composition $(OH)_4C_6H_7 \cdot OO \cdot C_6H_4 \cdot CH_2OH$, decomposing at 201°C., and soluble in water and in alcohol. It is used in medicine as an antipyretic and tonic, and as a reagent for nitric acid. It hydrolyzes to glucose and salicyl alcohol, and the latter is oxidized to Salicylic acid, $C_6H_4(OH) \cdot COOH$.

**Wire cloth.** Stiff fabrics made of fine wire woven with plain loose weave, used for screens to protect windows, for guards, and for sieves and strainers. Steel and iron wire may be used, either plain, painted, galvanized, or rustproofed, or various nonferrous metal wires are employed. It is usually put up in rolls in widths from 18 to 48 in. Screen cloth is usually 12, 14, 16, and 18 mesh, but wire cloth in copper, brass, or monel metal is made regularly in meshes from 4 to 100. The size of wire is usually from 0.009 to 0.065 in. in diameter. Wire cloth for fine filtering is made in very fine meshes. Mesh indicates the number of openings per inch, and has no reference to the diameter of wire. A 200-mesh cloth has 200 openings each way on a square inch, or 40,000 openings per square inch. Wire cloth as fine as 400 mesh, or 160,000 openings per square inch, is made by the Newark Wire Cloth Co., by wedge-shaped weaving, although 250 wires of the size of 0.004 in. when placed parallel and in contact will fill the space of 1 in. Very fine-mesh wire cloth must be woven at an angle since the globular nature of most liquids will not permit passage of the

liquid through microscopic square openings. Where accuracy of sizing is not important, the wire fabric is made with oblong or rectangular openings instead of squares to give faster screening. High-manganese steel wire is used for rock screens. For window screening in tropical climates or in corrosive atmospheres plastic filaments are sometimes substituted for the standard copper or steel wire. Lumite screen cloth, of the Chicopee Mfg. Co., is woven of vinylidene chloride monofilament 0.015 in. in diameter in 18 and 20 mesh. The impact strength of the plastic cloth is higher than that of metal wire cloth, but it cannot be used for screening very hot materials. Lektromesh, of the C. O. Jelliff Corp., is copper or nickel screen cloth of 40 to 200 mesh made in one piece by electro deposition. It can be drawn or formed more readily than wire screen, and circular or other shapes can be made with an integral selvage edge.

**Wire glass.** A variety of glass used in building construction for windows, doors, floors, and skylights, and having woven wire mesh embedded in the center of the plate. It does not splinter or fly apart like common glass when subjected to fire or shock, and has higher strength than common glass. It is made in standard thicknesses from ⅛ to ⅜ in., and in plates 60 by 110 in. and 61 by 140 in. Underwriters' specifications call for a minimum thickness of ¼ in. Wire glass is made with plain, rough, or polished surfaces, or with ribbed or cobweb surface on one side for diffusing the light and for decorative purposes. It is also obtainable in corrugated sheets, usually 27¾ in. wide. Wire glass ¼ in. thick weighs 2.25 lb. per sq. ft. Plastic-coated wire mesh may be used to replace wire glass for hothouses or skylights where less weight and fuller penetration of light rays are desired. Cel-O-Glass, of E. I. duPont de Nemours & Co., Inc., is a plastic-coated wire mesh in sheet form.

**Wolframite.** The chief ore of the metal tungsten. Its composition is $(FeMn)WO_3$. When the manganese tungstate is low, the ore is called Ferberite; when the iron tungstate is low, it is called Hübnerite. The ore is concentrated by gravity methods to a concentrate containing 60 to 65% of tungstic oxide, $WO_3$. To extract pure $WO_3$ from the concentrate it is fused with sodium

carbonate, $Na_2CO_3$, to form Sodium tungstate, $Na_2WO_3$, which is dissolved in water. When an acid is added to the solution, the $WO_3$ precipitates out as a yellow powder. The metallic tungsten is obtained by reducing, and is then pressed into bars and sintered. Wolframite occurs usually bladed or columnar in form. It has a specific gravity of 7.2 to 7.5, a hardness of 5, a black color, and a submetallic luster. It is found in the Mountain states, Alaska, China, and Argentina, but is also widely distributed in various parts of the world in small quantities. Chinese wolfram concentrates contain 65% of tungstic oxide; the Arizona concentrates contain an average of 67%. California and Nevada concentrates are scheelite containing from 60 to 67% of tungstic oxide.

**Wollaston wire.** Any wire made by the Wollaston process of fine wire drawing. It consists in inserting a length of bare drawn wire into a close-fitting tube of another metal, the tube and core then being treated as a single rod and drawn through dies down to the required size. The outside jacket of metal is then dissolved away by an acid that does not affect the core metal. Platinum wire as fine as 0.00005 in. in diameter is made commercially by this method, and gold wire as fine as 0.00001 in. in diameter is also drawn. Wires of this fineness are employed only in instruments. They are marketed as composite wires, the user dissolving off the jacket.

**Wood.** A general name applied to the cut material derived from trees. Timber, in general, refers to standing trees, while Lumber is the sawed wood used for construction purposes. In construction work the word timber is often applied to large pieces of lumber used as beams. Wood is an organic chemical compound composed of approximately 49% of carbon, 44 oxygen, 6 hydrogen, and 1 ash. It is largely cellulose and lignin. The wood of white pine is about 50% of cellulose, 25 lignin, and the remainder sugars, resin, acetic acid, and other materials. Wood is produced in most trees by a progressive growth from the outside. In the spring when sap flows rapidly a rapid formation of large cells takes place, followed by a slower growth of hard and close cells in the summer. In some woods, such as oak, there is a considerable difference in quality and appearance between the

spring and summer woods. In some long-lived trees, such as Douglas fir, there is a difference in the strength between the outside wood with narrow rings and the wide-ringed wood of the interior or young fast-growing trees. Heartwood is the dark center of the tree which has become set, and through which the sap has ceased to flow. Sapwood is the outer, live wood of the tree; unless treated, it has low decay resistance. The grain of sawed lumber results from sawing across the annual growth rings, varied to produce different grains.

Wood is seasoned either by exposing to the air to dry, or by kiln drying. The former method is considered to give superior quality, but requires more time, is expensive, and is indefinite. Numerous tests made at the U.S. Forest Products Laboratory did not reveal any superiority in air-dried wood when kiln drying was well done. Seasoned wood, when dry, is several times stronger than unseasoned wood. The safe working stresses of the common construction woods in compression perpendicular to the grain are 900 to 1,300 lb. per sq. in. In the United States the distinction between Hardwoods and Softwoods is made arbitrarily by the class of tree, the evergreens being softwoods without reference to the actual hardness of the wood. Wood decays easily when subjected to alternate wetting and drying, unless treated with creosote or zinc chloride.

Lumber is graded from A Select, which is practically free from defects, to D Select, which contains more defects than other selects but none detracting from a finished appearance. The common grades run from No. 1 Common, with only few and tight knots, to No. 5 Common, with coarse defects such as decay, holes, and wane. The term Log designates the tree trunk with the branches removed. Balk is a roughly squared log; Plank is a piece cut to rectangular section 11 in. wide; Deal is one 9 in. wide; and Batten is one 7 in. wide. Board is a thin piece of any width less than 2 in. thick. Flitch is half a balk cut in two lengthwise. Scantling is a piece sawed on all sides. Shakes are longitudinal splits or cracks in the wood due to shrinkage or decay. Some woods, such as fir, are obtainable in immense quantities, and can thus be used for general construction. Other woods are available only in small quantities and are used for their special character-

istics. Limewood, for example, from the lime tree, *Tilia cordata,* has a fine, close grain, cutting well in all directions, and is used for carving. Wood production is one of the great industries, the world total annual production, not counting firewood, is 1.2 billion tons.

**Wood flour.** Finely ground dried wood employed as a filler and reinforcing material in molding plastics, in linoleum, and as an absorbent for nitroglycerin. It is made largely from light-colored softwoods, chiefly pine and spruce, but maple and ash flours are preferred where no resin content is desired. Woods containing essential oils, such as cedar, are not suitable. Wood flour is produced from sawdust and shavings by grinding in burr mills. It has the appearance of wheat flour. The sizes commonly used are 40, 60, and 80 mesh; the finest is 140 mesh. Grade 1, used as a filler in rubber and plastics, has a particle size of 60 mesh and a specific gravity of 1.25. Since wood flour absorbs the resin or gums when mixed in molding plastics, and sets hard, it is sometimes mixed with mineral powders to vary the hardness and toughness of the molded product. Vast quantities of Sawdust are obtained in the woodworking mills. Besides being burned as a fuel, it is also used for packing glassware, for distilling to obtain resins, and in tumbling machines for finishing metal products.

**Wool.** The fine, soft, curly hair or fleece of the sheep, alpaca, vicuña, certain goats, and a few other animals. The specific designation wool always means the wool of sheep. Sheep's wool is one of the most important commercial fibers. It is used for the production of a great variety of Woolens, or wool fabrics under general trade names such as Flannel, Cheviot, Serge, Broadcloth, and Tweed. Worsteds are wool fabrics made from combed-wool yarn, usually from long, smooth wool. Wool is also employed for packings and for insulation, either loose or felted.

Wool quality is by fineness, softness, length, and scaliness. Fiber diameters vary from 0.0025 to 0.005 in. Long wools are generally heavy. Fibers below 3 in. in length are known as Clothing wool, and those from 3 to 7 in. are called Combing wools. Long wools are fibers longer than 7 in. Fleece wool is the unscoured fiber. It

may contain as high as 50% of grease and dirt, but this is the form in which wool is normally shipped because it then has the protection of the wool fat until it is manufactured. Wool is very absorbent to moisture and will take up about 33% of its weight of water. Carpet wools are usually long nonresilient fibers from sheep bred in severe climates, such as the Mongolian wool. The only breed of sheep developed for wool alone is the Merino. In Australia the Corriedale and the Polworth sheep are dual-purpose animals for wool and meat.

Wool differs from hair in fineness and in its felting and spinning properties. The latter are due to the fine scales on the wool fibers. The finest short-staple wool has as many as 4,000 scales to the inch. The average on long-staple wool is about 2,000 scales per in. These scales give to the wool the cohesive qualities. Some animals have both wool and hair, while others have wool only when young. There is no sharp dividing line between wool and hair. The finest of the sheep wools come from the Merino sheep, but these vary according to the age and breeding of the animal. The Lincoln sheep produces the longest fiber. It is lustrous but very coarse. Luster of wool depends upon the size and smoothness of the scales. Crimpiness in wool is due to the open formation of the scales. A fine merino will have 24 crimps per inch; a coarse crossbred will have only 6 per inch. Strength of wool fibers often depends upon the health of the animal and the feeding. One quarter of the world production of wool is in Australia. Argentina ranks second in production, with the United States third. New Zealand, Uruguay, Russia, and England are also important producers. England is the center of wool-sheep breeding, with more varieties than any other country. In general, warm climates produce fine wools, and hot climates produce thin, wiry wools, but the fundamental differences come from the type of animal and the feeding. The Recovered wool from old cloth was originally called Shoddy, but the name has an opprobrious signification in the United States, and is not used by manufacturers to designate the fabrics made from shoddy. It is used in mixtures with new wool for clothing and other fabrics. Extract wool is shoddy that is recovered by dissolving out the cotton fibers of the old cloth

with sulphuric acid. Short fibers of shoddy, less than ½ in., are known as Mungo fibers. They are used in woolen blends to obtain a napped effect.

**Wormseed oil.** An essential oil from the seeds and leafy parts of the annual plant *Chenopodium anthelminticum*, native to the West Indies but grown chiefly in Maryland and in the Central states. The oil is also known as Baltimore oil. It is used in medicine for treating intestinal worms. The active constituent is Ascaridole of which the oil contains 65%. U.S.P. oil has a specific gravity of 0.955 to 0.977. An ancient drug of this class which is still important is Santonin, an alkaloid extracted from the unopened flower heads of the Levant wormseed, *Artemisia cina* of Turkestan and the Near East. It is used as a specific for worms for human and animal treatment. Wormwood oil is obtained by distillation from the dried leaves and tops of the perennial herb *A. absinthium*, native to the Mediterranean countries and grown in the North Central states. It is used in medicinal preparations for fevers but is a dangerous drug. It is also used for flavoring the liqueur Absinthe, but its use is forbidden in many countries.

**Wrought iron.** The commercially pure iron resulting from the reduction of the carbon in cast iron. It is obtained by melting white cast iron and passing an oxidizing flame over it. The iron is left in a pasty condition full of holes, and is then rolled or hammered to unite it into one mass. Wrought iron as thus made has a fibrous structure, with fibers of slag extending through the iron in the direction of rolling. The commercial rolled iron has an average elastic limit of 30,000 lb. per sq. in., ultimate strength of 50,000 lb. per sq. in., elongation of 35%, and Brinell hardness of 100. Merchant bar iron is an old name of bars or rods of wrought iron which were made by the faggoting and forging process. Wrought iron has less than 0.12% of carbon, usually 0.08%. Wrought iron is also produced by the Aston process of shotting Bessemer iron into a ladle of molten slag. The sudden cooling breaks the iron up into small globules and the slag absorbs the gases, thus replacing the expensive puddling process. The shotted ball is rolled similarly to hand-puddled iron.

The quality grades of wrought iron refer to the amount of

working that the metal has received. When the word iron is used alone, it generally refers to wrought iron. Wrought iron is chiefly for rivets, staybolts, water pipes, tank plates, and general forged work. For other uses it is now largely replaced by ingot iron or steels containing only slight percentages of carbon, because of the greater uniformity, and freedom from slag cracks.

Iron fibered steel is a name of the Edgar Allen Steel Co., Inc., for rolled soft steel toughened with fine iron wire worked into it. Staybolt iron is an old name for tough and ductile iron made from charcoal iron or from carefully puddled iron, and used for forgings. Lewis iron, of Joseph T. Ryerson & Son, Inc., for staybolts and structural parts, is a highly refined, hand-puddled iron with a tensile strength up to 52,000 lb. per sq. in. and elongation of 30%. Swedish wrought iron, sometimes still called Norway iron because it was brought to America in Norwegian ships, is a charcoal iron made from high-grade ore, and it has great ductility and toughness. It contains 0.02 to 0.06% of carbon, 0.02 to 0.04 silicon, 0.04 to 0.07 phosphorus, 0.005 to 0.01 sulphur, and a trace of manganese. Swedelec, of the A. Milne Co., is a Swedish charcoal puddled iron produced in a Lancashire hearth and rolled into a soft product. It is ductile and has high magnetic permeability and low hysteresis loss, and thus is suitable for transformer cores. Swedish Lancashire iron has a fibrous structure, a tensile strength of 40,000 lb. per sq. in. and elongation of 33%.

**Ylang ylang.** Called Cananga oil in the East Indies. An essential oil distilled from the flowers of the *Canangium odorata,* a tree cultivated in the East Indies, Madagascar, and the Philippines. The oil contains linalol and geraniol, and is used in soaps and in perfumery. From 125 to 150 lb. of flowers are obtained from a tree, and about 400 lb. are required to produce 1 lb. of oil. Another famous perfume oil that rivals ylang ylang in fragrance is Champaca, distilled from the flowers of the large tree *Michelia* champaca, of southern Asia.

**Yucca fiber.** The fiber obtained from the leaves of a number of desert plants of the genus *Yucca* of the lily family native to Southwestern United States and northern Mexico. The fiber is similar to fibers from agave plants and is often confused with

them and with istle. The heavier fibers are used for brushes, and the lighter fibers are employed for cordage and burlap fabrics. In Mexico the word Palma designates yucca fibers and grades of istle as well as palm-leaf fibers. Palma samandoca is fiber from the plant *Samuela carnerosana,* the Date yucca. It is also called Palma istle. Palmilla fiber is from the *Yucca elata.* Palma pita is a fiber from the *Y. treculeana.* Pita fiber used for coffee bags in Colombia and Central America is from a different plant. Other yucca fibers come from the plants *Y. glauca, Y. baccata,* and *Y. gloriosa.* Some varieties of the *Y. baccata* yield also edible fruits. The roots of species of yucca yield saponin which is also obtained as a by-product in extracting the yucca fiber.

**Zinc.** A bluish-white metal, symbol Zn. When cast into slabs it is often called spelter. It is obtained chiefly from the mineral sphalerite. Zinc is hard and brittle, and has a highly crystalline structure when broken. It melts at 787°F. and boils at 1661°F. The specific gravity is 7.1. At about 250°F. it is ductile and can be rolled into thin sheets. The tensile strength cast is 9,000 lb. per sq. in., with elongation of 1%; the rolled metal has a strength of 24,000 lb. per sq. in. with elongation of 35%. The coefficient of expansion is 0.0000183. Zinc casts readily. On exposure to the air the metal becomes coated with a film of carbonate, and is then very resistant to corrosion. Zinc is employed for galvanizing iron and steel, and in electric batteries. It is also used in sheet or corrugated-sheet form for roofing and siding in building construction. For this use it is hardened with a small amount of copper or other element. Zilloy, of the New Jersey Zinc Co., is the name of a zinc alloy in the form of corrugated sheets, for roofing and siding and for drawn and formed parts. It has higher strength than rolled zinc. The alloy contains 1% of copper and minute quantities of cadmium and magnesium. Rolled zinc, for making sheet-metal parts, comes in standard gage thicknesses of pure zinc. Zinc sheet is widely used for stamping decorative articles, especially in the form of prefinished metal. As zinc and zinc-base alloys are self-annealing, they require no annealing between difficult bendings. Zinc is an important metal for

alloying with copper in making brasses. Zinc dust, zinc sulphide, and zinc oxide are used for paint making.

The highest grade of commercial zinc is 99.99%. This grade is used in making die castings and for some brass making. Grade A, or high-grade zinc, however, usually runs 99.8% pure, and Grade B, or intermediate, is 99.35% pure. Brass special is 98.7% pure. Zinc for brass making does not contain more than 0.60% of lead and 0.03 iron. Larger amounts of lead cause cracking. The Grade D, or Prime western zinc, contains 98% of zinc with lead up to 1.60% as the chief impurity. It is the grade used in galvanizing. Bunker Hill zinc, of the Sullivan Mining Co., is an electrolytic zinc of very high purity. Zinc comes in slabs of about 50 lb. each, rolled sheets, plates, and in ribbon with the grain in one direction. Mossy zinc, used in the making of face brick to obtain various color effects, is a disintegrated metallic zinc made by pouring the molten metal into water. The grade known as Feathered zinc is of small grain size.

**Zinc-base alloys.** This term now refers usually to alloys of about 92% of zinc with aluminum, copper, and other elements, used for die castings. One of the earliest die-casting alloys, known as Salge's bronze, contained 84% of zinc, 10 tin, 4 copper, 1 lead, and 1 antimony. Sorel's alloy, which was early used for casting small statues and novelties, was high in zinc with only a small amount of copper and about 1% of iron. It was prepared by adding zinc and iron to brass. The old Fontainemoreau bronze, or Reverse brass, widely used before the use of aluminum alloys and before the development of the modern zinc-base alloys with less copper, was an alloy with 90 to 92% of zinc, 7 to 8 copper, and sometimes lead and iron. The older die-casting alloys with considerable tin have been replaced by those with aluminum and copper, as the tin alloys have very low strength and were brittle. The alloys produced by the New Jersey Zinc Co. under the name of Zamak are in three grades containing 4.1% of aluminum. Zamak 2 has 2.7% of copper and 0.03 magnesium, Zamak 3 has no copper and 0.04% magnesium, and Zamak 5 has 1% of copper and 0.03 magnesium. The iron is less than 0.075%, the lead and cadmium below 0.003%, and the tin below 0.001%. Zamak 2 is

noted for hardness and tensile strength; Zamak 3 for impact strength and retention of dimensions; and Zamak 2 and 5 are noted for resistance to corrosion. The tensile strengths range from 40,000 to 48,000 lb. per sq. in., with elongation of 3 to 5%, and hardness of 74 to 83 Brinell. The specific gravity is from 6.6 to 6.7, and melting points 715 to 718°F. Apex zinc alloy, of the Apex Smelting Co., has about the same composition. The zinc-base alloys are now fairly closely standardized, but may vary in small proportions of elements, and are sold under many trade names in the cast articles, such as Miller metal, used by the Miller Co. for casting lamp and ornamental parts. Di-Metal No. 3, of the American Smelting & Refining Co., has 96% of zinc and 4 aluminum. It has high strength and hardness, but when high dimensional stability is needed grade No. 2 is used. It contains 93% of zinc, 4 aluminum, and 3 copper.

Zinc-base alloys are also used for bearings. They have lower antifriction properties, but have high compressive strength and are less expensive than tin alloys. An alloy produced by the Lumen Bronze Co., containing 86% of zinc, 10 copper, and 4 aluminum, has a compressive strength of 75,000 lb. per sq. in., Brinell hardness of 116, and low coefficient of friction. Ehrhard's bearing metal has 2.5% of aluminum, a small amount of tin to form copper-tin crystals, about 1% of lead and 10 copper, with the balance zinc. An alloy known as Fenton's alloy contains 80% of zinc, 14 tin, and 6 copper. It is used for high-speed bearings with low pressure. Binding metal, for wire-rope slings, is a hardened zinc alloy. A binding metal used by the Pennsylvania Railroad has 93.5% of zinc, 2.8 tin, and 3.7 antimony.

The War bronze used for bearings to replace bronze when copper was scarce was a zinc alloy containing 5% of copper and 2 aluminum, with sometimes a very small amount of tin. A substitute low-aluminum alloy for the standard 4% aluminum zinc-base alloy contains 1.5% of aluminum, 1 copper, and 0.03 magnesium. It has a tensile strength of 40,000 lb. per sq. in., and elongation of 6% as cast. Leddel alloy is a bearing metal containing 90% of zinc, 5 copper, and 5 aluminum. Hartzink is a German alloy hardened with 5% of iron and 2 to 3 lead. Iron forms with zinc chemical compounds, $FeZn_7$ and $Fe_3Zn_{10}$ crystals,

and even small amounts of iron in zinc will reduce malleability. Alloys containing more than 1% of iron are brittle, but the brittleness is not so marked when the copper content is high. Germania bearing bronze, with about 1% of iron, has 80% zinc, about 10 tin, and slightly less than 5% each of copper and lead. Pattern metal, for casting gates of small patterns, may be any brass made with high percentage of zinc and some lead.

Manganese-zinc alloys are high-strength brasses containing a high percentage of manganese. An alloy containing 60% of zinc, 15 copper, and 25 manganese has a tensile strength of 100,000 lb. per sq. in. It can be extruded readily. It has a bright silver color very resistant to tarnishing.

A zinc alloy of another class is Eraydo, of the Illinois Zinc Co. It is a patented material composed of zinc, copper, and silver, and is used for radio shields and condenser frames. It has the property of cutting off induction of stray currents from coils and tubes. The tensile strength is 50,000 lb. per sq. in., and it is about 20% lighter in weight than copper. Zam metal is an alloy of zinc with aluminum and mercury produced by the Hanson-Van Winkle-Munning Co. for zinc-plating anodes. It has the property of being free from acid attack until the electric current passes through it.

**Zinc chloride.** Also called Butter of zinc, and originally known as Spirits of salts. A white, crystalline, poisonous substance of the composition $ZnCl_2$, used as a soldering flux, for wood preserving, in dry-cell batteries, and in vulcanizing fibers. It has a specific gravity of 2.91 and melts at 262°C. It is soluble in water and in alcohol. It is made by the action of hydrochloric acid on zinc.

**Zinc chromate.** Also called Zinc yellow and Buttercup yellow. A yellow pigment stable to light and sulphur fumes, but with lower tinting strength than chrome yellow. It is a crystalline powder of the composition $4ZnO \cdot 4CrO_3 \cdot K_2O \cdot 3H_2O$ and specific gravity 3.4 to 3.7. It is used for mixing with Prussian blue to form greens, and the paler shades are used as fine color pigments in printing inks. Zinc bichromate, $ZnCr_2O_7$, is an orange-yellow powder used as a pigment. Zinc chromates are made by reacting zinc oxide with chromate solutions.

**Zinc ores.** The metal zinc is obtained from a large number of ores, but the average zinc content of the ores in the United States is only about 3%, so that they are concentrated to contain 35 to 65% before treatment. The sulphide ores are marketed on the basis of 60% zinc content, and the oxide ores on the basis of 40% zinc content. Sphalerite, or Zinc blende, is the most important ore and is found in quantities in Missouri and surrounding states, and in Europe. Sphalerite is a zinc sulphide, ZnS, containing theoretically 67% of zinc. It has a massive crystalline or granular structure, and hardness of about 4. When pure, its color is white; it colors yellow, brown, green, to black with impurities. The ores from New York state are ground and concentrated by flotation to an average of 58% of zinc and 32 sulphur, which is then concentrated by roasting to 68% of zinc and 1 sulphur. It is then sintered to remove lead and cadmium, and finally smelted with coke and the zinc vapor condensed. The Silesian zinc blende, known as Wurtzite, contains 15% of zinc, 2 lead, and some cadmium. Calamine is found in New Jersey, Pennsylvania, Missouri, and in Europe. It is the ore that was formerly mixed directly with copper for making brass. The ore usually contains only about 3% zinc, and is concentrated to 35 to 45%, and then roasted and distilled. Calamine is Zinc silicate, $2ZnO \cdot SiO_2 \cdot H_2O$. It is a mineral occurring in crystal groups of a vitreous luster, and may be white, greenish, yellow, or brown. The specific gravity is 3.4 and hardness 4.5 to 5. It occurs in Arkansas with Smithsonite, a zinc carbonate ore, $ZnCO_3$. Franklinite is an ore of both the metals zinc and manganese. Its approximate composition is $(FeZnMn)O \cdot (FeMn)_2O_3$, but it shows wide variation in the proportions of the different elements. It is found in the zinc deposits of New Jersey. The zinc is converted into zinc white, and the residue is smelted to form spiegeleisen. The mineral franklinite occurs in massive granular structure with a metallic luster and an iron-black color.

The ore Zincite is used chiefly for the production of the zinc oxide known as zinc white employed as a pigment. Zincite has the composition ZnO, containing theoretically 80.3% of zinc. The mineral has usually a massive granular structure with a deep-red to orange streaked color. It may be translucent or almost opaque. It is found in New Jersey. Willemite is a zinc ortho-silicate,

$Zn_2SiO_4$, containing theoretically 58.6% of zinc. Manganese often replaces part of the zinc, and it is then called Troostite. Its structure is massive or granular, and it has a vitreous luster. The color is white, yellowish green, or blue when pure, but with manganese it becomes apple green, red, or brown. It may be transparent or opaque. The hardness is about 5.5, and the specific gravity about 4. Willemite is found in various places in the United States. The crushed ore is used in fluorescent glass.

**Zinc powder.** Also known as Zinc dust, although zinc dust is more specifically only the powder produced by the redistillation of zinc drosses. A finely divided gray metallic zinc powder used in paints for the protection of iron and steel against corrosion. An important use, also, is for coating metals by the sherardizing process. It is usually made up with boiled or raw linseed oil, turpentine, and a drier such as manganese resinate. It may also be mixed with 10 to 25% of zinc oxide, to aid in keeping the powder in suspension, to harden the film, and to brighten the color. Zinc powder is a condensed zinc vapor, or an atomized zinc, and is of such fineness that 90 to 95% should pass through a 325-mesh screen. Standard zinc dust contains 96% of metallic zinc and the balance zinc oxide. Zinc powder is easily wetted by oils or lacquers, and does not have to be ground in a paint mill. The specific gravity is 7.06. The paints made with the powder are resistant to weathering. Merrillite is a zinc dust of high purity of the Alloys Co. used to precipitate gold and silver by the cyanide process. Zinc dust is also used as a reducing agent, in rust inhibitors, and in lubricants.

**Zinc sulphide.** A white powder of the composition $ZnS \cdot H_2O$ and specific gravity 3.92, used as a paint pigment, for whitening rubber products and for opacity in paper. About 55% in rubber makes an ivory-colored rubber. Cryptone is a trade name of the New Jersey Zinc Co. for various types of zinc sulphide pigments, varying from 98% pure zinc sulphide to mixtures with barium sulphate, calcium sulphide, or titanium dioxide.

**Zinc white.** The common name of Zinc oxide, ZnO, used as a paint pigment and as an activator and a whitener in rubber. In

automobile tires it aids in reinforcing and preventing tread cracking. It also aids heat dissipation. It is also called Chinese white. It is made directly from the ore, the mineral zincite, by reducing it in a special furnace with coal and an excess of air. It is also made from metallic zinc by vaporizing and burning the zinc in the air. This method is called the French process. Zinc white is a water-insoluble white powder, having a specific gravity of 5.66. As a pigment it is unaffected by the action of sulphides, and is thus used as an Inside white in paints and enamels. It is also employed in paints for exterior use as it resists the action of ultraviolet rays and retains its whiteness although it is not as whitening as lithopone. Zinc oxide has high electrical resistance, and it is put in insulating cable compounds. It is also used to give color, opacity, and finish to papers. Leaded zinc oxide is a pigment consisting of zinc oxide and basic lead sulphate. It may contain from 3 to 25% of lead, but oxide for use in rubber must be lead-free as the lead combines with the sulphur. Zinc-white paste should contain 90% of the pigment and 10 of linseed oil. Another white zinc compound, used for flatting paints, is Zinc stearate. It has the composition $Zn(C_{18}H_{35}O_2)_2$, and is a white, agglutinating powder, marketed in 300 and 325 mesh. It is also used as a filler in rubber. A U.S.P. grade of 325 mesh is used in cosmetics in face powders. Zinc peroxide is a white powder of the composition $ZnO_2$ used in medicine and dental pastes. It contains 8.5% of active oxygen which is released in contact with body tissue.

**Zirconia.** Zirconium oxide, a white crystalline powder having the composition $ZrO_2$, a specific gravity of 5.75, hardness of 6.5, and refractive index of 2.2. Its chief source is from the mineral Baddeleyite, which comes from Brazil. The melting point is 5350°F. when pure, and it is the most heat-resistant of the commercial refractories. The melting point of the commercial material is usually given as about 5000°F. It is used as a refractory and in some quartz ware, as an opacifier in ceramics, and for crucibles for melting aluminum, platinum, and other nonferrous metals for temperatures up to 3500°F. Tamco zirconium oxide refractories, of the Titanium Alloy Mfg. Co., are for temperatures up to 2300°C. Zirconia is also used as a pigment in plastics. It

has high ultraviolet repelling quality. Its high melting point, chemical stability, and hardness are valuable properties for a refractory, but zirconia bricks are subject to structural disintegration by cracking by alterations in the crystals unless other metallic oxides are added. These lower the softening point somewhat. Since molten aluminum does not wet zirconia and does not react with it, zirconia bricks are much used to line aluminum furnaces. Zirconia is also the chief source of the metal zirconium.

The type of baddeleyite of Brazil known as Brazilite contains 80% of zirconia; the mineral known as Zirkelite, or Zirconium sand, which is a Zirconium silicate, contains up to 50%. Zircon from the beach sands of Florida is Zirconium silicate, or Zironite. $ZrO_2 \cdot SiO_2$ is used as a refractory for firebricks and crucibles, and as an opacifier in ceramic glazes. The melting point is 4622°C., specific gravity 4.65, hardness 7.5, and it has a white color. The white Zircon sand from India contains less than 1% of iron, with a zirconium dioxide content of 62%. The naturally-concentrated beach sands of New South Wales average 74% zircon.

When zirconia is used as a refractory with other material as a binder, the melting point is lowered. But zirconia may be bonded with itself by grinding 20% of the material to 200 mesh. This ground ore becomes colloidal with water. The coefficient of expansion of zirconia is very low, 0.00000084, and dishes made of it can be plunged white hot into cold water without breaking. The material is also resistant to acids and alkalies. The coefficient of refined zircon is 0.0000045 in. per in. per deg. C. up to 1400°C. compared with 0.0000124 for chrome brick. Zircon has good heat-shock resistance and is also a good electrical insulator at high temperatures. It is thus valued for electrical heater units. Zircon is also used in mold facings, and as an abrasive. Clear zircon crystals are valued as gem stones because they have the greatest brilliance next to the diamond. The colorless stones are called Matura diamonds, and the yellow-red are known as Jacinth. By heating zirconia with carbon a Zirconium carbide, $ZrC_2$, is formed, which is a very hard abrasive. Zirconium oxychloride, $ZrOCl_2 \cdot 8H_2O$, is a cream-colored powder soluble in water used as a catalyst, in the manufacture of color lakes, and in textile coatings.

**Zirconium.** An elementary metal, symbol Zr, silvery white in color, having a specific gravity of 6.4 and melting point about 3000°F. It occurs chiefly in the minerals zircon and baddeleyite. It is more abundant than nickel but is difficult to reduce to metallic form as it readily combines with oxygen, nitrogen, carbon, and silicon. Because of its great affinity for oxygen it is used as an oxygen getter in electric bulbs, and as a corrosion inhibitor in mercury boilers. The metal is not attacked by nitric or sulphuric acid, but is dissolved by hydrofluoric acid. It has been alloyed with nickel for cutting tools and in copper alloys. It does not make copper sluggish as does titanium, and bronze containing zirconium can be poured freely. Small amounts of zirconium in copper gives age-hardening, 1% of zirconium giving a tensile strength of 70,000 lb. per sq. in. without appreciably lowering the electrical conductivity of the copper. Zirconium copper is a master alloy used to deoxidize and give hardness and strength to brasses and bronzes. It is marketed in two grades, with 12.5 and 35% of zirconium, in bars and lumps. Nickel zirconium is a master alloy used for deoxidizing and adding zirconium to nonferrous alloys, and for degasifying nickel. A nickel-zirconium of the Electro Metallurgical Co. has 40 to 50% of nickel, 25 to 30 zirconium, 10 aluminum, and a maximum of 10 silicon and 5 iron. Zirconium is also added to steel, and has a powerful deoxidizing action. It also combines with the sulphur and reduces hot-shortness in the steel, and also carries off the nitrogen, making a more ductile steel. Zirconium steels have uniform grains, are ductile, shock-resistant, and fatigue-resistant. Steels can be produced without manganese by the use of zirconium. When zirconium is present in steel in amounts above 0.15%, it forms zirconium sulphide and aids the rolling. This compound also aids machinability in stainless steels.

Zirconium metal is marketed in the form of wire, sheet, foil, and a powder of 300 mesh. Zirconium powder is very reactive, and it can be stored and shipped only in moist condition to be dried just before use. It is also marketed as Zirconium hydride powder of 300 mesh. This powder, $ZrH_2$, contains 1.5 to 2% of combined hydrogen which is driven off before use by heating the powder to 300°C. For making sintered metals, alloy powders are used. Zirconium copper, containing 35% Zr, Zirconium nickel, containing

35 to 50% Zr, and Zirconium cobalt, containing 50% Zr, are marketed by the Metal Hydrides, Inc., as alloy powders of 200 and 300 mesh for making sintered parts. Zirconium nickel and Zirconium cobalt are used for making magnet alloys.

**Zirconium-ferrosilicon.** An alloy of zirconium with iron and silicon, employed for adding zirconium to steel and to special ions. A typical analysis, as given by the Electro Metallurgical Sales Corp., is 9 to 12% of zirconium, 40 to 47 silicon, 40 to 45 iron, and 0.20 max. carbon. Zirconium deoxidizes the steel, carries off much of the sulphur and nitrogen, and makes a more uniform steel capable of withstanding shocks. When it is desired to add considerable amounts of zirconium without an excessive increase of silicon, a Silicon-zirconium alloy, containing higher percentages of zirconium, is used. These alloys contain from 35 to 40% of zirconium, and about 50 silicon, with less than 10 iron. SMZ alloy, of the Electro Metallurgical Co., is a Silicon-manganese-zirconium master alloy used for making high-strength cast iron and reducing chill effects in the iron without leaving residual zirconium in the cast iron. Grade 1 has 72 to 78% of silicon, 6 to 8 manganese, 6 to 8 zirconium, and 5 iron. Grade 2 has less alloying elements and 20% of iron.

# PART II

## *Elements of Materials Economics*

### INTRODUCTION

Materials economics, or the procurement and utilization of the raw materials of the world, is a profession, that is, a deductive art. It is a profession founded on positive science, and does not embrace the compromises, expediencies, and charlatanisms of social and political economics. Like the true professions, such as medicine, materials economics seeks to eliminate personal opinions and requires basic knowledge of the sciences upon which it depends. The scope of the contributing sciences is wider than for many other professions, and includes mineralogy, botany, metallurgy, agriculture, chemistry, physics, zoology, forestry, and geography. But the materials economist need not be a specialist in any of these any more than the medical doctor need be a chemist. But he must be able to finger the basic elements of all of these, as the player learns to finger instinctively the keys of an instrument, in order to give his best attention to the broader scope of the art.

Behind materials economics in our modern industries, with the thousands of raw materials interlocked in their uses in hundreds of varied industries, there is a host of variables, all of which must be fingered automatically before the engineer or the procurement official can be an artist in his judgments of the broad applications. Industrial materials come from every corner of the world, from minerals and earths, from plant leaves, stems, bark, roots, and from every part of a varied animal life, from the diverse life of the seas, from the air, and from the artificial or synthetic combination of any or all of these.

The materials economist must have an elemental knowledge of science to see why materials act as they do. He must fix in his mind the value of certain physical characteristics because everything is relative and no characteristic will have a tangible meaning unless it compares in his mind with a known characteristic. He must actually handle materials of different kinds, knowing the characteristics by sight and touch. He must know something of the important industries in order to form judgments of the relative values of the materials in use. He must have the economic geography of the world so implanted in his mind that he knows the relative positions of the materials and the trade routes. He must know the important characteristics of the important nations of the world that produce and market materials, and the background upon which they act and upon which the supply of their materials depends.

# GEOPHYSICS OF MATERIALS

## Formation of Earth Materials

It is estimated that it took at least 100 billion years for the earth to cool from the time it left the sun to a point where life could be supported. The core of the earth, called the Centrosphere, is still a dense plastic mass, probably largely nickel and iron just as the cores of the meteors that reach the earth are nickel-iron with the other materials burned off in penetrating the atmosphere at high speed. The crust of the earth, called the Lithosphere, and the surface of the water, called the Hydrosphere, are taken arbitrarily as 10 miles thick, and contain 93% of solid matter and 7 sea water. The sedimentary rocks and soil are only within the space of a thin veneer, igneous rocks forming at least 95%.

The height of the Atmosphere surrounding the lithosphere and hydrosphere is more than 200 miles above sea level as proved by the phenomena of the aurora borealis and of meteors, but the barometer proves that more than half of the air, by weight, reaches not more than 3.4 miles above sea level. As the distance from the earth increases, the air becomes colder, and because of the swift rotation of the earth the heavier colder air is thrown out in a ring around the equator. Animal and plant life are near the bottom of an atmospheric ocean with the pressure of the air at sea level 14.7 lb. per sq. in. Plant life derives its carbon, and animal life its oxygen, largely from the atmosphere, some of which is again returned to the air. Anaerobe bacteria release oxygen from solid materials. A balance of carbon in the air is maintained partly from volcanoes. The amount of carbon dioxide fixed at all times in the cellulose of plant life is about half the amount in the atmosphere. A considerable amount of metallic and nonmetallic elements falls continuously on the earth in the form of dust from meteorites. About one meteorite per 100 sq. mi. per year strikes the earth, most of its elements being diffused as hot gases in the atmosphere with only the residual core reaching the ground, though 1-ton meteorite cores are common.

The oceans cover 70% of the surface of the earth with an average depth of about 2 miles. The greatest depth is 34,219 ft., in the Pacific Ocean east of the Philippines, at which depth the pressure is more than 7.5 tons per sq. in. Water on the land areas sinks to a water table, seeping toward the seas. A few points on the land surface are below sea level, and here any water evaporates. Below the water tables the water gradually disappears until the deep mines are dry and dusty. The water in and on the land areas of the earth, not counting the seas, is equivalent to a sheet of water 225 ft. in depth over the continental areas. There is a third as much water underground as there is in all the oceans, and the simultaneous cessation of rain on all parts of the earth for even a

relatively short period would cause such a rise in the surface of the oceans as to cover all port cities. Actually, because of a balance of precipitation over the land surfaces, the changes in ocean levels have been slight. The volume of common salt in sea water is sufficient to cover the whole surface of the land to a depth of 110 ft. There are also enormous quantities of bromine, iodine, magnesium, potassium, and about 20 other elements in the sea water.

Temperatures increase below the ground surface at a little more than 1°C. for each 100 ft. At 9,000 ft. the temperature is theoretically the boiling point of water, but varies at different places. In the gold mines at Bendigo, Australia, the rock temperature at 4,600 ft. is 112°F. and the water is 114°F. Pressure increases at increasing depths in the earth. At 11 miles it is 70,000 lb. per sq. in., with a temperature of more than 550°C., and at increasing depths the rock is plastic.

The sway or tipping of the earth in its annual path about the sun, which brings the direct rays of the sun to a point 23½° north of the equator in June and 23½° south in December, is responsible for the seasonal climates. These are relatively uniform, because the larger oscillation of the earth which causes the advance and retreat of polar ice is too slow to make perceptible differences, this movement being complete in about 40,000 years. The latest ice age in Europe and North America reached its peak, with an advance of ice to about the latitude of New York City, about 12,000 B.C. The accelerated melting of ice and the migration of forests northward began about 8000 B.C. The slowing of the earth in its rotation is likewise too slow to cause perceptible differences. This slowing is about 15 min. every 1,000 years. The Egyptian day, therefore, at the time of the building of the Great Pyramid, was 1¼ hr. shorter than the present day.

**Composition of the Atmosphere**[1]

Per cent (by volume)

| | |
|---|---|
| Nitrogen | 78.03 |
| Oxygen | 20.99 |
| Argon | 0.94 |
| Carbon dioxide | 0.03 |
| Hydrogen | 0.01 |
| Neon | 0.00123 |
| Helium | 0.0004 |
| Krypton | 0.00005 |
| Xenon | 0.000006 |

In addition, the atmosphere is always diluted with varying amounts of water vapor, dust, and smoke.

[1] U.S. Geological Survey.

## Relative World Production of Metals[1]

Previous to the World War

| Metal | Metric tons, 1938 |
|---|---|
| Steel (ingots and castings) | 107,000,000 |
| Pig iron and ferroalloys | 92,000,000 |
| Manganese | 2,500,000 |
| Copper | 1,984,000 |
| Lead | 1,704,000 |
| Zinc | 1,590,000 |
| Aluminum | 583,000 |
| Chromium | 350,000 |
| Tin | 149,000 |
| Nickel | 110,000 |
| Titanium | 100,000 |
| Antimony | 30,000 |
| Magnesium | 25,000 |
| Tungsten | 17,500 |
| Molybdenum | 16,000 |
| Silver | 9,000 |
| Quicksilver | 5,200 |
| Zirconium | 5,000 |
| Cadmium | 4,000 |
| Vanadium | 3,150 |
| Cobalt | 3,000 |
| Gold | 1,100 |
| Bismuth | 1,000 |

[1] *Mining and Metallurgy*, September, 1940.

## Average Percentage of Metals in Igneous Rocks

| Metal | Percentage | Metal | Percentage |
|---|---|---|---|
| Silicon | 27.72 | Rare earths | 0.015 |
| Aluminum | 8.13 | Copper | 0.010 |
| Iron | 5.01 | Tungsten | 0.005 |
| Calcium | 3.63 | Lithium | 0.004 |
| Sodium | 2.85 | Zinc | 0.004 |
| Potassium | 2.60 | Columbium, Tantalum | 0.003 |
| Titanium | 0.63 | Hafnium | 0.003 |
| Manganese | 0.10 | Thorium | 0.002 |
| Barium | 0.05 | Lead | 0.002— |
| Chromium | 0.037 | Cobalt | 0.001 |
| Zirconium | 0.026 | Beryllium | 0.001 |
| Nickel | 0.020 | Strontium | 0.001— |
| Vanadium | 0.017 | Uranium | 0.001— |

### Relative Amounts of Engineering Materials[1]

| | | | |
|---|---|---|---|
| Aluminum | 4,000 | Nickel | 10 |
| Iron | 2,200 | Copper | 1 |
| Magnesium | 1,200 | | |

[1] Data from U.S. Geological Survey.

### Occurrence of the Elements in the Earth's Crust[1]

| Element | Percentage | Element | Percentage |
|---|---|---|---|
| Oxygen | 47.0 | Carbon | 0.2 |
| Silicon | 28.0 | Phosphorus | 0.1 |
| Aluminum | 8.0 | Sulphur | 0 1 |
| Iron | 4.5 | Nickel | 0.02 |
| Calcium | 3.5 | Copper | 0.002 |
| Magnesium | 2.5 | Lead and Zinc | 0.0001 |
| Sodium | 2.5 | Tin | 0.00001 |
| Potassium | 2.5 | Silver | 0.000001 |
| Titanium | 0.4 | All others | 0.48 |
| Hydrogen | 0.2 | Total | 100.00 |

[1] Data from U.S. Geological Survey.

### Composition of the Sea Water[1]

The average salt content of the sea is 3.5 per cent, with the salts divided as follows:

| | |
|---|---|
| $NaCl$ | 77.76 per cent |
| $MgCl_2$ | 10.88 |
| $MgSO_4$ | 4.74 |
| $CaSO_4$ | 3 60 |
| $K_2SO_4$ | 2.46 |
| $MgBr_2$ | 0.22 |
| $CaCO_3$ | 0.34 |

In addition, sea water carries perceptible quantities of the following: iodine, fluorine, arsenic, gold, silver, rubidium, copper, barium, phosphorus, manganese, lithium, lead, iron, strontium, and zinc. Ammonia is also usually present, together with free oxygen, nitrogen, and other gases, and in some seas hydrogen sulphide is also present. This does not include the mineral and organic materials carried in suspension by the water, especially near the mouths of great rivers.

[1] U.S. Geological Survey.

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# ELEMENTARY NUCLEAR PHYSICS

## Formation of the Elements

The tangible elementary materials of the earth number 92, ranging from the light gas hydrogen, Atomic No. 1, to the heavy metal uranium, Atomic No. 92, with atomic weights from 1 to 238. These are the same materials that pervade the whole universe, the solar system, stars, nebulae, and gaseous clouds.

The formation of the elements probably took place simultaneously rather than one by one, that is, within a short period compared with the length of formation of the universe. The enormity of this time can be judged from the fact that our own nebula, the Milky Way, a great wheel-shaped swarm of millions of stars to which our sun and earth belong, takes 240 million years to make one turn, and hundreds of thousands of turns were necessary in order to form the stars and planetary systems as they now exist within it. The enormous distances in space can be seen from the fact that there are millions of these wheel-shaped galaxies similar to the Milky Way, but many larger, within the relatively short space of the reach of a 100-in. telescope, or 500 million light years, one light year being 186,000 times 60 times 60 times 24 times 365 miles. It was estimated in 1946 that 11 billion galaxies would come within the reach of the 200-in. telescope. These galaxies are not isolated units, but form super-galaxy units similar to the molecular structure of materials. Our Milky Way, the two Magellanic Star Clouds, the Andromeda group, the Messier galaxy, with others, form one of these super-galaxies, or astronomical molecules.

The fixation, or freezing, of the elements began with the heaviest because the extremely large energy requirements to weld together the nuclei of the atoms of high molecular weight were gradually expended and lessened in the universe. At some distant point of time the universe was contained within a relatively small space with a density billions of times that of water and a temperature billions of times greater than normal earth temperatures. Under these conditions thermonuclear reactions of sufficient energy were possible to produce the atoms of those elements of highest atomic weight, the radioactive elements. At this point of element creation the original massive sphere of extreme density and temperature was expanding at the speed of light and was cooling. As the density and temperature decreased from the birth of uranium, the element of highest atomic weight reasonably stable at present conditions, the elements of lower atomic weights requiring less energy of formation were fixed or frozen. At about the region of nuclear freezing for the element silver, the physical conditions were critical for the freezing of all the elements of atomic weight lower than silver. The temperature at this point has been calculated as about 6 billion degrees centigrade, and the density perhaps 10 billion times that of water.

Since that time, myriads of millions of years ago, the universe has continued to expand into the incomprehensible limits of space. Hydrogen remains as the element of lowest atomic weight. Any elements below hydrogen would be relatively intangible under present conditions in the universe. All of the elements of atomic weight above uranium are very unstable at present conditions in the universe, and uranium itself and the other radioactive elements are relatively unstable and are slowly breaking down. The original energy of formation of the elements, estimated in uranium to be 5 million volts, remains pent up in the nuclear formation of the atoms. The artificial breaking of the atoms releases this energy. The artificial creation of transuranic elements, or elements with atomic weights above uranium, by the expenditure of energy on the uranium atom to increase its atomic weight, produces elements that are very unstable in the present conditions of the universe. Thus, plutonium, Atomic No. 94, made from uranium by cyclotron electronic bombardment, disintegrates relatively slowly, or can be made to disintegrate instantaneously with tremendous violence. Elements above plutonium are still more unstable.

## Elementary Structural Units of Materials

All **Material** is built up from four fundamental particles: the **Proton**, the **Neutron**, and the negative and positive **Electron**. There is apparently also another particle, the little neutron, or **Neutrino**, which is supposed to be the original tangible building unit. These particles are originally built up from the various **Rays** given off by all materials and reassembled into materials under given conditions and passing back and forth, to and from materials, at all times, and in all space. The **Photon** is a particle assumed in the theory of light. Its mass is a constant times the frequency of the light. When the energy of the photon is high it is designated as a $\gamma$ ray (gamma ray).

The units used in the chemical assembly of material are as follows:

**Element.** A substance composed of molecules with atoms all alike.

**Compound.** A substance, the molecules of which are alike, but the atoms dissimilar.

**Mixture.** A substance made up of dissimilar molecules not chemically combined.

**Solution.** A mixture, either liquid or solid, which is homogeneous to a high degree.

**Molecule.** Two or more atoms united to form a material dissimilar from the original atoms.

**Atom.** The smallest particles of an element still retaining the characteristics of the element, which cannot be broken up by ordinary chemical means.

**Ion.** A part of a molecule bearing one or more electric charges.

## The Elements

| Name | Atomic number | Symbol | Atomic weight O = 16.0000 | Melting point, deg. C. |
|---|---|---|---|---|
| Actinium | 89 | Ac | ..... | 1800 |
| Alabamine | 85 | Am | ..... | 470 |
| Aluminum | 13 | Al | 26.97 | 660.0 |
| Antimony | 51 | Sb | 121.76 | 630.5. |
| Argon | 18 | A | 39.944 | −189.3 |
| Arsenic | 33 | As | 74.91 | 814 |
| Barium | 56 | Ba | 137.36 | 704 |
| Beryllium | 4 | Be | 9.02 | 1280 |
| Bismuth | 83 | Bi | 209.00 | 271.3 |
| Boron | 5 | B | 10.82 | 2300 |
| Bromine | 35 | Br | 79.916 | −7.2 |
| Cadmium | 48 | Cd | 112.41 | 320.9 |
| Calcium | 20 | Ca | 40.08 | 850 |
| Carbon | 6 | C | 12.00 | 3700 |
| Cerium | 58 | Ce | 140.13 | 600 |
| Cesium | 55 | Cs | 132.91 | 28 |
| Chlorine | 17 | Cl | 35.457 | −101 |
| Chromium | 24 | Cr | 52 01 | 1800 |
| Cobalt | 27 | Co | 58 94 | 1490 |
| Columbium | 41 | Cb | 92 91 | 2000 |
| Copper | 29 | Cu | 63.57 | 1083.0 |
| Dysprosium | 66 | Dy | 162 46 | |
| Erbium | 68 | Er | 167 64 | |
| Europium | 63 | Eu | 152 0 | |
| Fluorine | 9 | Fl | 19 00 | −223 |
| Gadolinium | 64 | Gd | 157.3 | |
| Gallium | 31 | Ga | 69.72 | 29.78 |
| Germanium | 32 | Ge | 72 60 | 958 |
| Gold | 79 | Au | 197.2 | 1063.0 |
| Hafnium | 72 | Hf | 178.6 | 1700 |
| Helium | 2 | He | 4.002 | −271.4 |
| Holmium | 67 | Ho | 163.5 | |
| Hydrogen | 1 | H | 1.0078 | −259.2 |
| Illinium | 61 | Il | 140.0 | |
| Indium | 49 | In | 114.76 | 156.4 |
| Iodine | 53 | I | 126.92 | 114 |
| Iridium | 77 | Ir | 193.1 | 2454 |
| Iron | 26 | Fe | 55.84 | 1535 |
| Krypton | 36 | Kr | 83.7 | −157 |
| Lanthanum | 57 | La | 138.92 | 826 |
| Lead | 82 | Pb | 207.22 | 327.4 |
| Lithium | 3 | Li | 6.940 | 186 |
| Lutecium | 71 | Lu | 175.0 | |
| Magnesium | 12 | Mg | 24.32 | 650 |
| Manganese | 25 | Mn | 54.93 | 1260 |
| Masurium | 43 | Ma | 97.8 | 2300 |
| Mercury | 80 | Hg | 200.61 | −38.87 |
| Molybdenum | 42 | Mo | 96.0 | 2625 |
| Neodymium | 60 | Nd | 144.27 | 840 |
| Neon | 10 | Ne | 20.183 | −248.6 |

**The Elements.**—(*Continued*)

| Name | Atomic number | Symbol | Atomic weight O = 16.0000 | Melting point, deg. C. |
|---|---|---|---|---|
| Nickel | 28 | Ni | 58.69 | 1455 |
| Nitrogen | 7 | N | 14.008 | −210.0 |
| Osmium | 76 | Os | 191.5 | 2700 |
| Oxygen | 8 | O | 16.0000 | −218.8 |
| Palladium | 46 | Pd | 106.7 | 1554 |
| Phosphorus | 15 | P | 31.02 | 44.1 |
| Platinum | 78 | Pt | 195.23 | 1773.5 |
| Polonium | 84 | Po | ..... | 1800 |
| Potassium | 19 | K | 39.096 | 63 |
| Praseodymium | 59 | Pr | 140.92 | 940 |
| Protoactinium | 91 | Pa | 231 | |
| Radium | 88 | Ra | 226.05 | 700 |
| Radon | 86 | Rn | 222 | −71 |
| Rhenium | 75 | Re | 186.31 | 3000 |
| Rhodium | 45 | Rh | 102.91 | 1966 |
| Rubidium | 37 | Rb | 84.44 | 39 |
| Ruthenium | 44 | Ru | 101.7 | 2450 |
| Samarium | 62 | Sm | 150.43 | 1300 |
| Scandium | 21 | Sc | 45.10 | 1200 |
| Selenium | 34 | Se | 78.96 | 220 |
| Silicon | 14 | Si | 28.06 | 1430 |
| Silver | 47 | Ag | 107.880 | 960.5 |
| Sodium | 11 | Na | 22.997 | 97.7 |
| Strontium | 38 | Sr | 87.63 | 770 |
| Sulphur | 16 | S | 32.06 | 119.2 |
| Tantalum | 73 | Ta | 180.88 | 3000 |
| Tellurium | 52 | Te | 127.61 | 450 |
| Terbium | 65 | Tb | 159.2 | 327 |
| Thallium | 81 | Tl | 204.39 | 300 |
| Thorium | 90 | Th | 232.12 | 1700 |
| Thulium | 69 | Tm | 169.4 | |
| Tin | 50 | Sn | 118.70 | 231.9 |
| Titanium | 22 | Ti | 47.90 | 1820 |
| Tungsten | 74 | W | 184.0 | 3410 |
| Uranium | 92 | U | 238.14 | 1850 |
| Vanadium | 23 | V | 50.95 | 1735 |
| Virginium | 87 | Vi | | |
| Xenon | 54 | Xe | 131.3 | −112 |
| Ytterbium | 70 | Yb | 173.04 | 1500 |
| Yttrium | 39 | Y | 88.92 | 1490 |
| Zinc | 30 | Zn | 65.38 | 419.5 |
| Zirconium | 40 | Zr | 91.22 | 1700 |

The new names proposed for the elements Alabamine, Masurium, and Virginium by the scientists who first synthesized them by cyclotronic bombardment of adjacent elements are: Astatine, Technetium, and Francium, respectively.

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# ELEMENTARY GEOLOGY OF MATERIALS

## Formation and Location of Minerals

Geology and mineralogy are the sciences in which are tabulated the fundamental knowledge of the history and resources of the minerals of the earth. The two billion years represented in the five geologic eras are only a small part of the life span of the earth. It does not extend back to the time when the earth was molten, but only includes the time when the earth was not significantly different in material structure than at present, that is, to little beyond the point when there appeared the first traces of life, which point is well within the period of the fixing of the present elemental materials.

A geologist is a historian whose archives and written documents are the rocks and formations of the earth. The mineralogist is one who tabulates the elemental materials that are in the rocks and earths, and designates those which are ores, or from which materials may be extracted commercially. But to a geologist a rock or earth formation is a page from the earth's autobiography. The changes which took place, and the approximate length of time during which changes occurred, are determined by study of the types of formations and their relative size and positions, the animal and plant life as seen in fossil remains, and by the disintegration by erosions and by radioactive elements in the rocks. Geology is thus not an academic science, as the practical geologist can trace the probable location of metallic ores, petroleum, coals, and nonmetallic minerals.

There are three main types of rocks, igneous, sedimentary, and metamorphic. The igneous are the mother rocks which have carried all nonorganic mineral products from the original molten condition in the depths of the earth. Sedimentary rocks are the deposits from erosion of older rocks and from the deposits of organic matter. Metamorphic rocks are both igneous and sedimentary rocks which have been changed by intense heat and pressure within geologic times. They include the different chemical and physical changes caused by the upheavals and foldings in the earth's crust.

Compared to the amount of rock which makes up the crust of the earth, the percentage of mineral deposits that are rated as metallic ores is small. These deposits are found near large igneous intrusions, where they have formed from the molten rock as it cooled and crystallized, or from hot gases or hot aqueous solutions that came from the magma, and also at points of contact with other rocks into which the hot magma forced its way. Deposits may also be found in sedimentary rocks where they came from organisms or precipitates from the seas and from beds of decayed plant life.

The elements have played an important role in the concentration of minerals. These elements include the periods of high humidity and vio-

## Two Billion Years of Earth History [1]

| Geologic time | | Events | Rocks and economic products | Life |
|---|---|---|---|---|
| Archeozoic | Pre-Cambrian | Erosion and deposition. Vulcanism, folding of land | Conglomerates, shales, limestone, aqueous iron ore granites (for building), graphite (Canada), garnets (New Eng.) | No evid. of life |
| Proterozoic | Pre-Cambrian | Erosion and shallow seas. Vulcanism, glaciers, retreat of ice and uplift of lands | Sandstones (quartzite), limestone (marble) for building, black shale (carbonaceous slate and graphite), igneous rocks—cobalt, nickel, iron, copper, silver, gold ores—Sweden, Brazil, and Great Lakes area. Gold from Australia | First trace of life—marine |
| Paleozoic Era | Cambrian | Erosion, spread of shallow seas, uplift of land | Conglomerates, sandstones (quartz schist)—No. Central Am. shales (slate), limestone (marble), barite—So. and S.E. America | Much sea life |
| | Ordovician | Submergence of No. America. Vulcanism in N.W. Europe, So. America, China, Australia. Rise of mts. in E. No. America and W. Europe | Sandstones and shales with zinc and lead ores, oil and gas in W. and Central U.S A.; limestones, dolomite, manganese, calcium phosphate in E. and Central U.S.A. Shales, sandstones, and igneous rocks in Europe | Invertebrates |
| | Silurian | Highlands eroded, clear seas and evaporation, volcanos and folding—No. Europe to No. Africa, Greenland to No. America | Conglomerates, sandstone, shale with iron ore, oil, gas in East Interior U.S.A.; limestone, rock salt, gypsum in Central U.S.A., limestone in Europe. Igneous rocks and metamorphism | Fishes, early plants |
| | Devonian | Worldwide erosion and seas. Vulcanism in Asia, So. America, Europe. Uplift in East No. Am. and West Europe at close | Limestones, sandstones with oil and gas in Ontario, Texas, Penn., and N.Y.S.; blackshale—black phosphates in Tenn. Igneous intrusions in sediments give ores of iron, tin, copper in England and Europe | Amphibians, ferns, forests |
| | Mississippian | Wide, clear seas in No. Am. Swamps in Europe; waters evaporate. Erosion of highlands in Europe and America | Limestones—zinc, lead ores—Interior U.S.A., sandstones and shales—iron ore, oil, gas in Appalachian lowlands, sediments with coal beds—Moscow, Donetz areas, Ural Mts. Gypsum, salt, sulphur, bromine—Central U.S.A., Europe | |
| | Pennsylvanian | Slight worldwide uplift. Swamps and shallow seas in Europe, Asia, and No. America. First rise of Appalachian and Hercynian Mts. | Alternating shales, sandstones, limestones with barite, iron ore, and coal beds in Asia, West Europe, E. No. America, So. Brazil, Africa. Red sandstones with oil and gas in Central U.S.A. Limestone in Russia | Many plants, early reptiles |
| | Permian | Continued seas in Asia. Oscillating and evaporating seas in Eur. & No. Am. Swamps in Australia. Final rise of Appal. and Hercynian Mts. glaciation | Dolomite limestone in Russia. Black shale with copper ore, barite in Germany. Coal beds in Australia. Red sandstone and limestone, gypsum, salt, magnesium, and potassium salts, potash in Central U.S.A. and W. Eur. Igneous and metamorphic rocks—ore veins and deposits | Many reptiles, cold ends most life |
| Mesozoic Era | Triassic | Retreat of ice and erosion. Vulcanism in East No. Am. Shallow seas, salt lakes, and deserts, evaporating waters in Europe and No. America | Igneous rocks in red sandstones, metamorphism of shales and sandstones—feldspar, mica, copper, and iron ores. Source of diamonds in Africa. Oil and gas and copper ores in Rky. Mt. area. Salt, gypsum in Eng. and West No. Am. Limestone and coal—Sweden, So. Am., and U.S.A. | Early mammals, insects |
| | Jurassic | Sea invades Europe, Asia, and West America. Volcanos in No. America. Initial uplift of mts. on W. Am. coasts | Limestones in Texas, Mexico, England. Lithographic stone in Germany. Brown sandstones for building in East U.S.A. Coal in Hungary, Caucasus, Persia, Far East. Igneous and metamorphic rocks—ore veins—West U.S.A. | Reptiles dominant, first birds |
| | Cretaceous | Erosion of land, swamps, and flooding in No. America. Worldwide spread of seas. Worldwide uplift of land. Intense vulcanism and rise of Rocky Mts., Andes. No glacier | Sandstones—coal, oil, gas—Mid. and West U.S.A. and Canada. Clays in New Jersey, England, Belgium, Germany. Lignite, iron ore, potassium iron silicate on E. coast Am. Chalk in England, No. France, West U.S.A. Phosphates, lead, and zinc ores from limestones in Mex., Africa, Asia, So. Eur. Gold, copper, and silver ores in West Am. | Flowering plants, modern insects, end of large reptiles |
| Cenozoic Era | Tertiary | Shallow coast seas in Am. Erosion, swamps, volcanos in Central No. Am. Seas in Eur., Asia, and Africa. Lands rise, Alps, Himalayas, Caucausus, Pacific coast ranges of America | Clays, sands, lignite—East Am. coast. Phosphates of Florida. Oil, coal in N.W. Am. and Alaska. Salt and gypsum in U.S.A. and Paris basin. Limestones in Europe, Sahara, W. Indies. Igneous and metamorphic rocks—gold, silver, copper, arsenic, tellurium, antimony, borates, lead zinc ores, mercury—West U.S.A., Hungary, Mexico, New Zealand | Grasses, fruits, Anthropoids, height of large mammals |
| | Quaternary | Greatest glaciation. Land rises with retreat of ice. Present geography—erosion | Loess—carbonates, silicates, magnetite, quarts in Missouri River Basin, Asia. Gypsum in Interior U.S.A. | End of large mammals. Man |

[1] From J. B. Moulton.

lent rainfall and of periodic advance and regression of polar ice, as well as the normal erosion through the ages. During erosion, water may enrich natural deposits by dissolving out and carrying away soluble impurities, or it may form new ore veins by depositing mineral matter in the cracks of rocks as it seeps through. It may carry nonsoluble minerals, such as gold or gemstones, to placer deposits freeing them of all soluble content. Air has oxidized some materials near the surface, changing them to the alteration ores. Winds have formed some deposits of heavier materials by sifting out the softer ingredients.

Geology thus determines that mineral deposits of one type are likely to occur in rocks of one age or in deposits of certain types. It traces placers back to the original deposit. From the geologic formation it determines the probable size and depth of a deposit. From the folds of the strata it may determine where a continuation of the deposit is likely to occur in another area.

## Definitions Relating to Minerals

**Amorphous.** Without definite structure.

**Alluvium.** Fine material or sediment deposited by streams.

**Breccia.** Fragmental rock with angular components.

**Calcareous.** Containing sufficient calcium carbonate to effervesce visibly when treated with hydrochloric acid.

**Caliche.** Cemented deposits of calcium carbonate materials.

**Colloid.** Small particle size and high surface area per unit of mass. Colloid solutions are dispersed in particle state, not in molecular state like true solutions.

**Concretions.** Local concentrations of mineral compounds in other minerals.

**Detritus.** Heterogeneous mass of fragments of stone.

**Friable.** Easily crumbled in the fingers.

**Ferruginous.** Iron-bearing materials usually containing iron oxides.

**Igneous.** Rocks produced by the cooling of melted material. Those solidified beneath the surface are Intrusive rocks, or Magma. Those which flowed out and cooled on the surface are Extrusive rocks. Volcanic rocks are recent extrusive rocks, and may be called Lava.

**Marl.** Earthy crumbly deposit, chiefly of calcium carbonate and clay.

**Tufa.** A porous rock formed as a deposit from springs or streams.

**Tuff.** Rock composed of the finer kinds of volcanic detritus.

# FUNDAMENTALS IN THE PRODUCTION OF PLANT AND ANIMAL MATERIALS

## Determining Factors in the Production

About 55% of the land area of the earth is less than 1,500 ft. above sea level, and another 18% is between 1,500 and 3,000 ft. The remaining area consists of mountains above 3,000 ft. The lands below 3,000 ft. are in general the most productive in agricultural, forestal, and animal products because of the climate and better soil. But large areas of the low flatlands are in the colder climates of northern Canada and Russia with short growing seasons, or in the sandy or alkaline deserts of Asia, Arabia, Africa, Australia, and Patagonia, where production is low and restricted.

Climatic temperatures and humidity, that is, the amount of moisture in the air, are important elements in the productivity of a region. Climate in the various zones of the earth may be considered as relatively uniform as far as the earth's movement is concerned. But climates vary because of drifting air masses, and gradual to-and-fro shifting of great ocean currents. The normally fertile plains of the United States, for example, may be subjected to heavy rain precipitation when moist tropical air from the Gulf of Mexico collides with dry polar air from the western Canadian plains, or there may be periods as long as four months with no rain. Little tabulated data are yet available on the shift of ocean currents. It is believed that the to-and-fro shift of the Gulf Stream in the Atlantic Ocean makes a cycle of about a century with a notable effect on the climate of the Eastern states in that time.

Soil is a most important element of productivity. Although soils of great alkalinity are useful for producing some plants, they are a detriment to others. Acid soils will not produce some crops well, such as corn. Lack of various minerals in the soil will retard or stunt the growth of plants. Phosphorus, calcium, sulphur, boron, and other minerals must be added to the soils to produce the plants that need them. The absence of one mineral in the soil may sometimes prevent normal growth of a plant. Phosphorus, for example, is required for the production of the double sugar molecule in beets and cane. Even when the soil conditions are right, plants grown in an atmosphere deficient in carbon dioxide will be deficient in starch. The structure and color of plants, and of the animals that feed on them, may be altered if the soil lacks iron, copper, or other essential minerals. The rarer elements, such as rubidium, are sometimes required to produce some plants. Average land of good farming quality contains, per acre in 7 in. of surface, about 1 ton of nitrogen, 1 ton phosphoric acid, 10 to 20 tons potash, 5 to 10 tons lime, 4 to 5 tons magnesia, and ¼ ton sulphur. If not covered with grass this plant food material is washed out rapidly by erosions.

Temperature has an important effect upon the growth of plants and animals, and equality of tabulated mean annual temperatures is not always an indication of equality of climate. Thus, corn does not grow well if the nights are cold during a part of the growing season, though the average temperature may be the same as in the corn belt. The same species of fish will be less oily and yield less oil in warm waters than in cold waters. Oil seeds grown in hot climates tend to have more of the saturated fatty acids while those of cooler climates have increased contents of the unsaturated fatty acids such as linolenic.

While the climate and soil sets limits to what can be cultivated, the characteristics of the people who inhabit the region affect the use of the land. On the subhumid fertile neutral soils of India the natives raise cotton, while on similar areas in Africa the Buganda natives raise cattle, and on the same type of soil and with similar climatic conditions the white inhabitants of Northeastern Australia raise wheat. Another diversion from the climatic pattern is the availability of markets. In a belt across lower Brazil and Paraguay citrous fruits grow to the highest quality in superabundance with little or no effort and vast tonnages go to waste, while these fruits are cultivated with difficulty within areas in the United States not particularly adapted for a tropic plant because a ready market is available.

Vegetable and animal materials can normally be produced most economically where soil and climatic conditions suit their development, but they are often produced in less economic regions because of nearness of markets or for political reasons. Sometimes high tariffs are imposed to bring the cost of the foreign material to a point as high as the cost of the material produced in the less economic region.

Forests cover about 22% of the land area of the earth. Of this 7½ billion acres, 28% is in Asia, 28% in South America, 19.3% in North America, 10.6% in Africa, 10.3% in Europe, and 3.8% in Australia and Oceania. In the United States nearly 25% of the land is in forest, compared with 5.4% in Great Britain, 18% in France, and 27% in Germany where rigid laws have protected the forests. Wooded areas act as windbreaks, and also serve to balance atmospheric conditions and retain moisture in the soils. The ideal condition is not extensive wild forests, but well-proportioned forest areas on farms and plantations.

The conifers, or so-called softwoods, comprise 35.4% of the total forest area. Tropical hardwood forests cover about the same percentage of area. Most of the conifers are in the North Temperate Zone. About 27% of the land area of North America is forest, of which 72% is composed of conifers. In the United States 62% of the forest is coniferous and nearly 38% temperate climate hardwoods. The northern part of the continent is predominantly coniferous with evergreen trees from Newfoundland to Alaska bordering the treeless Arctic tundra. The

United States has the greatest variety of commercial woods of any of the temperate areas of the world, with more than 100 species of considerable commercial importance compared with less than 15 in Europe. The commercial forest land in the Southern pine-forest area is 40% of the total forest area of the United States, but the stand of commercial timber is less than 60% of the timber available in the big-timber forests of the Pacific states.

Although the breed or type of animal normally distinguishes the nature of the product derived from it, animal products also vary with the climate and the local feed available. Goats feeding in the semiarid regions of north-central Argentina furnish skins that make firmer and stronger leather than that produced from skins of the same type of goat feeding on the rich pampas. Some breeds of sheep yield soft wool while others yield wiry wool, and some breeds yield more and better meats, but climate and feeding may vary all of these. Cattle grown on semiarid ranges may be shifted at a certain age to richer grasslands for development before marketing. The overfed hogs of the prairies of the United States and Argentina yield more than twice the amount of lard obtained from the hogs grown in Canada for bacon. The semiwild hogs of the cold and impoverished districts of North China are notable for heavy bristles and for tough skins for leather.

## Classification and Naming of Plants

**Species** is a unit of classification, but is not a single plant type. It is a concept of a group of individual plants having certain essential characters in common. Thus, all oaks recognized as white oak constitute the species *Quercus alba.* In plant cultivation species are subdivided into smaller groups known as Varieties, and these into Subvarieties, Forms, and Strains, which may differ only in minor characteristics such as color of the flower.

**Genus,** plural Genera, is a group of related species. Thus, the plants recognized as constituting species of white oak, red oak, etc., belong to the genus *Quercus.* The chief structure of a genus is the flower and some other organs of the plant. **Family** is a group of similar and related genera. Thus, the oak genus *Quercus,* the chestnut genus *Castanea,* and the beech genus *Fagus* constitute the family *Fagaceae.* **Order** is a group of related families. Thus, the oak, and the beech and the hazel constitute the order known as *Fagales.* **Class** is a group of related orders having several outstanding characteristics in common. **Subdivision** is a group of related classes resembling each other in some characteristics. **Division** is the highest general grouping of the Kingdom of plants, each division having a common general similarity such as seed plants, mosses, and fungi.

## Relative Percentages of Vegetable and Animal Oils and Fats Used in the United States

Total annual use, 10,000,000 short tons

| Fat or oil | Per cent | Fat or oil | Per cent |
|---|---|---|---|
| Butter | 23.6 | Tung oil | 1.1 |
| Lard | 16.9 | Olive oil | 1.1 |
| Cottonseed oil | 14.4 | Whale oil | 0.9 |
| Tallow | 9.8 | Peanut oil | 0.8 |
| Coconut oil | 6.2 | Castor oil | 0.8 |
| Linseed oil | 5.7 | Babassu oil | 0.7 |
| Soybean oil | 4.5 | Perilla oil | 0.5 |
| Grease | 3.8 | Oiticica oil | 0.2 |
| Palm oil | 3.2 | Palm kernel oil | 0.1 |
| Fish and fish-liver oils | 2.6 | Wool grease | 0.1 |
| Corn oil | 1.6 | Sesame oil | 0.1 |
| Oleo and oleo stearin | 1.1 | Rape oil | 0.1 |
| | | Teaseed oil | 0.1 |

Less than 0.1 per cent each: Neatsfoot oil, Hempseed oil, Vegetable tallow, Kapok oil, Sunflower oil, Grapeseed oil, Candlenut oil, Walnut oil, Butea oil.

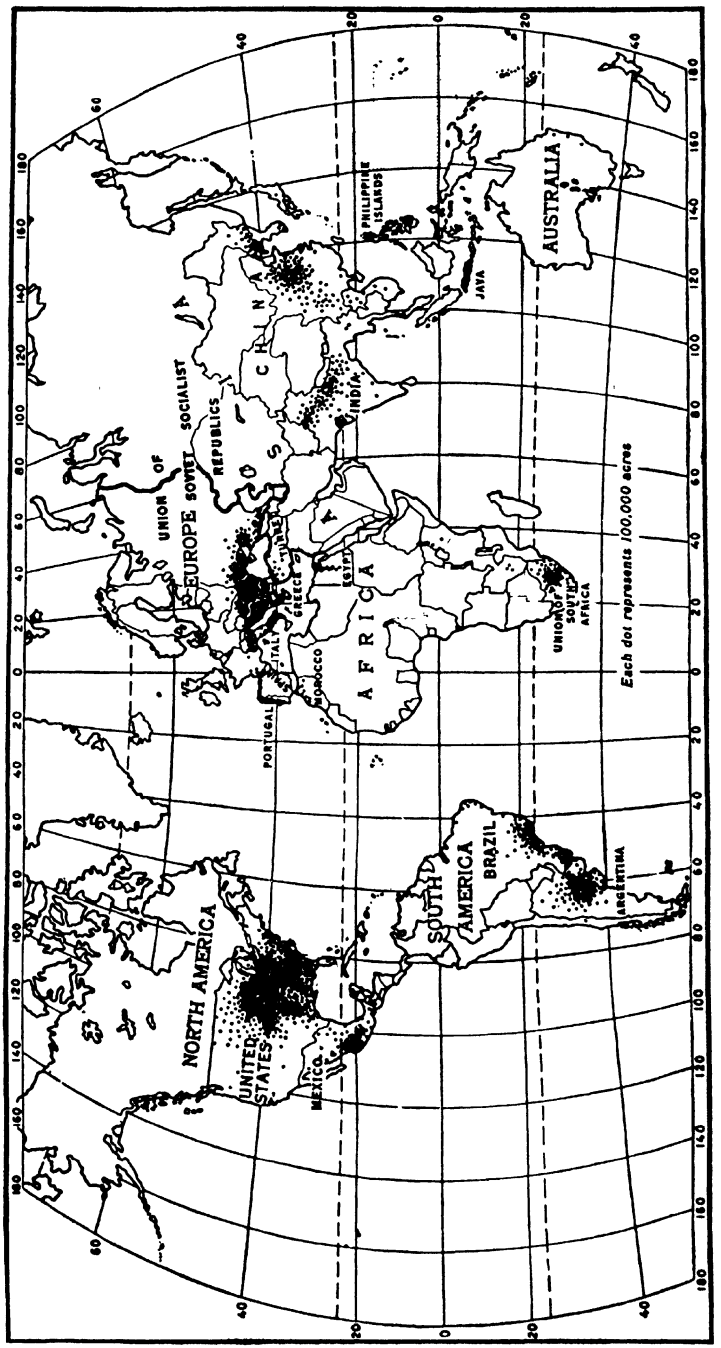
## World Production of Some Non-Mineral Materials *

Prewar 1937–1939 annual average except as otherwise noted

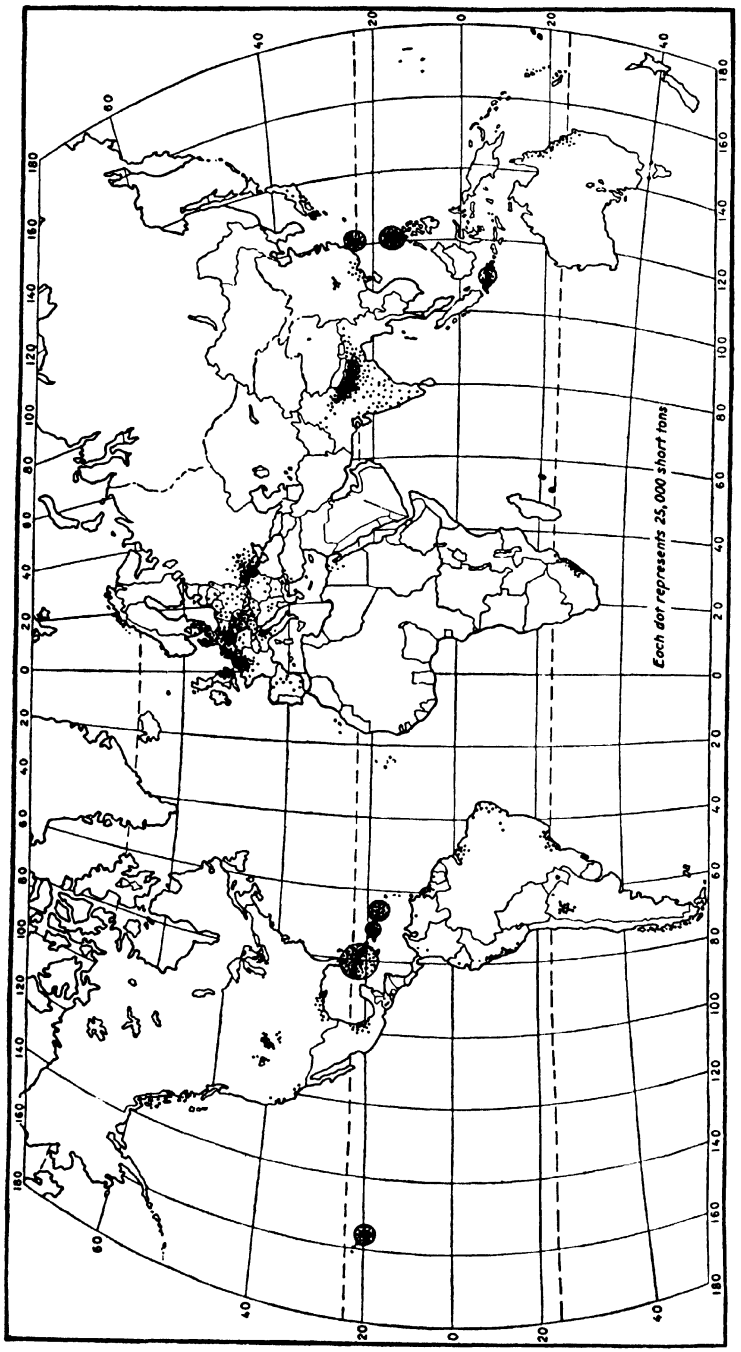
| Commodity | Amount | Per cent produced in U.S. |
|---|---|---|
| Corn | 5,020,000,000 bu. (1940) | 49 |
| Barley | 2,149,400,000 bu. | 16.3 |
| Linseed | 8,500,000,000 lb. (1940) | 20.6 |
| Oats | 4,810,000,000 bu. (1942) | 28.2 |
| Cocoa beans | 1,599,400,000 lb. | none |
| Coffee | 3,560,000,000 lb. (1941) | none |
| Coconut oil | 1,855,800,000 lb. | 15 † |
| Tung oil | 301,000,000 lb. (1940) | 1.7 |
| Hog bristles | 12,000,000 lb. | 0.01 |
| Casein | 165,347,000 lb. (1939) | 24.7 |
| Lard | 4,400,000,000 lb. (1938) | 39.3 |
| Manila fiber | 339,000,000 lb. | none |
| Cattle hides | 98,260,000 units (1941) | 18.2 |
| Carnauba wax | 14,000,000 lb. | none |
| Jute | 1,615,000 lg. tons (1942) | none |
| Mahogany | 28,675,000 bd. ft. | none |
| Cottonseed oil | 4,256,000,000 lb. (1940) | 29.9 |
| Corn oil | 325,555,000 lb. (1939) | 46.2 |

* All figures from U.S. Department of Commerce.

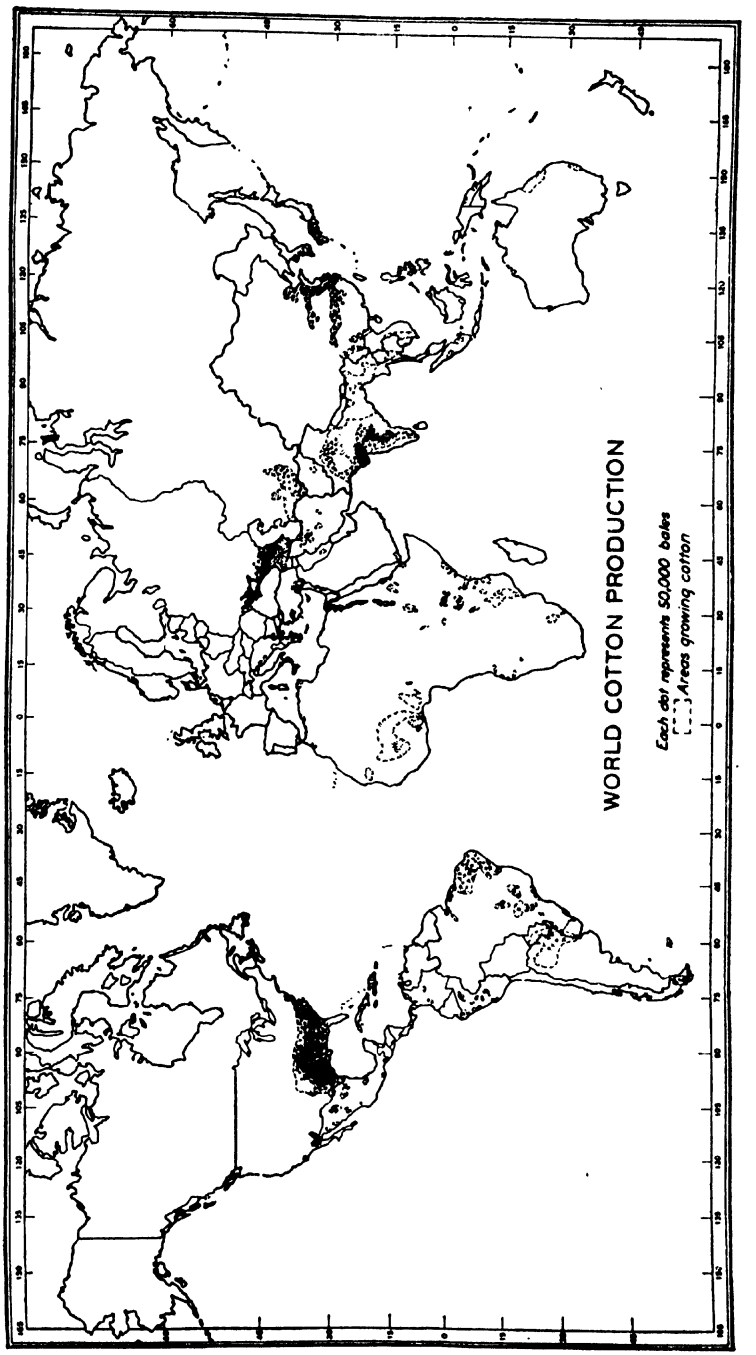
† From foreign copra.

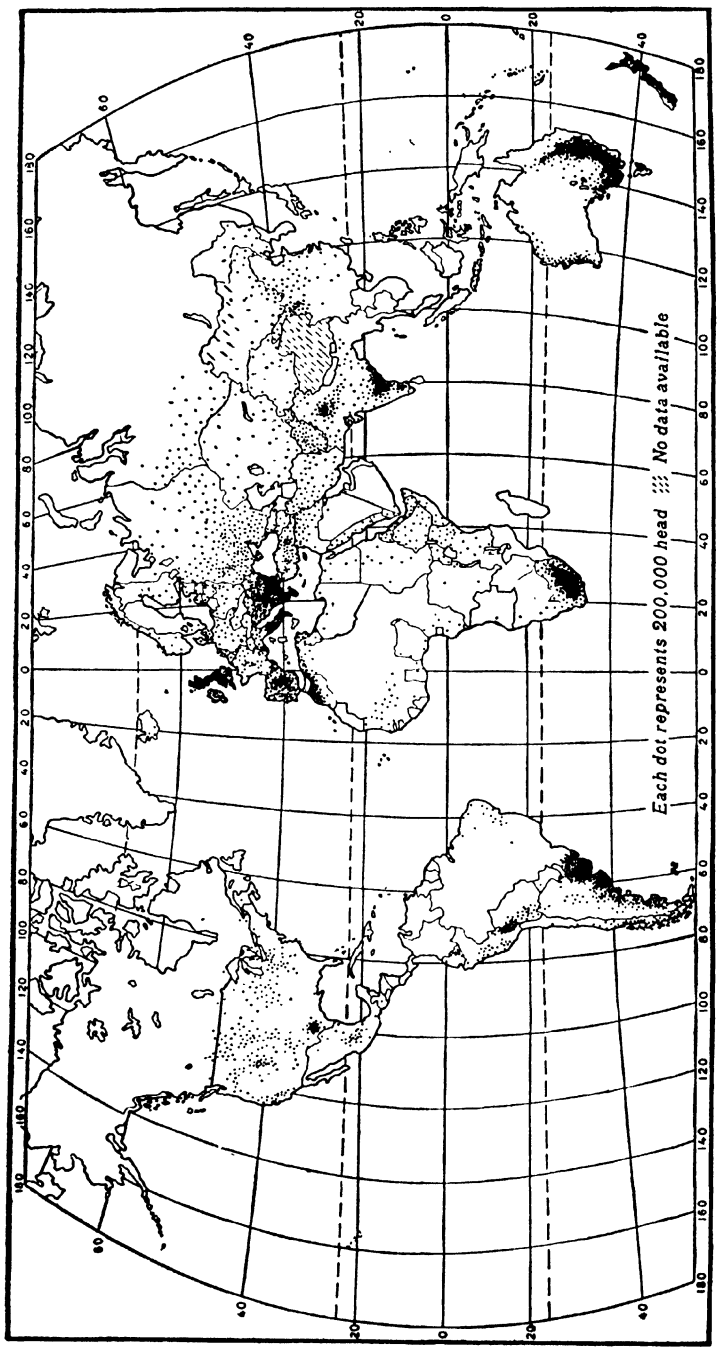



World corn-producing areas. Products: edible corn, corn for livestock and poultry feed, starch, glucose, corn sugar, beverage alcohols, industrial alcohol, hexahydric alcohols.

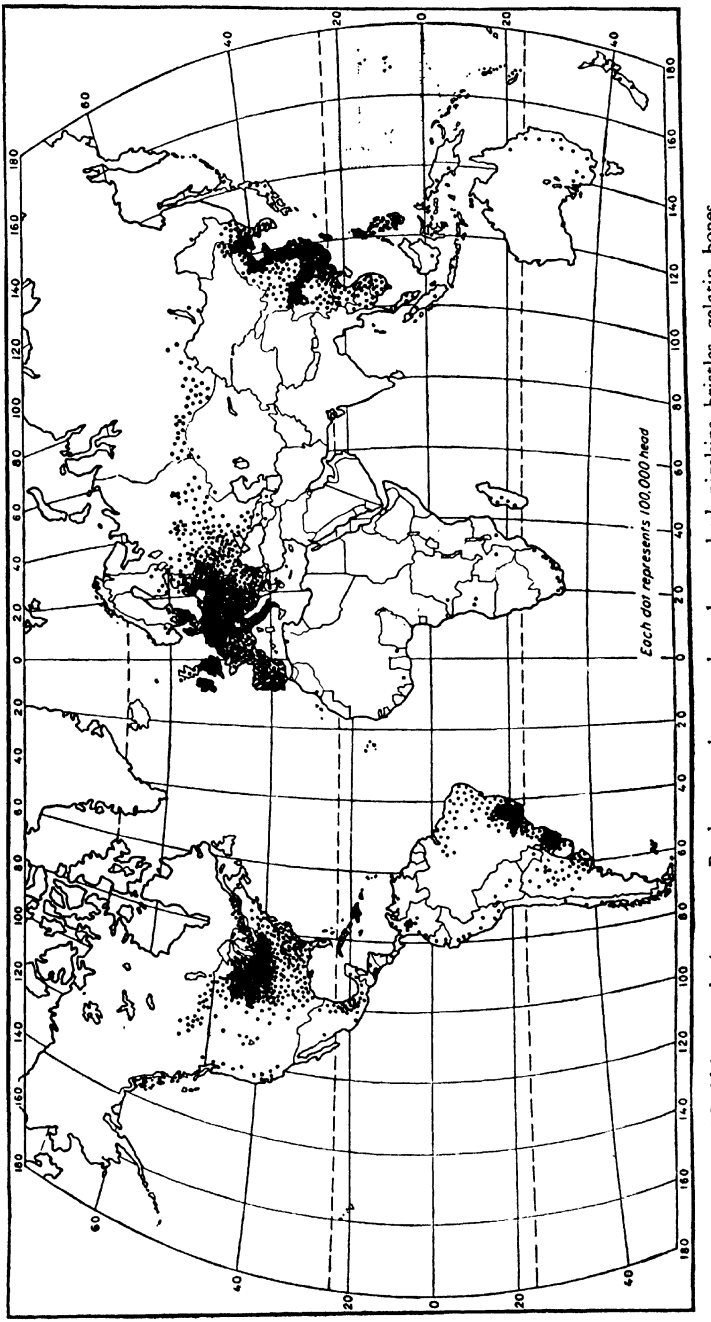



World sugar-producing areas. Products: edible sugar, edible molasses, industrial molasses, ethyl alcohol, rum, bagasse, beet pulp.

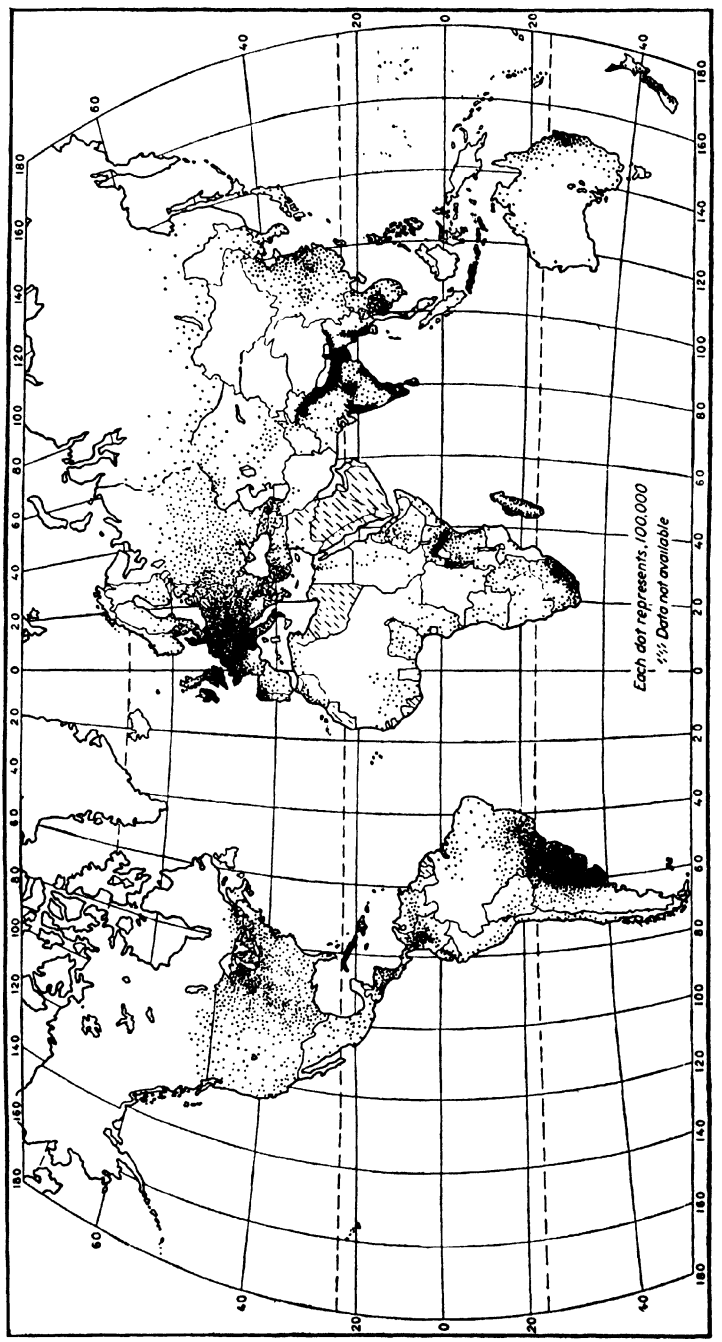

WORLD COTTON PRODUCTION
Each dot represents 50,000 bales
Areas growing cotton




World sheep-producing areas. Products: mutton and lamb meats, wool, sheepskins, lambskins, grease, lanolin, bones.




World hog-producing areas. Products: pork meats, ham, bacon, lard, pigskins, bristles, gelatin, bones.




World cattle-producing areas. Products: frozen and chilled beef, canned beef, beef extract, hides, calfskins, hair, horns, bones, oleo oils, tallow, gelatin, neatsfoot oil, glue.

## WAVES AND COLORS AS MATERIAL ELEMENTS

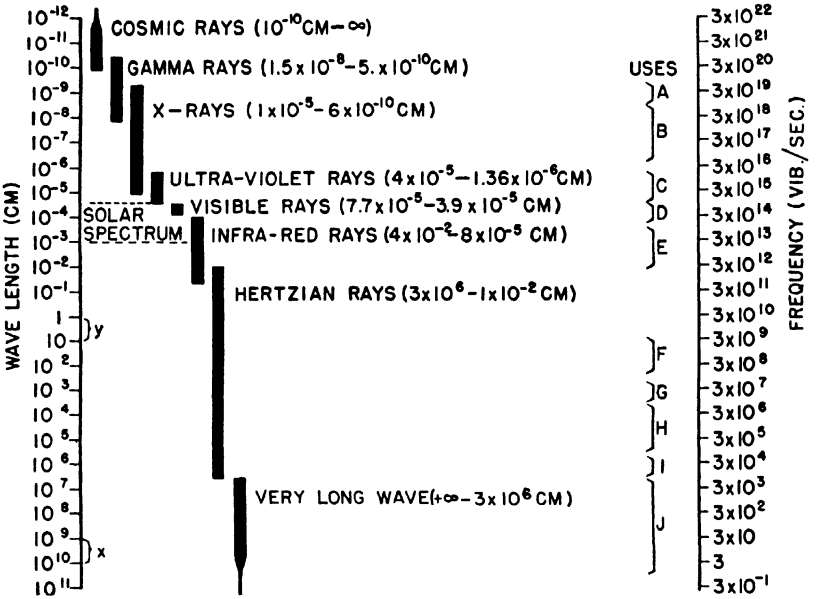
### Electromagnetic Radiations

Tangible materials and radiations have a common energy origin, and thus bear a cosmic relation, but radiation is not matter in the ordinary sense of the term. Radiation is caused by vibrations, and is measured in wave length and not in mass as is matter. Waves of high frequency and short wave length result from the vibration of extremely small particles such as electrons of the material atom, while those of low frequency and long wave length arise from slow vibrations such as those from a coil in a magnetic field.

Radiations are produced when materials are broken down or changed to another form, and there is then an actual loss of mass equal to the amount of energy emitted. In reverse, matter is produced when energy in the form of radiation is directed upon matter, and an actual increase in the mass of the matter results. All materials in nature are being constantly bombarded with various radiations, but it requires such an extremely large amount of energy to produce the most minute quantities of matter that the continuous changes in most materials are not noticeable in any historic period of time.

The spectrum of electromagnetic radiations extends from wave lengths of many hundred-millionths of a centimeter (1 cm. equals 0.3937 in.), or infinitely small, to wave lengths of many miles, or infinitely large. The velocity of these waves is the same for all lengths of wave, 186,000 mi. per sec. In the spectrum, the light waves which make objects visible to the human eye form only a small part. All animals do not see with the same wave lengths, and some animals do not have normal eyes but receive vibrations through special receiving parts of the body. The human eye can see through only such materials as these light waves will penetrate. But electrical eyes can be made to operate in other wave lengths and record vision not seen by the human eye. Different materials transmit, absorb, or reflect radiations differently. Quartz and glass, normally called transparent, transmit only a small band of light and heat waves, but will not pass very short radiations. By changing the composition of the glass the heat waves can be blocked, or some of the very short waves can be passed through. Some materials, like lead, will block the very short waves, and can be used for X-ray shields. Other materials, like beryllium, will pass only very short waves, and can be used for windows for radio tubes.

## Wave Lengths and Frequencies




SPECTRUM OF ELECTROMAGNETIC RADIATIONS

USES:

A–RADIOLOGY, RADIOTHERAPY, X-RAY DIAGNOSIS

B–PHYSICAL AND CHEMICAL ANALYSIS OF MATTER

C–THERAPEUTIC APPLICATIONS

D–LIGHT

E–HEATING, INDUSTRIAL BAKING

F–FM, RADAR, TELEVISION, SONAR

G–SHORT WAVE RADIO

H–WIRELESS

I–LONG WAVE RADIO

J–ELECTRIC POWER, ALTERNATING CURRENT

EXPLANATION:

THE CHART IS LOGARITHMIC, THE DISTANCE X, FROM $10^{9}$ TO $10^{10}$ BEING A BILLION TIMES THE DISTANCE y, FROM 1 TO 10

| | | | |
|---|---|---|---|
| $10^{1}$ = 10 | $10^{3}$ = 1000 | $10^{-1}$ = 0.1 | $10^{-3}$ = 0.001 |
| $10^{2}$ = 100 | $10^{4}$ = 10000 | $10^{-2}$ = 0.01 | $10^{-4}$ = 0.0001 |

From J. F. Moulton, Jr.

## Light Measurement and Balancing

Visible light waves, like all other electromagnetic radiations, travel through space at a speed of 186,000 mi. per sec. This speed is cut down perceptibly when light travels through materials. The speed through silica glass is only 122,000 mi. per sec., with a bending of the light beam and a scattering of the colors. The speed through a fluoride optical glass is 146,000 mi. per sec., with less color scattering than with silica glass.

The longest visible wave length is about 0.00008 in., and the shortest is about half that length. The unit of length is the angstrom unit, designated as Å and equal to 0.00000001 cm. The millimicron is 10 Å, or 0.0000001 cm.

The longest wave lengths are the reds, and the shortest are the violets. A low-intensity electric current gives a light with a yellow tint because the color composition has high percentages of red and orange-yellow. A very high-intensity current gives a higher proportion of violet, blue, and green. Adjustment of the intensity of the electric current, and incorporation of metallic elements of the proper flame color at incandescence can flatten out the color percentage balances to give the whiteness and brilliancy desired for any particular use.

## Element Colors at Incandescence

Flame colorations caused by heating materials to incandescence indicate the presence of certain elements, as the light from each element in burning has a predominance of rays or wave lengths that are characteristic of that particular element. Some elements, such as sodium, show a distinct bright color because of a predominance of wave lengths within that color range in the visible spectrum, while others show pale or intermediate colors difficult to distinguish, usually because the rays have no predominating wave length within the visible spectrum but are mixtures of many wave lengths. Other elements, such as iron, have a predominance of rays that are not in the visible band, with wave lengths shorter or longer than those visible to the eye. Flame coloration is used in metallurgical laboratories to determine the content of alloys by burning small pieces and studying the light with a refractive prism. This property of the elements is also utilized in making carbon electrodes for electric-arc lights to give the full white light of sunshine, or short waves for therapy or industrial use, or long wave lengths for heat. For example, carbon alone gives a predominance of short wave lengths with the visible rays predominantly on the red side of the spectrum. By blending cerium metals with the carbon the visible light is balanced with the blue-violet to give a more even white light. By blending the carbon with iron, nickel, and aluminum, which are all on the low-wave side of the spectrum, powerful lower zone ultraviolet rays are obtained. This type of carbon electrode is used in antirachitic therapy lamps and for ultraviolet light for catalytic purposes in chemical synthesis.

## Predominant Flame Colors of Materials

| Element | Color | Element | Color |
|---|---|---|---|
| Lithium | Deep red | Antimony | Blue-green |
| Strontium | Crimson | Copper | Green-blue |
| Calcium | Yellow-red | Arsenic | Light blue |
| Sodium | Bright yellow | Lead | Light blue |
| Barium | Yellow-green | Selenium | Blue |
| Molybdenum | Green-yellow | Indium | Deep blue |
| Zinc | Light green | Potassium | Purple-red |
| Boron | Green | Rubidium | Violet |
| Tellurium | Deep green | Cesium | Bluish purple |
| Thallium | Greenish blue | | |

## Reflecting Powers of Various Metal Surfaces

| | White light directly reflected, per cent | Color Silver = 0 |
|---|---|---|
| Silver | 90 | 0 |
| Chromium | 61 | Blue-green 12 units |
| Nickel | 50 | Red 16 units |
| Stainless steel | 49 | Blue-green 3 units |
| White bronze speculum | 70 | Red 1 unit |

## Reflecting Power of Various Colors in Paints

| Color | Light reflection, per cent | Color | Light reflection, per cent |
|---|---|---|---|
| Flat white | 85–89 | Sky blue | 58 |
| Bone white | 69–70 | Light orchid | 57 |
| Canary yellow | 68–72 | Buff | 47 |
| Light ivory | 70 | Pea green | 40 |
| Aluminum | 70 | Tan | 34 |
| Cream | 65–69 | Peacock blue | 34 |
| Light green | 66 | Steel gray | 30 |
| Ivory | 61–63 | Brown | 9 |
| Peach | 58–59 | | |

## Terms Used in Material Color Designation

**Hue** is the predominant light-wave length reflected by the coloring material, and determines the Color designation.

**Brightness** or **Value**, or **Chroma**, is the percentage of light reflected. A brilliant white approaches 100%, and a jet black approaches 0%. Black is the absence of light waves; White is a combination of all the various wave lengths. White light is broken down by refraction into separate wave bands, or hues.

**Saturation**, or **Intensity**, is the percentage of reflected light which is colored, and determines the **Tint**. A color, or hue, is tinted by its mixture with white.

The color circle is composed of 12 colors spaced at equal intervals: yellow, orange, red, violet, blue, green, and an intermediate between each. Pigment colors are obtained usually by Subtractive mixing; for example, when blue and yellow are mixed the blue absorbs the red, orange, and yellow rays, and the yellow absorbs the blue and violet rays, so that the result is green.

Under proper illumination it is possible to detect with the eye exceedingly slight color differences, the number of distinguishable colors being estimated (U. S. Bureau of Standards) at 10,000,000.

Colors or hues vary slightly with different batches of paints, dyes, etc. For this reason products that must be matched exactly in hue are usually finished from the same batch or lot.

Visibility at a distance varies with different colors. Red can be seen and recognized at long distances while blue can be seen at only short distances. The comparative visibility of colors at a distance are red, green, white, yellow, blue. Legibility, however, varies also with the background. Black on yellow is more legible than black on white. Green or red or blue on white are more legible than black on white. Visibility and legibility are important in signs, packages, or products that must be distinguished easily.

**Harmony** of color or **Tone design** is a complicated art. It comprises the color relationship to convey pleasing emotional reaction, and includes various terms. A Rich color is a hue at its fullest intensity. A Warm color is one in which the red-orange predominates. A Cool color is one in which the blue-green predominates. In general, warm colors are pleasing or exciting, while cool colors are not so pleasing or are restful to the senses. A Receding color is one giving the illusion of withdrawing into distance by a gradation toward another tone or hue. Color, from the standpoint of harmony and design, is a sensation effect. It is not inherent in the pigments, dyes, or other materials, but is the sensation effect from those light rays reflected to the eye by the material while the other rays of the light are absorbed by the material. Different materials absorb and reflect different light waves and thus appear as differently colored.

## PROPERTY OF FLAVOR IN MATERIALS

The quality of many materials is judged by the flavor. Flavor is the resultant of three senses: taste, smell, and feeling. Some materials, such as salt and quinine, may be detected by taste alone. Some, such as coffee and butter, depend largely upon smell. Flower perfumes are detected by smell alone. The flavor of fruits depends upon both taste and smell, and without smell would be only sour or sweet. Pepper has little or no taste, but is detected by the aroma and by the sense of feeling. Ginger also registers feeling through the nerves, and odor.

The four standard components of taste are: sweet, sour, salty, and bitter. Taste buds are located in the tongue. The tip, back, and edges of the tongue can detect all four sensations, but the center of the tongue can detect only a sour taste, and the surrounding area can detect only salty and sour. Sour taste is caused by hydrogen ions, and salty taste is due to cations from the alkali metals, accented when anions from the halogens are present. Sweetness and bitterness may or may not be from ions, and the stimuli are more complex. But all taste is electrochemical, translated to the nerves as sensations. Some materials when injected into the blood can be tasted when the blood stream reaches the underside of the taste buds in the tongue.

Odor detection is electrochemical but not entirely so, since molecules which have the same shape may have the same odor though unrelated chemically. The sense of smell is due to oscillations of the valance electrons in the molecules of the substance. The molecules of substances inhaled stimulate the tiny olfactory hairs high in the nasal cavity, and the effect is translated to the nerves as impressions or sensations. The sense of taste usually requires considerable material to register the sensation, but only the most minute molecular qualities are required to register smell. A normal person can detect a vast variety of odors, but for convenience the four fundamental odors have been designated as fragrant, acid, burnt, and caprylic. A material is then designated with a four-digit number to indicate the degree of each odor, each odor thus having ten degrees or variations, thus giving 9,999 variants. Various materials are taken as standards for the numbers, or 40 standards. The sense of smell is so discriminating that it can detect separate odors in highly complicated mixtures. Most odors are mixtures, and the art involved in the perfumery industry is to form chords or harmonies that give a resultant pleasant sensation.

Flavors that affect the touch sensation are described as pungent, sharp, acrid, and cool. These are caused by actual pain as the biting of an acid or the cooling effect of deoxidation. Greasiness and oiliness are sensations of feel that affect taste but are not a part of it. Texture also is a

feeling sense and not a part of flavor. The sensation of puckery of the tannin of some fruits is a definite constriction of membrane and is not taste. All of these have an effect upon the desirability of the material as a food, but in a manner apart from flavor. Too much sweetness, or sourness, or saltiness will clog the taste buds, and they must be then rested before a true flavor can be detected, but the recovery is rapid. Temperature also has an effect, and true flavors are detected only at about the temperature of the body. The judgment and grading of coffee, tea, butter, and many other products are done solely by the senses of experts in comparison with standards.

## FUNDAMENTALS OF BIOTIC MATERIALS

The Biotics constitute an extensive group of organic materials that are simple, living microorganisms and cannot be expressed as chemical formulas. All of these minute bits of living matter are of plant and animal origin and may be considered as chemical factories. It is the chemicals that certain species secrete under certain conditions that make them industrially and medicinally useful. The chemical secretions are enzymatic and catalytic in character and thus enable various chemicals to react on contact. In industry they are used as chemical activating agents, ferments, leavening agents, and in various processing. In medicine they are known as Antibiotics and are used to destroy the biotics, or bacteria, of diseases which locate themselves in the human body.

Biotics are found everywhere in myriad quantities. A cubic centimeter of raw earth may contain as many as 50,000 fungi, or microphytes, 500 million bacteria, and 250 million actinomycetes, the latter being living organisms that may be ascribed, with reservations, to either the plant or to the animal kingdom, and are distinguished by their mass of long silky filaments. All of these organisms lead a junglelike type of existence, attacking everything, decomposing plant debris to make humus, liberating nitrogen from proteins, liberating oxygen from rocks, liberating carbon dioxide and water from organic acids in plants and soil, and also preying on each other like jungle animals. Without these organisms the life cycles of all living things could not be maintained. It is this same teeming population that also furnishes the individual types or organisms that aid man in medicine and industry.

The number of species of these microorganisms is innumerable. Each species has at least one enemy species that it destroys on contact or by which it is itself destroyed. Each, apparently, has a certain definite range of activity, beyond the bounds of which it is useless. Where one biotic is used in the manufacture of a certain product, a similar but different species used under the same conditions produces an entirely different prod-

uct, or may affect the quantitative yield of the product desired. The formation of ethyl alcohol by the fermentation of starch or sugar is caused by a biotic which is then itself killed when the alcohol produced has arrived at a certain concentration. Other biotics may be killed by the heat that their own work produces, as at the "crisis" point of certain fevers. In general, biotics can withstand excessive cold but are usually killed by relatively low heats.

Besides the use of biotics for medicinal and industrial applications as are now known, there are also believed to be enormous possibilities for their use in large-scale chemical processing in the future. But the isolation of microorganisms is tedious laboratory work involving the extraction of a pure strain from cultures containing many species, and once separated, the proper conditions to promote rapid multiplication must be discovered. Even at this stage, a biotic found to be useful in the manufacture of a certain product may simultaneously manufacture another unwanted product, difficult and costly to separate from the desired one. But from each biotic some kind of chemical is secreted, and it is that chemical which is the ultimate end of biotic research.

Out of the many thousands of possibilities for the production of these microorganism, or biotic, chemicals, very few have as yet been isolated and put to use. In medicine, Penicillin, the sodium or calcium salt of the chemical extracted from the mold fungus *Penicillium notatum*, is an example, while in industry, there is the chemical secreted from the yeast plant *Saccharomyces cerevisiae*, which causes alcoholic fermentation. The secretions of biotics are true chemicals that can be expressed as formulas. The science of biotics opens vast possibilities for hitherto unknown chemical processing and for the prevention and cure of diseases.

## INDUSTRY TERMS

All industries have names and units peculiar to the particular industry. The two groupings that follow are illustrative.

### Terms Used in the Textile Industry

**A Fiber** is the basic individual filament of raw material from which threads, cordage, or fabrics are made.

**Carding** consists in cleaning the particles of leaf or foreign matter from the fiber. Originally a "card" was used which was a rectangular piece of wood with wire teeth. Carding by machine lays the cotton or wool in a continuous strand. **Drawing** consists in feeding card slivers of fibers between two pairs of rolls, the second revolving faster than the first to stretch the silver and reduce the diameter. The first drawn slivers with slight twist are called **Rovings. A Yarn** is the product of **Spinning**

the loose rovings into a continuous tight string, by running from one spool to another. The more twists to the inch the stronger the yarn.

**Combing** is a continuation of carding to eliminate short fibers, to give more evenness, and to free the fibers of all foreign matter. The finest yarns are combed. The eliminated short fibers are called **Noils.** At this point the yarns are dyed for yarn-dyed fabrics.

**Cloth** or **Fabric** is made by weaving, knitting, or felting. Weaving is the interlacing of two sets of yarns at right angles. Knitting is the looping of yarn to form rows, one row of loops being caught into the previous row. Felting is the mass interlocking of fibers by pressure.

**Cotton yarns** are designated by numbers, or **Counts.** The standard count of cotton is 840 yd. to the pound. Number 10 yarn is therefore 8,400 yd. to the pound. A No. 80 sewing cotton is 80 × 840 or 67,200 yd. to the pound.

**Linen yarns** are designated by the **Lea** of 300 yd. A 10-count linen yarn is 10 × 300, or 3,000 yd. per lb.

The size or count of spun **Rayon yarns** is on the same basis as cotton yarn. The size or count of rayon filament yarn is on the basis of the **Denier,** the rayon denier being 450 meters weighing 5 centigrams. If 450 meters (492.12 yd.) of yarn weigh 5 centigrams it has a count of 1 denier. If it weighs 10 centigrams it is No. 2 denier. Rayon yarns run from 15 denier, the finest, to 1,200 denier, the coarsest.

Reeled **Silk yarn** counts are designated in deniers. The International Denier for reeled silk is 500 meters of yarn weighing 0.05 gram. If 500 meters weigh 1 gram, the denier is No. 20. Spun silk count under the English system is the same as the cotton count. Under the French system the count is designated by the number of Skeins weighing a kilogram. The Skein of silk is 1,000 meters.

A **Ply yarn** is one that has two or more yarns twisted together. A two-ply yarn has two separate yarns twisted together. The separate yarns may be of different materials, as cotton and rayon. A six-ply yarn has six separate yarns. A ply yarn may have the different plies of different twists to give different effects. Ply yarns are stronger than single yarns of the same diameter. Tightly twisted yarns make strong, hard fabrics. Linen yarns are not twisted as tightly as cotton because the flax fiber is longer, stronger, and not as fuzzy as the cotton. **Filament rayon yarn** is yarn made from long, continuous rayon fibers, and it requires only slight twist. Fabrics made from filament yarn are called Twalle. Spun rayon yarn is yarn made from **Staple fiber,** which is rayon filament cut into standard short lengths.

The difference between **Thread** and yarn is one of more equal twist. In thread the plies are balanced in twist so that the finished thread approximates a perfect circle. In thread the plies are called Cords; a six-ply thread is designated as Six-cord. Cotton thread comes in counts from 8 to 100, coarse to fine.

## Group Terms Used for Drug Materials

**Analgesic.** A material that diminishes the conductivity of the nerve fibers and thus relieves pain, as wintergreen.

**Anodyne.** A drug that relieves pain, as opium, menthol.

**Anthelmintic.** A drug that causes expulsion of intestinal worms.

**Antibiotic.** A substance that destroys fungi, microbes, and other microorganisms. Usually living organisms, and not expressed by chemical formulas.

**Anticatarrhal.** A drug that reduces or controls inflammation of mucous membranes of the nose or throat, as buchu.

**Antiseptic.** A material that opposes or kills the microorganisms of decay, as thymol or alcohol.

**Antipyretic.** A drug that reduces fever, as quinine or atabrine.

**Antipyrotic.** A drug that relieves burns, as tannic acid.

**Antispasmotic.** A drug that relieves convulsions or spasms, as camphor, bromides, valerian.

**Antitoxin.** A chemical produced by the body, or injected into the body, which reacts with and alters poisons so that they are no longer poisonous.

**Carminative.** A drug promoting the expulsion of gas to relieve colic.

**Demulcent.** An oily or mucilaginous material that softens and soothes an inflamed part of the body.

**Diaphoretic.** A drug that stimulates the sweat glands and causes perspiration, as aconite.

**Dilatant.** A chemical that expands the muscles of the eye or other parts of the body, as belladonna.

**Diuretic.** A drug that increases the renal excretions and produces increased discharge of urine, as caffeine, citrates.

**Emetic.** A drug that causes vomiting to eject poisons, as zinc sulphate, lobelia.

**Emollient.** A drug applied externally to soften and soothe irritated or tense tissues, as zinc stearate for the skin and glycerin for throat tissues.

**Expectorant.** A drug that promotes secretion of mucus from the respiratory tract, as ipecac.

**Febrifuge.** A drug that reduces fever or prevents fever, as quinine.

**Hemolytic.** A material that causes destruction of the red blood corpuscles, as spider poison.

**Hypnotic.** A drug that produces sleep, as chloral.

**Lachrymator.** A chemical that causes a copious or blinding flow of tears, as chloropicrin.

**Narcotic.** A drug that produces stupor. There are three classes: those that produce deep sleep, as opium; those that produce illusions and

sleep, as cannabis or belladonna; those that produce exhiliration and sleep, as alcohol.

**Nutrient.** A material that can be injected to nourish the blood or a body organism, as glucose.

**Peristaltic.** A drug that increases intestinal movements, as cascara.

**Prophylactic.** A material given in advance to prevent disease, as quinine.

**Sedative.** A material that counteracts stimulation or irritation and has a calming effect, as bromides or henbane.

**Sternutator.** A chemical that causes sneezing, as diphenyl chloroarsene.

**Stomachic.** A drug that increases gastric secretions and stimulates appetite, as gentian or pepper.

**Vasodilator.** A material that lowers the blood pressure by dilating the arteries, as nitroglycerin or aconitine.

**Vermicide. Vermifuge.** A material that expels intestinal parasites.

**Vesicant.** A chemical that causes blistering of the skin, as mustard gas.

# AGENCIES OF THE U.S. GOVERNMENT DEALING WITH TECHNICAL ASPECTS OF MATERIALS RESOURCES

*Department of the Interior.* Charged by law with advancing the domestic interests of the people of the United States, which includes utilization and conservation of national resources.

*General Land Office* supervises the survey, management, and disposition of public lands and the resources thereon. It conducts scientific and professional investigations in the fields of land and mineral economics.

*Geological Survey* prepares and publishes reports upon the geology and mineral and water resources. Supervises technical phases of mineral leasing on public lands.

*Bureau of Mines* conducts scientific, technological, and economic investigations on the development, mining, preparation, treatment, and utilization of ores to determine and develop new domestic sources of supply. Is empowered to make inspections and investigations of mines to curb accidents and preserve the health of miners. Operates pilot plants to demonstrate methods.

*Fish and Wildlife Service* carries on programs for the perpetuation and restoration of renewable resources, bird life, fish, fur and other land mammals, seals, whale, lobster. Administers the conservation laws.

*Department of Agriculture.* Charged by law to acquire and diffuse useful information on agricultural subjects for the common benefit, farm products, soils, human nutrition, markets.

*Bureau of Animal Husbandry* deals with eradication and control of animal diseases and parasites and seeks to protect and develop the livestock, meat, poultry, and related industries.

*Bureau of Dairy Industry* investigates the breeding and management of dairy cattle. Records production. Develops sanitary methods on farm, in transit, and in dairy plants.

*Bureau of Agricultural and Industrial Chemistry* conducts investigations and experiments into the sciences relating to agricultural products and into the development of new and wider uses of agricultural products.

*Bureau of Entomology and Plant Quarantine* studies insects and pests injurious to agriculture and forestry and develops insecticides. Enforces the plant quarantine laws.

*Bureau of Human Nutrition and Home Economics* conducts research on foods essential to living and factors affecting foods and clothing for proper utilization and reduction of waste.

*Office of Experiment Stations* operates stations for research in agriculture and rural life. Supervises stations operated on Federal grants.

*Forest Service* promotes the conservation and best use of the forest lands of the nation. Operates forest and range experiment stations. Administers the forests.

*Soil Conservation Service* promotes the conservation and usage of soil and water through technical, material, and equipment aids. Conducts research into character, cause, and effect of erosion and depletion, and develops methods of conservation.

*Bureau of Agricultural Economics* is the central statistical and economic research office of the department. It collects, analyzes, and publishes facts on agriculture, production, demand and supply, consumption, prices, costs, income, markets, farm management, standards of living, and rural population matters. Issues crop reports.

*Office of Foreign Agricultural Relations* collects, analyzes, and disseminates information on foreign competition and demand for farm products, and on foreign agricultural policies.

*Department of Commerce.* Charged by law to conduct all censuses, promote foreign and domestic commerce, conduct coastal and geodetic surveys, establish weights and measures standards, supervise patents and trade-marks, establish and maintain aids to air navigation, supervise and issue weather forecasts and warnings for agriculture, commerce, and navigation, develop inland water transportation.

*Bureau of the Census* is the major fact-finding and statistical service of the government. Conducts various censuses, tabulates and disseminates periodic data. Promotes the adoption of uniform and improved standards for registering vital statistics by the states.

*Bureau of Foreign and Domestic Commerce* is charged with the duty to foster, promote, and develop the foreign and domestic commerce of the United States. Makes investigations of requirements, sources of supply, production capacity, procurement, and problems of commodity supply. Issues reports on conditions of trade, statistics, tariffs, and all matters affecting commerce. Maintains officials in foreign business centers, and operates domestic field offices for the collection and dissemination of information.

*National Bureau of Standards* develops and has custody of the working standards for measurement, quality, performance, and practice used in science, industry, and commerce. Is the central reference for all standards and specifications used in the United States.

*Textile Foundation, Inc.,* operates scientific and economic research for the benefit and development of the textile industry including the

production of textile raw materials. Makes economic studies and conducts technical research on materials, processes, and factors affecting the textile industries.

*Food and Drug Administration.* Charged by law with enforcement of the Food, Drug and Cosmetic Act, Tea Act, Import Milk Act, Caustic Poison Act, and Filled Milk Act. It is intended to promote purity, standard potency, and truthful and informative labeling.

## VISUAL AIDS

Motion picture films are available illustrating and explaining the processes in the extraction and preparation of raw materials. Those from commercial companies producing raw materials are often sent out on a loan basis to schools and to industrial companies conducting educational courses for employees. A few typical examples follow:

*Copper Smelting* (Phelps Dodge Refining Corp., 15 min, 16mm sd). Shows the crushing, roasting, and smelting to convert ores and concentrates into metallic copper; shows converters and anode furnaces; shows casting of copper. Another 34-min, 16-mm sound film of this company, entitled *Story of Copper,* shows open-pit and underground mining of copper ores.

*Aluminum: Mine to Metal* (Aluminum Company of America, 30 min, 16mm sd). Shows the mining and purifying of bauxite, and the uses of aluminum in building and in industry.

10,000 *Feet Deep* (Shell Oil Co., Inc., 20 min, 16mm sd). Shows modern methods of oil exploration and oil drilling.

*Synthetic Rubber* (Goodyear Tire & Rubber Co., Inc., 40 min, 16mm sd). Shows the various steps in the making of chemicals into rubber.

*How Steel Is Made* (Bethlehem Steel Co., 40 min, 16mm sd). Shows blast, bessemer, and open-hearth furnaces; animated drawings of what takes place in the furnace; rolling operations; hammer forges and press forges; cupola furnaces in the foundry.

*Mountains of Marble* (Vermont Marble Co., 22 min, 16mm sd). Shows the quarrying of marble, and the cutting and finishing of the stones.

*Story of Leather* (Tanners Council of America, 25 min, 16 and 35mm si). Shows the processes involved in the making of leather from the roundup of cattle to the finished product. Sound films are also available.

*Yellow Magic—The Story of Sulphur* (Freeport Sulphur Co., 35 min, 16mm sd). Shows operations in extracting sulphur from the ground in Louisiana, and refining. Shows the history of sulphur.

*Story of Coal* (Knowledge Builders Classroom Films, 10 min, 16mm sd). Shows the geologic formations of coal, peat, lignite, and the mining with hand tools and with machines. Shows the grading and washing of coal.

# UNITS OF MEASURE

## Useful Conversion Factors

1 acre = 43,560 square feet = 0.40469 hectare
1 angstrom unit = 0.003937 millionths of an inch
1 ardeb (Egypt) = 5.44 bushels
1 arshin (Russian) = 28 inches
1 barrel (U.S.A.), cement = 376 pounds
1 barrel, oils = 42 gallons
1 berkovets (Russia) = 361.13 pounds
1 board foot = 144 cubic inches
1 bolt, cloth = 40 yards = 36.576 meters
1 buncal (East Indies) = 1.49 troy ounces
1 bushel = 2,150.4 cubic inches
1 bushel, imperial (British) = 1.0315 U.S. bushels
1 candy (India) = 784 pounds
1 carat, metric = 0.200 gram
1 carat (U.S.A.) = 0.2056 gram
1 chittak (India) = 900 grains
1 circular mil = 0.0000007854 square inch
1 cuartello (Mexico), liquid = 0.482 liquid quarts
1 cuarteron (Spain), oil = 0.133 liquid quart
1 cubic foot = 1,728 cubic inches
1 cuffisco (Sicily), oil = 5.6 gallons
1 dram = 1.7718 grams
1 dinero (Spain) = 18.5 grains
1 dönüm (Palestine) = 0.25 acre
1 drachma (Turkey) = 49.5 grains
1 feddan (Egypt) = 1.038 acres
1 firkin = 9 U.S. gallons = 34.068 liters
1 flask, mercury = 75 pounds = 34.02 kilograms
1 foot = 12 inches = 0.3048 meter
1 gallon = 231 cubic inches
1 gallon, imperial (British) = 1.20094 U.S. gallons
1 gallon, proof (British) = 1.37 U.S. proof gallons
1 gil = 0.25 pint = 0.118292 liter
1 grain = 0.06480 gram
1 gram = 15.43 grains = 0.03527 avoirdupois ounce
1 grana (Libya) = 165.3 pounds
1 hamlah (Egypt) = 165.1 pounds
1 hectare = 2.471044 acres

1 hogshead = 63 U.S. gallons
1 hundredweight (British) = 112 pounds
1 inch = 0.0833 foot = 2.54005 centimeters
1 iron, leather thickness measure = 1/48 inch
1 kantar (Egypt) = 99.034 pounds
1 keel (British), coal = 21.2 long tons
1 kilogram = 2.205 pounds
1 koku (Japan) = 47.65 gallons = 5.119 bushels
1 kula (Tangier), oil = 4.00 gallons
1 kwan (Japan) = 1,000 momme = 8.267 pounds
1 ligne, metal button measure = 1/40 inch
1 liter = 1.057 liquid quarts
1 lug (Bahamas) = 30 pounds avoirdupois
1 maund (Tibet), wool = 82 2/7 pounds
1 meter, square = 1.196 square yards
1 mil, square = 0.000001 square inch
1 mettar (Tunisia), oil = 5.2 gallons
1 micron = 0.001 millimeter = 0.00003937 inch
1 mil = 0.001 inch = 0.0254 millimeter
1 mile = 5,280 feet = 1.60935 kilometers
1 mile, square = 640 acres
1 millimeter = 0.03937 inch
1 ounce, avoirdupois = 28.35 grams = 0.0625 pound
1 ounce, troy = 31.1 grams
1 peck = 0.25 bushel = 8.8096 liters
1 picul (China) = 100 catties = 133 1/3 pounds
1 picul (East Indies) = 136.2 pounds
1 picul (Japan) = 132.3 pounds
1 pint, dry measure = 33.6 cubic inches
1 pint, liquid measure = 28.875 cubic inches
1 pood (Russian) = 36.11 pounds
1 pound, avoirdupois = 16 ounces = 7,000 grains = 0.4536 kilogram
1 pound, Ionian (Greece) = 1 avoirdupois pound
1 pound, troy = 12 ounces = 0.37324 kilogram
1 pound, Venetian = 1.058 avoirdupois pounds
1 quart, dry measure = 2 pints, dry = 1.1012 liters
1 quart, liquid = 57.749 cubic inches = 0.9463 liter
1 quintal (British) = 100 pounds
1 quintal, metric = 100 kilograms = 220.5 pounds
1 ream, paper measure = 500 sheets = 20 quires
1 scruple, apothecary weight = 20 grains = 1.296 grams
1 shih tan (China) = 50 kilograms = 110.231 pounds
Specific gravity × 0.036 = weight in pounds per cubic inch
1 standard (British), timber = 1,980 board feet

1 standard (U.S.A.), timber = 16⅔ cubic feet
1 tank (India), gem stones and pearls = 24 rati = 0.145 ounce
1 tierce, thin-staved cask = 42 gallons, 310 to 370 pounds
1 ton, long = 2,240 pounds = 1016.047 kilograms
1 ton, metric = 1,000 kilograms = 0.9842 long ton = 1.102 short tons
1 ton, short = 2,000 pounds = 0.8929 long ton
1 tomin (Spain), silver = 9.25 grains
1 vedro (Russian) = 3.249 gallons
1 yard = 3 feet = 0.9144 meter

**Metric Length Measurements**

| Unit | Inches | Feet | Millimeters | Centimeters | Meters |
|---|---|---|---|---|---|
| One inch | 1 | 0.0833 | 25.4 | 2.54 | 0.0254 |
| One foot | 12 | 1 | 304.8 | 30.48 | 0.3048 |
| One millimeter | 0.03937 | 0.00328 | 1 | 0.1 | 0.001 |
| One centimeter | 0.3937 | 0.0328 | 10 | 1 | 0.01 |
| One meter | 39.37 | 3.2809 | 1000 | 100 | 1 |
| One yard | 36 | 3 | 914.4 | 91.44 | 0.9144 |

## Standard Metal Gages

The Brown & Sharpe, or American standard, wire gage is used for aluminum, brass, bronze, and German silver sheet, also for nonferrous wires and rod.

The Birmingham wire gage (B.W.G.), also known as the Stubs' iron wire gage, applies to seamless tubing and to sheet spring steel.

The British imperial gage (B.I.G.), also known as the legal standard gage (L.S.G.), is used in Great Britain, and also in the United States for copper wire.

The Washburn & Moen gage, also known as the Roebling gage, or the national wire gage, applies to all bare, galvanized, and annealed steel and iron wire, and to tinned steel wire and spring steel wire.

The music wire gage is used for "music" wire.

The U.S. standard gage is used for steel and iron plate, galvanized, tinned, or terne.

The twist drill gage, also known as the Morse gage, is used for drill-steel rod. Stubs' steel wire gage is used for steel drill rod. The American screw gage is applied to machine screws. The zinc gage is used for sheet zinc.

## Metal Gages in Common Use

| Gage No. | Brown & Sharpe | Birmingham wire | British Imperial wire | Washburn & Moen | Music wire | U.S. Standard Plate | Twist drill | Stubs steel wire | American screw | Zinc |
|---|---|---|---|---|---|---|---|---|---|---|
| 7-0 | ..... | ..... | 0.500 | 0.4900 | ..... | 0.5000 | | | | |
| 6-0 | ..... | ..... | 0.464 | 0.4600 | ..... | 0.4690 | | | | |
| 5-0 | ..... | ..... | 0.432 | 0.4300 | ..... | 0.4380 | | | | |
| 4-0 | 0.4600 | 0.454 | 0.400 | 0.3940 | ..... | 0.4060 | | | | |
| 3-0 | 0.4100 | 0.425 | 0.372 | 0.3630 | ..... | 0.3750 | ..... | ..... | 0.0315 | |
| 2-0 | 0.3650 | 0.380 | 0.348 | 0.3310 | 0.0085 | 0.3440 | ..... | ..... | 0.0447 | |
| 0 | 0.3250 | 0.340 | 0.324 | 0.3070 | 0.0090 | 0.3130 | ..... | ..... | 0.0578 | |
| 1 | 0.2890 | 0.300 | 0.300 | 0.2830 | 0.0100 | 0.2810 | 0.2280 | 0.227 | 0.0710 | 0.002 |
| 2 | 0.2580 | 0.284 | 0.276 | 0.2630 | 0.0110 | 0.2660 | 0.2210 | 0.219 | 0.0842 | 0.004 |
| 3 | 0.2290 | 0.259 | 0.252 | 0.2440 | 0.0120 | 0.2500 | 0.2130 | 0.212 | 0.0973 | 0.006 |
| 4 | 0.2040 | 0.238 | 0.232 | 0.2250 | 0.0130 | 0.2340 | 0.2090 | 0.207 | 0.1100 | 0.008 |
| 5 | 0.1820 | 0.220 | 0.212 | 0.2070 | 0.0140 | 0.2190 | 0.2055 | 0.204 | 0.1240 | 0.010 |
| 6 | 0.1620 | 0.203 | 0.192 | 0.1920 | 0.0160 | 0.2030 | 0.2040 | 0.201 | 0.1370 | 0.012 |
| 7 | 0.1440 | 0.180 | 0.176 | 0.1770 | 0.0180 | 0.1880 | 0.2010 | 0.199 | 0.1500 | 0.014 |
| 8 | 0.1290 | 0.165 | 0.160 | 0.1620 | 0.0200 | 0.1720 | 0.1990 | 0.197 | 0.1630 | 0.016 |
| 9 | 0.1140 | 0.148 | 0.144 | 0.1480 | 0.0220 | 0.1560 | 0.1960 | 0.194 | 0.1760 | 0.018 |
| 10 | 0.1020 | 0.134 | 0.128 | 0.1350 | 0.0240 | 0.1410 | 0.1940 | 0.191 | 0.1890 | 0.020 |
| 11 | 0.0907 | 0.120 | 0.116 | 0.1210 | 0.0260 | 0.1250 | 0.1910 | 0.188 | 0.2030 | 0.024 |
| 12 | 0.0808 | 0.109 | 0.104 | 0.1060 | 0.0280 | 0.1090 | 0.1890 | 0.185 | 0.2160 | 0.028 |
| 13 | 0.0720 | 0.095 | 0.092 | 0.0915 | 0.0300 | 0.0938 | 0.1850 | 0.182 | 0.2290 | 0.032 |
| 14 | 0.0641 | 0.083 | 0.080 | 0.0800 | 0.0320 | 0.0781 | 0.1820 | 0.180 | 0.2420 | 0.036 |
| 15 | 0.0571 | 0.072 | 0.072 | 0.0720 | 0.0340 | 0.0703 | 0.1800 | 0.178 | 0.2550 | 0.040 |
| 16 | 0.0508 | 0.065 | 0.064 | 0.0625 | 0.0360 | 0.0625 | 0.1770 | 0.175 | 0.2680 | 0.045 |
| 17 | 0.0453 | 0.058 | 0.056 | 0.0540 | 0.0380 | 0.0563 | 0.1730 | 0.172 | 0.2820 | 0.050 |
| 18 | 0.0403 | 0.049 | 0.048 | 0.0475 | 0.0400 | 0.0500 | 0.1695 | 0.168 | 0.2950 | 0.055 |
| 19 | 0.0359 | 0.042 | 0.040 | 0.0410 | 0.0420 | 0.0438 | 0.1660 | 0.164 | 0.3080 | 0.060 |
| 20 | 0.0320 | 0.035 | 0.036 | 0.0348 | 0.0440 | 0.0375 | 0.1610 | 0.161 | 0.3210 | 0.070 |
| 21 | 0.0285 | 0.032 | 0.032 | 0.0318 | 0.0460 | 0.0344 | 0.1590 | 0.157 | 0.3340 | 0.080 |
| 22 | 0.0254 | 0.028 | 0.028 | 0.0286 | 0.0480 | 0.0313 | 0.1570 | 0.155 | 0.3470 | 0.090 |
| 23 | 0.0226 | 0.025 | 0.024 | 0.0258 | 0.0510 | 0.0281 | 0.1540 | 0.153 | 0.3610 | 0.100 |
| 24 | 0.0201 | 0.022 | 0.022 | 0.0230 | 0.0550 | 0.0250 | 0.1520 | 0.151 | 0.3740 | 0.125 |
| 25 | 0.0179 | 0.020 | 0.020 | 0.0204 | 0.0590 | 0.0219 | 0.1500 | 0.148 | 0.3870 | 0.250 |

**Metal Gages in Common Use.—(*Continued*)**

| Gage No. | Brown & Sharpe | Birmingham wire | British Imperial wire | Washburn & Moen | Music wire | U.S. Standard Plate | Twist drill | Stubs steel wire | American screw | Zinc |
|---|---|---|---|---|---|---|---|---|---|---|
| 26 | 0.0159 | 0.018 | 0.018 | 0.0181 | 0.0630 | 0.0188 | 0.1470 | 0.146 | 0.4000 | 0.375 |
| 27 | 0.0142 | 0.016 | 0.0164 | 0.0173 | 0.0670 | 0.0172 | 0.1440 | 0.143 | 0.4130 | 0.500 |
| 28 | 0.0126 | 0.014 | 0.0148 | 0.0162 | 0.0710 | 0.0156 | 0.1410 | 0.139 | 0.4260 | 1.000 |
| 29 | 0.0113 | 0.013 | 0.0136 | 0.0150 | 0.0740 | 0.0141 | 0.1360 | 0.134 | 0.4390 | |
| 30 | 0.0100 | 0.012 | 0.0124 | 0.0140 | 0.0780 | 0.0125 | 0.1285 | 0.127 | 0.4530 | |
| 31 | 0.0089 | 0.010 | 0.0116 | 0.0132 | 0.0820 | 0.0109 | 0.1200 | 0.120 | 0.4660 | |
| 32 | 0.0079 | 0.009 | 0.0108 | 0.0128 | 0.0860 | 0.0101 | 0.1150 | 0.115 | 0.4790 | |
| 33 | 0.0071 | 0.008 | 0.0100 | 0.0118 | 0.0900 | 0.0094 | 0.1130 | 0.112 | 0.4920 | |
| 34 | 0.0063 | 0.007 | 0.0092 | 0.0104 | 0.0940 | 0.0086 | 0.1110 | 0.110 | 0.5050 | |
| 35 | 0.0056 | 0.005 | 0.0084 | 0.0095 | 0.0980 | 0.0078 | 0.1100 | 0.108 | 0.5180 | |
| 36 | 0.0050 | 0.004 | 0.0076 | 0.0090 | 0.1020 | 0.0070 | 0.1065 | 0.106 | 0.5320 | |
| 37 | 0.0044 | ..... | 0.0068 | 0.0085 | 0.1060 | 0.0066 | 0.1040 | 0.103 | 0.5450 | |
| 38 | 0.0040 | ..... | 0.0060 | 0.0080 | 0.1120 | 0.0063 | 0.1015 | 0.101 | 0.5580 | |
| 39 | 0.0035 | ..... | 0.0052 | 0.0075 | 0.1180 | ..... | 0.0995 | 0.099 | 0.5710 | |
| 40 | 0.0031 | ..... | 0.0048 | 0.0070 | 0.1250 | ..... | 0.0980 | 0.097 | 0.5840 | |
| 41 | ..... | ..... | 0.0044 | 0.0066 | ..... | ..... | 0.0960 | 0.095 | 0.597 | |
| 42 | ..... | ..... | 0.0040 | 0.0062 | ..... | ..... | 0.0935 | 0.092 | 0.611 | |
| 43 | ..... | ..... | 0.0036 | 0.0060 | ..... | ..... | 0.0890 | 0.088 | 0.624 | |
| 44 | ..... | ..... | 0.0032 | 0.0058 | ..... | ..... | 0.0860 | 0.085 | 0.637 | |
| 45 | ..... | ..... | 0.0028 | 0.0055 | ..... | ..... | 0.0820 | 0.081 | 0.650 | |
| 46 | ..... | ..... | 0.0024 | 0.0052 | ..... | ..... | 0.0810 | 0.079 | 0.663 | |
| 47 | ..... | ..... | 0.0020 | 0.0050 | ..... | ..... | 0.0785 | 0.077 | 0.676 | |
| 48 | ..... | ..... | 0.0016 | 0.0048 | ..... | ..... | 0.0760 | 0.075 | 0.690 | |
| 49 | ..... | ..... | 0.0012 | 0.0046 | ..... | ..... | 0.0730 | 0.072 | 0.703 | |
| 50 | ..... | ..... | 0.0010 | 0.0044 | ..... | ..... | 0.0700 | 0.069 | 0.716 | |
| 51 | ..... | ..... | ..... | ..... | ..... | ..... | 0.0670 | | | |
| 52 | ..... | ..... | ..... | ..... | ..... | ..... | 0.0635 | | | |
| 53 | ..... | ..... | ..... | ..... | ..... | ..... | 0.0595 | | | |
| 54 | ..... | ..... | ..... | ..... | ..... | ..... | 0.0550 | | | |
| 55 | ..... | ..... | ..... | ..... | ..... | ..... | 0.0520 | | | |
| 56 | ..... | ..... | ..... | ..... | ..... | ..... | 0.0465 | | | |
| 57 | ..... | ..... | ..... | ..... | ..... | ..... | 0.0430 | | | |
| 58 | ..... | ..... | ..... | ..... | ..... | ..... | 0.0420 | | | |
| 59 | ..... | ..... | ..... | ..... | ..... | ..... | 0.0410 | | | |
| 60 | ..... | ..... | ..... | ..... | ..... | ..... | 0.0400 | | | |

## Hardness Numbers

The Brinell method of determining hardness is by the indentation effect of a hard ball pressed into the surface of the metal to be tested. Tables of hardness numbers corresponding to the various indentation measurements are furnished by the makers.

The Scleroscope, or "Shore," method measures hardness by a comparison of the effect of the drop and rebound of a diamond-tipped hammer dropping by gravity from a fixed height. The resulting rebound is then read on a graduated scale.

The Rockwell hardness tester measures hardness by determining the depth of penetration under load of a steel ball or diamond cone in the material being tested. Rockwell hardness is expressed as a number, which is read on a graduated gage.

The Moh hardness scale for abrasives and minerals is measured by scratch comparison, the mineral talc being taken as 1, and the diamond as 10 on the scale.

The Vickers method is similar to the Brinell and Rockwell methods except that a diamond in the form of a pyramid is used as the penetrator. It is thus suitable for measuring metals of high hardness.

The Bierbaum microcharacter, or Bierbaum number, is used to determine the hardness by scratch. The width of a scratch made by drawing the point of a cube-shaped diamond across the surface under a 3-gram load is measured with a microscope and determines the degree of hardness.

### Comparative Hardness of Hard Abrasives

(Scale: Diamond 10, Corundum 9)

| | |
|---|---|
| South American brown bort | 10.00 |
| South American Ballas | 9.99 |
| Belgian Congo yellow (cubic crystals) | 9.96 |
| Belgian Congo clear white (cubic crystals) | 9.95 |
| Belgian Congo gray opaque (cubic crystals) | 9.89 |
| South American carbonados | 9.82 |
| Boron carbide | 9.32 |
| Black silicon carbide | 9.15 |
| Green silicon carbide | 9.13 |
| Tungsten carbide (13 per cent cobalt) | 9.09 |
| Fused alumina (3.14 per cent $TiO_2$) | 9.06 |
| Fused alumina | 9.03 |
| African crystal corundum | 9.00 |
| Rock-crystal quartz | 8.94 |

**Approximate Relationship of Vickers, Shore (Scleroscope), Rockwell, and Brinell Hardness Numbers**

| Vickers or Firth | Shore or Sclero-scope | Rockwell | | Brinell | Approximate Tensile Strength of Steels, lb. per sq. in. | Hardness Class of Steel |
|---|---|---|---|---|---|---|
| | | C | B | | | |
| 1,220 | 96 | 68 | ... | 780 | | |
| 1,114 | 94 | 67 | ... | 745 | | |
| 1,021 | 92 | 65 | ... | 712 | 329,000–380,000 | Hard to file |
| 940 | 89 | 63 | ... | 682 | | |
| 867 | 86 | 62 | ... | 653 | | |
| 803 | 84 | 60 | ... | 627 | | |
| 746 | 81 | 58 | ... | 601 | | |
| 694 | 78 | 56 | ... | 578 | | |
| 649 | 75 | 55 | ... | 555 | | |
| 608 | 73 | 53 | ... | 534 | | |
| 587 | 71 | 51 | ... | 514 | | |
| 551 | 68 | 50 | ... | 495 | | |
| 534 | 66 | 48 | . . | 477 | | |
| 502 | 64 | 47 | . . | 461 | 165,000–317,000 | Machining operations difficult |
| 474 | 62 | 46 | ... | 444 | | |
| 460 | 60 | 44 | ... | 429 | | |
| 435 | 58 | 43 | ... | 415 | | |
| 423 | 56 | 42 | ... | 401 | | |
| 401 | 54 | 41 | ... | 388 | | |
| 390 | 52 | 39 | . . | 375 | | |
| 380 | 51 | 38 | ... | 363 | | |
| 361 | 49 | 37 | ... | 352 | | |
| 344 | 48 | 36 | ... | 341 | | |
| 335 | 46 | 35 | ... | 331 | | |
| 320 | 45 | 34 | ... | 321 | | |
| 312 | 43 | 32 | . . | 311 | | |
| 305 | 42 | 31 | . | 302 | | |
| 291 | 41 | 30 | . . | 293 | | |
| 285 | 40 | 29 | ... | 285 | | |
| 278 | 38 | 28 | ... | 277 | | |
| 272 | 37 | 27 | ... | 269 | | |
| 261 | 36 | 26 | ... | 262 | | |
| 255 | 35 | 25 | . . | 255 | | |
| 250 | 34 | 24 | 100 | 248 | | |
| 240 | 33 | 23 | 99 | 241 | 78,000–159,000 | Commercial machine range |
| 235 | 32 | 22 | 99 | 235 | | |
| 226 | 32 | 21 | 98 | 229 | | |
| 221 | 31 | 20 | 97 | 223 | | |
| 217 | 30 | 18 | 96 | 217 | | |
| 213 | 30 | 17 | 95 | 212 | | |
| 209 | 29 | 16 | 95 | 207 | | |
| 197 | 28 | 14 | 93 | 197 | | |
| 186 | 27 | 12 | 91 | 187 | | |
| 177 | 25 | 10 | 89 | 179 | | |
| 171 | 24 | 8 | 87 | 170 | | |
| 154 | 23 | 4 | 83 | 156 | | |
| 144 | 21 | 0 | 79 | 143 | | |

## Moh Hardness Scale for Minerals

| Original Moh scale | | Modified Moh scale | | Bierbaum number |
|---|---|---|---|---|
| Hardness number | Mineral | Hardness number | Material | |
| 1 | Talc | 1 | Talc | 1 |
| 2 | Gypsum | 2 | Gypsum | |
| 3 | Calcite | 3 | Calcite | 15 |
| 4 | Fluorite | 4 | Fluorite | |
| 5 | Apatite | 5 | Apatite | |
| 6 | Orthoclase | 6 | Orthoclase | |
| | | 7 | Vitreous silica | |
| 7 | Quartz | 8 | Quartz or stellite | |
| 8 | Topaz | 9 | Topaz | |
| | | 10 | Garnet | |
| | | 11 | Fused zirconia | |
| 9 | Corundum | 12 | Fused alumina | |
| | | 13 | Silicon carbide | |
| | | 14 | Boron carbide | |
| 10 | Diamond | 15 | Diamond | 10,000 (1 micron scratch) |

## Hardness Grades in Woods

1. Exceedingly hard. Lignum-vitae, ebony
2. Extremely hard... Boxwood, lilac, jarrah, karri
3. Very hard..... Whitehorn, blackthorn, persimmon
4. Hard..... Hornbeam, elder, yew
5. Rather hard..... Ash, holly, plum, elm
6. Firm..... Teak, chestnut, beech, walnut, apple, oak
7. Soft..... Willow, deal, alder, Australian red cedar, birch, hazel
8. Very soft..... White pine, poplar, redwood.

## Temperature Conversion Scale

To change a temperature in degrees centigrade, to degrees Fahrenheit, multiply by $\frac{9}{5}$ and add 32, thus, $F = \frac{9}{5} C + 32$. To change degrees Fahrenheit, to degrees centigrade, subtract 32 and multiply by $\frac{5}{9}$, thus $C = \frac{5}{9} F - 32$.

| C. | F. | C. | F. | C. | F. | C. | F. | C. | F. |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 32 | 230 | 446 | 460 | 860 | 690 | 1274 | 920 | 1688 |
| 5 | 41 | 235 | 455 | 465 | 869 | 695 | 1283 | 925 | 1697 |
| 10 | 50 | 240 | 464 | 470 | 878 | 700 | 1292 | 930 | 1706 |
| 15 | 59 | 245 | 473 | 475 | 887 | 705 | 1301 | 935 | 1715 |
| 20 | 68 | 250 | 482 | 480 | 896 | 710 | 1310 | 940 | 1724 |
| 25 | 77 | 255 | 491 | 485 | 905 | 715 | 1319 | 945 | 1733 |
| 30 | 86 | 260 | 500 | 490 | 914 | 720 | 1328 | 950 | 1742 |
| 35 | 95 | 265 | 509 | 495 | 923 | 725 | 1337 | 955 | 1751 |
| 40 | 104 | 270 | 518 | 500 | 932 | 730 | 1346 | 960 | 1760 |
| 45 | 113 | 275 | 527 | 505 | 941 | 735 | 1355 | 965 | 1769 |
| 50 | 122 | 280 | 536 | 510 | 950 | 740 | 1364 | 970 | 1778 |
| 55 | 131 | 285 | 545 | 515 | 959 | 745 | 1373 | 975 | 1787 |
| 60 | 140 | 290 | 554 | 520 | 968 | 750 | 1382 | 980 | 1796 |
| 65 | 149 | 295 | 563 | 525 | 977 | 755 | 1391 | 985 | 1805 |
| 70 | 158 | 300 | 572 | 530 | 986 | 760 | 1400 | 990 | 1814 |
| 75 | 167 | 305 | 581 | 535 | 995 | 765 | 1409 | 995 | 1823 |
| 80 | 176 | 310 | 590 | 540 | 1004 | 770 | 1418 | 1000 | 1832 |
| 85 | 185 | 315 | 599 | 545 | 1013 | 775 | 1427 | 1005 | 1841 |
| 90 | 194 | 320 | 608 | 550 | 1022 | 780 | 1436 | 1010 | 1850 |
| 95 | 203 | 325 | 617 | 555 | 1031 | 785 | 1445 | 1015 | 1859 |
| 100 | 212 | 330 | 626 | 560 | 1040 | 790 | 1454 | 1020 | 1868 |
| 105 | 221 | 335 | 635 | 565 | 1049 | 795 | 1463 | 1025 | 1877 |
| 110 | 230 | 340 | 644 | 570 | 1058 | 800 | 1472 | 1030 | 1886 |
| 115 | 239 | 345 | 653 | 575 | 1067 | 805 | 1481 | 1035 | 1895 |
| 120 | 248 | 350 | 662 | 580 | 1076 | 810 | 1490 | 1040 | 1904 |
| 125 | 257 | 355 | 671 | 585 | 1085 | 815 | 1499 | 1045 | 1913 |
| 130 | 266 | 360 | 680 | 590 | 1094 | 820 | 1508 | 1050 | 1922 |
| 135 | 275 | 365 | 689 | 595 | 1103 | 825 | 1517 | 1055 | 1931 |
| 140 | 284 | 370 | 698 | 600 | 1112 | 830 | 1526 | 1060 | 1940 |
| 145 | 293 | 375 | 707 | 605 | 1121 | 835 | 1535 | 1065 | 1949 |
| 150 | 302 | 380 | 716 | 610 | 1130 | 840 | 1544 | 1070 | 1958 |
| 155 | 311 | 385 | 725 | 615 | 1139 | 845 | 1553 | 1075 | 1967 |
| 160 | 320 | 390 | 734 | 620 | 1148 | 850 | 1562 | 1080 | 1976 |
| 165 | 329 | 395 | 743 | 625 | 1157 | 855 | 1571 | 1085 | 1985 |
| 170 | 338 | 400 | 752 | 630 | 1166 | 860 | 1580 | 1090 | 1994 |
| 175 | 347 | 405 | 761 | 635 | 1175 | 865 | 1589 | 1095 | 2003 |
| 180 | 356 | 410 | 770 | 640 | 1184 | 870 | 1598 | 1100 | 2012 |
| 185 | 365 | 415 | 779 | 645 | 1193 | 875 | 1607 | 1105 | 2021 |
| 190 | 374 | 420 | 788 | 650 | 1202 | 880 | 1616 | 1110 | 2030 |
| 195 | 383 | 425 | 797 | 655 | 1211 | 885 | 1625 | 1115 | 2039 |
| 200 | 392 | 430 | 806 | 660 | 1220 | 890 | 1634 | 1120 | 2048 |
| 205 | 401 | 435 | 815 | 665 | 1229 | 895 | 1643 | 1125 | 2057 |
| 210 | 410 | 440 | 824 | 670 | 1238 | 900 | 1652 | 1130 | 2066 |
| 215 | 419 | 445 | 833 | 675 | 1247 | 905 | 1661 | 1135 | 2075 |
| 220 | 428 | 450 | 842 | 680 | 1256 | 910 | 1670 | 1140 | 2084 |
| 225 | 437 | 455 | 851 | 685 | 1265 | 915 | 1679 | 1045 | 2093 |

## Index of Refraction

Index of refraction indicates the relative amount of light transmitted by a material. As the index of refraction increases, the transmitted light decreases. The amount of light reflected back may be considered as in inverse proportion to the amount transmitted, though considerable of the light may be dissipated. A vacuum transmits 100% of the light and reflects 0%, and has a refractive index of 1.00. A polished diamond with parallel sides will transmit only 83% of the light, and the reflected light makes the diamond shine. The sparkle of angle-cut diamonds and highly refractive cut glass is caused by the dissipated or deflected light emerging from the angles.

| Material | Index | Material | Index |
|---|---|---|---|
| Diamond | 2.42 | Nylon | 1.53 |
| Ruby | 1.80 | Polyethylene plastic | 1.52 |
| Sapphire (synthetic) | 1.77 | Pyrex (borosilicate glass) | 1.52 |
| Iceland spar | 1.66 | Window glass (soda-lime) | 1.52 |
| Flint glass (dense leaded) | 1.66 | Acrylic plastics | 1.50 |
| Flint glass (dense barium) | 1.62 | Cellulose acetate | 1.48 |
| Vinyledene chloride | 1.61 | Cellulose acetate butyrate | 1.47 |
| Polystyrene plastic | 1.59 | Ethyl cellulose | 1.47 |
| Flint glass (light leaded) | 1.58 | Fused quartz | 1.46 |
| Flint glass (light barium) | 1.57 | Water | 1.33 |
| Amber | 1.55 | Ice | 1.30 |
| Quartz crystal | 1.54 | Air | 1.0003 |
| Urea-formaldehyde | 1.54 | Vacuum | 1.00 |

## Acidity and Alkalinity Scale

The degree of acidity or alkalinity of solutions is expressed by the pH value. Water is considered as neutral and is given a pH value of 7. Values below 7 are acid, each declining value being ten times more acid than the previous value. A pH of 6 is ten times more acid than a pH of 7, and a pH of 3 is 10,000 times more acid than pH 7. Solutions having values from 7 to 14 are alkaline by the same multiples of 10. A pH of 14 is ten million times more alkaline than a pH of 7. Chemical indicators used to indicate the acidity or alkalinity of solutions are shown at the top of the opposite page.

| | pH range | Color change |
|---|---|---|
| Meta cresol purple | 1.2–2.8 | Red to yellow |
| Thymol blue | 1.2–2.8 | Red to yellow |
| Bromophenol blue | 3.0–4.6 | Yellow to blue |
| Bromcresol green | 4.0–5.6 | Yellow to blue |
| Chlorphenol red | 5.2–6.8 | Yellow to red |
| Bromthymol blue | 6.0–7.6 | Yellow to blue |
| Phenol red | 6.8–8.4 | Yellow to red |
| Cresol red | 7.2–8.8 | Yellow to red |
| Thymol blue | 8.0–9.6 | Red to blue |

## Viscosity of Liquids

The viscosity of a liquid is its resistance to change its form caused by the internal friction of its particle components. Thus, the higher the viscosity the less fluid it is. When a liquid is hot, there is less internal friction owing to the greater motion and distance apart of the molecules, and the liquid will flow more readily than when it is cold. Thus, all comparisons of viscosity should be at the same temperature. Kinematic viscosity is the ratio of viscosity to density. Specific viscosity is the ratio of the viscosity of any liquid to that of water at the same temperature. The reciprocal of viscosity is called Fluidity. Viscosity is usually expressed in poises or centipoises, a poise being equal to 1 gram per cm. per sec.

| Liquid | Viscosity, centipoises | Liquid | Viscosity, centipoises |
|---|---|---|---|
| Benzene (0°C.) | 0.906 | Linseed oil (30°C.) | 33.1 |
| Carbon tetrachloride (0°C.) | 1.35 | Soybean oil (30°C.) | 40.6 |
| Mercury (0°C.) | 1.68 | Sperm oil (15°C.) | 42.0 |
| Ethyl alcohol (0°C.) | 1.77 | Sulphuric acid (0°C.) | 48.4 |
| Water (0°C.) | 1.79 | Castor oil (10°C.) | 2,420 |
| Phenol (18°C.) | 12.7 | Rape oil (0°C.) | 2,530 |

# PHYSICAL PROPERTIES OF MATERIALS

## Definitions of Physical and Chemical Properties

**Acid number** is the weight in milligrams of potassium hydroxide required to neutralize the fatty acid in 1 gram of fat or fatty oil.

**Aliphatic.** Having a straight chainlike molecular structure.

**Aromatic.** Having a ringlike molecular structure.

**Anhydrous.** Having no water of crystallization in the molecule. A hydrated compound contains water of crystallization which can be driven off by heating.

**Brittleness.** The property of breaking without perceptible warning or without visible deformation.

**Conductivity.** The relative rate at which a material conducts heat or electricity at normal temperature (60°F.). Silver is the standard of reference as it is the best known conductor of both heat and electricity.

**Ductility.** The property of being permanently deformed by tension without rupture, that is, the ability to be drawn from a large to a small size.

**Elasticity.** The ability of a material to resume its original form after the removal of the force which has produced a change in form. A substance is highly elastic which is easily deformed and quickly recovers.

**Elastic limit.** The greatest unit stress that a material is capable of withstanding without permanent deformation.

**Elongation.** The increase in length of a bar or section under test expressed as a percentage difference between the original length and the length at the moment of rupture.

**Factor of safety.** The ratio of the ultimate strength of a material to its working stress.

**Flash point.** The minimum temperature in degrees Fahrenheit at which a material or its vapor will ignite or explode.

**Flow, or creep.** The gradual continuous distortion of a material under continued load, usually at high temperatures.

**Fusibility.** The ease with which a material is melted.

**Hardness.** A property applied to solids and very viscous liquids to indicate solidity and firmness in substance or outline. A hard substance does not readily receive an indentation.

**Hygroscopic.** Readily absorbing and retaining moisture.

**Impact strength.** The force in foot-pounds required to break a material when applied with a sudden blow.

**Iodine value** is the number of grams of iodine absorbed by 100 grams of fat or fatty oil. It gives a measure of the chemical unsaturation of an oil or fat. High iodine value, 117 to 206, in vegetable oils, indicates suitability of the oil for use in paints. Low iodine value, not subject to oxidation, indicates nondrying suitable for soaps.

**Malleability.** The property of being permanently deformed by compression without rupture, that is, the ability to be rolled or hammered into thin sheets.

**Modulus of elasticity.** The ratio of the unit stress to unit strain.

**Modulus of rigidity.** When an elastic material is subjected to a shearing stress, a displacement takes place; the ratio of the unit shearing stress to the displacement per unit length is the modulus of rigidity.

**Plasticity.** The property in a material of being deformed under the action of a force and not returning to its original shape upon the removal of the force.

**Porosity.** The ratio of the volume of the interstices of a material to the volume of its mass.

**Reduction of area.** The percentage difference between the area of a bar before being subjected to stress and the area of the bar after rupture.

**Resilience.** The energy of elasticity, that is, the energy stored in a material under strain within its elastic limit which will cause it to resume its original shape when the extreme stress is removed. The modulus of resilience is the capacity of a unit volume to store energy up to the elastic limit.

**Saponification value** is the number of milligrams of potassium hydroxide required to saponify 1 gram of fatty oil or grease.

**Shrinkage.** The diminution in dimensions and mass of a material.

**Solubility.** Capacity for being dissolved in a liquid so that it will not separate out on standing, except the excess over the percentage which the liquid (solvent) will dissolve. A suspension is a physical dispersion of particles sufficiently large that physical forces control their dissolution in the liquid. A colloidal solution is a dispersion of particles so finely divided that surface phenomena and kinetic energy control their behavior in the liquid. A Colloidal solution is close to a molecular combination.

**Specific gravity** is the ratio of the weight of a given volume of a material to the weight of an equal volume of pure water at 4°C.

**Specific heat** is the number of calories required to raise 1 gram of the material 1°C. in temperature.

**Stiffness.** The material property which is measured by the rate at which the stress in a material increases with the strain.

**Strain.** The distortion set up in a material by the action of an external force.

**Strength.** The ability to resist physical forces imposed upon a material.

**Stress.** Internal forces set up in a material by the action of an external force.

**Tensile strength.** The maximum tensile load per square unit of original cross section that a material is able to withstand. Tensile strength is the most common measure of the strength and ductility of metals.

**Thermal conductivity** is the number of calories transmitted per second between opposite faces of a cube, 1 cm. by 1 cm. by 1 cm., when the difference between the opposite faces of the cube is 1°C.

**Thermal expansion.** The coefficient of linear thermal expansion is the increase in unit length with each change of 1 deg. in temperature.

**Thermoplastic.** Capable of being molded and remolded without rupture by heat and pressure at temperatures slightly above normal. When a material sets under heat and pressure into a hard solid not capable of being remolded, it is called Thermosetting.

**Toughness.** The relative degree of resistance to impact without fracture; the property of a material which enables it to absorb energy while being stressed above its elastic limit but without being fractured.

**Ultimate strength.** The stress, calculated on the maximum value of the force and the original area of cross section, which causes fracture of the material.

**Valency.** The capacity of an atom or radical to combine with other atoms. A radical is a group of atoms so combined as to act as a single atom, such as the hydroxyl radical —OH. Different atoms have different valencies. Hydrogen has a valency of 1, oxygen has a valency of 2. It thus requires 2 atoms of hydrogen to combine with 1 atom of oxygen to form a stable compound $H_2O$.

**Yield point.** The minimum tensile stress required to produce continuous deformation in a solid material.

## Modulus of Elasticity in Tension of Typical Materials

| | |
|---|---|
| Lead (cast) | 700,000 |
| Lead (hard-drawn) | 1,000,000 |
| Bakelite (fabric laminated) | 1,000,000 |
| Pine (static bending) | 1,200,000 |
| Ash (static bending) | 1,300,000 |
| Bakelite (paper base) | 2,100,000 |
| Tin (cast) | 4,000,000 |
| Tin (rolled) | 5,700,000 |
| Glass | 8,000,000 |
| Brass | 9,000,000 |
| Aluminum (cast) | 10,000,000 |
| Duralumin | 10,000,000 |
| Copper (cast) | 11,000,000 |
| Zinc (cast) | 11,000,000 |
| Zinc (rolled) | 12,000,000 |
| Cast iron (soft gray iron) | 12,000,000 |
| Brass (cast) | 13,000,000 |
| Bronze (average) | 13,000,000 |
| Phosphor bronze | 13,000,000 |
| Manganese bronze (cast) | 14,000,000 |
| Slate | 14,000,000 |
| Copper (soft, wrought) | 15,000,000 |
| Duronze | 15,500,000 |
| Cast iron (average, with steel scrap) | 16,000,000 |
| Clock brass | 16,600,000 |
| Copper (hard-drawn) | 18,000,000 |
| Cast iron (hard, white iron) | 20,000,000 |
| Mechanite metal | 22,000,000 |
| Monel metal | 23,000,000 |
| Malleable iron | 23,000,000 |
| Wrought iron | 27,000,000 |
| Carbon steel | 30,000,000 |
| Alloy steel (nickel-chromium) | 30,000,000 |
| Nickel | 30,000,000 |
| Tungsten | 60,000,000 |

## Order of Ductility of Metals

1. Gold
2. Platinum
3. Silver
4. Iron
5. Copper
6. Aluminum
7. Nickel
8. Zinc
9. Tin
10. Lead

## Melting Points of Materials Commonly Used for Heat-treating Baths

| Material | Melting points | |
|---|---|---|
| | Deg. F. | Deg. C. |
| 35 per cent lead, 65 per cent tin | 358 | 181 |
| 50 per cent sodium nitrate, 50 per cent potassium nitrate | 424 | 218 |
| Tin | 450 | 232 |
| Sodium nitrate | 586 | 308 |
| Lead | 620 | 327 |
| Potassium nitrate | 642 | 339 |
| 45 per cent sodium chloride, 55 per cent sodium sulphate | 1154 | 623 |
| Sodium chloride (common salt) | 1474 | 801 |
| Sodium sulphate | 1618 | 881 |
| Barium chloride | 1760 | 960 |

## Forging Temperatures of Steels

| | Maximum forging temperatures, deg. F. | Burning temperatures, deg. F. |
|---|---|---|
| 1.5 per cent carbon steel | 1920 | 2080 |
| 1.1 per cent carbon steel | 1980 | 2140 |
| 0.9 per cent carbon steel | 2050 | 2230 |
| 0.7 per cent carbon steel | 2140 | 2340 |
| 0.5 per cent carbon steel | 2280 | 2460 |
| 0.2 per cent carbon steel | 2410 | 2680 |
| 0.1 per cent carbon steel | 2460 | 2710 |
| Silico-manganese spring steel | 2280 | 2460 |
| 3 per cent nickel steel | 2280 | 2500 |
| 3 per cent nickel-chromium steel | 2280 | 2500 |
| Air-hardening Ni-Cr steel | 2280 | 2500 |
| 5 per cent nickel (casehardening) steel | 2320 | 2640 |
| Chromium-vanadium steel | 2280 | 2460 |
| High-speed steel | 2370 | 2520 |
| Stainless steel | 2340 | 2520 |
| Austenitic chromium-nickel steel | 2370 | 2590 |

## Temperatures Available for Melting and Welding

| | |
|---|---|
| Direct electric arc | 4000°C. |
| Oxygen-acetylene torch | 3500°C. |
| Electric furnace | 3000°C. |
| Aluminum-iron oxide powder | 2800°C. |
| Combustion furnace | 1700°C. |
| Oxygen-hydrogen torch | 1450°C. |

## Thermal Conductivity of Materials[1]

Conductivity measured in British thermal units transmitted per hour per square foot of material 1 in. thick, per degree Fahrenheit difference in temperature of the two faces

| | | | |
|---|---|---|---|
| Silver | 2,920.0 | Diatomite block | 0.58 |
| Copper | 2,588.0 | Magnesia, 85 per cent | 0.51 |
| Steel, 1.0 carbon | 328.0 | Wood pulp board | 0.39 |
| Building stone | 12.50 | Bagasse board | 0.35 |
| Slate shingles | 10.37 | Cork, ground | 0.31 |
| Concrete, 1–2–4 | 6.10 | Flax fiber | 0.31 |
| Glass, plate | 5.53 | Diatomite powder | 0.308 |
| Brickwork, mortar bond | 4.00 | Mineral wool | 0.296 |
| Gypsum plaster | 2.32 | Asbestos sheet | 0.29 |
| Brick, dry | 1.21 | Vermiculite | 0.263 |
| Air space, 3½ in | 1.10 | Wool | 0.261 |
| Pine wood | 0.958 | Hair felt | 0.26 |
| Clay tile | 0.60 | Cotton, compressed | 0.206 |

[1] From Paul M. Tyler, U.S. Bureau of Mines.

## Linear Expansion of Metals

Unit length increase per degree centigrade rise in temperature

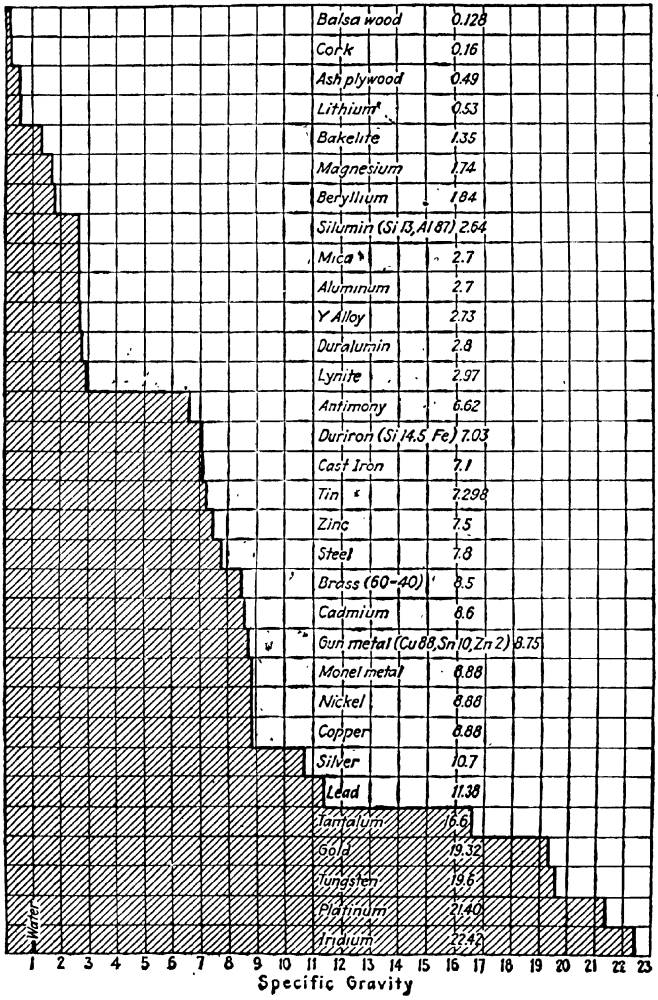
| | |
|---|---|
| Cast iron | 0.000010 |
| Steel | 0.000011 |
| Cobalt | 0.000012 |
| Bismuth | 0.000013 |
| Gold | 0.000014 |
| Nickel | 0.000014 |
| Copper | 0.000017 |
| Brass | 0.000019 |
| Silver | 0.000019 |
| Tobin bronze | 0.000021 |
| Aluminum | 0.000024 |
| Zinc | 0.000026 |
| Tin | 0.000027 |
| Lead | 0.000028 |
| Cadmium | 0.000029 |
| Magnesium | 0.000029 |

## Specific Gravities and Weights

For rough estimating of common construction materials

| | Specific gravity | Weight, pounds per cubic foot |
|---|---|---|
| Aluminum | 2.6 | 165 |
| Bronze | 8.0 | 509 |
| Cast iron | 7.2 | 450 |
| Copper | 8.9 | 556 |
| Glass | 2.5 | 160 |
| Lead | 11.37 | 710 |
| Magnesium | 1.74 | 109 |
| Nickel | 8.9 | 556 |
| Steel | 7.8 | 490 |
| Zinc | 7.0 | 440 |
| Ash, dry | 0.63 | 40 |
| Cedar, dry | 0.36 | 22 |
| Fir, dry | 0.56 | 32 |
| Maple, dry | 0.65 | 43 |
| Redwood, dry | 0.42 | 26 |
| White pine, dry | 0.41 | 26 |
| Granite | 2.6 | 165 |
| Limestone | 2.5 | 165 |
| Sandstone | 1.8 | 110 |
| Pressed brick | 2.2 | 140 |
| Common brick | 1.9 | 120 |
| Terra cotta | 1.9 | 120 |
| Concrete | 2.3 | 144 |
| Portland cement | 3.0 | 183 |
| Mortar | 1.7 | 103 |
| Earth, dry, loose | ..... | 76 |
| Earth, dry, packed | ..... | 95 |
| Sand and gravel | ..... | 60 |
| Asbestos | ..... | 153 |
| Marble | 2.7 | 170 |
| Shale | ..... | 92 |
| Tar | 1.2 | 75 |
| Bluestone | 2.5 | 159 |

**Relative Weights of Materials**



## Average Fatty Acid Composition and Constants of Fats and Oils

| | Chemical formula | Coconut | Palm kernel | Tallow | Lard | Palm | Olive | Cottonseed | Corn | Peanut | Soybean | Sunflower | Linseed | Perilla | Castor | Tung | Whale | Menhaden | Sardine | Herring |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Saturated Acids** | | | | | | | | | | | | | | | | | | | | |
| Caproic | $C_6H_{12}O_2$ | 0.2 | Trace | | | | | | | | | | | | | | | | | |
| Caprylic | $C_8H_{16}O_2$ | 8.0 | 3.0 | | | | | | | | | | | | | | | | | |
| Capric | $C_{10}H_{20}O_2$ | 7.0 | 6.0 | | | | | | | | | | | | | | | | | |
| Lauric | $C_{12}H_{24}O_2$ | 48.0 | 50.0 | | | | | | | | | | | | | | | | | |
| Myristic | $C_{14}H_{28}O_2$ | 17.5 | 15.0 | 2.0 | 1.0 | 1.0 | Trace | 0.5 | .... | .... | .... | .... | .... | .... | .... | .... | 8.0 | 7.0 | 5.0 | 7.0 |
| Palmitic | $C_{16}H_{32}O_2$ | 8.8 | 7.5 | 30.0 | 26.0 | 42.5 | 9.0 | 21.0 | 7.5 | 7.0 | 6.5 | 3.5 | 5.0 | 7.5 | ... | 4.0 | 11.0 | 16.0 | 14.0 | 8.0 |
| Stearic | $C_{18}H_{36}O_2$ | 2.0 | 1.5 | 21.0 | 11.5 | 4.0 | 2.3 | 2.0 | 3.5 | 5 0 | 4.5 | 3.0 | 3.5 | Trace | 2.0 | 1.5 | 2.5 | ..1.0 | ..3.0 | Trace |
| Arachidic | $C_{20}H_{40}O_2$ | .... | .... | .... | .... | .... | 0.2 | Trace | 0.5 | 4.0 | 0.7 | 0.6 | Trace | | | | | | | |
| Behenic | $C_{22}H_{44}O_2$ | | | | | | | | | | | | | | | | | | | |
| Lignoceric | $C_{24}H_{48}O_2$ | .... | .... | .... | .... | Trace | .... | .... | 0.2 | 3.0 | Trace | 0.4 | | | | | | | | |
| **Unsaturated Acids** | | | | | | | | | | | | | | | | | | | | |
| Myristoleic | $C_{14}H_{26}O_2$ | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 1.5 | Trace | Trace | Trace |
| Palmitoleic | $C_{16}H_{30}O_2$ | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 17.0 | 17.0 | 12.0 | 18.0 |
| Oleic | $C_{18}H_{34}O_2$ | 6.0 | 16.0 | 45.0 | 58.0 | 43.0 | 82.5 | 33.0 | 46.3 | 60.0 | 33.5 | 34.0 | 5.0 | 8.0 | 8.6 | 15.0 | 34.0 | 27.0 | 10.0 | 9.0 |
| Linoleic | $C_{18}H_{32}O_2$ | 2.5 | 1.0 | 2.0 | 3.5 | 9.5 | 6.0 | 43.5 | 42.0 | 21.0 | 52 5 | 58.5 | 61.5 | 38.0 | 3.5 | .... | 9.0 | Trace | 15.0 | 13.0 |
| Linolenic | $C_{18}H_{30}O_2$ | .... | .... | .... | .... | .... | .... | .... | .... | .... | 2.3 | .... | 25.0 | 46.5 | .... | .... | Trace | | | |
| Elaeostearic | $C_{18}H_{30}O_2$ | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 79.5 | | | | |
| Ricinoleic | $C_{18}H_{34}O_3$ | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 85.9 | | | | | |
| $C_{20}$ unsaturated | $C_{20}H_{2(20-x)}O_2$ | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 5.0 | 20.0 | 22.0 | 20.0 |
| $C_{22}$ unsaturated | $C_{22}H_{2\ 22-x)}O_2$ | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | 12.0 | 12.0 | 19.0 | 25.0 |
| **Constants** | | | | | | | | | | | | | | | | | | | | |
| Saponification value | ..... | 251–264 | 240–250 | 196–200 | 195–200 | 196–206 | 185–200 | 192–200 | 188–193 | 185–192 | 189–194 | 189–194 | 189–196 | 188–197 | 175–183 | 189–195 | 185–195 | 189–193 | 189–193 | 179–194 |
| Iodine number | ..... | 8–10 | 16–23 | 35–44 | 50–69 | 48–58 | 74–94 | 100–115 | 116–130 | 83–95 | 124–148 | 120–136 | 179–204 | 185–206 | 82–86 | 160–170 | 110–136 | 148–185 | 170–190 | 130–144 |
| Titer—°C. | ..... | 20–23° | 20–23° | 37–46° | 36–43° | 38–47° | 18–25° | 32–38° | 18–20° | 28–32° | 20–21° | 17–20° | 19–21° | 12–17° | .... | 37–38° | 22–24° | 31–33° | 28–34° | 23–27° |

## Relative Values of Insulating Materials

The usual comparisons of insulating values of materials are made on a comparison of their dielectric strengths. The Dielectric Strength of a material is the voltage that a material of a given thickness will resist. It is usually given in volts per mil (1 mil equals 0.001 in.). In any higher voltage the dielectric strength will permit a spark to pass through the material. The quoted dielectric strengths, however, are generally the minimum for the materials. Thus, although the minimum allowable for muscovite mica is 1,000 volts per mil, the best sheets may test up to 1,500 volts per mil.

| Material | Dielectric strength, volts per mil | Material | Dielectric strength, volts per mil |
|---|---|---|---|
| Mica, muscovite | 1,000 | Buna rubbers | 515 |
| Glass | 900 | Vinylidene chloride | 500 |
| Mica, phlogopite | 800 | Fish paper | 500 |
| Electrical porcelain | 800 | Methyl methacrylate | 480 |
| Steatite | 750 | Cellulose acetate | 400 |
| Hard rubber | 700 | Casein plastic | 400 |
| Silicone rubber | 600 | Shellac | 400 |
| Polystyrene | 600 | Varnished cambric | 400 |
| Pyroxylin | 600 | | |

## Standard Paper Sizes

| | |
|---|---|
| Folio note | 5½ by 8½ in. |
| Pocket note | 6 by 9½ in. |
| U.S. government writing | 8 by 10½ in. |
| Commercial writing | 8½ by 11 in. |
| Legal cap | 8½ by 14 in. |
| Foolscap | 13 by 16 in. |
| Denny | 16 by 21 in. |
| Folio | 17 by 22 in. |
| Royal | 19 by 24 in. |
| Super royal | 20 by 28 in. |
| Elephant | 23 by 28 in. |
| Imperial | 23 by 31 in. |

## The Electrochemical Series of Elements

In the table given below, the elements are electropositive to the ones which follow them, and will displace them from solutions of their salts

| | | |
|---|---|---|
| 1. Cesium | 23. Nickel | 45. Silicon |
| 2. Rubidium | 24. Cobalt | 46. Titanium |
| 3. Potassium | 25. Thallium | 47. Columbium |
| 4. Sodium | 26. Cadmium | 48. Tantalum |
| 5. Lithium | 27. Lead | 49. Tellurium |
| 6. Barium | 28. Germanium | 50. Antimony |
| 7. Strontium | 29. Indium | 51. Carbon |
| 8. Calcium | 30. Gallium | 52. Boron |
| 9. Magnesium | 31. Bismuth | 53. Tungsten |
| 10. Beryllium | 32. Uranium | 54. Molybdenum |
| 11. Ytterbium | 33. Copper | 55. Vanadium |
| 12. Erbium | 34. Silver | 56. Chromium |
| 13. Scandium | 35. Mercury | 57. Arsenic |
| 14. Aluminum | 36. Palladium | 58. Phosphorus |
| 15. Zirconium | 37. Ruthenium | 59. Selenium |
| 16. Thorium | 38. Rhodium | 60. Iodine |
| 17. Cerium | 39. Platinum | 61. Bromine |
| 18. Didymium | 40. Iridium | 62. Chlorine |
| 19. Lanthanum | 41. Osmium | 63. Fluorine |
| 20. Manganese | 42. Gold | 64. Nitrogen |
| 21. Zinc | 43. Hydrogen | 65. Sulphur |
| 22. Iron | 44. Tin | 66. Oxygen |

## Classification of Coal[1]

Computed on an ash-free basis

| Rank | Moisture, per cent | Volatile matter, per cent | Fixed carbon, per cent | Heat value, B.t.u. |
|---|---|---|---|---|
| Lignite | 43.4 | 18.8 | 37.8 | 7,400 |
| Subbituminous | 23.4 | 34 2 | 42.4 | 9,720 |
| Low-rank bituminous | 11.6 | 41 4 | 47.0 | 12,880 |
| Medium-rank bituminous | 5 0 | 40 8 | 54.2 | 13,880 |
| Cannel coal | 2 2 | 34 8 | 63 0 | 13,250 |
| High-rank bituminous | 3.2 | 32 2 | 64 6 | 15,160 |
| Low-rank semibituminous | 3.0 | 22.0 | 75 0 | 15,480 |
| High-rank semibituminous | 5 0 | 11.6 | 83 4 | 15,360 |
| Semianthracite | 6.0 | 10 2 | 83.8 | 14,880 |
| Anthracite | 3.2 | 1.2 | 95.6 | 14,440 |

[1] U.S. Geological Survey.

## Electrical Conductivity of Elements Used in Alloys

| | | | |
|---|---|---|---|
| Silver | 100.00 | Iron | 14.57 |
| Copper | 97.61 | Platinum | 14.43 |
| Gold | 76.61 | Tin | 14.39 |
| Aluminum | 63.00 | Tungsten | 14.00 |
| Tantalum | 54.63 | Osmium | 13.98 |
| Magnesium | 39.44 | Titanium | 13.73 |
| Sodium | 31.98 | Iridium | 13.52 |
| Beryllium | 31.13 | Ruthenium | 13.22 |
| Barium | 30.61 | Nickel | 12.89 |
| Zinc | 29.57 | Rhodium | 12.60 |
| Indium | 26.98 | Palladium | 12.00 |
| Cadmium | 24.38 | Steel | 12.00 |
| Calcium | 21.77 | Thallium | 9.13 |
| Rubidium | 20.46 | Lead | 8.42 |
| Cesium | 20.00 | Columbium | 5.13 |
| Lithium | 18.68 | Vanadium | 4.95 |
| Molybdenum | 17.60 | Arsenic | 4.90 |
| Cobalt | 16.93 | Antimony | 3.59 |
| Uranium | 16.47 | Mercury | 1.75 |
| Chromium | 16.00 | Bismuth | 1.40 |
| Manganese | 15.75 | Tellurium | 0.001 |

## Effect of Chromium in Cast Iron

| Chromium, per cent | Structure |
|---|---|
| 0.00 | Ferrite, coarse graphite, and pearlite |
| 0.30 | Ferrite, finer pearlite increasing, and graphite becoming finer |
| 0 60 | Fine graphite and pearlite; free carbides beginning to form |
| 1.00 | Pearlite, cementite, and fine graphite |
| 3 00 | Graphite disappears, matrix of cementite |
| 5 00 | Much massive carbide |
| 10 00–30 00 | Fine cementite |

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