Getting Acquainted With Chemistry

BY

ALFRED MORGAN

Author of
"Simple Chemical Experiments"
"Things a Boy can do with Chemistry"

Explains the importance of chemistry in making the world a better and easier place to live in. Chemistry is explained by the author in terms of articles and products we use every day. In order to understand the modern world it is necessary for the intelligent person to have a knowledge of the fundamentals of chemistry.

The author presents the facts of science in an interesting and understandable manner.

D. APPLETON-CENTURY
COMPANY
34 Bedford Street, London

GETTING ACQUAINTED WITH CHEMISTRY

By ALFRED MORGAN

GETTING ACQUAINTED WITH CHEMISTRY
THE BOY ELECTRICIAN
THE BOY'S OWN BOOK OF SCIENCE AND CONSTRUCTION
THE STORY OF SKYSCRAPERS
AN AQUARIUM BOOK FOR BOYS AND GIRLS
TROPICAL FISH AND HOME AQUARIA
A FIRST ELECTRICAL BOOK FOR BOYS
THINGS A BOY CAN DO WITH ELECTRICITY
THE PAGEANT OF ELECTRICITY
THINGS A BOY CAN DO WITH CHEMISTRY
GETTING ACQUAINTED WITH RADIO
THINGS A BOY CAN DO WITH ELECTROCHEMISTRY
SIMPLE CHEMICAL EXPERIMENTS
FIRST RADIO BOOK FOR BOYS

GETTING ACQUAINTED WITH CHEMISTRY

By ALFRED MORGAN

ILLUSTRATED BY THE AUTHOR

D. APPLETON-CENTURY COMPANY
INCORPORATED
New York London
1945

Printed in Great Britain by the

Contents

CHAPTER I

The Meaning of Chemistry

CHEMISTRY is a magic wand. The tricks that a chemist can do are just as amazing and surprising as those performed by the genie in a fairy-tale. They are as dazzling as the conjuring of a stage magician who pulls rabbits out of hats and pigeons from handkerchiefs.

A chemist can take a shovelful of coal, bake it in an oven, and presto! he has coke, tar, gas, and several liquids.

But he does not stop there.

He grinds up some of the coke. He mixes some of the tar with a teacupful of one thing and a tablespoonful of something else. He does more baking and some boiling, and then from his pots he pulls out the most amazing things: brilliant dyes, flavours, chemicals for fertilizers and paints, medicines, rubber tyres, stockings, leather bags, shingle stains, radio cabinets, brushes for dynamos, materials for batteries and a package of mothballs. Even the new sulphanilamide, a drug that can cure pneumonia and conquer dread infections, has its beginning in a lump of coal.

There is a great difference between the magic of the chemist and the magic of the stage magician. That of the chemist is real; that of the magician is an illusion.

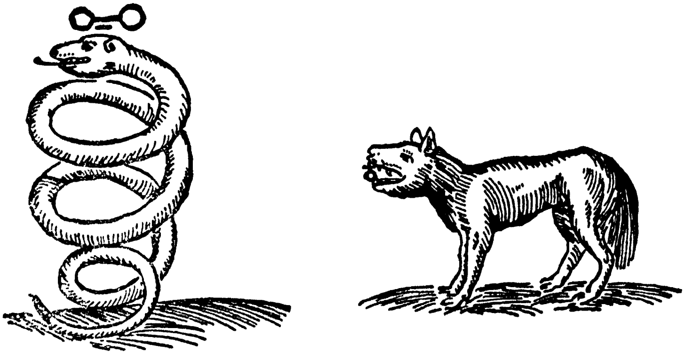
When the stage magician draws forth rabbits, pigeons and pigs from your hat, he is deceiving you. He is fooling your eyes. The creatures were not in your hat. But when a chemist does his tricks, he does not deceive you. He is not a magician: he is a scientist. Legerdemain has no place in chemistry. The chemist's wand is his knowledge of chemistry, the science which plays the most important part in every one's daily routine.

Chemistry is of the utmost importance to all of us. Both the luxuries and the essentials of life are the results of chemical processes. You, this book, your shoes, your food, every plant, every animal, everything that occupies space and has weight are embraced in the realm of chemistry.

WHAT IS A CHEMIST?

Unconsciously perhaps, we all are chemists. Our bodies are chemical factories, where raw materials in the form of food, air and water are fabricated into blood, bone, muscle, energy, thought and action. But the professional chemist, one who mingles the contents of crucibles, retorts and test-tubes for his livelihood, is a person who has a thorough knowledge of chemistry. He knows amazing things about the world, about you and me, about the things that surround us. This knowledge is beneficent. It makes us more comfortable and improves our health.

Chemistry is the branch of science that studies the materials of which the universe is built. It is concerned mainly with the *chemical changes* which take place or which may be brought about in materials.



SEVENTEENTH-CENTURY ALCHEMIST SYMBOLS FOR ARSENIC AND ANTIMONY

The alchemists were dabblers in the immature chemical science of the Middle Ages. They sought to transmute the base metals into gold, searched for an imaginary solvent that would dissolve all substances and for a panacea that would cure all diseases. Although the alchemists' theories were weird and their efforts to turn other metals into gold were misdirected, they discovered such processes as distillation and condensation, and devised much useful apparatus. They found out many chemical facts about lead, sulphur, mercury, salt, silver, gold and other elements and compounds. Out of alchemy, our chemistry was born two centuries ago.

The various special kinds of matter, such as wood, water, iron and air, which we call *substances*, may undergo two kinds of change, *physical* change and *chemical* change. If you understand the difference between these two kinds of change, you will understand what chemistry is.

A physical change is any action which does not alter the composition of a substance. The chopping of wood, forging of iron, melting of ice and tearing of paper are physical changes.

Physical changes are often more apparent than chemical changes.

A chemical change is any action which alters the composition of a substance.

The burning of wood, rusting of iron, souring of milk and digestion of food are examples of chemical changes.

You can chop a pine board into kindling wood, cut it into shavings, or reduce it to sawdust. It still remains wood. The change from a board to small chunks or to shavings or sawdust is a physical change because the *composition* is not altered in any way.

But throw the board into a fire. Ah, here is a different story. A chemical change takes place. The board becomes black. Most of it changes into smoke and burning gases. A few ashes are left. The *composition* of the wood has been completely altered by the effect of the fire.

Perhaps another example will help make clear the difference between a chemical and a physical change. When the fibres of cotton are spun into yarn and the yarn is woven into fabrics, the spinning and weaving are mechanical processes which produce physical changes. No matter how beautiful the fabric or how coarse and crude, the cotton remains cotton. When, however, the chemist treats cotton with acetic acid, the acid and the cotton combine *chemically* to produce an entirely different third substance which resembles neither cotton nor acid and is called *cellulose acetate rayon.* This time there is a chemical change: the cotton is no longer cotton.

A chemist can be either a man or a woman. In order to be an able chemist, it is not necessary to toil and study and experiment until the years have brought middle age or grey hairs. Many young men have made extremely important chemical discoveries. The story of chemistry is full of such instances. The process by which aluminium is extracted from the ore called bauxite was originated by a youth named Charles M. Hall.* The Hall aluminium process is the only commercial method of obtaining aluminium in use to-day. A schoolboy named William Henry Perkin discovered the first aniline dye. Many more instances could

---

* See pages 214-217 in "The Pageant of Electricity," by Alfred P. Morgan, published by the D. Appleton-Century Co.

be given of great achievements in chemistry which were accomplished by young men.

Anyone can mix chemicals together, but not everyone knows what the result of that mixing will be. Only a chemist has the knowledge, training and experience which enable him to mix chemicals together *intelligently*. Usually, he can foretell the results of his mixtures. Of course, sometimes he cannot. Sometimes he experiments, tries something new, delves into the unknown.

A great deal of a chemist's knowledge comes out of books. Much chemistry can be acquired by reading. A good portion comes from his experiments. It is by experimenting that chemists make and prove new discoveries.

When a chemist experiments, he does not mix chemicals at random. He *plans* his experiments. He has reasons for his actions. The result shows whether or not his reasons and methods are correct. Above all, a chemist tries to be accurate. He checks and re-checks his experiments before he draws any important conclusions.

DIFFERENT KINDS OF CHEMISTS

We find in the field of medicine many physicians who are "specialists" and so have concentrated upon certain diseases or upon the ailments of a particular part of the human body. There are heart specialists, brain specialists, stomach specialists, mental specialists and so on. There are many specialists in the chemical profession. In fact, the science of chemistry is so vast that practically every chemist is a specialist in some particular branch.

When a young chemist finishes his college training he may take a position as an instructor in chemistry or join the laboratory staff of a manufacturing organization. Instructors in chemistry at colleges and engineering schools usually carry on research work and become experts or authorities on a certain chemical subject. Young chemists in the laboratory of a manufacturing industry usually concentrate on the processes, materials and problems of that particular business. These young chemists, in the beginning, are usually assistants and work under the direction of an older and more experienced man. So we might find a chemist who perhaps has given years of time to peanuts and peanut oil, or another man whose work deals entirely with corn and the substances that are more or possibly can be made from corn. There are paint chemists, varnish chemists, insecticide chemists, glass chemists, rayon chemists, explosive chemists and many others, down a long list that includes a specialist chemist for everything under the sun, moon and stars.

WHAT IS A CHEMICAL ENGINEER?

Many boys have ambitions to become chemists but have a somewhat hazy idea of their proposed profession. When asked about their plans for the future, they aver that they intend to become "chemical engineers." Apparently the words *chemical* and *engineer* lure them. They do not have any accurate idea of the field of that particular profession.

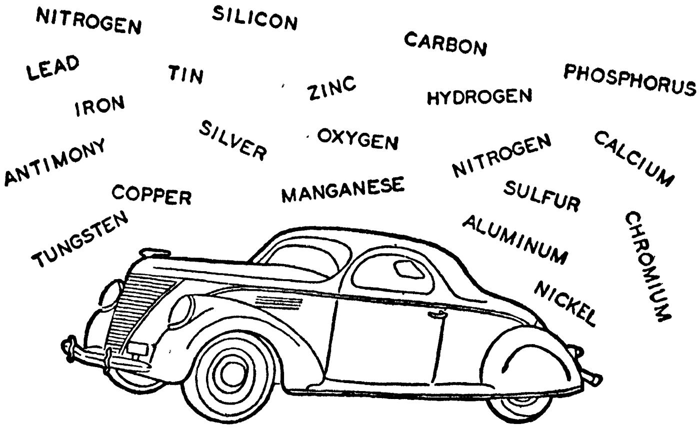
A chemist and a chemical engineer are not the same thing. They are separate professions. A chemical engineer studies chemistry, but he is also taught a great deal about physics and mechanical engineering that is not included in the course of the future chemist. When the chemical engineer begins to practise his profession, he will probably be mainly concerned with pumps, elevators, grinding machines, furnaces, pipes, filters, dryers, etc. In other words, his work is usually more concerned with the *physical* than the *chemical* principles of processes.

On the other hand, a future chemist is taught more chemistry than the future chemical engineer. He is prepared to *analyze* substances, which means to find out what they are composed of, to do research and develop new products, to improve processes and control those already in use.

A great many boys and some girls, although the latter are outnumbered by their brothers, enjoy chemistry as a hobby and pastime. It is not necessary to plan to enter chemistry as a profession in order to find this science interesting.

If you are interested in the world in which you live you will find chemistry interesting. During the twenty-four hours which make a day there is scarcely a single object coming within range of your five senses which does not have some direct association with chemistry. There is nothing that you can reach out and touch in your daily routine which has not been improved or perhaps created by chemists.

If we turn time back far enough, we find our ancestors sleeping on beds of dried leaves with animal skins to serve as clothing and blankets to keep out the cold. There were no chemists in those days. The soft, warm fibres of cotton, wool, rayon, and silk from which your clothing and bedding are made have been prepared by chemical processes. Prior to spinning or weaving they were cleaned, softened, bleached and dyed with chemicals. When you start your day by bathing and brushing your teeth, you use two chemist-made substances, soap and dentrifrice. The windowpane which admits light to your room but keeps out the weather is a chemical product. So are the paint and varnish on the walls and floor. When you have been awake only a few minutes you have already associated with a number of chemistry's benefits.



THE CHEMICAL ELEMENTS FOUND IN AN AUTOMOBILE

Both the luxuries and the essentials of life are the products of chemical processes whose raw materials are taken from the earth, air, forest, farm and sea. An automobile is composed of more than twenty chemical elements which are essential constituents of the alloys, fabrics, glass, rubber, paint, etc., of which it is built. The most important chemical elements in an automobile are named in the illustration.

You will continue to do so all day long and even after you have gone to sleep again at night.

Turn back the years again, this time only a hundred years. Almost everybody was poor in 1842 in the sense that he had small opportunity to get any enjoyment out of life. There was no adequate means of lighting after the sun went down. There were no radios, no motor-cars. It was necessary to work from sun-up to sun-down for a livelihood which provided the barest of homes, the simplest of clothes, and plain, coarse food. There was reason in that day for the old injunction: "Early to bed and early to rise, makes a man healthy,. wealthy and wise." It may still be good advice in some instances, but to-day there are opportunities to become healthy, wealthy and wise by staying up late.

CHEMISTRY HELPS US TO LIVE WISELY AND WELL

The scientists and engineers of modern industry have learned the secret of creating new wealth, and they are sharing it with all of us. By devising new products and making them inexpensive, they have created more real wealth in the last half-century than had been accumulated in the fifty centuries before that.

Inventors, physicists, mechanical and electrical engineers, and skilled mechanics have contributed to this proceess, but they have not accomplished it alone.

Chemists have helped.

Chemists have constantly surveyed distant horizons for new and better materials. Chemical science and industry do not merely produce drugs and chemicals with long-sounding names. They help in large measure to make the things we desire more plentiful and less expensive. They have produced more and better jobs at higher wages, more leisure and a richer life.

200,000 NEW THINGS IN 25 YEARS

Well over 200,000 products, entirely new to man, have come from chemical laboratories since 1914. It was about that year that research chemists went to work on a large scale to synthesize a new world from raw materials which are present in abundance in the air, earth and water. Chemists use the word synthetize to mean the putting of different things together into new from. By synthesis, first in laboratories, then in small, experimental "pilot" plants where problems can be solved and kinks ironed out, and finally in large factories, have come a dazzling array of chemistry's wonders. We find artificial fibres such as rayon and nylon, artificial rubber, new alloys better than anything we ever had before, plastics of all types, solvents, detergents, life-saving medicines, textile assistants, dyes, soaps, heat-resistant glasses, improved paints and varnishes, etc. The full list is longer than this.

The word synthesis used in the last paragraph needs further explanation.

Its adjective is *synthetic. Synthetic,* like certain people, suffers unwarranted public ill repute. To the average layman, *synthetic* suggests a substitute of low quality.

Let us banish this unfair implication. This word is honourable. Man-made synthetic chemical products are far superior to those made by nature. Synthesis is part and parcel of our great progress toward better and more plentiful materials from which to make the world's goods.

It all started, this making of synthetics, back in 1856, when an English school-boy spent his Easter vacation trying to make a synthetic quinine. Natural quinine is a medicine prepared from cinchona-bark and used in treating malaria. William Henry Perkin, as we have said, was the intrepid lad who sought to duplicate quinine with a coal-tar product, He puttered with some aniline oil, and instead of the clean white crystals he was hoping for, he obtained a tarry black mass. When he tried to wash the sticky stuff out of his utensils with alcohol, he was amazed to see it produce a beautiful purple solution, He found that the resulting purple could be used as a dye, and his father had the courage and means to back him in the manufacture of his discovery. The purple powder which young Perkin thus produced was *mauveine,* the first of the aniline dyes. His discovery showed the way to a great modern industry, that of making dyes from coal-tar.

Mauveine was soon followed by the discovery of a method of manufacturing the dye known as *alizarin* or Turkey Red, and also indigo from coal-tar products.

Until the time of these discoveries some colours were a luxury, some were unsatisfactory; they faded quickly. All dyes then in use were obtained directly from some natural source, from plants and minerals. For many centuries the only source of indigo had been the juice of a plant grown in the East Indies. Long experiments by the great German chemist, Baeyer, resulted in a method whereby *indigotin,* the chief colouring constituent of commercial indigo, can be cheaply manufactured from *naphthalene,* obtained from coal-tar.

In order to produce a dye, it is not required merely to produce a substance which has colour, In addition, dyes must also be able to fix themselves in such a way that they are not immediately faded by the effects of soap and water and also sunlight. There are many substances that will colour fabrics, but they are readily removed by washing and so do not make satisfactory dyes.

To-day many thousands of different dyes are made synthetically. A few of these are identical in chemical composition with the natural dyes, but the great majority are chemist-created: they do not exist in nature at all.

THE UNITED STATES LEADS THE WORLD IN CHEMISTRY

Numerical facts are perhaps like broccoli, since some like them and some do not. Here are some for those who do.

Before 1914, although the total production of chemicals in the United States was larger than that of either England or Germany, most of this output was the so-called "heavy chemicals," such as nitric, sulphuric and hydrochloric acids and various alkalis. They imported a great many chemical compounds which were not produced in the country. Some of these they did not know how to make.

When World War I began in 1914, Germany had practically a world monopoly in the synthesis of colours, perfumes, flavours, medicines, photographic chemicals and a host of other things made from coal-tar. Some of these substances were produced by secret processes. The United States had no dye industry. They depended upon Germany for most of their colours. The outbreak of the war cut off the source of supply and the stocks on hand were soon exhausted. White became a stylish colour in the country. Soon American chemists were making coal-tar and other dyes in an attempt to remedy the shortage. At first, some of the American-made dyes were not so good as the German dyes. During those days many a man bought a black hat which had been dyed with domestic dyes. When it had been in the sunlight for a short time it turned green.

They learnt with dismay that they could not be prosperous, healthy or safe unless they could produce the chemicals they had formerly imported from Germany. A vast amount of research was begun. Before long American chemists not only solved all the problems of the shortage but improved many German compounds and discovered new ones. To-day, American dyes are as good as German dyes or better.

Surplus stocks of war chemicals were another incentive to American chemists. After the war, the United States Government had on hand 40,000,000 pounds of phenol, great piles of nitrated cotton, tankfuls of butyl alcohol and other materials used in making explosives, the immediate market for which had disappeared.

The use of chemical raw materials on a large scale in industries that are not wholly chemical industries, grew out of the salvage of these surplus war materials. In wartime, plough-shares were beaten into swords. Now, with the coming of peace, chemistry was reversing the process. Swords were beaten back not only into plough-shares but also into some things quite new under the sun.

To everyone's astonishment, the 40,000,000 pounds of phenol, which was normally about ten years' supply, and the piles of nitrated cotton and tankfuls of butyl alcohol vanished in less than three years. The phenol went into bakelite. The nitrated cotton and alcohol were made into duco and other cellulose lacquers which replaced paint and varnish on motor-cars.

It took their rayon industry from 1910 to 1928 to grow to the point where it produced 1,000,000 pounds of rayon yarn in a year. It did not double its production and reach 2,000,000 pounds a year until five years later (1933), but in 1940 more than 500,000,000 pounds of rayon were produced in the United States. *One-half a billion pounds of rayon.* The same amazing growth took place in the production of plastics and many other synthetic substances.

Fortunately, synthetic rubbers are beginning to show the same rate of growth. Now that the supply of natural rubber from the East Indies is cut off by war, the synthetic rubber industry will undoubtedly grow like Jack's proverbial beanstalk.

To-day, the output of chemicals in the United States is greater than the combined production of England, Germany, Japan, Italy and Russia. In the year 1940 more than $2,000,000,000 worth of chemicals were produced in the United States. This country now holds the leadership in the development and production of new substances.

CHAPTER II

Chemical Research

MAKING A BETTER TO-MORROW

RESEARCH means scientific investigation. It is diligent, systematic investigation by experiment and test, carefully checked and repeated. Its purpose is to acquire knowledge which will improve old methods, develop new ones. More research is carried on in the chemical industry than in all others. In America alone, chemical research employs more than 9,000 scientists and engineers. These men have made scientific and industrial progress that leads the world.

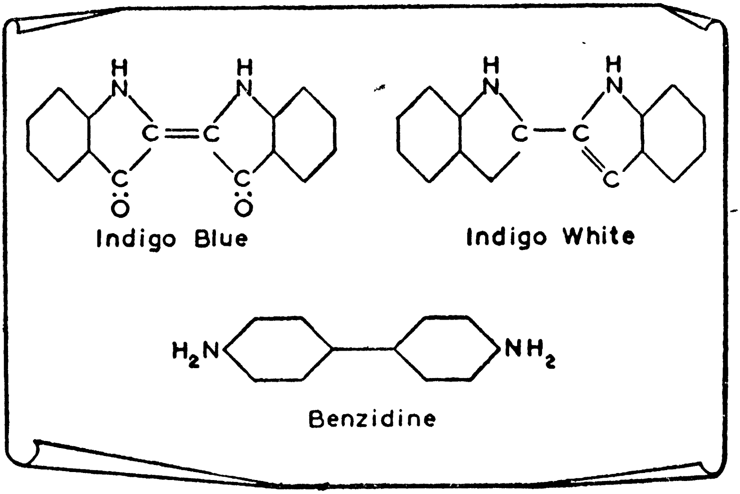
BUILDING A NEW CHEMICAL

The hit-and-miss mixing of chemicals has sometimes brought results, but discoveries made in chemical laboratories are by no means largely the result of accident. Neither are they due to any kind of black magic. Ability and lots of hard work, as well as luck, are necessary to create something new.

Many new medicines, dyes, plastics and other substances that nature does not supply have first been planned and built in the mind of a chemist somewhat as a new building is first pictured in the mind of an architect. Building a new chemical in the laboratory is, of course, not quite such a straightforward procedure as designing a house.

But there are times when a chemist can plan to some extent each step of building a new compound. He can decide in advance what materials and how much of each he will use and what "shape" his new chemical structure will take. In planning, the chemist makes sketches. A chemist's sketch of the shape of a chemical structure is a diagram of its invisible *molecule.* This is not the best place to explain a molecule. So, until it is explained more fully a little later in these pages, let your conception of a molecule be the smallest portion of a substance that can exist and still retain its composition and properties. A chemist's diagrams of the molecules he is interested in building are to him what sketches and blue-prints are to an architect.

Usually, there are several possible ways of making a substance in the laboratory. A great deal of chemical research consists of the investigation, testing and proving of possible ways of carrying out each step in the process. A common method is to begin with a substance containing some of the desired elements and mix it with another compound containing the other needed elements. When one element is chemically joined to another element, the result is unlike either of the ingredients. It is somewhat similar to mixing colours. For example, when blue and yellow are combined, green is produced.



SKETCHES OF A CHEMIST

These are diagrams of the molecules of two dyes and the brownish powder, called benzidine, from which several dyes can be made.

Unfortunately, building a new substance is not so simple as merely bringing together the necessary ingredients, at least in the beginning. The chemist usually has to discover how to make the ingredients unite and how to make them do so in the *proper proportions* and in a certain way. He is also vitally interested in the cost of the ingredients and of the process. In the end, the new substance may be produced by a simple process, but the methods may have been discovered only after months and years of following clues and trails that led nowhere.

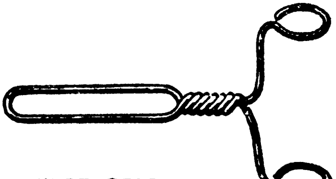
WE UNDERTAKE SOME RESEARCH

In order to become acquainted with chemistry and to perform chemical experiments, it is not necessary to possess a laboratory or to acquire a chemical kit, elaborate apparatus, or expensive chemicals.

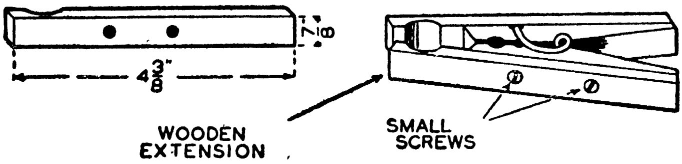
A kitchen table can be your laboratory. Probably everything else required is right at hand. You will need this book, a few test-tubes, a test-tube holder and a few chemicals.

Test-tubes are the most useful pieces of glassware in a chemical laboratory. They are made in several sizes. The little tubes included in toy chemical outfits for boys are too small to be entirely practical. The most useful size for performing the experiments described in this book is from five to six inches long and from ⅝ to ⅞ of an inch in diameter.

SPRING CLOTHES PIN



WIRE TEST-TUBE HOLDER

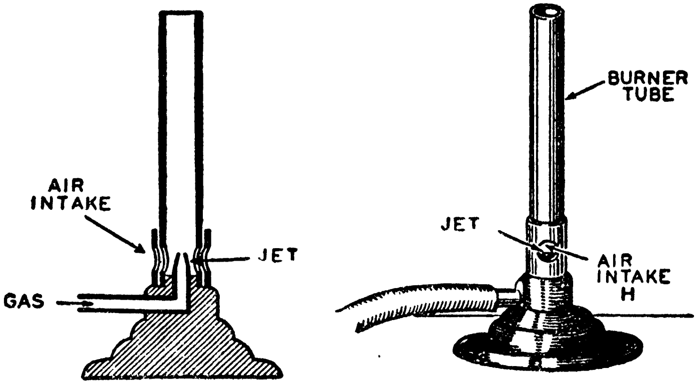


HOME-MADE TEST-TUBE HOLDER

Use a test-tube holder when heating the contents of a test-tube above a flame. You can make your own holder by bending a stiff piece of wire as shown in the illustration or by altering a spring clothes-pin.

When the contents of a test-tube are heated above a flame it is advisable to use a test-tube holder to avoid burning your fingers. You can make your own test-tube holder by bending a stiff piece of wire into the form shown in the illustration. Another type of simple test-tube holder which you can make from a spring clothes-pin is also illustrated.

Heat is used in many chemical experiments. Bunsen burners give a clear, blue flame which does not deposit any soot, and they are widely used in chemical laboratories. The fuel is illuminating gas; consequently, a gas connection is necessary. The principle of the Bunsen burner is employed in all gas heaters and in the burners on kitchen gas-ranges. When the burner is in use, gas enters the burner tube through the small jet (J) and mixes with a supply of air from the air intake (H). The air enters the intake holes at the base of the tube because gas issues from the jet at high speed and draws air along with it.



SECTION

THE BUNSEN BURNER

Bunsen burners are widely used in chemical laboratories because they produce a hot non-luminous flame which does not deposit soot.

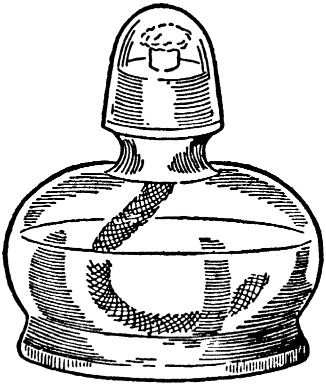
It was the first successful device for burning gas efficiently and its principle is used in all gas heaters, including the burners on kitchen gas-ranges. It was invented by the great teacher and brilliant investigator, Robert Wilhelm Bunsen, who also discovered the chemical elements cæsium and rubidium and together with Kirchoff invented the spectroscope.

When the burner is in use, gas enters the burner tube through a small jet and mixes with a supply of air which is drawn in through the air intake holes, H.

A burner on a kitchen gas-range can be used when heat is required for home experiments in chemistry. Do not hold a test-tube over the centre of the burner. Use the flame at the edge.

When gas is not available in your home laboratory, an alcohol lamp may be used as the source of heat. One like that illustrated, made of heavy glass, complete with brass burner, wick and ground-glass cap.

You can make an alcohol lamp out of a mucilage bottle, metal tube, wick and cork. The wick passes through a short piece of metal tubing fitted in a hole in the cork. The wick consists of several strands of white cotton cord packed tightly into the tube.



ALCOHOL LAMP

An alcohol lamp similar to the one illustrated above is inexpensive and a good substitute for a Bunsen burner in performing chemical experiments requiring heat.

Here is a word of caution in regard to alcohol lamps. After filling an alcohol lamp, wait long enough before lighting it, for any alcohol which may have spilled to evaporate. Be certain that there is no alcohol on your fingers when you strike a match. It is an excellent idea to keep an alcohol lamp standing in a shallow pan of sand, both when it is lighted and when it is not in use.

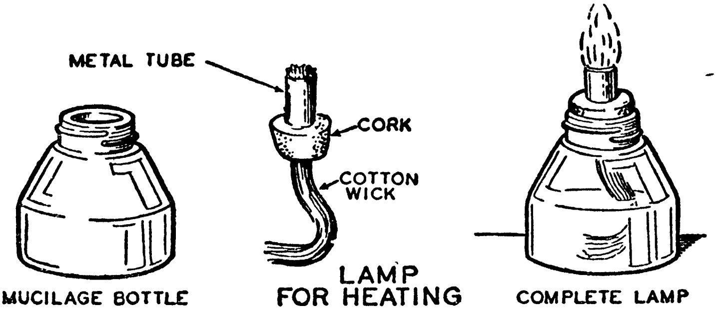
YOUR KITCHEN IS A CHEMICAL LABORATORY

You will not have to seek far for the chemicals to perform many revealing experiments. We usually have in our own homes a great many chemicals—some of them very interesting. They are to be found in the medicine cabinet and kitchen cupboard. The baking-powder, salt, vinegar and washing soda in the kitchen closet and the iodine on the medicine shelf are no less chemicals than those more mysterious substances with long-sounding names found in a chemist's laboratory.

A great many chemical processes take place every day in the kitchens of our homes. Actually, a kitchen is nothing more or less than a *domestic chemical laboratory.*

COOKING FOOD IS A CHEMICAL PROCESS

Heat brings about chemical changes in foods. Heat is one of the chemist's handiest tools. He uses it almost constantly. He warms, boils, bakes and roasts substances to bring about chemical changes. A great many industrial processes take place in a device called an autoclave. This is simply a large-scale edition of the household pressure-cooker. A double-boiler is often used in the kitchen to prepare puddings and cereals. Chemical factories have a counterpart of the kitchen's double-boiler in the steam-jacketed kettle.



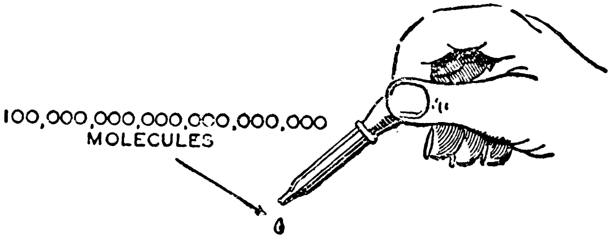
A SOURCE OF HEAT FOR YOUR EXPERIMENTS

If an alcohol lamp or a Bunsen burner is not available for performing the experiments in this book, you can use a lamp made from an ink or mucilage bottle. Roll a strip of sheet tin into a small tube and push it through a hole bored in the stopper. If the latter is metal, solder the tube in place. Provide a wick made of several strands of white cotton cord. Use enough string to fill the tube tightly. Use denatured or wood alcohol as fuel. Wait before lighting the lamp until any alcohol that might have been spilled has evaporated. Water will extinguish burning alcohol.

Washing your hands, laundering, doing the dishes are chemical processes. If ordinary soap were to be kept in a bottle on a shelf in a chemist's laboratory, it would undoubtedly be labelled *sodium stearate.* That is its chemical name. You may have been using soap for years without giving any thought as to how this extremely useful chemical compound performs its work.

In the short paragraph which follows, explaining the cleansing action of soap, it has been necessary to use the chemical terms *emulsify*, *adsorption* and *colloidal* suspension. They are not explained at this point but will be later when we penetrate their mystery by some experiments.

Soap and water help to remove dirt in two ways. The soap emulsifies (see page 173) the grease that is present with dirt, making it possible for the water to wash away both the grease and the dirt. It also cleans by forming soap-bubbles. The particles of dirt are adsorbed (see page 173) on the surface of the soap-bubbles and are thus removed. Both the emulsifying action of soap and its adsorption power result from the fact that soap forms a colloidal suspension in water. Many common substances—for example, milk and coffee—are colloidal suspensions. But more about colloids later.



100,000,000,000,000,000,000 MOLECULES

The number of molecules in a comparatively small quantity of ordinary matter is so great as to be beyond human comprehension. Even a single drop of water contains about 100 quintillion molecules.

That which takes place in the kitchen when baking-powder is put in cake batter is just as interesting a chemical process as the manufacture of some wonderful compound in a great factory. When you light a burner on the kitchen gas-range, throw the match away, set a pot over the flame and turn your attention to something else—well, that's that. But if you are curious about the gas and about its flame and want to know the "whys and wherefores," you will be digging into a chemical gold-mine.

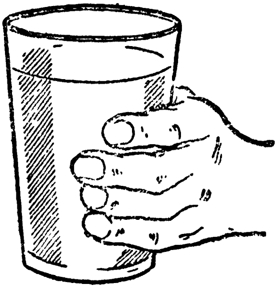
If it is natural gas, you will first uncover *methane*. Methane is the simplest of the *hydrocarbons*. A hydrocarbon is a compound containing only hydrogen and carbon. Methane, acetylene, benzene, turpentine and naphthalene are all important hydrocarbons and there is little that a chemist cannot do with them. He can make anything from a headache tablet to a motor-car tyre, starting with hydrocarbons as the raw material.

If the gas is artificial gas, it is made from coal. Some of the things that can be done with coal have been mentioned on the first page of this book.

So, you see, you do not have to go through the main entrance of a great laboratory in order to enter the wonderland of chemistry. You can enter through your kitchen.

THE ELEMENTS ARE THE CHEMIST'S ALPHABET

For countless centuries, men have known something about chemistry. The making of glass, baking of clay, fermenting of wine and preparation of primitive dyes are chemical processes, so old that their origin is lost.



AN IMAGINARY EXPERIMENT

Many elementary text-books of chemistry describe the following imaginary experiment to illustrate the vast number of molecules in a small quantity of ordinary substances.

Suppose some red dye were stirred into a tumbler filled with water and each molecule in the water was consequently stained red. Then suppose that this tumblerful of red molecules were poured into the ocean and time allowed for it to mix with all the oceans, lakes, and rivers on earth. If a glassful of water were thereupon dipped up out of the ocean, you would find over ONE THOUSAND red-stained water molecules in the glass.

Chemistry *as a science* did not really begin until the seventeenth century when Robert Boyle, the famous Irish chemist and physicist, stated for the first time the definition of a chemical *element.*

The chemical elements may be likened to the letters of the alphabet. The written or printed words of our language are formed by putting the proper letters together in the correct order. Out of the twenty-six elements or letters of the alphabet, thousands of words can be constructed.

Chemists recognize the existence of approximately ninety-two elements.* The more than *one-quarter million* different substances in the world are only different groupings of the ninety-odd elements into *molecules*. Molecules may be likened to printed words. Printed words are various groupings of letters; molecules are various groupings of elements.

The elements which enter into the composition of a substance are hidden from the eye. It is impossible to tell whether a sample of a pure substance is composed of one, two, three, four or more elements merely by looking at it. A chemist can tell the composition of almost any known substance by chemical tests called analysis.

"RESEARCH" ON A LUMP OF SUGAR

Here is a bit of "research" into the nature of sugar—an experiment which will prove that you cannot tell whether sugar is an element or composed of several elements merely by looking at it.

Consider for a moment a lump of cane sugar, the kind used on the dining-table to sweeten tea and coffee. You cannot tell what elements it may contain by looking at it. If you put it under a microscope, either an inexpensive boy's microscope or a laboratory instrument of the highest possible magnification you will not get a clue. You will have a magnified view which will show you that the tiny crystals all have the same geometric form and that all are equally transparent. Some crystals may be larger than others, but this is of no significance in searching for the elements of which sugar is composed.

In looking at sugar with the aid of a microscope, you have given it a *physical* examination. Now let us give it a *chemical* examination.

Break up the lump of sugar into small pieces and put them into a clean, dry test-tube. Use a test-tube holder so that you will not burn your fingers and heat the sugar over the flame of an alcohol lamp or Bunsen burner.

Since this may be your first chemical experiment, let's take time out for a short sermon.

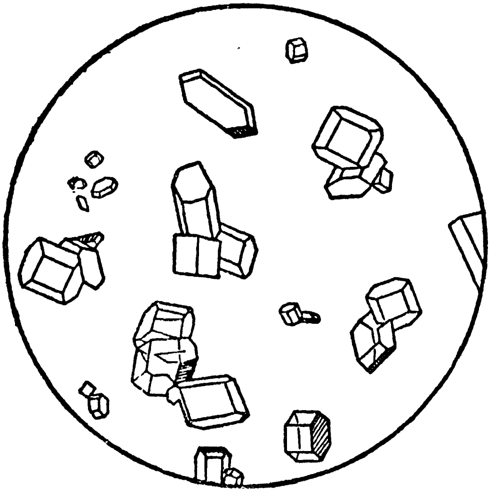
---

* Scientists believe that others exist which have not yet been discovered.

There is a proper way and a wrong way to heat a test-tube. Learn the right way now and do it the right way the first time and always.

Never hold a test-tube so that its open end is pointed at yourself or any one near by. When the contents of a test-tube are heated they may sputter or boil over suddenly. Therefore, do not hold your face close to a test-tube while heating it. Always remove the tube from the source of heat before examining it closely.

The way to avoid sudden splutters which may spatter hot substances out of a tube is not to heat the bottom of the tube. Shake it gently while heating and heat the contents near the top.



SUGAR CRYSTALS UNDER THE MICROSCOPE

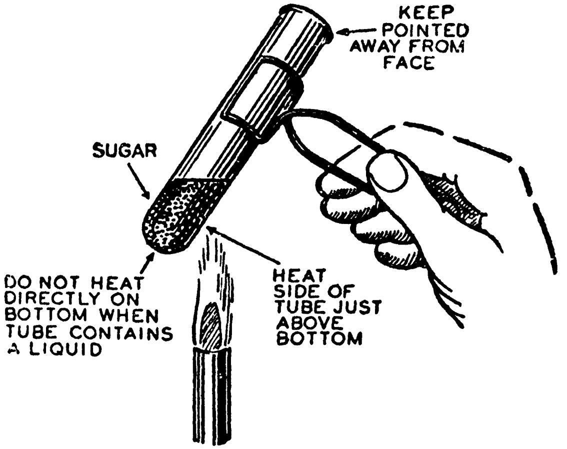
If a few drops of a solution of cane sugar in water are allowed to evaporate on a glass slide, small crystals of sugar will form. Viewed with a low-power microscope, the crystals appear as irregular octahedrons.

It is not necessary to hold the tube in the flame. A point just above the tip of the flame will provide a gentle heat sufficient for most experiments.

Now, back to our experiment with sugar.

If you heat the sugar gently, it will splutter and crackle. You can find a clue for this crackling if you look far enough. Notice that the upper part of the tube, the cool part near the open end, is cloudy. It is covered with vapour like that which often clouds window panes in cold weather.

A chemist would have no difficulty in proving that this vapour is water and that it came out of the sugar. The tiny sugar crystals contain water and when heated the water turns into steam which cracks the crystals wide open. We heard them cracking. The escaping steam condensed on the cooler upper portion of the tube and turned into the tiny droplets of water vapour.



THE EXPERIMENT WITH SUGAR

Heating sugar in a test-tube is not only an interesting experiment if you observe carefully what happens but it is also an opportunity to learn the proper way to heat a test-tube. Keep the open end pointed away from your face. Do not heat the bottom. Heat the side just above the bottom. Heat gradually, not suddenly. These precautions will prevent the tube from cracking or its contents from being suddenly blown out.

The water thus driven out of the crystals, which we could not see with the microscope, is called the *water of crystallization.* Many crystals contain water of crystallization.

Continue to heat the sugar. It melts, then turns brown and boils. Steam still comes forth from the thick, almost black syrup. Finally there is a solid black mass left which looks like coke or charcoal. It is in fact *carbon* and carbon is one of the elements. We have discovered one of the elements in sugar to be carbon. There are ways in which a chemist can prove the black mass is carbon.

Is carbon the only element in sugar? No. The water vapour which came out of the sugar tells us there are others. You probably know already that water is not an element, that is is composed of two elements, a gas called *hydrogen* and a gas called *oxygen*. That too is a fact which a chemist can prove easily in a number of ways. One way is to pass an electric current through water. The water will disappear. It decomposes into hydrogen and oxygen.

We now have the answer. Sugar crystals are composed of three elements: *carbon*, *hydrogen* and *oxygen*.

Chemists can carry their work of analysis much farther than we can or than we did in heating sugar in a test-tube. They can break up sugar in such a way that they find apparently:

12 tiny particles of *carbon*
22 tiny particles of *hydrogen*
11 tiny particles of *oxygen*

grouped together in the complicated structure which is a molecule of cane sugar. By the way, the chemist's name for cane sugar is *sucrose*.

This molecule is the smallest particle of sugar that can exist. If it is taken apart it is no longer sugar but merely particles of the three elements, carbon, hydrogen and oxygen. These particles are called *atoms*.

There are as many different atoms as there are elements.

A molecule is the smallest piece of a substance that can exist without being divided into atoms.

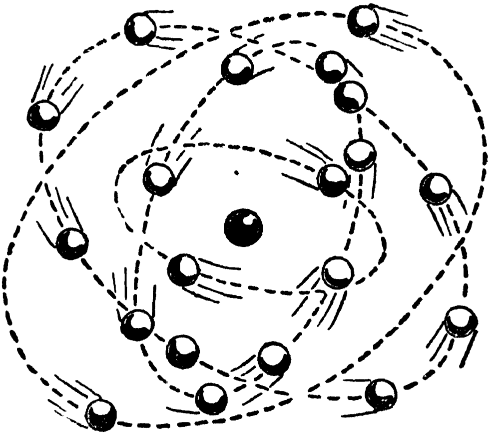
The amazing practical achievements made in chemistry during recent years could never have been accomplished without *theories* to guide chemists in their thinking and planning. The most important of these theories is that of the structure of matter. It has led and is still leading chemists to the successful solution of their problems. You may be familiar already with this theory. We are going to discuss it only briefly.

THE ELECTRICAL NATURE OF THE ATOMS

There is good reason to believe that the tiny atoms out of which molecules are built are electrical. According to this theory, the atoms of all the elements are made up of tiny particles of positive electricity called *protons* and tiny particles of negative electricity called *electrons*.

Of course, no one knows whether this is true or not. No one has ever seen an atom of any of the elements. They are too small to be seen. Nevertheless, atoms can be weighed and measured in spite of their infinitesimal size and their invisibility. Their measured weight and size and their behaviour uphold the theory concerning their nature. Moreover, the theory works. When the chemist uses it in his plans for tearing down and building up molecules, he gets results which he could not obtain otherwise.

The atoms of one element are not like the atoms of another element in respect of the number of electrons and protons they contain. The number of electrons and protons in an atom determines the element to which the atom belongs, whether it is the element copper or the element hydrogen, etc.



AN IMAGINATIVE FIGURE OF AN ATOM OF CALCIUM

An atom consists of one or more negative particles of electricity called electrons revolving around a positive nucleus. The individual character of the various elements can be readily explained by the arrangement of these "planetary" electrons. Their arrangement determines such things as whether the element is a metal or a non-metal, whether it enters into combination with other elements easily, or with difficulty, or not at all.

In an atom of calcium there are supposedly 20 planetary electrons whirling around the central nucleus. They travel in four circular paths or orbits. Two travel in a small circle near the nucleus. Eight whirl around in a slightly larger path. Eight more follow a still larger orbit and two follow an outer circle.

The electrons and protons in an atom are not in a mass like the kernels in a ball of pop-corn. They are separated from one another by space. All the protons and about half the electrons are in a nucleus at the centre of the atom. Around the central nucleus, the remaining electrons revolve at tremendous speed in one or more orbits or circular paths.

We can get a fair idea of the probable arrangement of an atom by making a picture in which the electrons are represented as small spheres moving around a larger sphere in circular paths. The circular paths are represented by dotted lines.

CHAPTER III

Carbon

HERE is an element which we eat, wear as a jewel, burn in stoves and use to cut glass.

In our "research with a lump of sugar" we happened upon the most remarkable of the elements. Like interesting people, carbon is not always the same. Charcoal, soot, diamonds, pencil lead, black smoke, drawing ink, stove-polish, and coal are all forms of carbon which go about, so to speak, with entirely dissimilar clothes on.

Carbon and the substances it forms when in chemical union with other elements are more important in daily life than those of us who are not chemists are likely to be aware.

Everything that has life contains carbon. It leads all other elements in the number of compounds which it forms. The black polish on your shoes and the pencil in your pocket are not your only intimate association with carbon. We are all relatives of the soot in the stove-pipe. All our foods contain carbon. It is one of the elements we are made of.

The great majority of substances known to chemical science are compounds of carbon. Indeed, they are so numerous that the name *organic chemistry* has been given to that division of the science which treats of *carbon compounds.*

Carbon itself and a few carbon compounds—the famous and infamous gases carbon dioxide and carbon monoxide among them—and the other elements and their compounds belong to the field of *inorganic chemistry.*

The known compounds of all elements except carbon total only 26,000. They are greatly outnumbered by carbon compounds which estimates place at anywhere from 225,000 to 500,000.

DIAMOND: A FORM OF CRYSTALLIZED CARBON

When carbon wishes to be left severely alone, chemically speaking, it takes the form of a diamond,

A diamond is pure carbon in sparkling, crystalline form.

It resists the strongest acids and alkalis. It shows no interest in any of the other elements unless it is heated. Then its atoms vibrate with excitement, and it looks around for its old friend oxygen. Heated to redness and plunged into a jar containing oxygen, it will behave exactly like its humble brother, a lump of coal. It will burn with a bright flame.

The diamond is the hardest substance known. It will cut any other material and so is frequently used to form the cutting edges of tools and drills. Diamond-tipped turning and boring tools maintain a cutting edge almost indefinitely and leave a smooth finish.

Diamonds are found in Brazil, Australia, India and South Africa. It is thought that they were formed millions of years ago when the earth was passing from the plastic to the solid state. Under the enormous pressure caused by the shrinkage of the earth's solid crust, molten carbon cooled and crystallized as diamonds.

Chemists have been able to imitate nature's process and make tiny microscopic diamonds from charcoal. Diamonds large enough to be useful cannot be made artificially by any method known at the present time.

The weight of a diamond is measured in *carats.* A carat is one-fifth of a gram.

GRAPHITE: A FORM OF CARBON WHICH IS THE "LEAD" IN A PENCIL

Graphite is also crystallized carbon, but the arrangement of its atoms in their molecules is different from the arrangement of the atoms in the molecules of a diamond. This makes graphite look and act quite different from the diamond, It is soft, metallic in appearance and slippery to the touch.

The smooth, slippery scales of graphite slide over each other so easily that graphite makes an excellent lubricant.

Graphite also has other properties which bring it into widespread use. It is a very good conductor of heat and electricity and will not melt or burn except at exceedingly high temperatures. Consequently, it is used in making high-temperature melting pots or crucibles, for electrodes in electric furnaces, and as brushes for electric motors and generators.

Lead-pencils are not made of lead at all. The business part of a pencil that leaves its mark on paper is a mixture of graphite and clay; the more graphite in proportion to the clay, the softer and blacker is the pencil. In the manufacture of a pencil, the graphite and clay mixture is squeezed through a die which forms it into a long rod. After baking, the rods are enclosed in strips of wood and cut to pencil length.

Graphite is also known as plumbago and black-lead. These are somewhat old-fashioned names. It is found in the earth in California, Ceylon, Siberia and England, but it is seldom found in a pure state. Once, our entire supply of graphite came from mines. To-day there would not be enough of this useful substance to make all the pencils and crucibles we need if the chemist had not come to our rescue.

Dr. E. G. Acheson, who also invented carborundum, developed the method used to make graphite artificially. Graphite can be cheaply produced in any desired quantity and quality by the Acheson process of baking powdered coke in an electric furnace at a temperature of 5,400° F.

COAL: ANOTHER FORM OF CARBON

One cool autumn night about a century and a half ago, a pioneer and adventurer named Neccho Allen built a camp-fire which, figuratively speaking, has been burning ever since. Allen built his fire on some black rocks. He did this as a precaution, thinking that the fire could not easily spread while he slept in its comforting warmth. The next morning, when he awoke, all the wood had been consumed but *the black rocks were burning.*

The astonished Allen was not the first to discover that the "black rocks" which we call coal will burn. Theophrastus, one of Aristotle's pupils, mentioned rocks that burned in a treatise he wrote *On Stones* in 371 B.C. From time to time others commented also on the phenomena of burning stone, but Allen was the first to do something about it. He urged people to use the black rocks as fuel instead of wood and charcoal. It was not long before coal came into use as a fuel.

Good coal is largely carbon, uncrystallized.

A ton of carbon in the form of coal costs from four to five pounds, depending upon the size of the pieces, the variety and the place where it is delivered. A bit of carbon the size of a pea in the form of a diamond costs a hundred pounds. Diamonds are scarce. Coal is plentiful. Therein lies the reason for the difference in cost.

Coal is, as we all know, a black or brownish-black solid, not at all handsome or decorative like a diamond. Yet in spite of its lack of beauty and its much lower cost, coal is infinitely *more valuable than diamonds*. Coal-mines are one of the earth's greatest natural resources. They are an important source of *energy* and *raw material*. Practically every manufacturing process is in some way dependent upon coal. The greatest manufacturing nations are those which possess and utilize an abundant coal supply.

Coal-beds were once great swampy forests in which trees and plants fell and slowly turned into coal. The coal now being mined is believed to have been formed 40,000,000 to 150,000,000 years ago. Fossils found in coal-beds give us clues as to what the world was like at that remote period. Some of the fossil trees are forty feet in diameter and proportionately tall.

It is thought that the fallen trees and plants which formed the coal-beds became covered with earth deposits which shut off the air from the decaying vegetation. Under the influence of moisture, pressure and lack of air, the decaying vegetable matter turned into the dark solid which we know as coal.

THE CHEMIST USES COAL

Do not think of coal merely as a fuel to be used for making steam or for heating and cooking. Coal, to the chemist, is not just a fuel: it is an almost limitless supply of carbon.

Coal, the air we breathe, and the water in our rivers are inexhaustible reservoirs of carbon, oxygen, hydrogen and nitrogen. These four elements are the primary building blocks which nature employs in the creation of cotton, silk, wool, sugar, rubber, camphor—in short, most organic things.

When a chemist wishes to imitate nature or perhaps do things nature never intended to do, the chances are he starts with a coal pile.

Coal is a sort of scrap heap of the vegetable kingdom. In a scrap heap are all sorts of odds and ends. In coal are all sorts of odds and ends of carbon compounds. Out of these, a chemist can can find the raw materials for building up thousands of useful substances that never existed before they were made in the laboratory.

If you want to salvage the lumber in a crate and build something out of it, first you must take the crate apart. That is the method a chemist uses when he wishes to make something out of coal. First, he *takes the coal apart.*

When coal is heated in the open air or burned in a stove or furnace where it is plentifully supplied with air, it combines with oxygen. It burns up and nothing but ashes is left. The ashes are worthless to a chemist. They are mineral substances, any of which, if wanted, can be obtained more cheaply than by burning coal.

But when coal is heated in a closed vessel where the oxygen of the air does not reach it, it does not burn up, it *breaks up.* That is the way the chemist takes coal apart when he wishes to use its lumber for making something else.

AN EXPERIMENT WITH A LUMP OF COAL

If you put some soft coal in a test-tube and heat it, very little oxygen will reach the coal. It will not burn, it will break up. Several interesting substances will be produced. The commercial manufacture of these, by heating coal in much the same manner as you can do it in a test-tube, is a large industry.

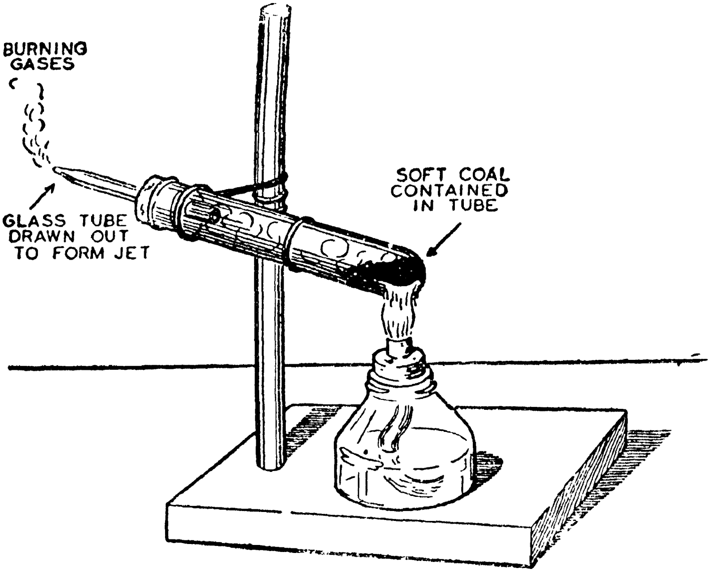
Fit the open end of the test-tube with a cork and a glass tube as shown in the illustration. Use soft or *bituminous* coal for the experiment. If you do not use soft coal at home, you can probably find some fragments at a factory or power-station, or along a railway line.

Crush the coal into a coarse powder with a hammer. A heaping teaspoonful will be enough. Put the powder in the test-tube and shake it down to the closed end. Then place the test-tube in a holder and heat the powdered coal over the flame of a Bunsen burner or an alcohol lamp.

A MINIATURE GAS FACTORY AND COKE OVEN

Soon an unpleasant-smelling gas will be given off and escape from the glass tube. Apply a lighted match and the gas will burn with a smoky yellow flame. This gas is a mixture of several compounds of carbon and hydrogen called *coal gas.* In fact, it is *illuminating gas* and is made on a large scale commercially in much the same manner as you have made it, namely, by heating coal. This is one of the methods of producing the gas used in the kitchen gas-range.

If you continue to heat the coal until no more gas is given off, you will find a small, dry, bright, grey, porous mass remaining in the test-tube. This is called *coke*. It is an excellent fuel and is indispensable in the manufacture of iron and steel, It is mainly fixed carbon and ash.



A MINIATURE COKE OVEN

This experiment illustrates one of the most important commercial chemical processes.

One of the greatest sources of cheap and plentiful raw materials for chemical industries is coal. By heating coal in a closed retort chemists can obtain materials that they can transform into almost innumerable other substances. Take *phenol*, for example. It helps make plastics, printing-inks, soaps, medicines, aspirin and dyes. Dozens of different industries need phenol in the things they make. Or take another chemical from coal, *ammonium thiocyanate*. Explosives, resins, adhesives and fly sprays are made from it. On and on the story goes. Coal can be said to have a thousand chemical "grandchildren."

However, it is not coke that we are interested in at the moment. If you are observant you will notice in the glass tube leading from the test-tube some drops of dirty water and some black sticky stuff. We are interested in this foul-smelling substance. It is called *coal-tar*.

Once, the water and tar that formed in the pipes at a gas or coke plant, just as they formed in the glass tube in your experiment, were nuisances. The gas-makers and the coke-makers washed them out and threw them away. They did it until chemists took a hand in the matter.

There is nothing chemists like to do more than utilize waste materials. First, they showed how to save the valuable ammonia which was going to waste in the water and gas. Later, when they started fussing with the coal-tar, it proved to be one of the most useful things in the world.

THE MAGIC IN A BARREL OF TAR

From the nasty-smelling, sticky mess four different oils were obtained by distillation. The oils were found to contain various *enes*, *lenes*, *cenes*, and *ols*, called: benzine, toluene, xylene, phenol, naphthalene, cresol, anthracene, phenanthrene and carbazole. These substances are quite different from coal-tar in appearance. They are all either white solids or colourless liquids.

Some of these names may be slightly familiar, but to anyone who is not a chemist, they probably do not have much significance. However, they are the *beginning substances* of that amazing list of carbon compounds known as *coal-tar products*, which include thousands of dyes capable of putting a rainbow to shame, pain-killing and disease-healing medicines, fertilizers, explosives, such as the famous T.N.T., food preservatives, disinfectants, antiseptics, perfumes, photographic materials, roofing and paving compounds, wood preservatives and flavours.

It is said that "beauty is only skin deep," and it might be added that ugliness is sometimes only on the surface. Coal-tar has no outward beauty. It is too sticky, too messy and smelly, to have any social status whatsoever. Yet when the chemist delves beneath its surface, he finds some of the most exalting perfumes, sweetest flavours and loveliest colours in the world.

A PARTIAL LIST OF PRODUCTS OBTAINED FROM COAL-TAR

Benzene
Toluene
Xylene
Naphthalene
Phenol
Cresol
Anthracene
Creosote
Nitrobenzene
Quinol
Resorcinol
Hexylresorcinol
Pyrogallic acid
Pyridin
Carbon bisulphide
Chlorobenzol
Explosives
Hydroquinone

Aniline
Azo-dyes
Nitrotoluene
Benzaldehyde
Benzoic acid
Nitrophenol
Naphthols
Anthraquinone
Carbolic acid
Picric acid
Salicylic acid
Aspirin
Phenacetin
Benzidin
Para Amidophenol
Flavours
Sulpho acids
Phthalic acid
Indigo
Alizarin
Paints
Paving materials
Roofing
Tarvia
Lysol
Thymol

CHAPTER IV

Ammonia

A COMPLETE list of the chemicals required to perform all the experiments described in this book is given below. They are almost all "household chemicals," everyday substances in common use, which are usually to be found in the kitchen closet or the medicine chest. Lime can be obtained at a builder's supply yard, paint or hardware store. Litmus and phenolphthalein can be bought at a hardware store.

Common Name	*Chemist's Name*
Household ammonia	Dilute ammonium hydroxide
Borax	Sodium borate
Boric acid	Boric acid
Chalk	Calcium carbonate
Quicklime	Calcium oxide
Carbon tetrachloride	Carbon tetrachloride
Hydrogen peroxide	Dilute hydrogen peroxide
Clorax	Sodium hypochlorite
Iodine	Tincture of iodine
Litmus paper	Litmus paper
Epsom salts	Magnesium sulphate
Baking soda	Sodium bicarbonate
Washing soda	Sodium carbonate
Phenolphthalein	Phenolphthalein
Starch	Starch
Sugar	Sucrose
Salt	Sodium chloride
Sal ammoniac	Ammonium chloride

The first substance on our list of household chemicals is *ammonia.* This takes us back again to the coal-pile, for from a pile of soft coal a chemist can make, among other things, ammonia. With ammonia, he can make ice, fertilizers, smelling salts, dry cells, explosives, nitric acid and washing soda.

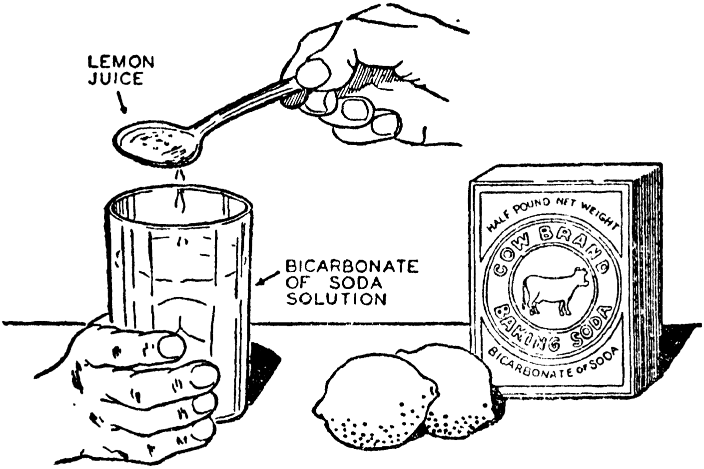
When coke and gas for heating and cooking are manufactured by distilling soft coal, one ton of coal produces the materials shown in the following list;

THE CRUDE PRODUCTS OF ONE TON OF COAL

1,400-1,500 pounds of coke
10,000-12,000 cubic feet of gas
9-10 gallons of coal-tar
2 gallons of creosote

80 pounds of pitch
4 gallons of concentrated ammonia liquor or
18-30 pounds of ammonium sulphate.

Small gas plants scrub their gas free from ammonia by washing with water. The resulting liquor is usually concentrated and sold to a chemical firm where it is made into aqua ammonia and ammonium sulphate. Large plants use a more elaborate method of recovering the ammonia.



FOODS ARE CHEMICALS

Many common substances in everyday use in the household can be used in chemical experiments. For example, if lemon juice is added to bicarbonate of soda (baking soda) a reaction takes place which releases carbon dioxide gas and causes the solution to bubble and "fizz." The same sort of reaction takes place in baking powders and in some types of fire extinguishers. If enough lemon juice is added to the bicarbonate of soda the solution which remains is principally a solution of sodium citrate, a medicine.

Ammonia is not one of the elements. It is a compound of two of the elements, a pungent-smelling gas consisting of one atom of hydrogen and three of nitrogen. Its odour is very distinctive; there is nothing else like it. When compressed under a pressure of 66 lbs. per square inch or more, ammonia becomes a liquid.

Probably the most familiar form of ammonia is that used in the household as a cleansing agent. It is commonly called ammonia, but actually it is a rather weak solution of ammonia in water, or what a chemist would call dilute *ammonium hydroxide.* Household ammonia is usually cloudy because of impurities. Pure concentrated ammonium hydroxide, which the chemist uses, is a clear liquid.

If ammonia was limited to household use as a dissolver of grease and a remover of dirt, it would not be of much interest or of great value, because there are other substances which could be used in its place. But it is more than a household drudge. It is of great importance in the chemical laboratory, in industry, agriculture and warfare. Ammonia is the starting point for making many useful ammonium compounds. Some of these are ammonium nitrate, used to make explosives; ammonium hydroxide ; liquid ammonia, used in refrigerating plants, and ammonium chloride used in making dry cells.

THANK AMMONIA FOR YOUR FLASH-LIGHT

This is an electrical as well as a chemical age. Most of the electricity used in our factories and homes is produced by large electric generators in power-stations. The power is transmitted over wires.

It is not practical for the wires from a power-plant to extend everywhere. For certain purposes we need a compact and portable source of electric power. We have therefore become very dependent upon batteries. They are portable power-plants which produce electricity through chemical action.

Flash-lights and portable radios utilize "dry" batteries. The terms "dry cell" and "dry batteries" are really misnomers. Dry cells are not dry. They are moist. There must be a considerable percentage of water in the cell in order for the necessary electrochemical process to occur.

A dry cell consists of two *electrodes* and some chemicals. One of the electrodes is a carbon rod. The other is the zinc container. In order for an electric current to be produced by the cell, the zinc electrode must be consumed or dissolved by chemical action. A paste made of *ammonium chloride* is used for this purpose.

AMMONIA'S ROLE AS JACK FROST

We all like comfort. One of the things that adds to our comfort is ice—ice to preserve foods, to make ice-cream and to cool drinks on a hot day.

Not many years ago our summer supply of ice, if we were fortunate enough to have one, was *natural* ice, cut from ponds and lakes or rivers and stored until needed in huge refrigerators called ice-houses. The cost of this natural ice, delivered to your door, gradually increased from year to year. For this, the ice-man always had an explanation. He said either, "last winter was so mild we had a poor ice crop" or "last winter the ice was so thick it was hard to cut."

Contrary to a rather widespread opinion, when water freezes the impurities *do not* "freeze out of it." Consequently, natural ice was no purer or cleaner than the pond or river water from which it was frozen. A frozen piece of unfiltered, untreated river water was not the most hygienic thing to put in your iced-tea.

There were, you see, good reasons why artificial ice made from pure water by means of ammonia should replace natural ice made by cold weather. Artificial ice could be made from distilled water or from water out of deep artesian wells—in other words, from clean water. Furthermore, artificial ice did not have to be stored for long periods or hauled long distances. It could be made as needed and any fair-sized town could use enough to make an artificial ice-plant possible.

Natural ice is a thing of the past. Ammonia has taken over the role of Jack Frost. Artificial ice is made on a commercial scale by using ammonia as a *refrigerant.* The process is a simple one.

HOW AMMONIA IS USED TO MAKE ICE

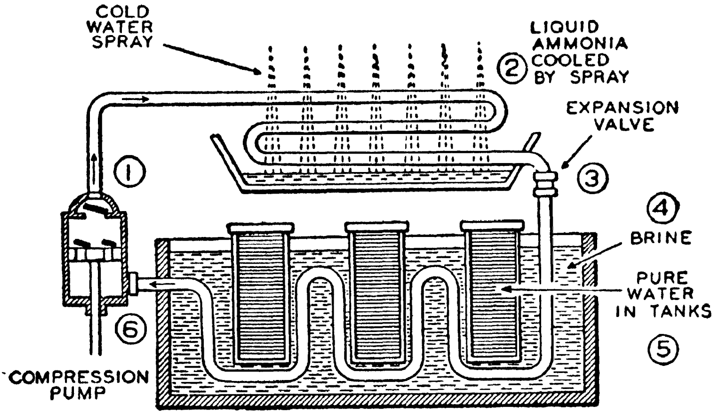
First, ammonia gas is liquefied by compressing it with a power-driven pump. Compressing the ammonia not only liquefies the ammonia but causes it to *give out* heat. The heat is carried away by a cold water spray falling over the pipe coils through which the liquefied ammonia flows.

The liquefied ammonia, under pressure, escapes from the cooling coils through an expansion valve. The expansion valve produces a sudden decrease in pressure which permits the liquid ammonia to expand back into a gas. When this takes place, the gas *absorbs* heat and there is a sharp drop in the temperature of any substance warmer than the gas which the gas comes into contact with.

You will understand what takes place if you bear this in mind:

when something feels hot, it is *giving out* heat; when it feels cold, it is *absorbing* heat.

The cooled ammonia gas, looking for heat which it can absorb, is then sent through coils of pipe which are immersed in brine and surround cans of pure water. The heat-absorbing ammonia gas draws heat from the brine and cools it below the freezing-point of water. The water in the cans is converted into blocks of ice.



ICE-MAKING

Artificial ice is made on a commercial scale by using ammonia as a refrigerant. When ammonia gas is compressed it becomes a liquid and in so doing gives out heat. If allowed to expand it becomes a gas again and absorbs heat. An ammonia ice-making plant is essentially a system of pipes and a pump or compressor. The pump compresses the ammonia gas and turns it into a liquid. The heat which is given out is carried away by a water spray. The liquid ammonia is then allowed to expand in the pipe system. It becomes a gas and absorbs heat from the brine solution in which the pipes are immersed. The brine is chilled below the freezing point of water. Metal tanks containing fresh water surrounded by the cold brine are quickly frozen.

It is a continuous process and the ammonia is used over and over again. The ammonia gas, after absorbing heat from the brine, is returned to the compressor pump where it is again liquefied and gives up to the cooling water spray the heat which it withdrew from the brine.

For cold storage or refrigeration purposes in warehouses and packing-plants, the cold brine is pumped through coils of pipes in the storage rooms.

ELECTRICAL REFRIGERATORS OWE A DEBT TO AMMONIA

The mechanism of a household refrigerator of the Frigidaire type is a *heat pump*. The cooling mechanism is merely a compact little machine for *pumping heat out of a box* and radiating it into the surrounding atmosphere. It uses a chemical as a refrigerant and operates on much the same principle as a commercial ice-plant.

The first "mechanical ice-boxes" for household use employed ammonia as the refrigerant or chemical cooling agent. This had a serious disadvantage. If a leak occurred in the mechanism it was necessary for everyone in the building to run for his life. The fumes from a very small amount of ammonia are overpowering. So, ammonia was discarded in household refrigerators and the easily liquefied gases *sulphur dioxide* and *methyl chloride* employed in its place. These, too, were unsatisfactory. In case of a leak they also were dangerous. Both were poisonous and one was inflammable.

Many people preferred not to take the risk involved in having a mechanical refrigerator in the house. The manufacturers were anxious to make their machines perfectly safe. Engineers could not solve the problem. They had to put it up to the chemists.

The ideal refrigerant would be a non-poisonous and non-inflammable gas which would be obliging enough to boil between 32 degrees above zero and 15 degrees below zero on the Fahrenheit thermometer. There was no such gas known and it was decided to create or synthesize a new gas. Experiments proved successful and a non-poisonous and non-inflammable substance given the long name of *dichlorodifluormethane* was produced. Each modern mechanical household refrigerator uses from 2 to 4 lbs. of this refrigerant. If a leak occurs and dichlorodifluormethane escapes, it is merely inconvenient, not dangerous.

The dichlorodifluormethane is compressed by a motor-driven pump. It passes into a heat radiating coil of copper tubing located outside of the cold compartment. The heat in the liquid gas is given up to the surrounding atmosphere. The cooled liquid, still under pressure, escapes from the cooling coil through an expansion valve, which relieves the liquid to boil or expand back into a gas. The gas is then ready to reabsorb the heat which it gave away when it passed through the cooling coil. It flows through a coil of tubing surrounding the ice cube compartment and absorbs the heat from the foods, air and water inside the ice-box. The gas then returns to the pump where it is compressed and reliquefied.

A switch operated by a thermostat controls the motor which drives the pump. When the temperature rises to the point where the box needs cooling, the thermostat puts the pump to work again.

AMMONIA CAN BE MADE BY SYNTHESIS

Not all the vast quantity of ammonia in one form or another which finds its way to market has its source in coal. If nitrogen and hydrogen are mixed and then heated and compressed while in contact with specially prepared porous iron granules, they unite to form ammonia. There are several systems of manufacturing *synthetic* ammonia which depend upon this principle. The necessary nitrogen is secured from the atmosphere, the hydrogen from water. Atmospheric nitrogen is available in inexhaustible quantities. So is water. Thus does modern science offer compensation to coal-poor nations.

AN EXPERIMENT IN WHICH AMMONIA IS MADE

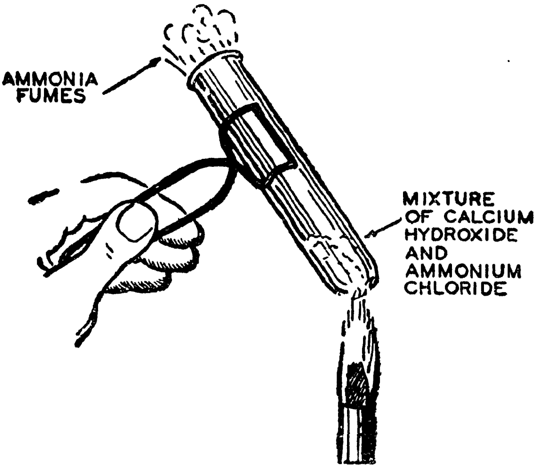
We can not easily imitate any of the processes used to manufacture ammonia commercially, but we can prepare ammonia the way chemistry students in a laboratory commonly do it.

Put half a teaspoonful of dry slaked lime and the same amount of sal ammoniac into a test-tube.

The chemist's name for slaked lime is *calcium hydroxide.* You will also need some to prepare other experiments in this book. A cupful will come in handy. You can get some from a plasterer or mason or from a dealer in builder's supplies. They call it hydrated lime. You can obtain sal ammoniac (the chemist's name for this is *ammonium chloride*) at a pharmacy or hardware store. The drug-store handles a pharmaceutical or pure grade. Hardware stores carry a commercial or technical grade, which is cheaper and good enough. If you buy half a pound you will have enough to use also in the voltaic cells described later in this chapter.

Smell the open end of the test-tube into which you have put the calcium hydroxide and the ammonium chloride. Notice that there is no odour.

Heat the mixture over a flame. The heat causes the two substances to react upon one another and form *ammonium hydroxide* and *calcium chloride*. But ammonium hydroxide is *unstable*, which means that it is ready to change upon the slightest provocation.



PREPARING AMMONIA

When dry slaked lime and sal ammoniac (ammonium chloride) are heated together ammonia gas is one of the products of the reaction. Chemistry students commonly use this method of preparing ammonia in the laboratory. Ammonia is made on a commercial scale from coal and by combining nitrogen obtained from the atmosphere with hydrogen obtained from water.

It has plenty of provocation in the hot state of affairs inside the tube. The heat causes it to break up into *ammonia* and water vapour.

Remove the tube from the flame and smell cautiously near the open end. This time there is an odour. You will recognize the odour of ammonia.

AN EXPERIMENT WHICH SHOWS THE UNSTABLE NATURE OF AMMONIUM HYDROXIDE

Water, at ordinary room temperature, will dissolve an amazing amount of ammonia gas—in fact, from 600 to 700 times its own volume. If a room 15 feet long, 10 feet wide and 9 feet high were to be filled with ammonia gas, all the gas could be dissolved in 15 gallons of water.

When a solution of ammonia in water (ammonium hydroxide) stands in an open dish or an uncorked bottle, the ammonia gas evaporates rapidly from the solution. That is the reason for the strong odour of household ammonia; and it is the reason why the bottle must be tightly corked to preserve its strength.

When an ammonia solution is heated, the escape of ammonia gas is speeded up. All the ammonia can be driven out by boiling.

Open a window near-by so that there will be a good draught of air to keep the fumes away from your eyes and nose, and then pour a small amount of household ammonia into a test-tube. Keep the bottle and the tube away from your face. It will not hurt you, but the odour may be so strong as to be disagreeable.

Heat the ammonia solution in the test-tube over a flame. Use a test-tube holder. The ammonia will escape very rapidly from the water in which it is dissolved and will spread in the surrounding atmosphere. You will smell it. After the water has boiled gently for two or three minutes pour what remains into another test-tube or on to a saucer. Smell it. The strong ammonia odour has disappeared.

USING AMMONIA AS A REAGENT

In almost every chemical laboratory there is to be found a row of bottles containing chemicals called *reagents*. A chemist uses these to ascertain the nature or composition of a substance.

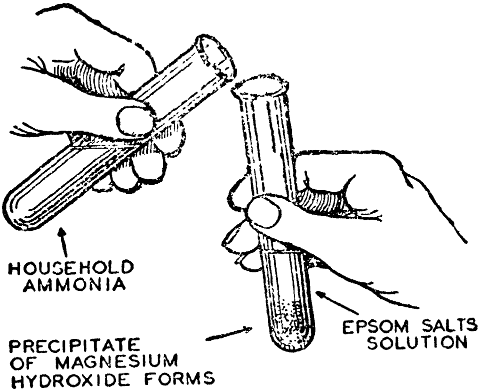
Ammonium hydroxide is one of the common reagents. It is used sometimes in a laboratory to precipitate a hydroxide. You can learn what this means by the following experiment.

Dissolve half a teaspoonful of Epsom salts in a test-tube half filled with water. The Epsom salts will dissolve more quickly if you shake the tube. The chemist's name for Epsom salts is *magnesium sulphate*. It is inexpensive and can be purchased at any drug-store.

Add a small amount of household ammonia to the solution in the test-tube. A solution of Epsom salts is clear like water, but when the ammonia is added it becomes white and opaque. A new substance has been formed which did not exist in either of the solutions. It was created by the chemical reaction between the two liquids and is called a *precipitate*. A precipitate may vary from a clear, gelatinous substance or a white flaky material to a dense brilliantly coloured mass.

A precipitate is insoluble in the liquid in which it forms. Otherwise it would remain in solution and be invisible. Eventually it settles in the liquid.

The white precipitate which formed in this experiment is *magnesium hydroxide*. Magnesium hydroxide is a compound made up of the light-weight metal, magnesium, and oxygen and hydrogen, and it is called a BASE. Most bases are insoluble. The name of any base suggests the name of the three elements that compose it. The word *hydroxide* indicates the presence of the elements hydrogen and oxygen.



USING AMMONIA AS A REAGENT

Ammonia is used sometimes in a laboratory to precipitate a hydroxide. You can produce a precipitate of magnesium hydroxide by adding a few drops of household ammonia to a solution of Epsom salts.

Farther along in these pages, we experiment with a base called *calcium hydroxide*. Its name reveals to you that it is a compound containing the metal calcium combined with oxygen and hydrogen.

Another base which can be precipitated from a common chemical by ammonia is *aluminum hydroxide*.

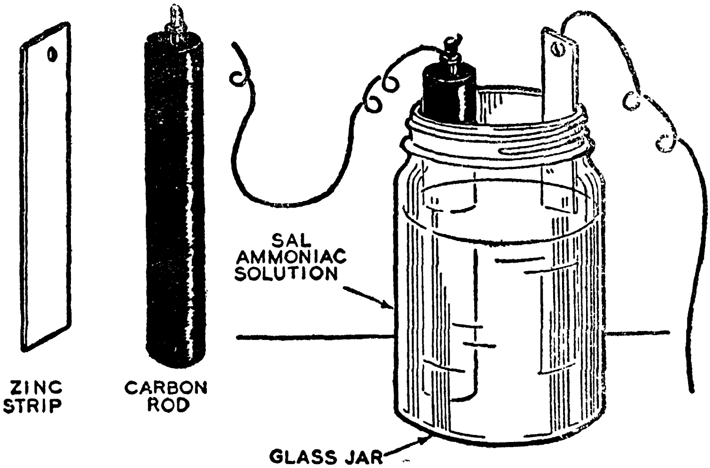
Dissolve half a teaspoonful of alum in a test-tube half filled with water. Add household ammonia. A gelatinous precipitate of aluminum hydroxide will be formed.

One of the uses for aluminum hydroxide is to clarify water. When it is added to water, all clay and other foreign matter suspended in the water, which may give it a muddy or cloudy appearance, settle to the bottom.

Aluminum hydroxide is also used as a medicine.

AN EXPERIMENTAL CELL MADE WITH SAL AMMONIAC

A voltaic cell (named after its inventor, Alessandro Volta) is one method of bringing about, by chemical action, the procession of electrons which is called an electric current. The original voltaic cell consisted of a strip of zinc and a strip of copper immersed in an acid solution. Many other forms have been devised. The one from which the modern dry cell was developed was invented by a Frenchman named Leclanchè and consists of a piece of zinc and a piece of carbon immersed in a solution of sal ammoniac (ammonium hydroxide).



YOU CAN MAKE AN EXPERIMENTAL VOLTAIC CELL

The carbon rod from an old dry cell and a strip of zinc immersed in a solution of sal ammoniac form an experimental voltaic cell of the type invented by Leclanché. This was the forerunner of the modern dry cell. Before the day of dry cells, it was extensively used for ringing door bells and operating telephone lines.

Electricity is produced in a voltaic cell by an action which converts chemical energy into electrical energy. The experimental cell illustrated will ring a bell, light a small flash-light bulb.

You can easily make an experimental cell which will ring an electric bell or light a small incandescent lamp. A strip of sheet zinc about one inch wide and five inches long, some sal ammoniac, and the carbon rod from an old dry cell will be needed. Three ounces of sal ammoniac dissolved in a pint of water make a solution of the proper strength. To make the solution it is necessary merely to shake the sal ammoniac into the water and stir it with a clean stick until dissolved. Use a one-pint mayonnaise jar.

A piece of copper wire (Nos. 18-22) about 20 inches long should be connected to one end of the zinc strip and a similar piece to the carbon rod. If you use the carbon rod from an old No. 6 dry cell it will be provided with a brass cap and a thumb-nut on one end, making it a simpler matter to attach the wire. If the carbon rod is one from an old radio "A" battery, it will not be provided with a screw and thumb-nut, and it will be necessary to solder the wire to the brass cap on one end. The wire may be attached to the zinc with a small machine screw and a nut. It will be necessary to bore a hole in the zinc, through which the screw will slip. Soldering the wire is another good way of making the connection.

When the zinc and the carbon are immersed in the sal ammoniac solution (called the electrolyte), they should be kept at opposite sides of the jar and not allowed to touch. The cell will deliver about 1.5 volts. Connect the wires leading from the zinc and copper, to a 1.5 volt incandescent lamp of the type used in flash-lights, and the lamp will light. It will operate a bell or buzzer.

If too much current is drawn from the cell for too long it will act tired. This is due to the accumulation of hydrogen on the carbon and is called polarization. In order to refresh the cell when it is polarized, it is necessary to let it rest.

In a dry cell, polarization is prevented by surrounding the carbon rod with powdered manganese dioxide. This substance absorbs the hydrogen.

CHAPTER V

The Chemist Waves His Wand at Salt and Produces a Metal and a Gas, Both with Peculiar Properties

WHEN foods, especially vegetables, taste flat and need seasoning, more salt is the remedy. The tiny white crystalline cubes are a necessity for the health of the human body. Many animals also require salt.

Salt was not always easily obtained by every one. All through history it has played important parts in life's drama. Peoples living in lands bordering the sea could obtain a plentiful supply of salt by evaporating sea water. Inland peoples, with no access to the ocean, had to barter for it. Lack of salt in other days caused wars and rebellions. Part of a Roman soldier's pay was given to him in salt and called *salarium.* From this Latin word comes our word *salary.*

To-day, salt is universally plentiful. And it is inexpensive. You can purchase a bag containing four pounds of table salt for a few pence at any grocery.

For long ages salt has been put to other uses besides seasoning food. It has been used for preserving fish and meat and for tanning leather. A generation ago, salt pork, salt mackerel and salt codfish were common articles of food. To-day modern refrigeration makes it possible to preserve meats and fish by freezing and cooling, with the consequence that salt preserved foods are not as common as they were when our grandparents were young.

SALT-MAKING AND MINING

Salt is obtainable in two ways: by the evaporation of water containing salt—or brine, as it is called—and by mining rock salt.

There are two kinds of brine: surface brine from sea-water and salt lakes, and brine from wells. Salt from surface brine is commonly obtained by the natural evaporation of shallow pools in the sun's rays. This ancient method is still practised on the shores of the Mediterranean, where acres of land are flooded and then allowed to dry out under the heat of the sun. After a year of alternately flooding and evaporating these shallow pools, sufficient salt accumulates on the bottom so that it can be raked up and carted away.

The brine obtained from wells is either natural brine lying underground and pumped to the surface or artificial brine made by pumping fresh water into wells drilled in underground deposits of rock salt. Wells are drilled hundreds of feet deep to tap huge deposits of natural salt. Water is pumped into the salt bed; it dissolves the solid salt and is pumped back above ground and evaporated. Most of the table salt used in America is refined salt, artificially evaporated from brine secured from deep brine wells.

About one-half the salt produced in the United States is rock salt. This is mined in much the same manner as coal is mined. Rock salt is used in industry.

What a contrast there is between the black tunnels of a coal-mine and the dustless snow-white crystal galleries of a salt-mine. The gleaming white corridors reflect the light from myriads of crystals. Ingenious machinery cuts the top, bottom and sides of 50-foot blocks of salt out of the walls. Mechanical drills bore holes in preparation for blasting. Then expert powder men tamp dynamite into the holes and explode the charges by electricity from a safe point when all other workmen are out of the mine. Down tumbles 250 tons of rock salt, ready to be loaded into cars and carried to the foot of the shaft, where it travels up to the surface on a conveyer.

MORE LUMBER FOR THE CHEMIST

To the chemist, the small white grains flowing from a salt shaker are *sodium chloride* and an important raw material of the chemical industry. It is the only practical source of that highly important chemical called *hydrochloric acid.* It is the raw material for making such useful compounds as sodium carbonate, sodium bicarbonate, sodium sulphate, sodium hydroxide, sodium hypochlorite, metallic sodium and the greenish-yellow gas called chlorine. Bleaches for paper, wool and cotton; products to purify drinking water; solvents for dry-cleaning; dental powders; refrigerants for electric ice-boxes; material for soap-making;

fumigants for protecting food from pests—all these and many other chemical materials are derived from salt.

Salt and the chemicals made from salt find more than 150 different applications in agriculture, industry, medicine and the home.

THE CHEMICAL NATURE OF SALT

It seems almost unbelievable that harmless little cubes of white salt could be composed of a soft, silvery, poisonous metal (*sodium*) and a greenish poisonous gas (*chlorine*). Yet such is the case. Salt is sodium combined with chlorine. When salt is dissolved in water, the chemist has available the atoms of four elements, namely: sodium, chlorine, oxygen, and hydrogen. He can do tricks with these.

There are several large plants at Niagara Falls engaged in decomposing salt by electricity. The falling water of the Niagara River turns the generators which supply the electric current. Two different processes are used. In one of them metallic sodium is produced.

In the sodium-producing process, purified salt is placed in what is known as a Downes cell and a powerful current sent through it. The current melts the salt and breaks it down into its two components: the beautiful silver-white metal sodium and the greenish-yellow, irritating gas chlorine. The molten sodium is drawn off from the Downes cells and stored in tanks or moulded into bricks of various sizes. The chlorine is collected for use in making a great variety of chemicals as will be described later.

SODIUM—A FREAKISH METAL

Ten to one you have never seen sodium or do not realize what a strange substance this metal is. At ordinary room temperatures it is soft enough to be cut with a knife. When thrown into water it splutters around and dissolves. Hydrogen gas escapes from the water and takes fire. To all appearances the sodium burns. Actually, it enters into a new compound called *sodium hydroxide* or caustic soda, a substance used in soap-making.

Sodium has a strong affinity for oxygen. Or, putting it in other words, sodium likes oxygen. If sodium is to remain sodium it must be protected from air and moisture. In the laboratory it is kept submerged in kerosene to preserve it. The kerosene excludes all oxygen and moisture.

The powerful attraction of sodium for oxygen is one of the reasons why such a freakish metal is useful. It can be used to extract oxygen and impurities from other metals. For this purpose the sodium is mixed or alloyed with lead and zinc. A small amount of this sodium-zinc or sodium-lead alloy introduced into molten metals such as brass or bronze will remove oxygen and other impurities and produce stronger, more uniform products.

But that is not the only use for sodium.

Sodium is an excellent conductor of heat and electricity. Engineers sometimes employ sodium to transfer heat where intense heat is to be applied or removed. For example, the exhaust valve of an aeroplane engine operates in very hot surroundings. Every time the valve opens, a roaring flame rushes past its head. This head must be kept as cool as possible if it is not to become pitted and warped. So the spindle or shank of the exhaust valve is made hollow and filled with metallic sodium. The sodium helps draw off the heat from the hot valve heads.

Sodium is an inexpensive metal. A cubic foot weighs about 61 pounds. A cubic foot of iron weighs 480 pounds. We are accustomed to think of aluminium as a light metal, yet aluminium weighs two and one-half times as much as sodium.

By combining sodium with oxygen, a powerful bleaching agent called *sodium peroxide* is produced. Manufacturers of Turkish towels and underwear often use sodium peroxide to bleach these products to dazzling whiteness. Bleaching is not sodium peroxide's only accomplishment. It enters into the manufacture of several active oxygen compounds. One of them, SODIUM PERBORATE, when dissolved in water, is an excellent mouth-wash. Tiny bubbles of oxygen are formed in the solution. When it is used as a mouth-wash, the oxygen destroys certain types of bacteria and checks putrefaction of food particles. Sodium perborate is one of the ingredients of many tooth-powders.

Not all of us ride behind aeroplane engines or gargle with sodium perborate. But we all ride in automobiles or buses, and sodium, the metallic half of salt, is one reason the modern automobile seldom has gear trouble.

The transmission and the differential gears of an automobile must withstand sudden heavy shocks and strains. In order to take such terrific abuse, the surface of these gears must be so hard that even a file cannot scratch it. And it must be the surface only which is hardened. If the gears are hardened all the way through they will snap and crack under strain, the teeth will strip off.

A compound of sodium, called *sodium cyanide*, makes it possible to harden the surface of steel and leave the core tough but not brittle. The gears and some of the wearing parts of an automobile transmission are hardened on their surface in a bath of molten sodium cyanide. Cyanide hardening produces a wear-resistant surface, while the tough core beneath the surface remains unchanged.

Sodium cyanide is produced by a reaction of sodium with ammonia and coke.

Sodium is required in the manufacture of ethyl petrol. And there are many uses for it we have not mentioned.

CHLORINE, THE OTHER HALF OF SALT

One day early in 1915, at Ypres, Belgium, British soldiers watched a cloud of greenish-yellow gas, released from the German trenches, roll across no-man's-land, pushed along by a gentle breeze. Soon the Allied soldiers were coughing and clutching their throats. The greenish-yellow gas was chlorine. It was the first poisonous gas to be used in the World War. Thereafter, it was necessary to equip troops with gas-masks.

Some lyric-minded technician once called chlorine "the green goddess of modern chemistry." Chlorine is not a poison only; it is a life-saver as well. It has saved tens of thousands of lives. Not many years ago typhoid fever was a common disease due to typhoid bacteria in reservoirs and wells. Then came one of those heavenly gifts which science frequently makes to mankind It was discovered that as little as one single drop of liquid chlorine in 50 gallons of water will kill all bacteria present. Many times this amount of chlorine in water would still be harmless to human beings, but more is unnecessary: the single drop works just as well.

Three-quarters of all water in the United States supplied for household purposes is chlorine treated, and nowadays typhoid fever is seldom heard of.

The chlorine used for purifying water is all made from common salt. The production of metallic sodium and chlorine by passing an electric current through salt has already been described. Chlorine can also be produced by passing an electric current through strong brine. A visit to a chlorine plant reveals row upon row of cylindrical cells connected to pipes and copper bars. The cells contain brine, and the result of passing an electric current through them is caustic soda, chlorine and hydrogen. Metallic sodium is not produced by this process. The hydrogen is used for the manufacture of ammonia which, when dissolved in water, is our old acquaintance, household ammonia, The caustic soda (*sodium hydroxide*) or lye, goes to the soap, paper and explosive industries. The chlorine gas is dried, compressed and liquefied. It is then stored in strong steel cylinders. In one form or another we find chlorine used in the textile and paper industries, in hospitals and swimming pools, and in manufacturing coal-tar dyes, chloroform, carbon tetrachloride for fire extinguishers and dry-cleaning and rayon manufacture, benzoate of soda and for purifying oils and preparing valuable drugs.

AN EXPERIMENT IN ELECTROLYSIS

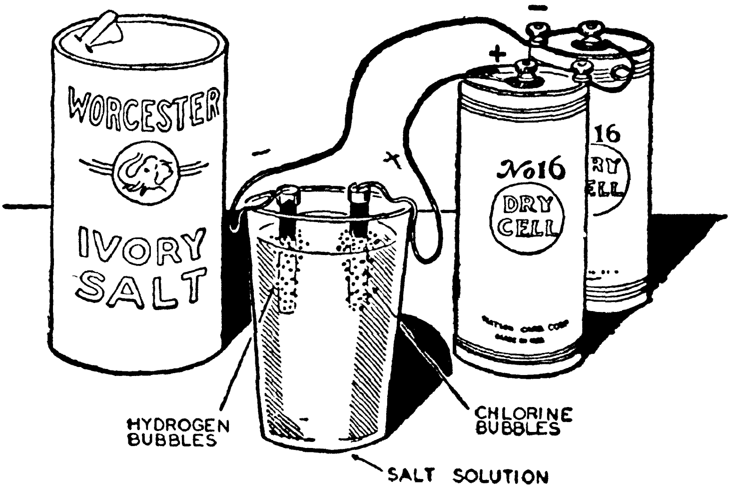
The carbon rods of two old flash-light cells will make excellent electrodes for your experiment with the electrolysis of brine. Solder a flexible copper wire to the brass cap on one end of each carbon rod. A battery of two 1.5 volt dry cells is needed. The cells should be connected in series.

Dissolve three or four heaping teaspoonfuls of table salt in a tumbler nearly filled with water. This forms a strong brine solution and since it is a conductor of electricity it is called an electrolyte. Connect the wires attached to the carbon electrodes to the terminals of the battery and place the electrodes in the electrolyte.

Small bubbles will rise from both electrodes. The bubbles from the negative electrode or cathode are hydrogen. Those from the positive electrode or anode are chlorine. The negative electrode is the one connected to the negative terminal of the battery and the positive electrode is the one connected to the positive terminal of the battery. The positive terminal of each cell is the one in the centre.

If you hold your nose close to the bubbles as they come to the surface of the electrolyte you will detect chlorine's characteristic strong irritating odour.

Chlorine was first recognized as a distinct substance in 1774 by the Swedish chemist, Karl Wilhelm Scheele. Chlorine acts as an oxidizing agent despite the fact that it is an element. For years it was supposed to be a compound containing oxygen. It was Sir Humphry Davy who established the fact that it is an element.



AN EXPERIMENT IN ELECTRO-CHEMISTRY

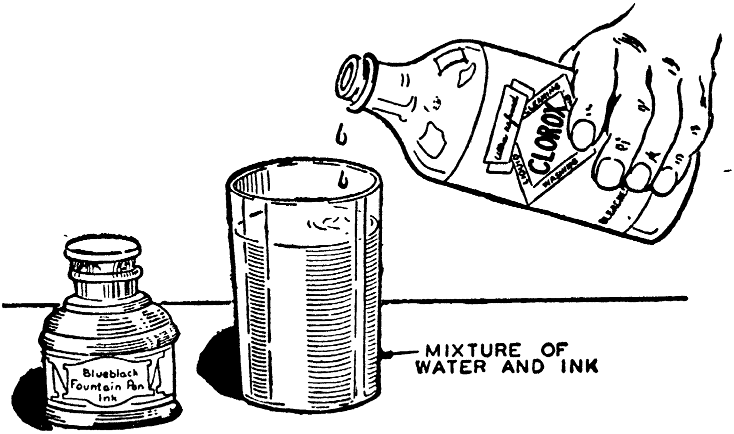
Chlorine is an industrial gas of great importance to man and his affairs both in peace and war. It is manufactured by passing an electric current through a solution of salt in water.

You can imitate the process experimentally with the simple apparatus illustrated above. Dissolve several teaspoonfuls of salt in a tumbler of water. Immerse two small carbon rods connected to two or three dry cells, in the solution. Bubbles will rise from both carbon rods. The bubbles from that connected to the negative terminal of the battery are hydrogen. Those from the positive rod are chlorine. Chlorine's characteristic strong, irritating odour can be detected if you hold your nose close to the tumbler.

Sodium is also liberated in our experiment, but we do not see it and we see very little of the chlorine. Only part of the latter forms bubbles and escapes. As soon as the sodium is liberated it reacts immediately with the water in the solution, forming sodium hydroxide. Some of the chlorine reacts with this sodium hydroxide forming *sodium hypochlorite.* Sodium hypochlorite is a useful sterilizing and bleaching agent sold for household purposes.

BLEACHING WITH CHLORINE

Chlorine, either alone or as a constituent of bleaching powder, acts as a bleach. It will whiten paper pulp, cotton yarns, and fabrics, and destroy the colour of many dyes. Chlorine itself does not do the bleaching: it decomposes water and liberates oxygen during the process. It is the oxygen that actually does the work.



INK ERADICATOR

Chlorine is often used in the household for bleaching and as a disinfectant. The most convenient source of household chlorine is the 5 per cent. solution of sodium hypochlorite sold at grocery stores under such names as Oxol and Clorox.

Discolour some water in a tumbler by adding ordinary fountain pen ink. Pour in a few drops of Clorox and stir. The ink will disappear.

Chlorine itself does not actually bleach. It causes bleaching to occur. The presence of water is necessary. The chlorine reacts with water and releases oxygen. It is really the action of the oxygen that destroys the colour.

Bleaching is an essential part of manufacturing some cotton textiles, because natural cotton fibre is not perfectly white. At one time white cotton fabrics were bleached on grass in the sun. Acres of bleaching fields were required for what can now be done in a small vat with the aid of chlorine.

It is essential that moisture be present in order to carry on a bleaching process by means of chlorine. Either the chlorine gas must be moist or the material to be bleached must be moist.

Chlorine gas is not used for bleaching as frequently as bleaching powder, a compound made from chlorine and lime.

A BLEACHING EXPERIMENT

Add a few drops of ordinary blue-black fountain pen ink to a glass tumbler half filled with water. Stir until thoroughly mixed. The mixture will be dark blue.

Add a few drops of Clorox. This is a household cleaning and sterilizing compound consisting of a 5 per cent. solution of sodium hypochlorite and can be purchased at almost any grocery store. Stir the mixture again and most of the colour will disappear. The water will be light brown. It has been bleached by oxygen, which was liberated from the water by chlorine in the sodium hypochlorite solution.

CHAPTER VI

Chemistry on the Farm

OF what benefit is chemistry to the farmer? First, he shares its blessings to the extent that he uses manufactured products which have been made possible or improved by chemical science. Then, through fertilizers and soil conditioners, chemistry increases and improves the output of his fields.

Through what Henry Ford calls *agrindustry*, which is the liaison of agriculture with manufacturing and chemistry, the farmer's economic status is bettered.

THE GROWTH OF PLANTS IS A CHEMICAL PROCESS

The greater part of the food supply of the human race comes from the soil in the form of vegetables and grains, or in the form of meat from animals which feed on the products of the soil.

Soil is not just any bit of earth or dirt. It is finely divided mineral matter mixed with decayed organic material and contains more than a dozen chemical elements. The farmer who raises food for men and animals is unwittingly a chemist, for the process by which plants grow is a chemical one. Plants are chemical factories: they consume raw materials; they require water, nitrogen compounds, potassium, phosphorus, sulphur, calcium, magnesium, carbon, oxygen and minute quantities of zinc, iron, manganese and boron.

The observation that soils become exhausted of the chemicals needed for plant growth was first made many centuries ago. In order to prevent this exhaustion, our farming ancestors allowed their fields to remain idle or "lie fallow" every third year. While thus bare of crops, particles of mineral in the soil weathered and became soluble, so replacing some of the chemicals which previous crops had consumed.

FERTILIZERS REPLENISH THE CHEMICALS WHICH PLANTS CONSUME

To-day the practical farmer not only allows his fields to rest occasionally but replenishes them with the substances called fertilizers. In order to enrich the soil with nitrogen compounds, manure is spread on the ground and crops of clover are grown and ploughed under. Wood ashes are used to a small extent to supply potassium carbonate. But a considerable portion of all fertilizer is produced, or at least modified, by industrial chemical operations. Chemical industries in the United States prepare as fertilizers: dried blood and powdered bones from slaughterhouses, sewage disposal sludge, dried fish scraps, oil meal from pressed cotton seed, finely powdered phosphate rock, lime, potassium chloride, ammoniated superphosphates, sodium nitrate and urea. More than 6,000,000 tons of these substances are turned out every year. By their aid the productivity of a farmer's fields may be increased and a greater number of people supported by their yield.

AGRINDUSTRY

We are dependent upon farmers for our food. It may come to us from a market or store, but it was produced on a farm. The only exceptions to this are sea-food and game. If there were no farmers who made a business of raising food for other people, every one would have to live in the country and spend a large part of his or her time planting crops, raising poultry and cattle, cultivating, spraying and harvesting. There would be little time left for pleasures. There could be no cities if everyone raised his own food. To be certain, some aspects of a large city or town are nothing to be proud of, but cities do have great advantages and confer many benefits upon human beings in general.

For many years farmers as a whole have not been prosperous. The farmer, collectively, is the greatest buyer of manufactured goods, *when he has money to spend.* The farmer's purchases provide employment to millions of city workers. When the farmer lacks spending money, industry suffers and millions lose their employment.

There are many causes for what is commonly called the "farm problem." This book is not the place to discuss a farmer's troubles, but we will see that chemistry helps farmers to increase their annual income. It may help them even more. Let us see how.

The purchases which city dwellers make from farmers consist principally of food. The farmers of America produce more food than can be consumed. They do not receive enough cash in return for their labour. Therein lies the root of the difficulty.

Henry Ford once summed it up well when he said: "Business is only exchange of goods. If we want the farmer to be our customer we must find a way to be his customer."

Since Ford usually practises whatever he preaches, for years he has spent and is still spending much time and thought and many millions of dollars in teaching farmers not to devote their land entirely to raising food but to grow *raw materials for industry* as well. He has made it his principal task to develop agriculturally new products that industry can use. Consequently, an enormous tonnage of farm products goes into the making of Ford cars and trucks.

FARM PRODUCTS IN FORD V-8's*

Into the construction of every million Ford cars and trucks (Ford total production of cars and trucks now tops 28,000,000) to-day go:

89,000,000 pounds of cotton, the crop from 558,000 acres, for making upholstery, brake-linings, timing-gears and safety glass;
800,000 bushels of corn, the harvest of 11,280 acres, for rubber substitute, butyl alcohol and solvents; also for core binder in foundries and binder for charcoal briquettes;
2,400,000 pounds of linseed oil, the yield of 17,500 acres of flax, for making paints, core oil, soft soap and glycerine;
2,500,000 gallons of molasses, from 12,500 acres of sugar cane, for making anti-freeze, shock absorber fluids and solvents;
3,200,000 pounds of wool, from 800,000 sheep, which go to make upholstery, gaskets, anti-rust, floor-coverings and lubricants;
1,500,000 square feet of leather, from 30,000 head of cattle, for making upholstery and hide glues;
20,000 hogs to supply 1,000,000 pounds of lard for lubricants, oleic acid and bristles for brushes;
350,000 pounds of mohair, from 87,500 goats, for making pile fabric for upholstery; and
2,000,000 pounds of soya-bean oil, from the crop of 10,000 acres, for making lustrous and long-wearing enamel.

These figures show that more than *half a million acres*, 609,280 acres, to be exact, are planted in order to furnish part of the raw materials required in building 1,000,000 Ford V-8 cars and trucks. This is in addition to the vast acreage required for grazing the almost 1,000,000 goats, swine, sheep and cattle whose products are also utilized.

* Furnished by Ford Motor Co., Dearborn, Michigan.

None of the materials which the farmer supplies to the automobile industry are *finished.*

The chemist must take a hand in order to convert cotton into safety glass, soya-beans into paint, etc.

Here is a short list of some of the raw materials for industry which a farmer can produce, together with their uses:

SOYA-BEANS. Food for man and beast and raw material for paint, varnish, lacquers, plastics and soap.

TUNG NUTS. Oil for quick-drying varnish.

FLAX. Fibres for linen; linseed cake and meal for cattle food; linseed oil for paints and varnishes.

CASTOR BEANS. Oil as lubricant, when mixed with mineral lubricating oil, plasticizer for celluloid and for lacquers, used in dyeing.

MILK. Food for man and beast, casein for glues and plastics, paper coating.

COTTON. Fabrics, thread, string, photographic films, explosives, safety glass, plastics, lacquers, salad oils, cooking fats, soap.

CORN. Starch for laundry purposes, cattle food, salad oil, soap-making, paint and varnish.

SOYA-BEANS AS A RAW MATERIAL

After numerous tests with other farm products, Henry Ford finally chose the soya-bean for a vast experiment in "agrindustry."

The soya-bean has been grown and used for thousands of years by the Chinese, Japanese and other peoples of Eastern Asia. It yields both an oil and a rich meal which has been used for centuries as food for man and beast. Soya-beans, if properly treated, will grow on any soil on which ordinary crops grow and will prosper in all agricultural regions in the United States. The roots of the soya-bean plant attract and deposit nitrogen, thus constantly building up the soil wherever it grows.

Starting with a small patch of soya-beans planted behind the Research Laboratories at the Ford Motor Company, Ford now has thousands of acres planted with this crop. In addition to 82,000 bushels of soya-beans raised on his own farms in 1939. Ford bought that year an additional 350,000 bushels and a large amount of soya-bean oil.

The great bulk of the beans are put through a specially devised soya-bean oil extractor. As the beans are fed into one end of this machine they are crushed between rollers and then given a thorough washing in high-grade gasoline which extracts the oil. The oil goes into a tank and the bean meal goes into a compartment where it is cleaned with steam and all traces and odour of gasoline removed.

The meal is now ready to be made into a plastic for moulding various parts of the Ford V-8. The oil is used for making the enamel with which Ford cars are painted and is also employed in the foundry as core oil. Core oil is the binder used to hold together the sand in the cores of moulds for hollow castings.

Under the Ford process a ton of dry beans yields about 400 pounds of oil and 1,600 pounds of meal.

There is not yet a great demand for soya-bean oil and meal in industry, but the near future may bring new uses. Ford chemists have discovered how to make from soya-bean meal a fibre that compares favourably with wool.

Wool is largely the substance which the chemist calls *protein.* Soya-bean meal, when free from oil, is almost one-half protein. The oil-free soya-bean meal is put through a chemical process which extracts the protein. This is then made into a viscous solution. When forced into dilute acid through a nozzle having very small holes, the viscous solution hardens into fine fibres or threads. These fibres, when subjected to further chemical treatment, can be spun and woven into a good upholstery material. Some day, perhaps, the upholstery in Ford cars will be made partly from soya-beans. Therein is a good example of how the chemist turns the products of the farm to industrial uses.

FLAX AND LINSEED

The flax plant is an annual with stems about two feet high, having seeds called flaxseed or linseed and an inner bark that yields soft fibres which are the flax of commerce. You may have some flax fibres tucked in your pocket: the fabric woven from the fibres of flax is linen.

Flax is grown in the north-western part of the United States, notably in Minnesota, Montana and North and South Dakota. The bulk, however, comes from Argentina.

Linseed oil is made by pressing warmed flaxseed which has been previously crushed. The main product is the oil, but an important by-product is also obtained. The residue or press cake remaining after the oil is extracted forms a valued cattle food.

Flaxseed is familiar to many country boys. It is stored in elevators at the linseed oil refineries very much as wheat and other grains are stored. The seeds are so small and slippery that they flow like water. The boards in the bottom of a farm wagon hauling flaxseeds must be perfectly tight or the seeds will escape through the cracks. If a man falls into a bin of flaxseed he will go to the bottom.

Extracting the linseed oil is a simple process. The seed flows by gravity from the elevator to the various machines which prepare it for pressing. First it passes through horizontal screens which remove all coarse foreign matter. Then it is fed into a machine called a rotary bag blower which blows out the chaff and small dirt. The clean seed is stored in bins until it is allowed to flow between the heavy steel crushing-rolls located on the floor below. When the seeds have passed between these crushing-rolls they have lost all trace of shape. They are an oily mash.

The mashed meal is warmed in steel-jacketed kettles and then squeezed in presses under a pressure of 4,000 pounds. About 20 bushels of seed are required to produce one barrel of oil.

The pressed cake, which is the residue of the mash after the oil has been extracted, resembles a stiff board. It is removed from the press, broken up into a powder, and packed in 100-pound bags.

More than 500,000,000 pounds of linseed oil and 1,000,000,000 pounds of cake and meal are produced every year in the United States.

After the oil from the press has been filtered through canvas and flannel cloths it is the yellow-brown raw linseed oil of commerce.

Linseed oil is used in making paints, varnishes and linoleum. Although raw linseed oil will "dry," or harden through oxidation, on exposure to air, it does so too slowly for practical purposes. The linseed oil used in paints and varnishes is "boiled"—that is, it has been treated to accelerate its drying time by adding small amounts of the oxides of cobalt, lead or manganese and then heating under reduced pressure. Boiled linseed oil dries in a few hours. The so-called drying of the oil is not drying due to evaporation. It is a hardening due to oxidation.

TUNG OIL

The tremendous quantities of explosives and the chemicals used in their manufacture which were on hand in the United States at the close of World War I were soon consumed in peace-time industries. Some were utilized in the manufacture of quick-drying lacquers which dried in a few minutes and were sold to the general public for use with a brush. These were nitrocellulose, also called pyroxlin lacquers, quite similar to the lacquers used in finishing automobiles, but they were unsatisfactory in the hands of the average person. The pigment settled and hardened in the cans; it required considerable skill to apply such a rapidly drying liquid with a brush.

This type of lacquer was eventually withdrawn from the market and replaced with the so-called 4-hour enamels.

Tung oil is the "secret" of the quick-drying varnishes and 4-hour enamels. It dries in one-third the time which linseed oil requires and has other valuable properties of its own. All these things give it tremendous importance in varnish-making. Paints are notoriously slow-drying and it is a great advantage to have decorative and protective coatings which will dry in a few hours.

The seeds, contained in a nut the size of a small orange which grows on the Chinawood or tung tree, contain 53 per cent. of tung oil. Large quantities of tung oil are imported from China. Within the past fifteen years, thousands of tung-nut trees have been planted in the United States, chiefly in Florida, Texas and Mississippi.

CASTOR OIL

The famous castor oil of the nasty lingering taste has many uses more important than its use in medicine. It is valuable as a lubricant when mixed with mineral oil; it is also used in the dyeing and plastics industries.

Castor oil is obtained by pressing the seed of the castor plant, which grows in Florida, the West Indies, India and other tropical and sub-tropical parts of the world.

Turkey Red Oil, used extensively in the preparation of fibres for dyeing, is castor oil which has been treated with sulphuric acid. The *sulphonated* (treated with sulphuric acid) oil is washed with a sodium sulphate solution, and a slight amount of ammonia is added. If cotton, either as yarn in skeins, or in the form of a fabric, is treated with Turkey Red Oil before dyeing, the colours are more even and the dyed fibres are softer.

Industry often requires substances called *plasticizers* in its processes. The purpose of the plasticizer is to make the substance in which it is used more workable and flexible. Castor oil is a non-drying oil and is a valuable plasticizer for Celluloid and various lacquers.

CASEIN: YOUR DAIRY MAY BE IN THE GLUE AND BUTTON BUSINESS

Cow's milk is often called the "perfect" food for growing children. That is because it has all the essential food elements in proper proportion for health.

But not all the milk produced by dairy farms is for food. Not all the milk which comes to your door-step is in a paper carton or a glass bottle. Milk is also a raw material used in the chemical industry. It may come into your home in the form of buttons, glue, umbrella handles, and in other diverse ways. For, in addition to water, butter fat, mineral salts and milk-sugar, cow's milk contains a small amount of a substance called *casein.* There are about three pounds of casein in 100 pounds of skim-milk.

As a raw material for industry, casein is used in paper coating, plastics, paint, glue, insecticides, pharmaceuticals, and, more recently, textiles and felt hats.

Casein is a substance which chemists called a *protein.* Proteins are found in such foods as lean meat, fish, milk, beans, peas, eggs and wheat. Their primary work in the body as a food is to build tissues and make repairs.

The casein in milk is a white to yellowish solid substance suspended in the water of the milk. When lactic acid or acetic acid or the substance called rennet is added to skim-milk, the casein gathers in a spongy mass commonly called *curd.*

Casein has been known and used for centuries. In medieval times it was used in making paint. The interiors of many European cathedrals of the fourteenth and fifteenth centuries to-day have the same casein paint that was put on when they were constructed, and the colours remain bright and unfaded.

BUTTONS AND UMBRELLA HANDLES FROM MILK

Casein, separated from milk by adding one of the three substances mentioned above, is employed for many purposes. Beautiful buttons, knobs, handles, costume jewellery, rods, sheets and tubes, resembling amber or ivory, or of a great variety of colours, are produced from casein plastic.

In order to prepare the plastic material casein is first extracted from milk, dried and powdered. It is then mixed with colouring matter or a filler, moistened with hot water, and mixed into a dough. The dough is pressed between heated steel rollers to form sheets. It may be pressed or moulded into almost endless shapes. The shaped pieces are placed in a solution of formaldehyde which "sets" them and makes them as hard as stone. Finally, they are dried in a warm closet.

HOW YOU CAN MAKE CASEIN

It is a simple matter for the amateur chemist to separate casein from milk.

Put about one pint of sweet skimmed milk into an agateware saucepan (do not use an aluminum pan) and heat it very gently to a temperature of 90° F. The temperature is important. In order for the experiment to be a success, buy a thermometer and immerse it in the milk while heating. As soon as the milk reaches a temperature of 90° F. remove the saucepan from the fire, and while stirring continuously with a glass rod or tube pour a half cupful of vinegar into the milk.

The milk will curdle immediately, and after continued stirring, the white curd or casein will gather in a gummy mass which can be lifted out and placed in a dish. It can be washed and then, by squeezing the rubbery mass like a sponge, you can press most of the water out of it.

HATS AND APPAREL FROM SKIMMED MILK

The time has come when it is within the realm of possibility that Mrs. Thingembody's new spring jacket will be made of a pleasing fabric called Ayrshire or Guernsey. These names you will recognize as belonging to cattle. This does not mean that Mrs. Thingembody will be wearing a cowskin coat, but rather that she may be prancing around in clothes made of *fabrics* from *cow's milk.* Felt hats containing fibres made from milk are already on the market.

After four years' experimentation, National Dairy Products Corporation has perfected a new fibre called "Aralac" made from cow's milk. It can be blended with wool, mohair, cotton, rayon or fur in varying proportions and produces fabrics of unusual beauty. Aralac is more expensive than rayon or cotton, less costly than fur and wool. It is not a substitute for other fibres, to be used in place of something else because that something else is scarce or more expensive. It possesses characteristics which improve some fabrics: give them what the textile trade calls "drape and substance."

Making fibres from milk is not new. Late in the last century—even before rayon was developed—chemists were experimenting with casein fibres. However, milk-derived fibres were not acceptable to the American textile industry until Aralac was produced.

Aralac is made from casein. After being extracted from milk, the casein is dried and ground, treated with chemicals and heated into a viscous, honey-like form. The thick, sticky liquid is then forced under heavy pressure through tiny holes called spinnerets. Thousands of strands of fibre called "wet tow" emerge from the spinnerets. After many treatments with chemicals, the fibres become soft and luxurious.

The felt hat industry was the first to use Aralac. The principal raw material used in making felt is rabbit fur, most of which is imported. War conditions have made it difficult to import sufficient rabbit fur and have increased the cost of that which is available. To-day most fur-felt and wool-felt hats in the United States, Canada and South America are made in part from Aralac. Thus cow's milk has enabled hat manufacturers to maintain reasonable prices without impairment of quality despite the scarcity of rabbit fur.

CASEIN GLUES AND ADHESIVES

You have probably heard of Casco glue. Perhaps you have used it in repairing furniture, building a model aeroplane or a boat. Casco is a powdered casein glue which is prepared for use by mixing with water. When the glue has set it is water resistant and very strong.

Casco is only one of many glues, cements, sizes and adhesives made from casein. The paste used for the seam gluing of cigarette paper in high-speed cigarette-making machines is a casein adhesive. It sets quickly and forms a water-resistant, colourless and odourless glue line. Many of America's largest bottling plants use a special ice-water-proof casein glue for fastening paper and foil labels to soft-drink, beer and wine bottles. When such bottles are stored in ice or ice-water coolers, the labels do not loosen. The labels on bottles returned to the plant are easily removed by special bottle-washing machines using water containing alkali. Most calcimines and water paints for coating walls and ceilings contain casein glue binder.

THE IMPORTANCE OF CASEIN

Every new use found for casein is important to the dairy farmer. It increases his chance for more income from the products of his farm.

Last year about 75,000,000 pounds of casein were used in the United States. About 50,000,000 pounds were produced in the United States. Argentina supplied more than 22,000,000 pounds. Casein has been produced in quantity in the United States since the beginning of the century. Between two-thirds and three-quarters of the casein in the United States is made in Wisconsin, California and New York. But billions of pounds of skim-milk—the residue after butter-fat has been extracted for butter, table cream or other purposes—now do not have any commercial market. Most skim-milk has been used as feed for livestock.

It is not profitable to transport bulky skim-milk long distances for manufacturing casein. Only three pounds of casein can be obtained from 100 pounds of skim-milk. Perhaps a method may be devised by which casein can be produced by the farmer in his own barn. Machinery and skill are required to produce *high-grade* casein by present methods. Casein cannot yet be made in every milk-products manufacturing plant. Eventually this problem may be solved. If it is, and farmers are enabled to make casein, the farmers' income will be increased.

CHAPTER VII

Cellulose, One of Man's Blessings

WHEN the first white settlers came to America, they found this to be a well-wooded continent. An axe was an essential part of the pioneer's equipment. Trees had to be cut to clear land for crops, and to obtain fuel and building materials for cabins, forts, stockades, furniture and boats.

Trees are no longer cut down solely to get them out of the way or to use them for fuel and timber. Wood is now used as fuel only to a limited extent. Trees are no longer merely a hiding-place for birds' nests and a source of lumber for building boats, boxes, houses and furniture. A tree may be represented in your home to-day by a book or a rayon stocking. Wood is now an important raw material of the chemical industry because it contains *cellulose.* The principal constituent of the woody fibre in plants is this extremely useful compound of carbon, hydrogen and oxygen.

Cellulose is one of the group of chemicals called *carbohydrates.* A piece of dry wood is one-half to three-quarters cellulose. That is the main reason why chemists are interested in wood. With cellulose a great variety of useful substances can be produced.

Cellulose can be made in the laboratory and could if necessary be manufactured on a commercial scale in "cellulose factories." But there is no necessity for making synthetic cellulose. Nature furnishes an excessive supply of this material. It is easily procurable not only from wood but also from cotton, linen, straw, flax, hemp, etc.

The proper treatment of cellulose with certain chemicals produces pyralin, celluloid, cellophane, rayon, nitrocellulose or guncotton, cellulose acetate for moulding and insulation, artificial leather, photographic and motion-picture film, and pyroxylin, used in quick-drying lacquers for automobiles. It does not take long to roll this list off your tongue, but in doing so you have named several vast industries which use cellulose as their principal raw material.

PAPER

The first and foremost cellulose product is paper.

The importance of paper can best be realized by picturing the confusion and discomfort that would exist if we were suddenly deprived of all paper.

Do not imagine only the elimination of books, magazines and newspapers. Let your imagination run on and include wrapping paper of all sorts, paper boxes, food containers, labels, paper napkins, paper towels, insulation for the wires in telephone cables, electrical condensers, roofing paper, wall paper and writing paper.

Without paper or a good substitute for it, our present civilization could hardly exist.

Essentially, paper consists of a large number of tiny, hair-like fibres so closely matted together that they form a continuous surface. You can easily discover the fibres by tearing a sheet of paper and examining the torn edges. You can see the hair-like fibres without a magnifying glass.

The "best" paper, that used for fine stationery and expensive books, is made of fibres obtained from rags. Ordinary paper is made of the cellulose fibres secured from chips of spruce, balsam and poplar. The tough, strong, slightly brownish wrapping paper known as "kraft" is made from the cellulose fibres obtained from yellow pine. Newsprint is made from spruce and hemlock.

STOCKINGS FROM SAWDUST

Man is the only animal who has to earn his clothing. His skin does not usually grow fur or feathers to any great extent.

To warm and protect his bare hide, ancient man was accustomed to make rude garments of leaves and grasses and to kill and rob other creatures for their pelts. Being always vain and becoming in time slightly aesthetic, our forefathers learned to shear the hair of sheep and goats and to card and weave the wool into cloth. They also thumped fibres out of the bark of trees and the leaves and stems of plants. Pounding the flax plant provided linen thread and cloth. Plucking fluffy fibres out of the seed capsule of another plant provided cotton. Twisting cotton fibres produced cotton yarn. Cotton yarn could be spun into cotton cloth.

But it was a caterpillar that gave us what was once our finest fabric, the strongest and glossiest, the one that pleased our vanity most. From the cocoon of a caterpillar, feeding on the leaves of the mulberry tree, came silk to be woven into the raiment of kings and queens.

In endeavouring to produce silk artificially, chemists developed rayon, a modern textile fibre made from wood pulp, or, in other words, fine sawdust.

THE SILK-PRODUCING CATERPILLAR

Many insects are miniature chemical factories equipped with spinning machinery and can produce a strong, gossamer thread. But none are able to do it as well as the caterpillar misnamed "silkworm."

As the silk-producing caterpillar grows from a tiny speck to become one of the largest of our caterpillars, a fat fellow three inches long, it forms and fills with a sticky fluid two large sacs that run along the sides of its body. This fluid is the building material for a castle which the fat caterpillar will construct to live in while a chrysalis and until ready to emerge as a moth.

When the important time comes to begin spinning, the caterpillar ceases to eat. Two tiny streams of the sticky fluid issue slowly from openings or spinnerets in its lower lip. The fluid becomes hard as it emerges. Manipulated by the caterpillar, the two streams of fluid harden into a single strand or thread of silk. Patiently swinging its head around and around two, three, four or even five days, the caterpillar encloses itself in a hollow ball of silk, a cocoon spun of material perhaps destined for a ball gown. The thread of which the cocoon is spun is from 2 to 3,000 yards long and so fine that 700 to 1,000 strands of it, laid side by side, would measure only an inch in width.

To obtain this thread for weaving silk, satin or damask, the caterpillar must be killed and robbed. The cocoon is plunged into scalding water and the gossamer thread becomes loosened so that it can be unwound and reeled on to a wheel. The silk-maker inside the cocoon dies.

Four or five of the caterpillar threads twisted together make a thread strong enough to weave light fabrics with. About one pound of raw silk thread is obtained from two and one-half pounds of cocoons.

Once all silk came from China. For long ages, the Chinese kept it a secret where and how they obtained silk. Eventually the secret was stolen and Europeans learned how to make silk. The first silk factory outside China was set up in Constantinople.

Thereby hangs a tale.

THE CHINESE SECRET

From Constantinople to the nearest point in the Chinese Empire is approximately 2,500 miles. But that is the shortest span, a straight line drawn between two points as a crow would fly it. Overland and afoot, the distance is much greater, a gruelling journey of more than 3,000 miles. Arid deserts and the snow-capped Himalayas stand ready to test any stout hearts that dare it.

About 550 B.C. two Persian monks made the journey. They walked all the way from Constantinople to China and then walked back again. They struggled up steep mountains, forded swift rivers and found their way around impassable barriers. Their two-year walking trip was undertaken to steal if possible the secret of Chinese silk. It would have cost their lives if the purpose of their visit had been known.

The Chinese were the first to learn that a very ordinary-appearing big fat green caterpillar could provide the material for a beautiful fabric. They found that the caterpillar could be kept in captivity and would thrive and multiply if kept clean and well fed. For thousands of years the precious secret was guarded as closely as possible and kept from all foreigners. If the people of other lands wanted the beautiful Chinese fabric they must barter with the Chinese for it.

The Romans bought a great deal of silk from the Chinese, for even Rome, with all her power and glory, did not know how silk was produced—at least not until after 550 B.C. It was then that the Roman emperor Justinian ordered the two Persian monks to go to China and discover the sources of silk and its manufacture.

They made the journey, saw the process of rearing silkworms and the method of unwinding the cocoons. They carried back to Constantinople some eggs of the caterpillars in a hollow bamboo rod.

The eggs hatched and became caterpillars. For the first time

Europeans had possession of the source of silk. China's secret was a secret no longer.

The caterpillars spun their cocoons and became moths. From each female moth came 500 or more eggs. From these in turn there was soon another great increase. A silk factory was set up inside the emperor's palace.

In the course of time eggs were carried to other countries and silk factories started there. Italy and France became famous for their silks.

England, Germany, and America have tried to cultivate silkworms but have found it impossible to compete with the Japanese and instead have become skilled weavers of silk fabrics from raw silk imported from China and Japan.

THE VISCOSE RAYON PROCESS

Chemists never satisfy their own curiosity. That is why a large part of our present-day industrial life was bred in a test-tube.

Chemists were not satisfied to leave the job of making silk to a caterpillar. They made various sticky fluids and whirled them out of tiny holes in spinning cups. They dabbled and puttered until they imagined that they could make a huge silkworm out of pipes and tanks, feed it on sawdust instead of mulberry leaves, and whirl silk out of its spinnerets.

They succeeded. One of the important new industries which chemistry has brought us in recent years is the manufacture of the artificial silk called rayon.

The process for making rayon has been known for more than half a century. But it was only during recent years, through the close co-operation of chemists and textile experts, that rayon manufacture became of commercial importance.

For a time, rayon was only an imitation, a cheap substitute for silk which found its market among those who could not afford the more expensive real silk. Now it is a textile fibre that stands on its own feet. It is no longer an imitation but ranks with silk, cotton and wool. It takes more than eyes to distinguish rayon from silk. Rayon now outsells silk six to one.

In principle it is simple to manufacture rayon. It is merely necessary to imitate the silkworm. Essentially, the process consists of feeding wood-pulp to a man-made chemical and mechanical caterpillar.

Chemists have developed four methods of imitating the leaf-eating worm. They all have in common, as a starting point, cellulose, derived from wood-pulp or cotton linters. The cellulose in the mulberry leaf is the raw material which the silkworm changes into a sticky fluid with the aid of its digestive apparatus. The chemist changes the cellulose of wood-pulp or cotton linters into a sticky fluid with the aid of such chemicals as caustic soda, acetic acid, nitric acid or ammoniacal copper oxide. Of the four methods, that known as the viscose process has found the greatest application and is used on a large scale in this country to produce a yarn that now outrivals that of the humble silkworm.

A "SILKWORM" WITH GOLD AND PLATINUM LIPS

The viscose rayon machine feeds on fine spruce wood-pulp. The pulp comes to the rayon mill in thick sheets that look like blotting paper. It is 92 per cent. pure cellulose. The pulp has already been chewed by grinding machines at the pulp mill. The digestive organs of the rayon machine are vats and pipes.

The process of digestion begins in the first vat. Steeping and grinding in caustic soda reduces the sheets to a white mass called "crumb". The excess liquid is then pressed out. After the crumb is a few days old it is churned and mixed with carbon disulphide. Carbon disulphide is the fearful-smelling liquid which gives rubber cement its bad odour.

The crumb dissolves in the carbon disulphide. The result is a clear orange-tinted liquid called *viscose*. It is an equivalent of the sticky fluid of the silkworm. Before it is spun into thread, however, the liquid viscose must be filtered and aged.

One of the important secrets of rayon making is proper ageing and timing of all parts of the process. It must be aged under conditions where the temperature is controlled to a fraction of a degree and timed to the minute before it is forced through pipes to the spinneret. The spinneret is the head of the chemical and mechanical rayon caterpillar. But instead of the two orifices which the silkworm has in its lips, the tiny spinneret (approximately one-half inch in diameter) made of platinum and gold has 96 to 150.

The tiny holes are so small that the mechanic who makes the spinneret has to use a microscope to see what he is doing. Out of these small holes, under carefully adjusted pressure, the viscose squirts in tiny streams and emerges into an acid bath. The acid hardens the liquid streams, changing them into silken strands, and they pass on to the spinning boxes where they are twisted into yarn.

When it has been washed, dried and wound into skeins, there is nothing about the soft, pliant yarn to suggest that it was once the trunk of a spruce tree. It can be dyed or cross-dyed in an intricate manner impossible with silk. The 500 yards or more of very fine filament unwrapped from a silkworm cocoon is never uniform. It is not spun under even pressure as the worm swings its head around. There is not the mechanical exactness about the strands of the silkworm that there is in rayon yarn. The chemical and mechanical man-made rayon caterpillar produces a uniform thread of perfectly equal diameter and strength. Here again the chemist has improved upon nature.

One ton of purified spruce pulp produces about 1,500 pounds of rayon or 45,000,000 yards of standard yarn.

THE CHEMICALS IN A WOOD-PILE

If you light a wooden match or splinter and then extinguish the flame, the blackened end is no longer wood. The heat has changed it into an impure form of carbon called *charcoal.*

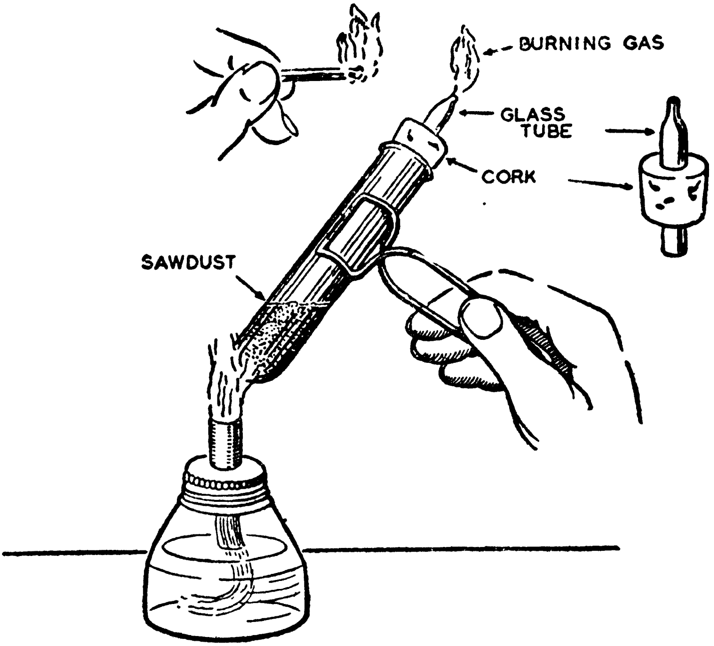
Charcoal is *amorphous* carbon. "Amorphous" means "without definite form" and is the term which a chemist applies to the non-crystalline forms of a substance. Soot, lamblack, coal, coke and bone-black are other forms of amorphous carbon. If these should crystallize instead of being without definite form, they would become graphite or diamonds.

Charcoal is an excellent fuel for some purposes because it burns with no smoke and practically no flame. There is no method of cooking steaks and chops which quite equals broiling them over a charcoal fire.

THE CHEMIST TAKES OVER AN ANCIENT TRADE

For centuries, charcoal has been made on a large scale by setting fire to great heaps of wood covered with sod and earth. Small openings are left to allow some air to enter and the smoke and gases to escape. By thus shutting off most of the air, the wood is prevented from burning quickly and completely. Instead, it slowly chars. When the charring is complete, all openings are entirely closed so as to shut off all air and smother the fire.

But no chemist could rest content if all charcoal were made in the wasteful manner just described or if charcoal were used only for broiling steaks and chops. He would cast a glittering eye on the smoke rising from the charring wood and say, "By gum, here is something going up in smoke. I'll see what is in that smoke and whether there is not a better way to make charcoal. I'll make something out of that smoke and find other uses for charcoal."



AN EXPERIMENT WITH SAWDUST

Heating sawdust in a test-tube represents a process carried out on a large scale in the chemical industry to produce charcoal, tar and pyroligneous acid. By refining pyroligneous acid, wood alcohol and acetic acid are obtained. From acetic acid, acetone may be made. Acetic acid and acetone play a major role in the manufacture of acetate silk and certain plastics. Wood alcohol is a good solvent for shellac and other gums and resins. The tar yields guaiacol, solvent oil and pitch.

AN EXPERIMENT WITH WOOD

Put several teaspoonfuls of sawdust in a small tin can with a tight-fitting cover which has a nail hole in it. Heat the can on a gas-stove or over the flame of an alcohol lamp or Bunsen burner so as to char the sawdust. A combustible gas will escape from the nail hole and, if you apply a lighted match, will take fire and burn.

You can perform the same experiment, if you wish, by putting a heaping teaspoonful of sawdust in a test-tube as shown in the illustration. When the sawdust is heated, gas will escape from the glass tube. This gas will burn if ignited.

When wood is heated in this manner (the chemical name for the process is destructive distillation) it breaks up into several useful by-products. The solid black material remaining in the can or test-tube is charcoal. The gases and vapours which escape contain wood alcohol, acetic acid, acetone, hydrogen, marsh gas, pitch and tar. The nature of these by-products of charcoal-making varies somewhat according to the temperature used in the process.

With more elaborate laboratory equipment than the tin can or test-tube used in your experiments, you could make wood alcohol, acetic acid, etc., in this manner. It is done on a large scale commercially and the process is called the distillation of hardwood for charcoal and by-products.

THE DISTILLATION OF HARDWOOD FOR CHARCOAL AND BY-PRODUCTS.

The charcoal briquets sold by the Ford Motor Company and used as fuel by a great many campers and picnickers, are pressed from powdered charcoal produced in the wood-distillation plant of the Ford Motor Company. The plant was erected in order to utilize the scrapwood from the automobile factory and can handle 400 tons of scrap-wood per day.

The scrap from packing crates and other sources is chopped into small pieces in a machine called a hog-mill. Then it is dried and fed into the top of the retorts. The tin can which you used in your experiment in the destructive distillation of wood is a retort. The retorts at the Ford plant are vertical cylinders of steel 40 feet high and 10 feet in diameter. The finished charcoal drops out of the bottom into a cooler. From the cooler, it passes into the briquetting machines.

The gases and vapours passing out of the retort are cooled and refined. The gas is piped to the power-house and burned under boilers. The various chemicals secured from the vapours are used in the Ford factories or sold. The ethyl acetate is used by the Ford Motor Company in its lacquer and artificial leather departments.

One ton of dry wood distilled in this manner will yield approximately:

Charcoal	650 pounds
Gas	5,000 cubic feet
Wood alcohol	4 gallons
Tar	38 gallons
Pitch	66 pounds
Creosote oil	3¼ gallons
Acetone	1½ gallons
Ethyl acetate	15 gallons

Charcoal is an excellent filter for purifying water. It has the ability to absorb large volumes of gases and is therefore employed in gas-masks for both industrial and military purposes.

Bone-black is a special porous form of charcoal used in sugar refining to remove objectionable gases and colouring matter. It is made by the destructive distillation of bones.

COTTON, A CONVENIENT FORM OF CELLULOSE

One of the most useful plants in the world is that which bears the snowy cotton boll as its harvest.

Cotton is the chief crop of the southern portion of the United States. The textile industry and shipments to foreign countries probably consumed 15,000,000 bales in 1942.

When cotton is picked, before its soft fibres can be spun into thread and yarn, they must be separated from the seeds. From the insignificant little seeds, which for many years went to waste, the chemist has developed sixteen important commercial products and hundreds of minor ones.

A cottonseed is a fuzzy oblong object about the size of a BB shot. The fuzz is the lint which is left attached to the seed when separated from the long fibres in the gin. Inside the thin woody hull of the seed is a yellow meaty kernel. The kernel contains minute brown specks which are cells containing oil. The oil cells are about one-third of the weight.

CELLULOSE, ONE OF MAN'S BLESSINGS

Cotton fibres, the long soft fibres used for spinning, are cellulose. So is the fuzzy lint or "linters" remaining attached to the seeds when they have been separated from the long fibres.

A chemist delights in cellulose in such convenient and inexpensive form as the cotton linters. The long fibres go to the textile mills. They are too expensive for the chemist since he can obtain the cheaper linters.

We are not going to discuss textile chemistry except to mention the fact that chemistry plays an important part in the cotton mill.

Some of the linters are used as stuffing material for pads and cushions and in making low grade yarns, but some the chemist gets, and he immediately applies his magic. From the fuzzy lint he makes artificial silk, writing paper, explosives, photographic film, celluloid, plastics, insulation and other things. Motion-picture film is acetate of cellulose. Guncotton is a mixture of cellulose nitrates.

EXPLOSIVES FOR WAR

When cotton fibre is allowed to stand in a properly proportioned mixture of nitric acid and sulphuric acid, a mixture of cellulose nitrates results. This, after washing to remove all traces of acids, is similar in appearance to cotton but more crisp to the touch. It has been converted into the powerful explosive called guncotton or nitrocellulose.

When treated with alcohol, then a mixture of alcohol, water, ether and diphenylamine, guncotton changes into a plastic mass which may be forced through a die into rods and tubes. The rods are cut into short lengths by an automatic machine and dried. The result is one form of smokeless powder. When exploded this substance decomposes into colourless gases.

Cordite is another smokeless explosive used in warfare which consists of nitrocellulose mixed with nitroglycerine and a small amount of paraffin.

PYROXYLIN

Pyroxylin is a form of nitrocellulose which is made by treating cotton linters with a mixture of sulphuric and nitric acids. The nitration is not allowed to proceed as far as when making nitrocellulose for explosives. By heating this product with water under pressure a low viscosity nitrocellulose is produced which makes an excellent lacquer. A lacquer is a protective coating which dries rapidly by the evaporation of the solvents with which it is mixed. A standard varnish dries slowly, partly by evaporation and partly by hardening due to oxidation. In order to make a lacquer of pyroxylin, it is necessary only to dissolve it in a suitable solvent. Such a lacquer is colourless like a varnish. If a coloured lacquer is desired it is merely necessary to add suitable coloured pigments.

The solvents used in present-day lacquers to dissolve the pyroxylin have such awesome names as butyl lactate, cyclohexanol acetate and amyl propionate. If pigments are incorporated in the lacquer a small amount of castor oil is also included. The castor oil makes the lacquer more flexible. It is a "plasticizer", which prevents the film of nitrocellulose and lacquer from wrinkling and buckling away from the surface being coated after the solvents evaporate.

Believe it or not, the finish on your automobile is made from cotton.

There are three uses for pyroxylin lacquers which require a tremendous tonnage.

Artificial leather is made by coating a cotton fabric with a pyroxylin solution and embossing it to simulate the grain of a leather.

Automobile bodies are finished with pyroxylin lacquers. They are superior to varnish finishes in durability.

Interior woodwork and furniture is often finished with lacquer. It is more durable than paint and dries in a much shorter time.

COTTONSEED WAS ONCE A NUISANCE

Once upon a time the problem of many cotton gins was what to do with the seeds. They could be used to some extent as a fertilizer and as a cattle feed, but vast piles remained to rot and give off an unpleasant odour. There are still laws in some states, harking back to the days when the disposition of cottonseed was a problem, which prohibit throwing them into streams.

Hundreds of chemists made the insignificant-looking seed their life study and to-day there are hundreds of millions of dollars invested in plants using the cottonseed as a raw material.

Through the science of chemistry cottonseed is no longer a nuisance. It is the basis of an industry.

COTTONSEED PRODUCTS

The cottonseed produces four main products: the linters, oil, meal and hulls. We have learned what can be done with the linters.

The oil is the most valuable part of the seed. In order to obtain the oil, the seeds are first cleaned of sand and foreign matter by machinery. Then the linters or short fibres are removed by gins. From these machines the seeds go into machinery which cuts them up with sharp knives and separates the hulls and meats as completely as possible.

The meats next go to heavy steel rolls which crush them and break open the oil cells. When the crushed meats have been cooked by steam under pressure they are ready for pressing. The presses develop a pressure of two tons per square inch. The crude oil is forced out and a hard cake left. The cake is ground into meal.

Cottonseed meal is used in the manufacture of dyestuffs and fertilizer; it is a food for cattle and a raw material for bakers and confectioners.

The crude cottonseed oil in tank cars is purchased by refiners. After going through bleaching, filtering and deodorizing processes at the refinery, it is a neutral oil of great purity and is used extensively as a cooking or salad oil. Wesson Oil is refined cottonseed oil.

By treating the refined oil with hydrogen it is hardened into a vegetable substitute for lard.

Thus the rather ugly little cottonseed goes marching off to war, upholsters our chairs, paints our automobiles, feeds our livestock and comes to our own dinner table.

CHAPTER VIII

The Carbohydrates

ASIDE from various minerals and vitamins, the three foods essential to the well-being of man are proteins (meat), fats and carbohydrates.

The important group of chemicals called carbohydrates are compounds containing carbon, hydrogen and oxygen, the last two elements being present in the same proportion in which they exist in water, that is, two to one.

Nature is the chemist of the carbohydrates. They are produced by plants. Starch, the various sugars and cellulose are the chief carbohydrates. Starch and the sugars are important food elements unless we are overweight and trying to reduce.

PHOTOSYNTHESIS

Plants and animals both require food in order to grow, repair waste and possess energy. Both require as food, water, inorganic salts and organic substances such as protein and carbohydrates. The most significant difference between plants and animals, in general, is the manner in which they acquire their food, although both absorb their water and inorganic salts directly. The animals must have their organic substance supplied in the form of carbohydrates and proteins. But many of the plants have the ability to *manufacture their own organic substances* by synthesizing carbohydrates from inorganic materials.

This process of carbohydrate manufacture by nature is called *photosynthesis*. Sunlight is necessary to furnish the energy required for this chemical reaction. The reaction can take place only in green plants because the presence of the green colouring matter *chlorophyll* is required. The reaction consists of the chemical combination of carbon dioxide (carbon and oxygen) and water (hydrogen and oxygen) to form a simple plant sugar (carbon, hydrogen and oxygen). Not all the oxygen in the carbon dioxide and water is used in forming the sugar and that which is left over is a "by-product." Most of it diffuses into the atmosphere. Any part of the plant which is green may carry on the operation, but in all the higher plants most of this photosynthetic activity takes place in the green leaves. The supply of water is drawn from the soil by the roots and supplied through the veins of the leaf. The carbon dioxide gas is drawn in from the atmosphere through the small pores, called stomata, in the epidermis of the leaf. Then, in a manner which is not understood, the green chlorophyll converts the sun's radiant energy into chemical energy and the sugar and oxygen-producing activity occurs.

This is considered to be the most important chemical process on earth. As a result of photosynthesis, men and animals are provided with a food supply and with oxygen for respiration. If it were not for chlorophyll, life as we know it would not be possible. It is the only substance by which the energy of sunlight can be converted into chemical energy available as food for plants, animals and mankind.

Chemists, in spite of their knowledge and ingenuity, have not been able to duplicate the process.

Green plants may use the simple sugar or by further chemical processes may convert it into forms more suitable for storage, such as starch, cellulose, oil and any of the complex sugars.

STARCH

Starch is found in the roots, seeds and leaves of plants. Corn is 65 per cent. starch. Wheat, rye and rice contain a high percentage of starch. Potatoes contain 15 per cent.

Whenever we eat vegetables and grains we are eating starch and our mouths are the scene of an important chemical process. A chemical substance in the saliva called *ptyalin* ferments the starch and changes it into sugar. We seldom chew our food long enough to mix the starch thoroughly with saliva and change all of it into sugar, and so the process is completed in the intestines by enzymes called *amylopsin*, *amylase* and *maltase*. The chemical process which began when the starch was mixed with saliva ends in all the starch being converted into sugar called *glucose*. Starch cannot pass through the intestinal wall, but glucose can. And so the starch that once might have been a piece of bread, a potato, or a dish of rice or tapicoa becomes glucose and filters into the blood. It is carried by the bloodstream to the liver, where it again undergoes a chemical change and becomes glycogen. When muscles move or do work they use glycogen.

Not all the glucose passing into the bloodstream is used by the muscles. Some of it is converted into fat and stored.

HOW TO FIND THE STARCH IN A POTATO

Grate a raw potato on a fine grater so that it is reduced to a pulp. Put this raw potato pulp in a tumbler and add water until the tumbler is almost full. Stir this mixture gently for two or three minutes. A light brown cloudy liquid will form. After a thorough stirring strain out the pulp by pouring the liquid through a coarsely woven handkerchief spread across the top of a second tumbler. If the strained liquid is allowed to stand for a few minutes a white powder will settle to the bottom.

This powder is *starch.*

Save it for another experiment.

SOME OF THE PROPERTIES OF STARCH

Starch does not dissolve in cold water because each tiny granule or individual particle really consists of an outer shell, or husk, that encloses the starch itself. The shell is an insoluble material, but boiling in hot water causes the husk to burst open. The enclosed starch then dissolves and forms a solution.

STARCH UNDER THE MICROSCOPE

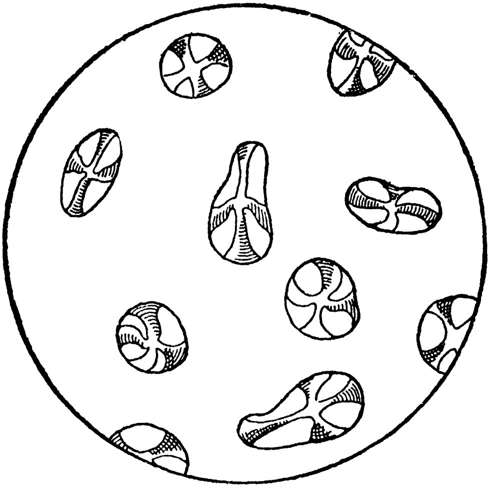
By means of the microscope one can examine starch granules and determine whether they come from corn, potato, wheat or some other plant.

If you put some of the starch obtained in the experiment with a potato on a glass slide and examine it under a microscope you will see small particles which look like miniature clams. These are the starch grains. A first-class microscope is not necessary. One of the toy instruments furnished with a boy's microscope outfit will reveal them.

STARCH GRAINS UNDER POLARIZED LIGHT

Some toy microscope sets are furnished with two small disks of Polaroid or Polaroid, Jr. This material polarizes light.

When potato starch is examined under polarized light, bright-coloured crosses appear in the grains. The fine structure within the starch grains sets up interference of the polarized light as it



STARCH GRAINS UNDER THE MICROSCOPE

When potato starch is examined under polarized light with a microscope, bright-coloured crosses appear on the grains. Some toy microscopes are furnished with two small disks of Polaroid (for polarizing light) and may be used for this experiment.

passes through and the colours you see come from the interference of the light rays with each other.

To use polarized light with a microscope, place one Polaroid disk under the stage of the microscope so that it centres under the hole in the stage. The clips under the stage will hold it in place. A second piece of Polaroid should be placed over the ocular or eye-piece.

AN EXPERIMENT WITH STARCH

Pour almost all the water off the potato starch which settled to the bottom of the glass tumbler. If this is done carefully none of the starch will be lost. Stir the starch in the remaining water and pour it into the bottom of a small saucepan. If necessary, add enough water so that there is about ⅓ of a cupful in the pan. Heat the mixture slowly until it comes to a boil. At the same time stir it. Boil gently for two or three minutes. Boiling with water causes the starch grains to swell up and burst open. The mixture will thicken and become gelatinous. Dip some out in a spoon, and when it has cooled, feel it with your fingers. It is slippery and is known as starch paste.

Add a drop of tincture of iodine to the starch paste in the spoon. Use ordinary tincture of iodine, the kind that is used to sterilize cuts and scratches and that can be purchased at any drug-store. The brown iodine will stain the starch blue or blue-black, depending upon how much you use.

A TEST FOR STARCH

The fact that a drop or two of iodine added to starch paste produces a deep-blue colour provides the chemist with a simple method of testing for the presence of starch. And by the same token, starch may be used as a test for iodine.

Make a flour paste by stirring a teaspoonful of white wheat flour in a small amount of cold water. Stir this mixture into about half a cupful of boiling water and boil it gently for a few minutes. The paste will thicken and become slippery. This is due to the presence of starch in the flour. You can prove the presence of starch by adding a few drops of tincture of iodine. The blue-black colour shows that the "thickening" contains starch.

Mash some well-cooked rice into a thin paste in hot water and then add a drop or two of tincture of iodine. Try the same experiment with some baked or boiled white potatoes. What does the blue colour show?

CORN, GRIST FOR THE CHEMICAL MILL

Give a chemist a bushel of corn and he can do several things with it. With fried chicken or pork chops in mind he can feed it to the chickens or pigs; he can grind it into corn meal for muffins and corn bread; he can ferment it and from it distil whisky, or he can employ some of the more elaborate tricks of his trade and produce salad oil, starch, table syrup, candy and rubber balls.

In Europe starch for commercial use is made chiefly from potatoes. In America, it is obtained principally from corn.

In preparing starch from corn, the corn is soaked in warm water containing a small amount of sulphurous acid. The acid does not play any chemical part in the process. It is used to kill any germs, fungus, and bacteria present on the corn. When the corn has softened, it is shredded, mixed with water and agitated. The corn seed or germ floats and is run off with a gentle flow of water from the surface of the tank.

The corn germs are rich in oil. They are dried and pressed in a way very similar to that used in pressing flaxseed for linseed oil. The result is an edible, nutritious oil called corn oil, sold under various names as a salad oil. Mazola is a well known brand of corn oil. The press cake, which is what remains of the corn germs after the oil has been pressed out, is used as cattle food.

Remaining behind in the tank from which the corn germs have been floated is a milky liquid containing starch, gluten and hulls. This is strained through bolting cloth. The hulls remain behind but the starch and gluten pass through the cloth with the water. The liquid is then passed through a long shallow trough. The starch grains settle on the bottom of the trough and the gluten floats off.

After that the water is drained off and the starch is removed and dried. The gluten is made into gluten meal for special breads.

SUGAR FROM STARCH

Many fruits, flowers and vegetables abound in a natural sugar called dextrose. This is built up by the energy of sunshine and the process called photosynthesis. In the process of digestion, as explained previously, starch is changed into glucose. Glucose is used extensively in baking, in making candies, jams, table syrups, beverages and other food products.

Although as yet chemists have been unable to produce starch in the laboratory, they can easily convert starch into glucose. There is really no need to make starch synthetically. There is a plentiful low-cost supply of nature's own manufacture and it is easily extracted. It is more important to be able to change starch into glucose.

The process is simple. Starch is mixed with much water to which a small amount of sulphuric acid has been added. The mixture is heated by steam under pressure in a closed tank called a converter.

The acid acts as a *catalyst.* It does not actually take any part in producing the glucose which is formed. It is like the director of an orchestra. The director does not make any of the musical sounds but directs the sound producers. Without the acid present, the little starch grains would simply swell up and burst, forming a slippery adhesive. Under the direction of the acid, each starch molecule takes and adds to itself one molecule of water. The result is a sweet syrup.

The process which a molecule of starch carries out in adding to its own structure the two atoms of hydrogen and atom of oxygen is called *hydrolysis*. Hydrolysis is one of the tricks a chemist uses frequently in doing a presto-change act.

The syrup coming out of the converter is neutralized with soda ash, filtered and variously treated with little touches. With the addition of cane-sugar syrup and a small amount of salt it becomes a table syrup, known for example as Karo syrup.

By evaporation it may be solidified into slabs which are chipped into smaller pieces for shipment. This is corn sugar, also called grape sugar. Or it may be crystallized into the perfectly white crystalline sugar called dextrose sugar in the food industry and dextrose hydrate by the chemist.

Thus water, carbon, the energy of sunshine and the ingenuity of the chemist provide us with a prime food.

CHAPTER IX

Water, the Most Abundant Chemical Compound

WATER is the most familiar, most abundant and most useful chemical compound. It covers a large portion of the surface of this planet and is present in a host of common substances.

A great portion of the weight of all living things is water. From one-half to three-quarters of all plant tissues is water, and water is approximately three-quarters of our own bodies. It makes up nearly 94 per cent. of the total weight of tomatoes. Potatoes are 78 per cent. water, apples from 80 to 90 per cent. A full-grown man has been described as about 12 pounds of mineral ash and 8 buckets of water. Without water, life would be impossible.

Water dissolves most substances to some extent. Rain dissolves fine particles of substances floating in the air. Water that flows through the soil dissolves substances from the soil and rocks. Rivers and lakes become contaminated with waste matter from dwellings and factories on their banks. As a result, natural water is never pure. Whether water is pure or impure cannot be judged by its appearance. It may be as clear as crystal yet contain deadly germs or poisonous substances.

The liquid used to dissolve a substance is called a solvent. Other liquids are solvents to a certain extent, but water is the most widely used solvent because it will dissolve the greatest number of substances.

There are countless ways in which water is used as a solvent, even in the most ordinary circumstances of life. Foods and medicines can be absorbed only when they are dissolved. Cleanliness of body, clothing, home and community is possible only because water is a solvent.

The chemist uses water more often than any other compound. Since water is so abundant, it is never necessary to prepare it from other materials. Paper mills, gasworks, dye plants, starch and soap factories, refineries for petroleum and sugar, many other industrial establishments where chemical processes are carried on, need water on an enormous scale. They are frequently located on the bank of a river so that they can obtain water for their processes.

WATER IS ONE OF THE CHEMIST'S TOOLS

Many chemicals which have no effect upon one another while dry will act upon one another when dissolved in water. Consequently, the chemist frequently uses water to bring about a chemical reaction. A good illustration of this is found in the baking-powder on the pantry shelf.

Baking-powder is a mixture of chemical compounds which do not react upon one another while dry. It can be stored for an indefinite period in a closed can where damp air or moisture cannot reach it. But when baking-powder is made an ingredient of wet dough, it dissolves in the water contained in the dough and chemical action takes place. Carbon dioxide gas contained in the bicarbonate of soda, which is one of the ingredients of all baking-powders is released by the action. This is exactly what the baking-powder is designed to do. The bubbles of carbon dioxide work through the dough making it into a spongy mass, thus changing what would otherwise be a hard tough cake or biscuit into something light and digestible. If you examine a piece of bread or cake, you will have no difficulty in seeing the pores formed by the bubbles of carbon dioxide gas.

AN EXPERIMENT

All baking-powders contain sodium bicarbonate and cream of tartar, alum or sodium phosphate. All these substances readily dissolve in water. Cream of tartar, alum and sodium phosphate are acid substances. Their reaction with sodium bicarbonate is quite similar to the reaction between lemon juice and sodium bicarbonate but is more rapid. (See page 40.)

If you put a pinch of baking-powder into a test-tube containing water, the dry ingredients will go into solution quickly and begin action. Bubbles of carbon dioxide will keep the liquid in a turmoil until the reaction is complete.

AEROSOL: HOW THE CHEMIST MAKES WATER WETTER

Water has always seemed quite wet to most of us. There have been times when we could not imagine it as ever being any wetter. But water, to the chemist, is often obstinately "dry."

You can appreciate the fact that this is possible if you have ever sprayed plants with water containing insect and fungus-destroying substances. The solutions roll merrily off the leaves of some plants without wetting them. You have heard the old saying, "like water off a duck's back." Water does not wet feathers easily. Water frequently behaves that way and will not wet some substances.

THE "SKIN" ON WATER

This peculiar behaviour of water is due to its *surface tension.* Tension means "stretching." The surface of all ordinary water is like an elastic skin which is somewhat stretched. This surface tension squeezes the water together and tries to reduce the area of the liquid surface to the least possible size.

The strength of the water skin is very small when big things and some substances are concerned, and very strong when small things and other substances are encountered. A small dressmaker's needle carefully laid upon the surface of the water in a saucer will float because it does not easily break through the "skin" caused by surface tension. A heavier object will break through and sink.

Those who have lived in the country and have explored the mysteries of brooks and ponds have seen "skating bugs" running around over the surface. The water does not wet the feet of these insects, and they do not break through its surface skin. There is a small depression in the surface of the water where each foot rests. Here the "skin" on the water is pressed down. It is the surface tension of the water surface at each little depression which supports the weight of the tiny creatures and enables them to run about over the top of the water.

When an object coming into contact with water has sufficient attraction for the water to break the surface tension, the object is wetted. When an oily, waxy or otherwise water-repellent surface comes into contact with water, the water surface is not broken and the object is not wetted. You can prove this by a simple experiment.

EXPERIMENT

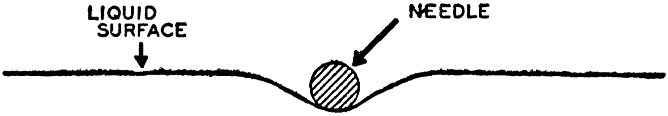
Dip a strip of ordinary paper in a tumbler of water. The surface of the paper and the water have an attraction for each other. The paper breaks through the surface tension and becomes wet.

Try a strip of waxed paper. Dip it in the water. The waxed surface is water repellent. It does not break through the water surface. It pushes and stretches the "water skin" but does not go through. Consequently it is not wetted.

You can find ready evidence of the elastic skin which surface tension forms on water by another simple experiment, and, by the way, it exists on the *free* surface of all liquids. In the case of a tumbler filled with water, the free surface is the top surface exposed to the air.

AN EXPERIMENT WITH SURFACE TENSION

A dressmaker's needle or a safety-razor blade made slightly oily by rubbing through the hair will not wet readily and will float on water. Use clean cool water in a saucer or dish. Wait until the water is at rest before you try to float the needle or blade. A small, slender needle and a thin blade of the double-edge type are best. Both must be polished and without rust spots. They must also be dry. The easiest way to place the needle on the surface of the water is to balance it near the end of a wooden match and bring it close to the water surface. Then spill it off.



THE "SKIN" ON A WATER SURFACE WILL SUPPORT A SEWING NEEDLE

The surface tension of a liquid causes it to behave as if it were a tight elastic skin. The surface tension of water will support a sewing needle. The illustration shows how a needle carefully laid horizontally on a water surface depresses but does not break through the surface "skin." Surface tension prevents water from quickly and thoroughly wetting some materials. Chemists have devised useful wetting agents or detergents which reduce the surface tension of liquids and improve their wetting qualities.

Note that the liquid surface curves upward on all sides under the razor blade and needle. Not only can you actually see the curve, but there is other evidence of its existence. If an electric light is held above the needle so as to cast a shadow of the needle on the bottom of the saucer, it will be noticed that the shadow is several times as wide as the needle. The curving liquid surface bends the light and causes this thickening of the shadow.

If the needle is near the centre of the dish and you touch the surface of the water gently with a piece of soap, the needle will "scoot" away from the soap. Surface tension is destroyed when soap dissolves in water. When the tension on one side of the needle is weakened by the soap, the tension on the opposite side pulls the needle to one side of the dish.

Many industrial processes are conducted under conditions where normally poor wetting would prevail. In order to make water "wetter" and eliminate poor wetting, chemists employ a *wetting agent.*

Wetting agents are substances which are added to water, water solutions, and oils to lower their surface tension and thus increase their spreading and penetrating action. They have many applications in industry. For example, they are added to dye solutions to aid penetration of colours into the fibres of yarns and fabrics and to adhesives such as pastes and glues to improve their contact and hence aid adhesion.

AN EXPERIMENT WITH A WETTING AGENT

Soap weakens the surface tension of water and its action may be demonstrated as follows:

Half fill a sauce-dish with cool clean water. Float a clean dry double-edge razor blade on the surface. Have on hand a strong solution of soap in water which is free of suds and bubbles. Pour some of this soap solution into the dish. Trickle the soap solution into the dish at the edge so that it does not create any turbulence in the water. The razor blade will sink. As the soap solution mixed with the water in the dish, it weakened the surface tension so that the weight of the razor blade broke through the "skin."

A THOUSAND WETTING AGENTS

There are many wetting agents which are far more efficient than soap. Their manufacture began during World War I when fats for soap-making were scarce, and German chemists tried to concoct soapless soaps. Fifteen years ago the United States production was zero. To-day it is over 100,000,000 pounds per year. About 1,000 different wetting agents, sold under 275 bewildering trade names, are made.

Wetting agents now touch upon almost every aspect of life. Growing fruits and vegetables are often sprayed with a solution containing a wetting agent, and poisonous substances such as arsenic, in order to kill harmful insects. In canning factories, wetting agents efficiently remove these poisons. They are used in paints, enamels, printing inks, etc., to improve their spreading quality. In laundries they sometimes replace soap. Dreft and Drene are examples of soapless soaps whose secret is a wetting agent. Several top-notch medical men are exploring the possible uses of wetting agents in medicine and surgery. It is probable that they will help antiseptics to spread more thoroughly, reach into tiny pores and crevices, make antiseptics "more antiseptic". Laboratory wizardry has recently produced a substance which is perhaps the most powerful wetting agent ever made commercially available. Its trade name is Aerosol OT-100%, and its technical name is *dioctyl sodium sulpho succinate*. Aerosol OT-100% is a waxlike material supplied in pellet form. It is somewhat plastic.

One of the most useful characteristics of Aerosol OT-100% is that only a very minute quantity is required for results. One part mixed with 10,000 parts of water will cut the surface tension of water nearly in half. If a few drops of Aerosol OT solution are added to the water in a saucer upon the surface of which a needle is floating the surface tension will be so lowered that the needle will sink. It would require much Aerosol OT-100%, added to the water of a small pond, to lower the surface tension so that skating-bugs could no longer "skate" on its surface. Ducks would be miserable in water containing Aerosol. Their feathers would become wet, and instead of being able to paddle gaily over the surface of the water they would find themselves immersed nearly to their ears.

There are several Aerosol wetting agents. They are all related chemical compounds. They have been adopted by the textile industry where there is need for wetting water in dyeing and washing yarns and fabrics. Aerosol OS (another variety) is used in paper making for cleaning paper-mill felts. Paper towels made from kraft stock lose their absorbency on ageing. When

Aerosol OT is applied as a dilute solution in the form of a spray just before the paper sheet from which the towels are made reaches the calendering rolls, they do not lose their absorbency so rapidly with age.

The use of Aerosol OT in metal polishes promotes more rapid wetting of the metal surface. It improves the action of hair washes, cleaning fluids, soldering fluxes, insect sprays, cough mixtures, cosmetics, flavours, printing inks and photographic solutions.

One-quarter of an ounce of Aerosol OT-100% in a gallon of water makes an excellent cleaner for windows, car wind-shields, spectacles and glassware of all kinds.

THE COMPOSITION OF WATER

Almost every boy, aged nine or ten, learns that the chemical formula for water is H_2O. Thereafter for a time he calls water "aitch-two-oh." We may profitably pause to consider what water is, since it is not an element.

Water, as its formula indicates, is a compound of oxygen and hydrogen in which two atoms of hydrogen are combined with one of oxygen. Oxygen and hydrogen are elements—nothing but oxygen can be obtained from oxygen and nothing but hydrogen from hydrogen. On the other hand, water being a compound, it can be broken up into oxygen and hydrogen. Until 1781 water was supposed to be an element. That year, Joseph Priestley, the famous discoverer of oxygen, found that the explosion of oxygen and hydrogen in a closed tube produced water.

When atoms combine to form compounds, they always do so in definite proportions by weight that are characteristic of the elements. The atomic weights of each of the ninety-two elements are known. Hydrogen is the lightest—atomic weight 1.008. The atomic weight of oxygen is 16. The chemical formula, H_2O, expressing the composition of water, therefore, means that eighteen parts by weight of water are composed of two parts by weight of hydrogen and sixteen of oxygen. In other words, the oxygen in water weighs eight times as much as the hydrogen.

If these same proportions of the two gases are measured out by weight, that is, 8 to 1, and mixed together in a tube, they will form an invisible gaseous mixture, but they are not water. Their mixture does not possess any of the properties of water. However, if an electric spark is made in the tube, there will be an explosion. The gases will disappear. In their place will be found a drop, perhaps even a few drops, of water. Synthesis produced water from hydrogen and oxygen. By analysis, water can be decomposed into a mixture of the two gases.

Water may be decomposed by electrolysis. Electrolysis is the process of decomposing a compound by means of an electric current.

Pure water will not conduct an electric current. But if it contains a small quantity of any of the chemicals which are "electrolytes," current will pass through and in doing so will cause electrolysis.

AN EXPERIMENT IN ELECTROLYSIS

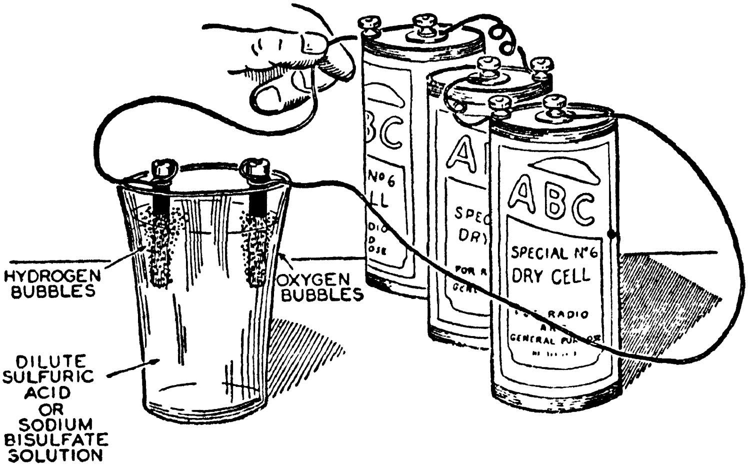
Fill a glass tumbler three quarters full of water. Add to this two teaspoonfuls of sodium bisulphate. Stir until dissolved: this is the electrolyte, added to make the water a conductor of electric current. Sodium bisulphate is inexpensive and is usually one of the chemicals furnished with boys' chemistry outfits. It may be purchased at a drug-store. It is one of the class of chemicals called *a salt.*

Instead of a solution of sodium bisulphate in water, you can use water to which an equal quantity of storage-battery electrolyte (dilute sulphuric acid obtainable at a battery service station) has been added. Handle this liquid carefully. Don't spill any—it eats holes in things. If electrolyte is accidentally spilled or spattered, wipe it up quickly, wash the spot first with water, then with household ammonia or bicarbonate of soda solution.

You will need two carbon rods from old flash-lights cells as electrodes. Attach a piece of copper wire about eighteen inches long to each carbon rod. The best way to make a good electrical connection is to solder the wire to the brass cap. You can, however, make a good contact by scraping the wire bright and twisting it tightly around the end of the rod immediately under the cap.

Connect the wires attached to the carbon electrodes to the terminals of a battery consisting of two or three dry cells, and place the electrodes in the tumber of water containing the electrolyte. Bend the wires over the edge of the tumbler so as to support the rods and keep the wires and brass caps out of the electrolyte.

Small bubbles will form on each of the carbon rods. As they grow larger, the bubbles will break away and float up to the surface.



A FAMOUS EXPERIMENT FIRST PERFORMED IN 1800

One hundred and forty-five years ago, two English experimenters performed an experiment that thrilled the scientific world. They discovered that an electric current will bring about chemical action. They sent the energy of Volta's newly discovered "pile" through some water and found that the fluid decomposed into two gases—hydrogen and oxygen.

You can perform this famous experiment by sending the current from a dry battery through a solution of sodium bisulphate or sulphuric acid in water. Connect two carbon rods from old flash-light cells to the battery and immerse the rods in the solution. Bubbles of hydrogen gas will rise from the rod connected to the negative terminal. Oxygen bubbles will be produced at the positive rod.

Those formed on the carbon rod which is connected to the positive pole of the battery are *oxygen.* The bubbles form more rapidly on the carbon rod connected to the negative pole of the battery. They are *hydrogen.* The water is being broken up into the two gases of which it is composed. The sulphuric acid or the sodium bisulphite, whichever is used, does not undergo any chemical change. If the electric current is passed through the electrolyte for a sufficient length of time almost all the water will be decomposed into oxygen and hydrogen.

WHEN IS WATER PURE?

The chemist, who uses water for laboratory and manufacturing purposes, and the plain citizen, who ordinarily uses water for cooking, drinking and bathing, have different definitions for the term *pure* water.

Water that contains bacteria and organic matter, or simply dangerous bacteria, is unfit for drinking. Clear sparkling water may abound in bacteria of the most dangerous types. On the other hand, very few minerals ordinarily found dissolved in water render it unfit to drink: they are not injurious to health. In fact, it is really desirable that drinking water contain certain mineral substances necessary to the body.

However, for laboratory use, water must be absolutely free from every foreign substance of any kind whatsoever. The remarkable property of water which enables it to dissolve nearly every other known substance makes it impossible to find pure water which complies with the chemists' definition of *pure* unless it has been distilled.

Distillation consists of boiling the water until it vaporizes and then condensing the resulting vapour. The distillation process destroys all bacteria, leaves behind all mineral matter and produces the purest water that can possibly be obtained in any way.

WHAT IS MEANT BY HARD WATER

Water that contains an excess of dissolved mineral matter is so-called *hard* water. Calcium and magnesium occur in the soil and in many minerals and rocks. Consequently, the water of many springs, rivers and wells contains the salts of calcium and magnesium in solution. They are the most common cause of hard water, sometimes so hard that it is not only unfit for use as a beverage but is particularly unfit for many manufacturing processes. Tanning and paper-making are typical of such industries.

The reluctance of soap to form a lather in hard water is due to the presence of certain minerals in the water. When ordinary soap is dissolved in hard water, these minerals, which include calcium bicarbonate and gypsum, interact with the soap and precipitate it. Thus they interfere with or prevent the cleansing action of the soap. Special "hard-water soaps" are made for use with hard waters. Boiling some hard waters makes them soft by precipitating many of the minerals held in solution. Gypsum and some other minerals cannot be precipitated by boiling. They must be eliminated by means of chemicals.

AN EXPERIMENT WITH HARD WATER

Dissolve a little ordinary soap in soft water. Half fill a glass tumbler with this solution; add some clear lime-water to it. The soap solution will become turbid. White flakes which feel sticky to the fingers will be deposited on the sides of the vessel.

To make lime-water, put one teaspoonful of lime into a clean milk bottle or one-quart fruit jar nearly filled with water. Shake it up thoroughly and then let it settle. Pour off the clear liquid at the top into another bottle. This clear liquid is lime-water. Keep it tightly corked. It contains calcium hydroxide in solution and can be used in this and other experiments.

THE DIFFERENT KINDS OF SOLUTIONS

Water and other solvents form three kinds of solutions.

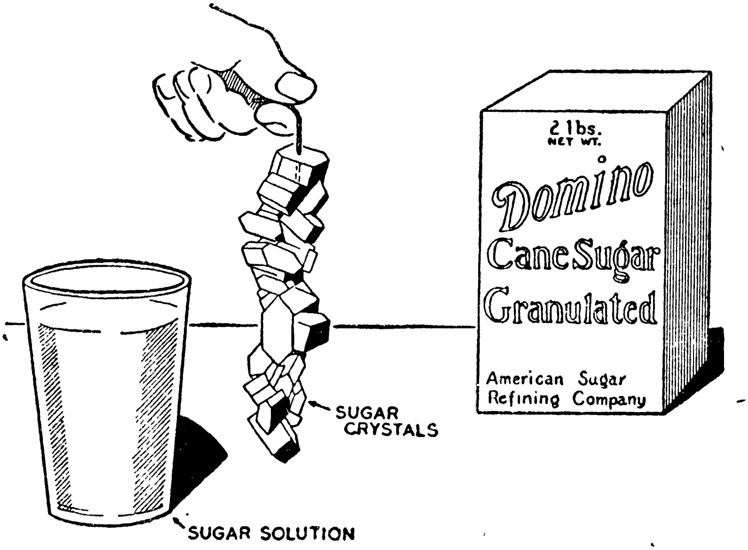
If a quarter of a teaspoonful of sugar is put into a pint of water, the amount of sugar used in comparison with the amount of water is small, and the result will be a weak or *dilute* solution. If the amount of sugar is proportionately large in comparison with the water, large enough, for example, to form a syrup, the result is a *concentrated* solution. Finally, if the amount of sugar is so increased that the water is unable to dissolve more of it, the solution becomes a *saturated* solution.

AN EXPERIMENT WITH A SATURATED SOLUTION

Some compounds which have been dissolved in water will form crystals if the liquid is evaporated. Some, under the right conditions, will form crystals from a concentrated or a saturated solution.

Pour a cupful of water into a saucepan and heat it until it boils. Turn the fire down and add granulated cane sugar slowly to the boiling water, stirring well at the same time. Add sugar until no more will dissolve. This will form a saturated solution of sugar in water.

Pour the hot solution into a glass tumbler. Cut a square of cardboard large enough to cover the glass and suspend a short piece of cotton cord from a hole in the centre. The string should be long enough to reach nearly to the bottom of the glass when the cover is in position. It may be necessary to tie a small weight on the lower end of the string to make it hang down. Set the glass of syrup with its cover and string in a place where it can cool and remain undisturbed. After a few hours, small sugar crystals will begin to form on the string. They may also form on the sides of the tumbler. They will grow to a substantial size in a few days. The large crystals are called "rock-candy." They were a treat to boys and girls fifty years ago.



HOME-GROWN CRYSTALS OF CARBON, HYDROGEN AND OXYGEN

When you buy a pound of sugar you are buying a pound of carbon, hydrogen and oxygen. Raw cane sugar goes through an astonishing series of chemical transformations before it gets stirred into a cup of coffee. It is heated, treated with lime, diatomaceous earth and charcoal. It becomes a sweet, heavy syrup which then undergoes a complicated heat and pressure process that causes crystallization.

If a string is hung in a saturated sugar solution and undisturbed for a few days, it will become covered with the large, hard sugar crystals called "rock-candy."

WATER

SEA WATER

In comparison to the water of lakes and streams, sea water is not water at all but is a solution of salt and many other chemicals.

Rivers running into the ocean carry in solution a host of different minerals. The percentage of these substances is not great, but the ocean becomes more and more loaded with dissolved substances because there is no outlet for them. Ocean water evaporates but it leaves the solids behind.

Among the elements there is a group of four called the *halogen* family. They are chlorine, fluorine, bromine and iodine. The word *halogen* is derived from two Greek words which together mean *salt-forming*, and this name was applied to this family because the four elements composing it are salt-formers. All of them are found in sea-water, chlorine to a considerable extent, the others in minute quantities.

At the moment our interest lies in the third member of the family, *bromine*, a dark red liquid, whose name comes from a Greek word meaning *stench*. Its name is justified: it really does smell bad and it has a very irritating effect on the mucous membrane of the nose and throat. If spilled upon the hands it does considerable damage to the tissues. In other words it is not the sort of stuff you leave around where children might find it. Pure bromine is wicked. Combined with other elements in the form of various bromides it is more kindly. Bromides are valuable pharmaceuticals, used to quiet pain and irritation.

Enough bromine to supply the medical profession with its requirements, and also to supply the dye industry with the small amount it requires, is easily obtained from salt wells. When the brine from which table and dairy salt is made contains bromides, the bromine may be recovered from the mother liquors. But in these days of high-powered automobile and aeroplane engines, many millions of pounds of bromine are required. The use of ethylene bromide with tetraethyl lead as an anti-knock compound in petrol has meant a large consumption.

Consequently, in order to obtain enough bromine, sea water has become a raw material. At Wilmington, North Carolina, vast quantities of bromine are obtained from sea water. About 1,800 gallons of sea water must be treated for each pound of bromine obtained, but this is done in such an efficient manner that the process is a commercial success and is America's largest source of this essential for "anti-knock."

ANOTHER COMPOUND OF HYDROGEN AND OXYGEN

The well-known household antiseptic, hydrogen peroxide, is another compound that results from the chemical union of hydrogen and oxygen. Hydrogen peroxide molecules consist of two atoms of hydrogen and two of oxygen—one more atom of oxygen than the water molecule possesses. To produce this compound thirty-two parts by weight of oxygen must combine with two parts by weight of hydrogen.

Pure hydrogen peroxide is a clear syrupy liquid which is so unstable that it explodes when exposed to heat or light. It is manufactured at the rate of many tons a day for use as a bleaching agent in the felt-hat industry and in the manufacture of metallic peroxides and many other "per" compounds. It is sold in the form of a water solution in strengths varying from 3 to 30 per cent.

The ordinary variety to be found in the medicine cabinet, where it is kept for use as a gargle and an antiseptic for cuts and wounds, is a water solution containing about 3 per cent. hydrogen peroxide.

Hydrogen peroxide molecules hold their extra atom of oxygen so loosely that some of it is continually escaping. The solution slowly decomposes and forms water and free oxygen. If you pour some into your hand you can see the bubbles of oxygen form. The 3 per cent. household variety of hydrogen peroxide is also known in the trade as "10 volumes," which means that the solution will liberate, under proper conditions, oxygen to the extent of ten times the volume of the solution.

The fact that hydrogen peroxide gives up its oxygen so readily is the reason why it is useful as an antiseptic and a bleach. The liberated oxygen is very active and destroys germs and colouring matter.

CHAPTER X

Air and the Things It Is Made Of

RESTING upon every square mile of ocean and also upon the land at sea-level are almost *30,000,000 tons* of atmosphere or air. There is slightly less upon the hills and uplands. The total on the earth's surface is an inconceivable amount.

WHAT IS AIR?

Human beings, animals and plants need a constant supply of air to continue their life activities. We have been breathing the atmosphere since time unknown, and for a few thousand years we have been using it to dry our shirts and make fires. Until quite recently, we did not know what else to do with air. We did not know that the atmosphere is a vast ocean of chemicals, 200 miles high, at the bottom of which we live.

It has always been usual to refer to air as though it were a single substance. Actually it is a mixture of nine different elements in the form of ten gases. To the chemist, it is a convenient and inexhaustible stockpile of some of the raw materials he needs for his brews.

He uses the oxygen in the air for making countless compounds. The nitrogen is used for ammonia, making explosives and fertilizers. The neon and argon are used in electric lamps.

Oxygen and nitrogen are the two constituents of air present in the greatest quantity. They are also the most useful. The average composition of dry air is as follows:

Gas	*Percentage by Volume*
Nitrogen	78.00
Oxygen	21.00
Argon	.96
Carbon dioxide	.04
Neon	traces
Helium	,,
Ozone	,,
Zenon	,,
Hydrogen	,,
Krypton	,,

The relative amounts of these substances remain practically constant. Gases from the countless cities and towns produce scarcely any effect, because the total quantity of air is so great.

Small amounts of many other substances occur in the atmosphere besides those in the list above. There is always some water vapour and in addition traces of dust particles, bacteria, minute quantities of ammonia and certain gases like hydrogen sulphide and sulphur dioxide, produced by volcanoes and various manufacturing processes. The dust particles include a great variety of materials. A microscope reveals such things as soot, soil, stone, steel, spores, cotton and wool.

OXYGEN

Oxygen is the most abundant element. It is found in the free state chiefly in the atmosphere. It exists, combined with other elements, in water, limestone, clay, quartz and many other minerals, and in plant and animal substances. In fact, about 50 per cent. of the earth's crust is oxygen.

We give Joseph Priestley, an English chemist and clergyman, credit for discovering oxygen.

On Sunday, August 1, 1774, Priestley performed an historical experiment. He heated some red oxide of mercury and from it obtained an "air" which he collected in a bottle. A lighted candle stood near-by. With no particular purpose in mind and in a moment of curiosity, he inserted the candle in the bottle to see what would happen. The candle burned more brightly than ever. Priestley became quite excited. He made more of this new "air" and continued his experiments with it for weeks. He found that it made charcoal burn violently.

He determined that this new "air" was five or six times as pure as ordinary air and decided that it was "dephlogisticated" air. This belief was in keeping with the theory existent at that time that an unknown substance called "phlogiston" was an ingredient of all combustible things and was released into the air when anything burned. He did not realize that he had discovered the most important element of the earth—that he had isolated pure oxygen.

The outstanding chemical property of oxygen is its tendency to combine with other elements. It combines readily with nearly all other elements to form *oxides*. Many of the chemist's most useful compounds, a large number of his creations, contain oxygen combined with other elements. The oxides, hydroxides, sulphates, carbonates, bicarbonates, nitrates, acetates, borates, sugars, alcohols and numerous others are oxygen compounds.

At ordinary temperatures, oxygen does not react with many substances by itself. At higher temperatures its action is very rapid and is usually accompanied by noticeable heat.

Ordinary burning is oxidation accompanied by noticeable light and heat.

You have seen an old tin can which has been lying on the ground exposed to the weather for a long time and has almost completely changed into the reddish-brown substance called rust. A close examination and any tests that you may care to make would show that there is no similarity between the original iron and the resulting rust. The iron has gone through a chemical change. The rust is the combination of iron and oxygen called an oxide. Rusting is slow oxidation. Slow oxidation is the combination of a substance with oxygen without noticeable light and heat.

AN EXPERIMENT IN SLOW OXIDATION

Pack some clean, fine, steel wool in the lower end of a dry test-tube. Twist some soft wire around the tube and fasten it upside down in a glass tumbler as shown in the illustration. Fill the tumbler with water until the mouth of the test-tube is under the surface of the water. Set the apparatus away where it will remain undisturbed for a few days.

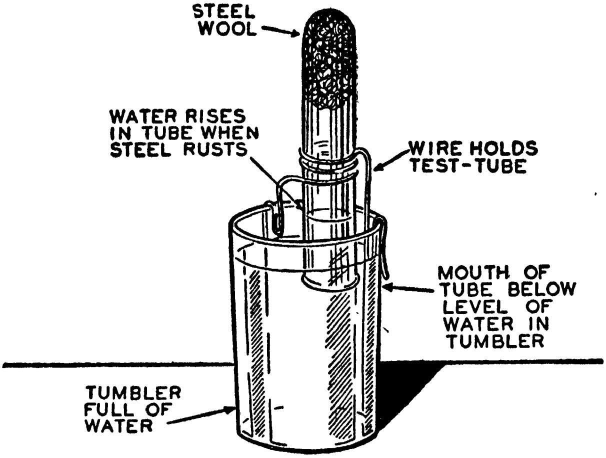
After four or five days, it will be noticed that the steel wool is rusty and that the water has risen about one-fifth of the way in the tube. The oxygen in the air confined in the tube occupied about one-fifth of the space. It combined with the iron in the steel, and water was drawn in to fill the space it formerly occupied.

AN EXPERIMENT WITH MORE RAPID OXIDATION

A small, shallow can, an old spoon and some lead are needed to perform this experiment.

Put the lead in the can and heat it on the gas-stove until the lead melts and becomes red-hot. Impurities called dross will rise to the surface of the molten metal. Skim off the dross with the old spoon. Continue to heat the lead and notice the yellow powder which collects on the surface.

Lead oxidizes quite rapidly when it is hot. The action is much



A CHEMICAL REACTION WHICH COSTS MANY MILLIONS PER YEAR

Rusting is the great enemy of iron and steel. It damages or destroys many iron and steel articles every year.

Rusting is a chemical reaction in which iron combines with oxygen. Rust is a complex oxide of iron. Iron combines with oxygen from the air only in the presence of moisture. It does not rust in absolutely dry air or in a vacuum.

Steel wool placed in a test-tube and inverted over a glass of water is in an ideal situation to rust. If the mouth of the test-tube is under the surface of the water, after several days it will have risen partly into the tube. It took the place of the oxygen in the air which combined with the iron in the steel wool.

more rapid than the rusting of iron, but it is not rapid enough to produce noticeable heat and light.

The lead oxide formed in this manner is lead monoxide or litharge. It is used in making glass, in decorating porcelain, in glazing pottery and in making certain oils and varnishes.

KINDLING TEMPERATURE

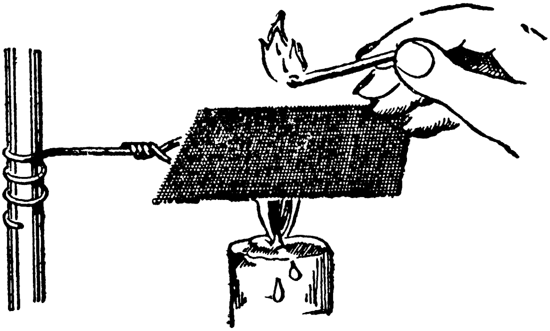
Heat must be applied to some substances to make them unite with oxygen rapidly enough to take fire and burn, and some substances must be made much hotter than others before they will *kindle* or take fire in air and continue to burn.

The kindling temperature of phosphorus is so low that a piece left exposed to air at the ordinary temperature of a room is likely to catch fire.

In order for burning to continue, the temperature of the burning object must not fall below its kindling temperature. Water extinguishes fires by lowering the temperature of the burning material. Too much cold air can also extinguish a fire.

EXPERIMENT

Hold a piece of wire gauze or screen in the flame of a burning candle. The flame will not pass through the spaces in the screen. The heat of the flame is conducted away by the iron and the gas which passes through the gauze is cooled below its kindling point. Hold a lighted match above the gauze immediately over the flame underneath and the gas will take fire and burn. The heat of the match brings the cooled gas back to its kindling temperature.



KINDLING TEMPERATURE EXPERIMENT

Hold a piece of fine screen (window screen) in the flame of a burning candle. The flame will not pass through the screen. The hot gases are cooled by the screen to a point below their kindling temperature. Hold a lighted match above the gauze immediately over the flame and the gas will take fire and burn. The heat of the match brings the cooled gas back to its kindling temperature.

LIQUID AIR AND LIQUID OXYGEN

If air is sufficiently compressed and at the same time cooled it becomes a liquid. It is a solution of the two elements, oxygen and nitrogen. The inert gases, mainly argon and neon, remain gases during the liquefying process and may be separated easily.

Liquid air is so extremely cold that it boils furiously if placed on a block of ice. A rubber ball or a rose immersed in liquid air becomes so cold that it is as brittle as glass.

There are more than one hundred plants in the United States where liquid air is manufactured for the purpose of obtaining oxygen and the inert gases, neon and argon. Thousands of tons of "bottled" oxygen are used annually in this country. Argon and neon are sold to the manufacturers of incandescent lamps and neon signs.

It is a simple matter to separate the oxygen and nitrogen in liquid air. Liquid oxygen boils at −182.5° and nitrogen at −195.5° on the Centigrade thermometer. As liquid air warms, the liquid nitrogen boils off first, leaving behind the light blue liquid oxygen.

Liquid oxygen is highly concentrated oxygen and substances soaked in it burn with explosive violence.

Oxygen is now a regular article of commerce. It is compressed in strong steel cylinders and sold for use in industry and medicine. By means of a torch burning oxygen and hydrogen or oxygen and acetylene, temperatures as high as 4,000° C. are produced for cutting and welding steel.

Sometimes, in cases of pneumonia, drowning and carbon monoxide poisoning, ordinary air is inadequate for respiration and pure or nearly pure oxygen is administered.

NITROGEN

There could be no Earth in an atmosphere of pure oxygen. It would burn up. Nitrogen, the most abundant constituent of the atmosphere, dilutes the oxygen in the air and slows down burning and oxidation. Likewise, there could be no world in an atmosphere of pure nitrogen. Nitrogen will not support respiration or combustion.

The large amount of this tasteless, odourless and colourless gas is due to its inactivity. It does not combine with many substances and is found in only a few mineral compounds. Most of those are substances which have been created by plants and animals. Its compounds are easily decomposed; in fact, some of them decompose so easily and with such violence that all the common explosives contain nitrogen compounds.

Not all nitrogen compounds are violent in their decomposition. Many easily undergo the gentle chemical changes suitable and necessary to life; consequently, we find many nitrogen compounds directly concerned with life processes. For example, all living things contain protoplasm, and protoplasm is a complex compound made up of nitrogen, carbon, hydrogen, oxygen and other elements.

When we eat meat, eggs, fish, milk, beans, peas and wheat, we are eating compounds containing nitrogen.

Ammonia, nitric acid, all the many nitrates and nitrites, ammonium chloride (used in dry cells), nitrous oxide (used as an anæsthetic), ammonium sulphate and cyanamide are common nitrogen compounds, dear to the chemist and used extensively in industry and agriculture.

Air is liquefied for the commercial production of both nitrogen and oxygen. Nitrogen is used in electric light bulbs. The filament does not oxidize in nitrogen and the pressure of the nitrogen permits the tungsten filament to be heated to a very high temperature without vaporizing.

Atmospheric nitrogen, obtained from liquid air, is also used to make cyanamide. Cyanamide is sometimes used in fertilizers, It is also the starting point in making ammonia, nitric acid and ammonium nitrate, which enters into the manufacture of explosives. The government plant at Muscle Shoals, Alabama, employs the cyanamide process.

EXPERIMENTS IN PREPARING NITROGEN

Light the stump of a candle, and when it is burning well, set an inverted one-pint fruit jar over it. Watch the candle-flame. In a moment it will flicker and go out. The candle-flame burned all the oxygen out of the air inside the jar, and when the oxygen was exhausted combustion ceased. The atmosphere remaining in the jar consists principally of nitrogen and some carbon dioxide, soot and water vapour.

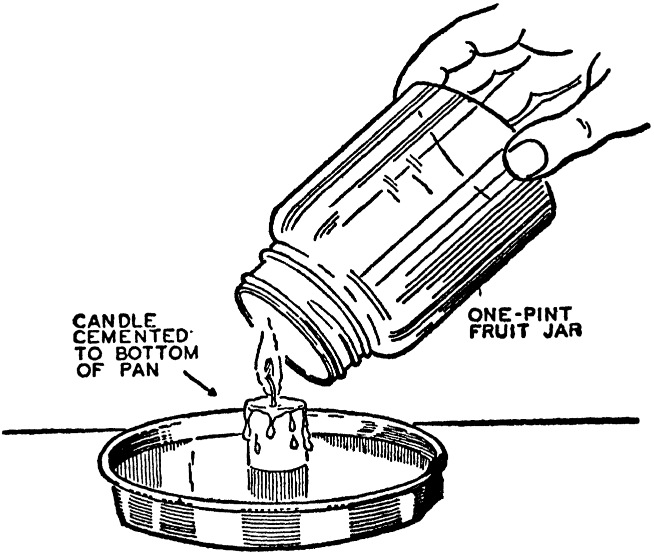
Modern candles are moulded from a mixture of stearin and paraffin. These substances are called *hydrocarbons*. They contain hydrogen, oxygen and carbon, and when they burn, they form water vapour, soot (carbon) and carbon dioxide.

You can perform this same experiment in a manner which makes it more interesting.

Fasten a candle stump about an inch and a half long in the centre of a shallow pan (cake tin) with a few drops of molten wax. Pour water in the pan until it is nearly filled and light the candle.

When the candle is burning well, set an inverted one-pint glass jar over the candle and let it rest on the bottom of the pan.

In a moment the candle-flame will flicker and go out. The water in the pan will rise inside the jar. The candle flame burned all the oxygen out of the air inside the jar, creating a partial vacuum and the water took its place. Some of the vacuum is due to the cooling contraction of the hot gas inside the jar when the candle goes out. As before, the atmosphere remaining in the jar is principally nitrogen.



NITROGEN

Light the stump of a candle set in a shallow pan of water. When it is burning well set an inverted one-pint fruit jar over it. The candle-flame will go out and the water in the pan will rise inside the jar. The atmosphere remaining inside the jar is principally nitrogen.

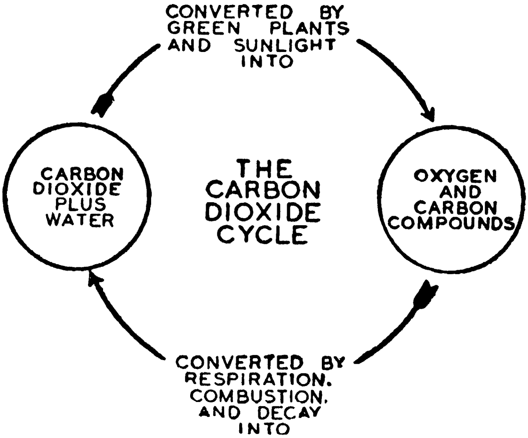
AN EXPERIMENT PROVING THAT NITROGEN EXTINGUISHES FIRE

Fill a one-pint fruit jar with nitrogen by inverting it over a lighted candle stump. When the candle-flame has been extinguished, slip a piece of cardboard under the jar and turn it right side up. The nitrogen in the jar is warmer than the surrounding air and will escape if you do not keep the jar covered.

Insert a burning splinter into the jar. It will go out as soon as it is thrust in. Nitrogen does not support combustion.

CARBON DIOXIDE: AN IMPORTANT OXIDE OF CARBON

In a large, well-ventilated room ten feet high, fifty feet long and twenty feet wide, there are normally only about three bucketfuls of carbon dioxide. But all life depends on this, for it is the carbon dioxide of the atmosphere which plants combine with water to form substances which finally become starch. This process of photosynthesis has been described in Chapter VIII.



A DIAGRAM TO SHOW HOW PLANTS AND ANIMALS ARE INTERDEPENDENT

Nature keeps the composition of the air nearly constant by processes called the nitrogen- and carbon-dioxide cycles.

The carbon-dioxide cycle is illustrated in the diagram above. Animals inhale oxygen which combines with the carbon of their food and is exhaled as carbon dioxide. Most fuels and all organic matter contain carbon which is oxidized to carbon dioxide by burning and decay.

All green plants in the sunlight absorb carbon dioxide from the air. They convert this gas into starch and other plant foods, returning a portion of the oxygen to the atmosphere. Men and animals breathe the oxygen and eat the plants. The cycle goes round and round.

Natural processes of decay and fermentation, the respiration of animals and the fires which human beings need for many of their activities furnish carbon dioxide to the air. Green plants give off carbon dioxide at night and in many places carbon dioxide issues from the earth.

In addition to its basic service in providing food for plants, animals and mankind, carbon dioxide is one of our most useful commercial substances.

About 90 per cent. of the carbon dioxide made in this country is used for "carbonating" soft drinks. Club soda is a solution of carbon dioxide in water. Soda-water, root-beer, ginger-ale and other carbonated beverages are sweetened and flavoured solutions of carbon dioxide in water. Seltzer, vichy and other "sparkling" or bubbling mineral waters are charged with carbon dioxide. The gas is held in solution under a slight pressure. When the bottle is opened, the pressure is relieved and the carbon dioxide escapes. It forms bubbles, which provide the sparkle of effervescence.

AN EXPERIMENT SHOWING THAT SODA-WATER IS AN ACID

Dip a piece of blue litmus paper in a glass of club soda. It will turn red. This shows that soda-water is an acid. When carbon dioxide is dissolved in water it forms a mild acid called *carbonic acid.*

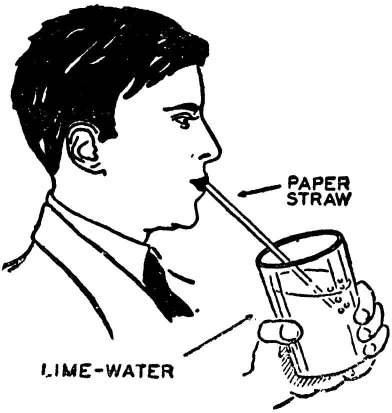
AN EXPERIMENT SHOWING THERE IS CARBON DIOXIDE IN THE BREATH

When human beings and animals inhale air, the oxygen in the air is absorbed by the blood and combined with the carbon of their food. The product of this oxidation process is carbon dioxide, which is exhaled.

Pour some clear lime-water into a glass tumbler. Blow air through it with a glass tube or a soda straw. The lime-water will become turbid, and if you continue to blow your breath through it, the liquid will become white and milky. The carbon dioxide in your breath acts upon the calcium hydroxide dissolved in the lime-water and forms a fine white precipitate of calcium carbonate or chalk. The chalk is insoluble in water and is responsible for the milky appearance.

Carbon dioxide comes in handy in the kitchen and baker's shop. Without it, eating bread, cake and biscuits would be somewhat of a job. Carbon dioxide is formed in dough by the action of yeast on sugar and by the action of water on baking powder.

Two common household chemicals, sodium carbonate (washing soda) and sodium bicarbonate, contain carbon dioxide. Carbonates are much more common than any one but a chemist realizes. Chalk, tooth-powder, marble, putty, the shells of oysters and clams, limestone and mortar are all carbonates.

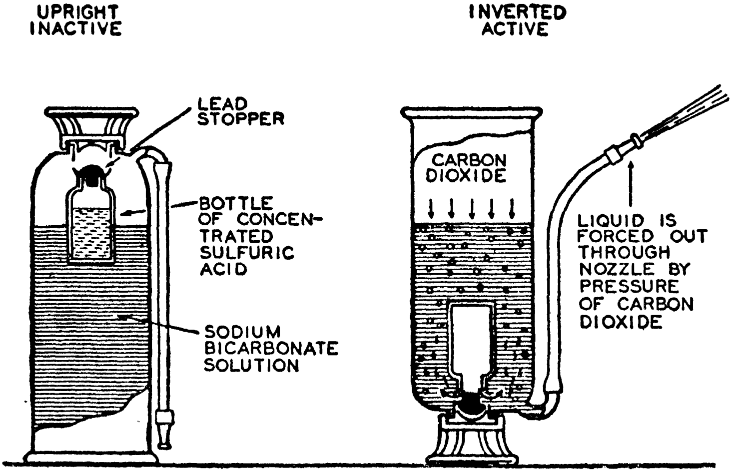


THE CARBON DIOXIDE IN YOUR BREATH PLUS LIME-WATER PRODUCES CHALK

Blow through a paper straw into a clear solution of lime-water until the solution becomes milky-white. The whiteness is due to the formation of calcium carbonate or chalk. Chalk is insoluble in water. Continue blowing and the chalk will disappear. The water becomes charged with carbon dioxide from your breath. In other words it becomes a weak solution of carbonic acid. Chalk is slightly soluble in carbonic acid. Hence it disappears and the solution becomes clear again.

When an acid and a carbonate meet, the reaction which takes place releases carbon dioxide. This is the principle of some baking powders and of certain types of fire extinguishers.

The type of fire extinguisher shown in the illustration contains a solution of sodium bicarbonate. In the upper part is a bottle filled with sulphuric acid and closed by a loose-fitting lead stopper which will fall out and allow the acid to mix with the solution of sodium bicarbonate when the extinguisher is turned upside down. The carbon dioxide which is released by the reaction of the acid and bicarbonate produces considerable pressure and forces the water out through the nozzle.



FIRE EXTINGUISHER

When an acid and a carbonate meet, the reaction which takes place releases carbon dioxide. This is the principle of the fire extinguisher shown in diagram above. The extinguisher contains a solution of bicarbonate of soda and a bottle of sulphuric acid. When the extinguisher is inverted the lead stopper falls out of the bottle and the acid mixes with the bicarbonate solution. Carbon dioxide is generated and its pressure forces the liquid out of the hose nozzle.

AN EXPERIMENT IN MIXING AN ACID AND A BICARBONATE

You can reproduce the chemical action that takes place in baking-powder and in fire extinguishers by mixing vinegar with a solution of bicarbonate of soda. Vinegar is dilute acetic acid.

Put a teaspoonful of sodium bicarbonate into a tumbler half filled with water. Stir until it dissolves, then add some strong vinegar. As soon as the vinegar mixes with the bicarbonate solution, a reaction will take place in which carbon dioxide will be released and cause the liquid to "fizz."

Extinguishers for fighting oil and gasoline fires throw their liquid in the form of a thick foam made up of very minute bubbles of carbon dioxide. The foam is sticky and will adhere to vertical surfaces. It forms a wet blanket which excludes oxygen from the burning material. The foam is produced by the reaction of aluminum sulphate upon a solution containing sodium bicarbonate and liquorice. The purpose of the liquorice is to make a durable foam.

Carbon dioxide is produced commercially and sold in compressed form as a liquid in steel cylinders. Its principal uses are in the manufacture of soda ash, for refrigeration, for soda fountains and in soft drinks. It is obtained in a number of ways: by burning coke in a good supply of air, by heating limestone, as a by-product in fermentations (beer, wine and alcohol making), by the action of sulphuric acid on the mineral *dolomite* and from wells. Carbon dioxide from any of these sources is easily purified and compressed. It is sold in the form of a gas, a liquid and a solid.

The solid form, called "dry ice," is often put in containers with ice-cream. It is an ideal refrigerant for shipping food products long distances in trucks and railway cars.

Carbon dioxide is heavier than air and can be poured like a liquid. It does not burn, nor do substances, with the exception of potassium, sodium, and magnesium, burn in it.

AN EXPERIMENT WITH DRY ICE

Dry ice can be obtained at many ice-cream stores and soda-fountains. Do not handle dry ice with your fingers; use a spoon. It will blister your skin.

Put a piece of dry ice in an empty lemonade pitcher and set it on a table where there is no draught. The evaporation of the dry ice will fill the pitcher with carbon dioxide and it will spill over the sides and flow down over the table. Carbon dioxide is invisible. The white vapour which fills the pitcher is water vapour condensed from the air by the low temperature of the carbon dioxide.

Light a candle, and then, moving the pitcher slowly so as not to create strong air currents, hold it above the candle and pour gas out on to the flame just as if it were a liquid. The carbon dioxide flowing down on to the candle will extinguish the flame.

Compressed carbon dioxide is used to extinguish fires on ships, aeroplanes and motor-boats.

ARGON

About one per cent. (.96) of the atmosphere is the gas called *argon*, whose name means "won't work." All attempts to make it react chemically have failed; it is perfectly inert.

The discovery of argon is an interesting example of scientific investigation. In 1892, an English scientist, John William Strutt, observed that nitrogen obtained from the air was slightly heavier than that secured by breaking up a nitrogen compound such as ammonia. He felt quite certain that nitrogen from the air contained some unknown heavier gas which had so far escaped detection in spite of the careful attention which scientists had given to the atmosphere for more than ten decades.

Sir William Ramsay, another English chemist (born in Glasgow) and a remarkably skilful experimenter, proved Strutt's conviction to be correct. Ramsay passed nitrogen, taken from the air, over heated magnesium. This combined with the magnesium, forming magnesium nitride, but the other gas, argon, did not react and thus was isolated and identified as something hitherto unknown.

Argon is secured in commercial quantities by liquefying air. A small amount is included with the nitrogen in incandescent electric lamps. It prevents the nitrogen from becoming ionized and wasting current.

NEON, XENON AND KRYPTON

The discovery of argon led Strutt (Lord Rayleigh) and Ramsay to search for other possible undiscovered inert gases in the air. Long, painstaking and often baffling experiments revealed three new ones: *neon*, *krypton* and *xenon*. Neon means "the new one," krypton, "the hidden one," and xenon, "the stranger."

They all closely resemble argon. Neon is the only one of the three which has any commercial value. Neon is used in electric sign lamps, in voltage-regulating tubes for radio apparatus, in stroboscope lamps. Neon lamps have many special uses. They will give fluctuations from full brilliancy to total darkness as often as 100,000 times a second.

HELIUM

Helium is a very light gas which is chemically inert. Since it is non-inflammable it is ideal for inflating balloons and dirigibles. Nitrogen is slightly soluble; helium is not. It is nitrogen dissolved in the bloodstream that gives the disease known as "bends" to men who work in compressed air. Helium, since it does not dissolve in the blood, is used as a substitute for nitrogen in making artificial air for treating the "bends." It is also employed in electric lamps and radio tubes because it possesses heat conductivity which is six times that of air.

Helium can be obtained at great expense from the air but comes chiefly from natural gas. The United States has a world monopoly in the supply of helium from natural gas.

OZONE

The word ozone is sometimes used as slang for "fresh air." Actually, it is a form of oxygen such as that which exists in the atmosphere, but in a molecule of ozone there are three atoms of oxygen.

Ozone shows marked differences from ordinary oxygen. It has a strong, pungent odour which is often noticeable where electrical machinery is in operation. Silver, rubber and many organic materials are oxidized by ozone.

During thunderstorms, ozone is produced by lightning discharges through the air.

Ozone is used commercially in purifying oils and bleaching starch. It can be produced commercially by passing dry, cold oxygen through an electrical ozone generator.

CHAPTER XI

New Metals and Old

WHEN we require objects possessing great strength, rigidity and durability, we turn to metals. From them we make our tools and machines. They are the fundamental aids in our continually developing culture. Without tools made of metals—and by "tools," in this case, we do not mean mere hammers and screw-drivers, but rather picks, shovels, drills, pipes, tanks, presses, pumps, furnaces, engines, crushers and industrial machines—our control over nature is very limited. We need metals, too, when we wish to print quantities of books, send messages by telephone or telegraph, produce and transport power, or travel quickly.

WHAT IS A METAL?

The ninety-two elements which are the building-stones of matter may be conveniently grouped into two general classes, the *metals* and the *non-metals*. More than seventy come under the heading of metals, and of these, the more familiar ones, such as iron, silver, copper, platinum, nickel, etc., may be recognized by their names. The others, those you have probably never heard of, such as virginium, rhenium, praeseodymium, hafnium, etc., have names ending in "um."

The definition of a metal cannot be understood by anyone who is not a chemist unless he also knows the meaning of "bases" and "hydroxyl groups." Perhaps the best way to gain an idea of what metals are is to compare them with non-metals.

Metals are lustrous, are good conductors of heat and electricity, and are solids at ordinary temperatures (except mercury). They are generally dense—which is to say, heavy—and can be stretched and bent.

Non-metals are not lustrous, are poor conductors of heat and electricity, and are solids or gases at ordinary temperatures (except bromine). They are generally of low density—that is, light—and cannot be stretched or bent.

If we judge them by their physical properties, it is evident that metals and non-metals are opposites in many ways.

The common non-metals are carbon, chlorine, hydrogen, sulphur and oxygen. If we compare their chemical properties with the chemical properties of any of the common metals, we find that in these qualities also they are opposites.

For example, metals combine with non-metals. All acids contain hydrogen, and if metals are brought into contact with an acid under the proper circumstances to bring about chemical action, they displace the hydrogen and take its place.

On the other hand, non-metals combine with metals and do not replace the hydrogen of acids.

If we pry into things which go on behind the scenes, into the "goings on" within the atoms, we find that metals frequently lend electrons to non-metals. The non-metals never lend to metals. They are always borrowers. The metals are the lenders. Here again we find opposites.

Remember about metals lending electrons. It is one of the reasons we are able to secure a good supply of many metals.

ORES

A few metals, and only a very few—notably copper, gold, mercury, platinum and silver—are found to some extent in a free or native state. An element is free or native when it occurs uncombined in a nearly pure state. None of the native metals are found in great chunks or blocks. Usually they are mixed with sand or rocks and are in small particles or dust. Occasionally they are in small lumps or nuggets.

These native metals are not always found in a free state. They occur also as compounds. In a compound they are chemically united, not mechanically mixed with another substance.

The rest of the metals, those that are not native—such as iron, aluminum, lead, zinc and others—are found only as compounds, usually in the form of oxides, carbonates and sulphides. Most of these compounds will yield us metals when properly treated. A mineral which yields a metal is called an *ore*.

When an ore contains a metal in the free state, the metal can be obtained by mechanical methods. It may, however, have to be purified or refined by chemical methods before it is fully useful. Ores which do not contain free metal but hold it in the form of a compound require both mechanical and chemical treatment.

THE REDUCTION OF ORES

The chemical methods of reducing metals from their ores vary greatly in detail, but they involve a simple principle. They employ some method of coaxing the metal and the other element or elements with which it is combined to break up their union.

It has been explained that metals are lenders of electrons. When we have an ore which is an oxide or a sulphide, we have an instance where the atoms of the metal have lent their outermost electrons to the oxygen or sulphur in the ore. If we want to break up the partnership and secure the metal in a free state, we must give back to its atoms the electrons which they lent. There are two general ways in which this can be done.

We can return the lent electrons with the electrons of an electric current. An electric current is nothing but a stream of electrons flowing through a wire. Or we can find some other element willing to take over the loan and become a lender. Carbon is often willing to do this. It will lend its electrons to the sulphur or oxygen and push the metal out of the compound.

It is most convenient and least expensive to use the electrical method in refining aluminum from its ores. Iron is the best example of a metal obtained by using a replacing lender.

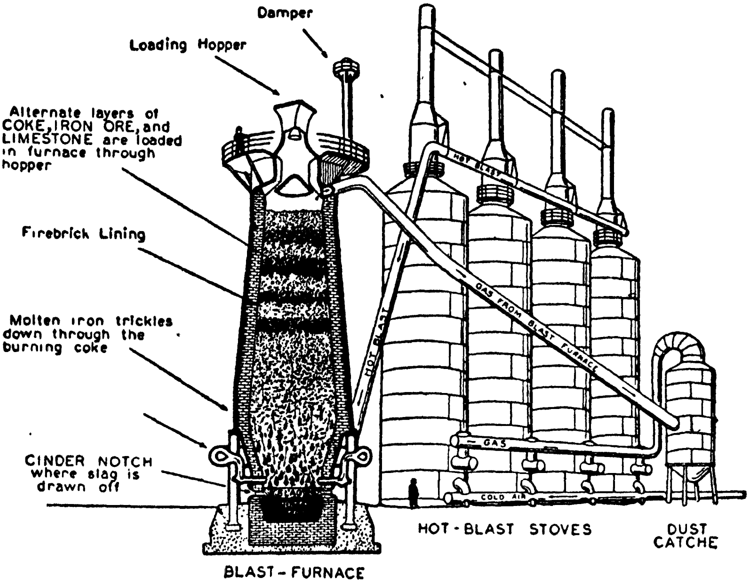
In principle, reduction is a chemical action in which an atom regains in whole or in part the electrons it has lent to other atoms.

IRON: THE MOST USEFUL METAL

Iron is our most valuable metal, not only because of the innumerable different parts and objects which we make of iron but also because *steel is made of iron.*

The principal iron ores are hematite, magnetite, siderite and limonite. Hematite, the most important of the iron ores in the United States, is a compound of iron and oxygen called *ferric oxide.* It is mined in northern Minnesota and shipped to the iron and steel mills at Buffalo, Cleveland, Gary, Pittsburgh and Chicago.

There are two processes involved in refining hematite. The first is to release the iron from its union with oxygen by replacing the iron with carbon. The second is to get rid of the impurities, for the ore contains many things besides ferric oxide. The prin-



A BLAST FURNACE

Iron is reduced from its ore by mixing the ore with coke and limestone and heating in a blast furnace. This is perhaps the most basic of all industrial chemical processes. The details are explained in the text. An idea of the huge size of a modern blast furnace can be gained from the silhouette of a man at the foot of one of the hot-blast stoves.

cipal impurity is sandy matter. This can be removed with limestone.

At ordinary temperatures, carbon and limestone have no tendency to chemical action, but with the aid of heat, carbon becomes a very willing lender of its electrons. The limestone then also becomes active. It combines with the sandy matter to form the gas carbon dioxide and an easily melted glass-like material called slag which floats on the top of molten iron.

Since iron is used in vast quantities, its ore must be refined on a large scale. This is done in blast furnaces. A modern blast furnace which will produce 500 tons of iron in twenty-four hours is not extraordinary.

THE BLAST FURNACE

A large blast furnace is a huge steel cylinder about 100 feet high and 25 feet in diameter, lined with fire-brick. In the lower portion, tubes called tuyères admit strong blasts of hot dry air to the furnace.

Alternate layers of coke (carbon), iron ore and limestone are skilfully put in the furnace through a hopper at the top so as to be loose and porous. Once started, a furnace is kept going continuously night and day, month after month, until repairs are necessary.

The fires, fanned by the hot air blast coming from the tuyères, produces a temperature of 3,500° F. in some parts of the furnace. The heat and the chemical action between the coke and the iron ore separate the iron and oxygen and reduce the iron to a spongy mass. Lower down in the furnace, the iron melts and becomes fluid. It trickles down through the burning coke and the hot limestone. The limestone helps get rid of the impurities by forming a "slag." The molten iron runs to the bottom of the furnace, where it is drawn off through a tap hole and cast into pigs or blocks of cast-iron. The slag floats on top of the molten iron. It plays an important role by protecting the melted iron, preventing it from being reoxidized by the highly heated air it encounters as it drips its way to the bottom of the furnace. The slag is drawn off from time to time at the "cinder notch."

Extracting iron from its ore requires a great deal of heat, and heat, like everything else, costs money. Heat is economized in the operation of a blast furnace by a clever arrangement for using the hot gases which are formed when the iron is reduced.

Each furnace is connected to four "hot-blast stoves." These are tall tank-like affairs filled with a honeycomb of fire-brick and very much like the blast furnace itself in appearance. The hot gases in the top of the blast furnace are sent through a dust catcher for cleaning and then into two of the stoves where they are mixed with air and burned. The burning gases heat the fire-brick honeycomb to a high temperature. When the proper heat is reached, the gases are turned into the other pair of stoves. At the same time, air from a large engine-driven blower is sent through the two heated "stoves." This air becomes very hot as it passes through the fire-brick honeycomb. Before it has had an opportunity to cool, it is blown into the blast furnace through the tuyères.

STEEL

There are many different kinds of steel.

Ordinary steel and iron look much alike to the untrained eye. There is a great difference, however, and this difference is quite apparent when the metal is put into use.

Carbon is responsible for the greatest difference between iron and ordinary steel. Cast-iron, wrought-iron and ordinary steel are all forms of iron among which the simple difference is the amount of carbon they contain.

Wrought-iron contains very little carbon, much less than steel. In ordinary steel, about one pound out of every one hundred is carbon. In one hundred pounds of cast-iron there are about three pounds of carbon. These differences in the amount of carbon make a vast difference in the physical properties of cast-iron, wrought-iron and steel.

Cast-iron is very strong when it is squeezed or compressed, but it is brittle and likely to break if bent or stretched.

Wrought-iron can be bent into various shapes, but it is soft, not stiff or elastic.

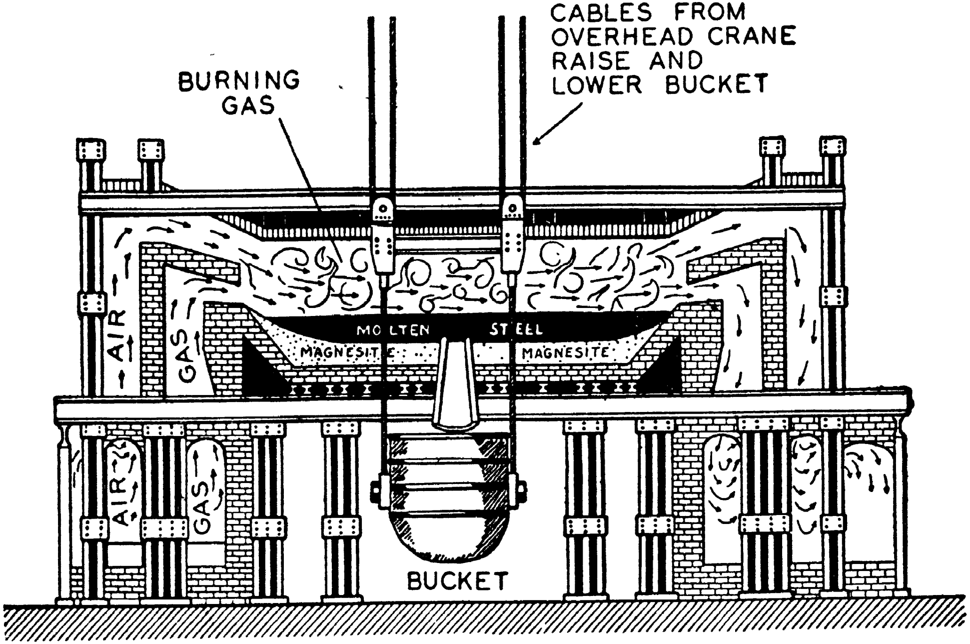
Steel has all the virtues of iron and some entirely its own. It will withstand great compression strain, in which it is merely squeezed. It is stronger and less brittle than cast-iron and more elastic. It will stand up under an amazing tensile or stretching strain.

STEEL-MAKING

Cast-iron can be changed into common steel (carbon steel) by eliminating the right amount of carbon. Steel-making is simply a process of getting rid of most of the carbon and some of the impurities in cast-iron. If just the right amount of carbon is allowed to stay in the iron, and if in the process the proper conditions of cooling, etc., are complied with, the result is steel.

Some of the carbon in cast-iron is free carbon, not chemically compounded with the iron. Carbon steel is a chemical compound of iron and carbon, with no carbon in the free state.

Carbon steels are graded according to the percentage of carbon they contain. The carbon usually varies from 0.15 to 1.5



OPEN-HEARTH FURNACE

Steel making is simply a process of getting most of the carbon and other elements out of cast-iron. All structural steel, that is, steel used for bridges, buildings, ships, tanks, automobile bodies, etc., is made in open-hearth furnaces. The per cent. Low carbon steel, with 0.15 to 0.30 per cent. carbon, and medium carbon steel, with 0.30 to 0.60 per cent. carbon, are used in construction work. High carbon steel, with 0.60 to 0.90 per cent. carbon, is used for tools.

When raised to a red heat and chilled suddenly, steel becomes exceedingly hard. This hardness can be modified and controlled by subsequent heating and cooling called tempering. Steel containing less than 0.15 per cent. carbon hardens only slightly. On the other hand, if it has more than 1.5 per cent, it becomes brittle.

BESSEMER STEEL

In 1858, Sir Henry Bessemer, a British engineer, invented a simple process (now called Bessemer) for making a fine grade of steel. Molten cast-iron is placed in a crucible called a converter, and the carbon and slag are burned out of the molten metal by cold air which is blown through it. The process requires only a few minutes. The skilled steel-maker can tell when the iron has been converted into steel by the appearance of the flames which roar out of the converter.

CRUCIBLE STEEL

Crucible steel is made by melting small pieces of wrought-iron in a graphite or clay crucible with charcoal and cast-iron or ferro-manganese. The crucibles usually hold about 100 pounds of metal. The molten metal is kept at a high temperature for some time but not allowed to boil. The process is used for making tool steels.

THE OPEN-HEARTH METHOD OF CHANGING IRON INTO STEEL

Steel is made by the open-hearth process in furnaces built of brick held in place by heavy steel beams and rods. The furnaces are made in sizes capable of handling from ten to three hundred tons of metal in a batch.

The hearth or bottom of the furnace is a large shallow basin built of several layers of bricks covered with a thick layer of magnesite. Magnesite is a heat-resisting mineral and it protects the bricks from the seething mass of molten steel.

Carefully measured quantities of pig-iron, steel scrap, limestone and iron ore are dumped into the furnace and heated until the mass melts and boils. The boiling is continued for a period of three or four hours. Silicon, carbon, manganese, phosphorus and other substances burn out during this "working" process, as the steelmaker calls it. Samples are taken at all stages of the process, quickly analyzed in a laboratory and the chemical composition of the batch kept under control with as fine an accuracy as a prescription in a drug-store.

When tests show that the batch or "heat" is finished, a retaining plug in the rear of the furnace is knocked out and the white-hot steel pours forth into a huge bucket supported from an overhead crane. It is poured out of the bucket into moulds and allowed to cool into blocks or ingots.

The ingots, after reheating in "soaking pits" or ovens until bright red and an even temperature all the way through, are sent to the rolls. The rolls squeeze the soft, hot steel into sheets, strips, rails, bars and other "shapes."

ALLOYS

Pure metals are rarely seen outside a laboratory or a chemical collection. They are expensive to produce and usually have properties which make them unsuitable for most uses. Chemically pure iron—that is, iron which has no trace of any other substance—is more costly than gold and too soft for any practical purpose. Pure gold and silver are too soft to make satisfactory coins.

When strength is required, metals must usually be alloyed with other metals. An alloy is a mixture of two or more metals which have been melted together to form a metallic substance of practically uniform composition. An alloy has properties of its own. Not all metals can be made to alloy but most of them do, and consequently there is an almost bewildering number of alloys, each having a more desirable combination of properties than any one of the metals of which it is composed. Many different alloys go into the construction of a machine like an automobile. We find zinc-base, die-cast alloys, copper, brass, bronze, aluminium and solder among others. All these, even "copper" and "aluminium" in this case, are alloys. For although, for some electrical purposes, care is taken to secure copper and aluminium which are quite pure, where strength is required, both are alloyed with other elements.

NEW METALS AND OLD

COPPER AND ITS ALLOYS: THE FIRST METAL MEN LEARNED TO USE

Copper is an intimate part of the long history of human progress. It was the first metal which primitive man learned to use for making tools and weapons. Previously, he used stone. Copper tools were soft, but their cutting edges could be hardened by pounding.

Copper is one of the metals which are occasionally found free, and our remote ancestors did not need to reduce it from its ores. Where and how the discovery of a method to reduce copper from an ore occurred we do not know.

Only a negligible amount of the copper which we use comes from native copper ore. Most copper ores are very complex compounds. They contain oxides, carbonates, silicates and sulphides. Many contain, in addition to copper, other metals such as silver, gold, platinum, etc.

In general, the first part of the process of obtaining copper consists of roasting the ores. Then other steps are taken, depending upon the kind of ore. These will not be described. In any case, the final step in securing pure copper is refining by electrolysis. The impure copper is cast into large plates called anodes. These plates, along with thin sheets of pure copper called cathodes, are suspended in wooden tanks containing a solution of copper sulphate and sulphuric acid in water. An electric current is sent through the solution, entering via the anode and leaving by the cathode.

The copper in the impure anodes goes into the solution and is carried to the cathode plates where it is deposited. The once thin cathodes soon grow into thick copper slabs 99.94 to 99.97 per cent. pure. They are lifted out and carried to a furnace where they are melted and cast into various bars, ingots, slabs, billets and cakes, ready to be rolled or drawn into wire, tubing, sheets, etc.

During the electrolytic refining process the impurities in the anode fall to the bottom of the tank in the form of a slimy mud. No one but a chemist would suspect that this is very valuable mud. From it, by proper processes, gold, silver, lead, antimony, platinum, palladium, selenium and tellurium are recovered.

BRASS

The essential metals in brass are copper and zinc, although some brasses may contain other elements. The proportions vary according to the use to which the brass is put. There is usually twice as much copper as zinc. Yellow brass usually contains about 2 per cent. of lead. It is very resistant to corrosion. Lead improves its cutting qualities. Brass makes excellent castings and is stronger than either copper or zinc.

BRONZE

The name bronze is given to a large number of alloys in which there is a high percentage of copper alloyed with tin, zinc, phosphorus, aluminium or manganese.

No one knows when bronze was discovered, but probably it came naturally with the casting of copper objects. The primitive foundrymen noted that if tin or zinc were mixed with copper it made casting easier and produced harder axes, swords and knives.

Phosphor bronzes are very tough and resistant to water. They are used for ships' propellers and various marine fittings. All grades of bronze can be converted to phosphor bronze by the addition of a very small amount of yellow phosphorus to the molten metal.

Manganese bronze is really a brass containing iron and manganese. It is strong and tough, resistant to sea water and used for ships' propellers.

Aluminium bronze is a copper alloy usually with about 10 per cent. aluminum and a small amount of iron and manganese. It is very tough and strong and makes excellent bearings. Its colour can be varied from silver to gold by changing the proportion of aluminium. It is often used for ornaments and cheap jewellery.

TYPE METAL

Any lead-antimony alloy used for making printing type is called type metal. A great variety of mixtures is used and some of them contain tin in addition to lead and antimony.

Lead is too soft to use alone as type. Antimony hardens it and produces an alloy that expands slightly on cooling, thus filling the mould and producing sharp accurate type.

Standard linotype-machine metal has 79 per cent. lead, 16 per cent. antimony and 5 per cent. tin.

MONEL METAL

This is one of the most remarkable of alloys. It usually contains about 67 per cent. nickel, 28 per cent. copper, the remaining 5 per cent. being carbon, iron, manganese and a trace of silicon. It is produced directly from ores containing both copper and nickel.

Monel metal is strong and hard and has high resistance to corrosion. It does not wear under the action of water and steam. These properties make it very useful for window screens, salt-water pumps, steam turbine blades, high-pressure steam valves, cooking utensils, table tops, ship propellers, spark plugs, and apparatus used in chemical manufacture.

DURALUMIN

Duralumin was the first of the light-weight, heat-treated, strong, wrought-aluminium alloys which provide structural material for use in aircraft.

A German chemist named Alfred Wilm experimented for twelve years to produce Duralumin. It was put into commercial production shortly before the beginning of World War I and immediately used for building Zeppelins. The design of the framework of a Zeppelin and the material used in building it was a German secret until the Allies shot down one of the huge craft flying over France on its return home from bombing London. The ship burned, but the ruins were thoroughly investigated. Salvaged pieces of Duralumin were sent to laboratories and before the end of the war the Allies succeeded in reproducing the new alloy.

Duralumin contains 3 to 4.5 per cent. of copper, 0.4 to 1 per cent. of magnesium, 0 to 0.7 per cent. manganese. The remainder, more than 90 per cent, is aluminium with small quantities of iron and silicon. It is heated to a temperature of 950° C., quenched in hot water and then allowed to stand for several days to undergo age-hardening. Age-hardening results from chemical combination of the magnesium with the aluminium.

Other alloys of the "duralumin" type are Alloy 17S of the Aluminum Company of America, Aludur, Aldrey and Almelec.

GERMAN SILVER

German silver was the general trade name for a group of hard, copper-nickel-zinc alloys which take a high polish and do not corrode easily. A ruling of the Federal Trade Commission forbids the use of the name German silver for alloys containing no silver, and so the terms Nickel silver, Nickel brass and Nickel bronze are now used.

Nickel silver is the "white metal" used for the interior of silver-plated ware.

MAGNESIUM

Along with the salt in brine wells and ocean water is a compound which, in the hands of the chemist, yields a useful metal weighing only two-thirds as much as aluminum and one-quarter as much as steel. It is magnesium, a metal useful in peace and a necessity in warfare. As powder, chips and foil, it burns with dazzling brilliance and provides photographers with their flashlights.

Until 1914 the U.S. bought magnesium from Germany and used it mostly for photographic purposes. In 1918 they produced, from brine wells in Michigan, 284,000 pounds. Plants now built or building will soon produce 400,000,000 pounds annually from brine wells and from sea water. There are nearly 6,000,000 tons of magnesium in a cubic mile of sea water.

Ocean water, mixed with slaked lime, yields magnesium hydrate, the familiar "milk of magnesia" of the medicine chest. Treating with hydrochloric acid changes the milk of magnesia into magnesium chloride. When an electric current is passed through fused magnesium chloride, magnesium results.

Millions of pounds are needed in warfare for tracer bullets, star shells and incendiary bombs. More millions of pounds are needed to make tough, light-weight alloys for aeroplane-engine building. One hundred and eight pounds of magnesium alloy will do the work of two hundred and seventy pounds of aluminium alloy, saving ninety pounds in the weight of a motor.

A typical strong tough magnesium alloy contains about 90 per cent. magnesium, 5 per cent. aluminium, 3 per cent. zinc and a small amount of manganese.

With the coming of peace the wartime uses of magnesium will naturally cease. We will have on hand extensive plants for producing inexpensive magnesium alloys, light as wood and strong as iron. These alloys will replace aluminium to considerable extent. They will appear in kitchen pots and pans, bicycles, automobiles and household appliances.

METALS THAT YOU HAVE PROBABLY NEVER SEEN

All but twenty of the seventy-odd metals have been regarded as laboratory curiosities until recently. They were museum specimens. In many cases they were rare or costly to secure in usable form and apparently had no desirable qualities. Of late, intensive research has put many of these metals to work. They are no longer buried in textbooks and show-cases. They have graduated from the laboratory and found application in industry. Most of them are used in alloys or for such obscure purposes that the man-on-the-street never sees them and has probably never heard of them.

BERYLLIUM

Along with feldspar amd mica in scattered localities from Maine to Georgia, in Colorado, Calfornia, New Mexico, Nevada, Wyoming, Utah and North and South Dakota, occurs an ore called beryl. It is a capricious stone, sometimes vitreous-green, emerald-green or light-blue. Then again it is yellow, pink or white. The aquamarine and emerald varieties are used as gems.

Beryl is also found in Argentina, Brazil and Russia's Ural Mountains. From it is obtained *beryllium*, a metal which you have probably never seen. Yet there may be some in your camera, electric refrigerator and automobile.

Beryllium is the lightest of all the rigid metals, one-third lighter than aluminum. Twenty years ago it was so unimportant in the chemist's scheme of things that it was not even mentioned in many textbooks of general chemistry. Many experienced chemists had never seen pure beryllium, had never handled any of its compounds. Then it began to be rumoured in research laboratories that this strange metal which had once been called *glucinum* (meaning *sweet*) might have possibilities. It was tricky sort of stuff—so brittle that it would shatter when dropped.

Perhaps it would be useful in making alloys? Metallurgists combined it with other metals and were disappointed. Beryllium apparently produced no miracles and the resulting alloys were of little or no value.

Because one man, ten or even a hundred before him have failed, never deters a chemist. Two young men, Andrew J. Gahagan and J. Kent Smith, both indefatigable workers, took up the challenge. They matched patience, time, money and wits with the baffling metal. For two years, they were outwitted; their experiments were all failures. Then an amazing discovery was made: a small amount of beryllium—2 per cent. to be exact—added to copper, resulted in something that men had been hunting for centuries, *copper that could be hardened* by heat treatment as steel is hardened.

When the new beryllium-copper was taken to the testing laboratory and its tensile strength measured, the needle on the testing-machine moved around past the figures for bronze, cold-drawn steel rod and stainless steel. The needle did not stop until it had indicated a tensile strength of 185,000 pounds per square inch. Among common materials only plough-steel, tempered carbon tool-steel, steel suspension-bridge wire, crucible-steel wire and piano wire are stronger. All these rust. Beryllium copper does not.

A round rod of beryllium copper, one-quarter of an inch in diameter, will lift a load of five tons. Its strength is amazing. Then came another surprise. Tests showed beryllium-copper to be a metal that does not get tired.

A metal's strength is not eternal. When subject to shock, twisting, vibration, bending, stretching or compression, it becomes "tired." It will not last for ever; eventually it becomes brittle and breaks. This tiring of metals, which engineers call *fatigue*, is sometimes the cause of serious accidents. Steel springs, especially, are subject to fatigue. But for all practical purposes, beryllium-copper springs are tireless. They will withstand three hundred times as many vibrations as a similar steel spring. Consequently, in many places where there are high speeds or exceptional strains to be dealt with, you will find beryllium-copper doing its duty. More than one hundred parts of modern transport and bombing planes are made of this metal that does not get tired.

MOLYBDENUM

The chances are that you have also never seen any of the silver-white, iron-like metal called *molybdenum*, or "moly," as it is known in industry. But it plays an important part in your comfort and safety. It is indispensable for some of the metal parts used in the vacuum-tubes required in radio broadcasting. "Moly" works miracles in steel-making. The tough alloys it produces when used as an ingredient of steel have resulted in stronger, more dependable automobiles and aeroplanes during the past decade. The axles, drive-shaft, gears and crankshaft of to-day's automobiles are a molybdenum-steel, which means that the cars of to-day are stronger and safer than the cars of yesterday.

Molybdenum is found chiefly in the ores wulfenite (lead, molybdenum and oxygen) and molybdenite (molybdenum and sulphur). Molybdenite resembles black lead or graphite and its appearance suggested the name for the element. *Molybdenum* is derived from the Greek word for "lead."

MOLYBDENUM HELPED TO WIN WORLD WAR I

It has long been known that certain quantities of molybdenum would improve the quality of steel. But until recently only small deposits of the ores had been located. Moly was scarce, and because it was scarce, it was expensive, too expensive to put into extensive use. Just before World War I, large deposits of molybdenite were discovered in Colorado, and molybdenum became plentiful. It was put to work and helped to win the war. It imparted an amazing hardness to the steel tools used in boring heavy artillery. It toughened the steel crankshafts of the old Liberty engines used in World War I, improved armour plate and made the rifling of big guns more resistant to the corrosion of the hot, flaming explosion which propels the heavy shells.

MOLYBDENUM IS USED IN AUTOMOBILES

With the cessation of war, molybdenum's career seemed ended. There was no immediate market for the metal. Finally it found a champion. C. Harold Wills, once Chief Metallurgist of the Ford Motor Company, appreciated the possibilities of molybdenum steels in making automobiles. In 1921, he introduced a car fabricated from molybdenum steel alloys. It was the Wills-St. Claire, at that time one of the finest motor-cars made in America. Its success showed steel-makers that molybdenum steels were cheap and effective substitutes for many tungsten, chromium, vanadium and nickel-steels.

Only small quantities of "moly" are required in order to obtain its benefits. The addition of only five pounds to a ton of steel results in a stronger, tougher steel to withstand the wear and shock imposed on forging dies, axles, crankshafts, drive-shafts, gears, steering knuckles and spindles. It does its best work, however, when used in combination with one or more of the steel alloy metals. The four standard "moly" steels are nickel-molybdenum, carbon-molybdenum, chrome-molybdenum and chrome-nickel-molybdenum.

OTHER USES FOR MOLYBDENUM

Chemists have found other useful qualities in molybdenum besides the strength it gives to steels. It belongs to the same chemical family as the metal chromium, a famous producer of colours. Like its colourful brother, it too will produce colours. Molybdenum orange is a pigment, used in paints, which has twice the covering power of chrome orange, its predecessor.

HOW MOLYBDENUM IS SECURED FROM ITS ORE

The first step in preparing molybdenum for use in steel-making, is to grind the ore, *molybdenite*, to a fine pulp. The pulp is placed in small tanks containing a mixture of pine oil and water agitated with streams of compressed air blown up from the bottom. The particles of molybdenite cling to the froth of oily bubbles which rise to the top of the tank and are scraped off. The waste and foreign matter sink to the bottom. This method of separation is called a *flotation* process. The molybdenite thus refined is roasted with lime and forms a yellow chalky powder called *calcium molybdenate*. Twelve pounds of this molybdenate contain five pounds of molybdenum. It is usually packed in twelve-pound bags, ready to be tossed, bag and all, into a steel furnace.

CHAPTER XII

The Chemistry of Some Familiar Things

PRINTING INK

AT the moment, you are looking at printing ink. Have you ever wondered what it is?

Printing ink is not an ink in the same sense as ordinary writing ink. It is a variety of *paint* which must dry as fast as it is applied. Black ink is made by mixing lamp-black with rosin varnish, rosin oil, linseed oil and a drier. Rosin oil is distilled from rosin. Rosin varnish is made by heating rosin to rid it of water, acetic acid and "pinoline," and then mixing it with warm linseed oil.

Coloured printing inks are made similarly by replacing the lamp-black with coloured pigments such as Prussian blue and chrome yellow and the metallic pigments of organic dyes such as lithol red, lake Bordeaux and helio fast red.

The manufacture of printing inks is a large industry. A daily newspaper uses tremendous amounts. The consumption of a daily newspaper is said to be 4,000,000 pounds in a year.

AN AUTOMOBILE IS A CHEMICAL FACTORY

An automobile is a chemical factory on wheels. It has all the elements of an efficient chemical plant, such as raw material, storage tanks, mixing chambers, pipe lines and means for disposing of waste products.

The raw materials used by an automobile are air and gasoline. The product is power—power which turns the rear wheels and moves the car. Several by-products, which at the present time are wasted, are also produced. The waste products which come from the average automobile engine are heat, water, carbon, carbon dioxide, carbon monoxide, hydrogen, oxygen and nitrogen.

The gasoline used in an automobile is stored in a tank in the rear of the car away from the passengers and the hot engine. This arrangement helps to eliminate the danger from fire in case of damage to the car through collision.

A fuel pumps lifts the gasoline from the storage-tank to the carburettor through a small pipe. The carburettor corresponds to the chambers or tanks in a chemical factory where the raw materials are mixed together. It is the mixing chamber for the raw materials, air and gasoline. Air is drawn into the carburettor by the engine and mixed with a fine spray of gasoline. Air, it will be remembered, is a mixture made up principally of oxygen and nitrogen and contains small amounts of water vapour, carbon dioxide, argon, neon, krypton, xenon and helium. When air is used in an automobile engine as a raw material, the oxygen is the important part of the mixture, for it is this element which burns the gasoline. The air is pulled through the carburettor past the fuel jet at speeds as high as 250 miles per hour. From 9 to 15 pounds of air are mixed with one pound of gasoline. In other words, about 1,200 cubic feet of air are mixed with one gallon of gasolene.

The mixture of air and gasoline passes from the carburettor into the combustion chamber in the engine. Here the gasoline is burned and new products are formed. One of these is *power*, which pushes against the pistons and turns the engine. Power is the *useful* product of the automobile chemical factory. The other products, contained in the exhaust gas, are *waste* and must be eliminated from the combustion chamber to make room for a new charge of air and gasoline.

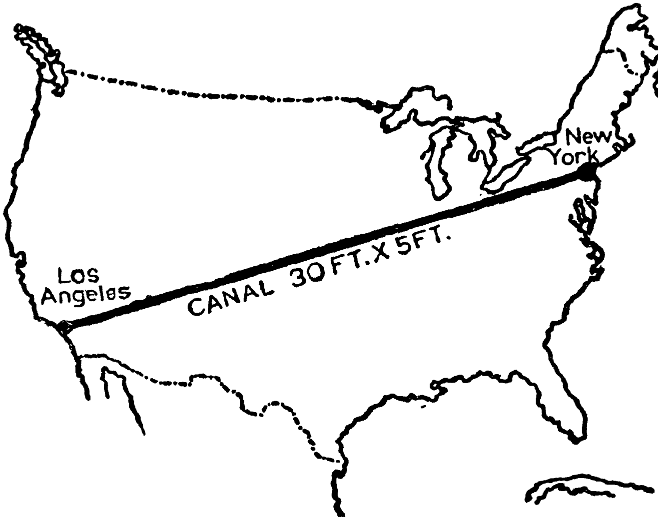
If allowed to escape directly into the atmosphere, the hot gases would make a loud barking roar like the noise from the exhaust of an aeroplane engine. To eliminate this, the exhaust gases are passed through a *muffler* before reaching the air.

A cooling system is provided to carry away the *waste heat*. The engine cylinders and the combustion chamber are surrounded with a jacket filled with water. The water absorbs most of the heat and carries it away to the radiator, where it is transferred to the air.

The nitrogen in the air drawn into the carburettor is an *inert* gas. It passes through the engine unchanged.

When the gasoline burns in the engine cylinder, the carbon and hydrogen in the gasoline combine with the oxygen in the air. Carbon dioxide and water are formed if the burning is complete. Otherwise carbon *monoxide*, a deadly poisonous gas, will also be one of the results. There is usually a considerable amount of carbon monoxide in the exhaust gas from a gasoline engine. Since this may cause death if breathed, it is necessary to be careful to have the garage doors open when an automobile engine is running. There is no danger from carbon monoxide in the open or even on congested streets because the gas is then diluted by a large quantity of air.

The carbon dioxide and water vapour in the exhaust gas, if cooled and mixed, would make plain soda water. The water vapour may be seen on a cold day coming out of the exhaust pipe. Sometimes, during very cold weather, the vapour is condensed and water trickles from the pipe. For every gallon of gasoline burned in an automobile about seven pounds of water vapour are produced. If condensed this would make between six and seven pints of water. The trucks and passenger automobiles running over the roads of the United States create about 17,500,000,000 gallons of new water every year. This is enough

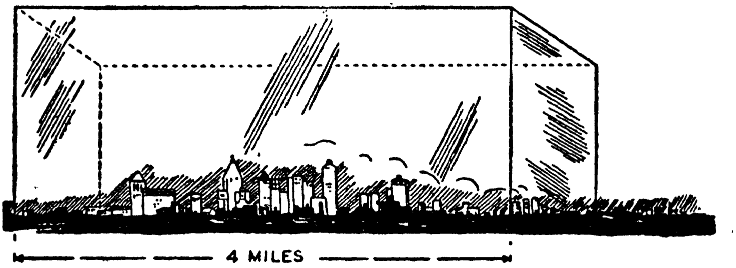


AUTOMOBILES INCREASE THE WORLD'S SUPPLY OF WATER BY 17,500,000,000 GALLONS YEARLY

One of the chemical products made by an automobile engine is water. It comes out of the exhaust pipe mainly in the form of vapour, but on a cold day may condense and trickle out in drops. The automobiles in the United States produce enough water yearly to fill a canal 30 feet wide and 5 feet deep, extending across the continent from New York to Los Angeles.

water to fill a canal thirty feet wide and five feet deep running across the United States from New York to Los Angeles.

For every gallon of gasoline burned in an automobile engine, about ten pounds or ninety cubic feet of carbon dioxide are produced. The burning of gasoline in automobiles produces yearly 2,700,000,000,000 cubic feet of carbon dioxide. This would fill a space four miles square to a depth of more than a mile.



A CHEMICAL FACTORY ON WHEELS

One of the chemical products of an automobile engine is carbon dioxide. Carbon dioxide puts the "fizz" in soda water. When frozen it makes the familiar "dry ice" used for keeping ice-cream and other foods.

In one year 2,700,000,000,000 cubic feet of carbon dioxide pours out of the exhaust pipes of automobiles in the United States. This would fill a space four miles square to a depth of one mile. It would make 160,000,000 tons of dry ice.

If this vast amount of carbon dioxide could be captured and not allowed to escape into the atmosphere, it would make about 160,000,000 tons of "dry ice."

GLASS, AN ENIGMA

We are all influenced by glass.

Glass is part of our living.

We live in houses with glass windows which allow the sunlight to brighten the interior but at the same time keep out wind and cold. When the sun goes down behind the horizon we depend upon artificial illumination, upon lamps of some sort, and all satisfactory lamps are built of glass. Many of us see and read with the aid of glass lenses. Much of the food we eat is packed and preserved in glass. We drink from glass tumblers. Many times when we find a bargain, we see it first through the plate-glass of a show window.

We cannot be certain whether the Assyrians or the Egyptians discovered the art of glass-making. From relics that have come down to us, we know that from three to four thousand years before the beginning of the Christian era, the Egyptians were casting blue and green beads in a primitive form of glass called faience. A thousand years later these amazing people along the banks of the Nile discovered how to make glass vessels in a crude manner. Threads of hot, soft glass were wrapped around a clay mould. Then the glass winding was fused together in a hot oven. After the fusing process, the clay was scraped out.

In the days of Augustus Caesar, first ruler of the Roman Empire, the process of glass blowing was invented in the City of Tyre. The glass vessels of the Egyptians were luxuries, ranking in value with gold and silver, but the new art of glass blowing made better glass containers as cheap as pottery.

GLASS, AMERICA'S FIRST EXPORT

The first American-made products to be exported were glass bottles. The art of glass-making came to the Western Hemisphere in 1608, the year the telescope was invented. Several glass blowers were sent from Europe to Captain John Smith's colony at Jamestown. Their first work in the new land was making glass beads which were bartered with the Indians for valuable furs. They also made bottles for use by the colonists, and some of the bottles were shipped back to England.

Until shortly before the beginning of the present century, glass-making and fabricating were a handicraft dependent upon the skill of the individual workers. Jealously guarded trade secrets of glass-making were handed down from father to son.

Toward the latter part of the nineteenth century, a group of German scientists started a scientific inquisition into glass-making that has never ceased. New glasses were developed which looked like the old glasses but which made much better lenses and prisms for optical instruments. Others were found which were more resistant to heat and chemical attack than any previous varieties. These were at once put to work in making better laboratory flasks and beakers, thermometers and lamp chimneys.

WHAT IS GLASS?

Glass conceals a secret within its own transparent walls.

Although glass-making is a chemical industry which has probably existed for four thousand years, no one has been able to determine the real constitution of glass. Chemists know what ingredients to use and how much of each should be mixed together to make many different kinds of glass. But when the glass has been made no one knows what it really is. No microscope, no attempts at analysis reveal the chemical constitution and molecular structure of this ancient material.

Recent researches have resulted in the view that nine-tenths of glass is oxygen. The arrangement of the molecules in a piece of glass can be studied by sending X-rays through it and photographing the patterns which the X-rays form when scattered by the molecules. In crystalline substances, the molecules are arranged in regular rows and columns. In glass they have no regular arrangement; they are like those in a liquid. At ordinary temperature, glass is a liquid which is too chilly to flow.

MAKING GLASS

In making common glass, silicon dioxide (sand), sodium carbonate (soda ash), and calcium carbonate (chalk) are mixed with some broken glass and melted in a huge tank furnace which can hold several hundreds tons of the mixture. The raw materials are put in at one end of the furnace, the clear glass is withdrawn at the other end. If we look at the edge of a piece of common glass it appears green. This is due to a minute quantity of iron dissolved in the glass as an impurity.

A small amount of aluminum, added to the sand, soda ash and calcium carbonate used in making ordinary glass, makes a stronger glass employed in the manufacture of beer, wine and whisky bottles.

Substituting potassium compounds for the soda ash makes Bohemian glass for tableware.

Chemical glassware made to withstand heat and rough usage usually contains some boron, and more silicon than ordinary glass.

Glass may be coloured by adding various compounds to the raw materials used in making glass.

A little selenium added to ordinary glass makes it orange. Sodium chromate gives a green colour. Copper oxide produces aquamarine blue. Cadmium sulphide, zinc oxide, selenium and charcoal are added and the calcium carbonate omitted to make the clear red glass used for traffic lights.

If a piece of ordinary glass is heated too quickly or suddenly chilled, it will crack. It will fly to pieces if placed on a hot stove.

Pyrex glass does not break when placed in the oven or when heated carefully on top of the stove. This heat-resisting type of glass is the result of a search for a lantern globe for railroad trainmen which would not crack when raindrops struck its hot surface. The cracking was caused by the contraction of the glass when it was suddenly chilled. It was found that by using borax, a glass could be made which would change its volume less than one-ninth as much as ordinary glass when its temperature changed.

Glass insulators, ash-trays, heavy tumblers, percolator tops and thick glass cooking utensils are cast or pressed. A red-hot piece of glass of the proper size is pushed into a mould. When partially cooled, the piece is released from the mould and sent to an annealing furnace where it cools slowly and is freed from strains. If hot glass cools too rapidly, the outside cools and contracts first, compressing the still warm inner portions and setting up strains which crack the glass at the first opportunity. Thin tumblers, bottles, electric-light bulbs and chemical glassware are *blown*. A bit of molten glass at the end of a hollow blow-pipe is blown into a bubble in the same way that soapy water is blown into a bubble. If the glass bubble is blown inside a mould, the bubble will take the form of the mould. The mould is in two halves which close together like the two halves of a clam shell. A hole through the top permits the end of the blow-pipe to enter. Special glassware and articles needed only in small quantities are blown "by hand." Bottles, electric-light bulbs and glassware needed in large quantities are blown by machines which turn out as many as 48,000 pieces an hour.

Measured in terms of its usefulness, glass is one of the most valuable substances we have.

PHOTOGRAPHY: PICTURES FROM CHEMICALS

The word photography is formed from two Greek words and means "light-writing." Photography is made possible by chemistry.

The making of a photograph is a series of chemical processes dependent upon the power of light to decompose silver compounds.

EXPOSING

Modern photography consists in forming an image of the object to be photographed upon a light-sensitive plate or film. The sensitized plate or film is placed in the back of the camera. A miniature image of the picture being made is formed on the film by light rays passing through the lens in the front of the camera.

The sensitive film or plate consists of a strip of transparent cellulose acetate coated with a thin layer of microscopic particles of silver bromide suspended in gelatine. Silver bromide is very sensitive to blue or violet light but not very sensitive to green, yellow or red light.

On its brief exposure in the camera, different parts of the light-sensitive layer will be exposed to the different degrees of light which form the image. Wherever the rays strike, decomposition of the silver bromide takes place. It breaks up into silver and bromine, the degree of decomposition at any spot depending upon the intensity of the light.

DEVELOPING

After the film has been exposed in the camera, it bears a chemical image of the object photographed, but this is not visible.

In order to make the image visible, the film is dipped into a chemical solution called a "developer." The developer contains a reducing substance like pyrogallol or hydrochinone which further decomposes or reduces the silver bromide into silver and bromine. It reduces the silver bromide particles which have been exposed to strong light more rapidly than it reduces those particles exposed only to weak light. The reducing process precipitates black, finely divided silver. The portions of the film that have not been exposed to light are unaffected by the developer. This results in a visible image.

FIXING

In order to make the image permanent, so that it will not undergo any further change when exposed to light, the developed film is bathed in a solution of sodium thiosulphate. This dissolves away all the unchanged silver bromide but leaves the finely divided black metallic silver intact. The film is then washed thoroughly.

THE NEGATIVE

The film is now a *negative*. It is an accurate picture of the object photographed, but all the shades of light and shadow are reversed.

PRINTING

In order to obtain a picture with the areas of light and shade in their proper relationship, a print is made.

The negative is placed upon a piece of photographic paper which has a sensitized coating, similar to the original film on the negative, and exposed to light. The light passes through the negative on to the paper. The silver compound on the paper is thus subjected to varying degrees of decomposition depending upon how much light each portion of the negative allows to pass through. The clear parts of the negative (not exposed to light in the camera) will allow the most light to pass. Those exposed to light and covered with black silver will allow the least light to pass.

The print is then developed and fixed similarly to the original plate or film. In this way a print yielding a faithful image of the object originally photographed is secured.

TONING

Frequently, the print is bathed in a solution of gold, copper or platinum compounds. The silver on the paper is replaced by the particular metal being used, and a print of pleasing colour is produced.

PANCHROMATIC FILMS

Films can be made sensitive to yellow, red and green light by the addition of certain aniline dyes. This type of film is called *panchromatic* and has to be developed and handled in total darkness or very dim green light.

PAINTS, VARNISHES, ENAMELS AND LACQUERS: CHEMICAL SURFACE SAVERS

This would be a rather dilapidated, ramshackle-appearing world without paints, varnishes, enamels and lacquers. It would be weather-beaten and rusty. Applied to inside or outside surfaces, these substances harden to an unbroken film which prevents contact with rain, smoke or direct sunlight, and prevents loss of moisture to the atmosphere. The film is a protective and preservative coating. It is also a beautifier. It may be made any colour.

Not only is a building, a bridge, a tank, a boat or a piece of machinery improved in appearance when painted; it will last much longer. It is economy to use "a chemical surface saver."

Paints, varnishes, enamels and lacquers are all intended to protect or beautify or both, but they cannot always be substituted one for another. Each has certain characteristics which make it the most suitable for certain conditions. For example, a varnish on the outside of a building bathed in sunlight and rain will not last as long as a suitable paint. On the other hand, a coating of paint on the top of an indoor table or counter will not endure ordinary usage as long as a coating of furniture varnish will. Paints and varnishes will not preserve the appearance of and afford protection to the body of an automobile as well or as long as a lacquer. The enamels called baking enamels will resist heat and mechanical injury better than paints, varnishes or lacquers.

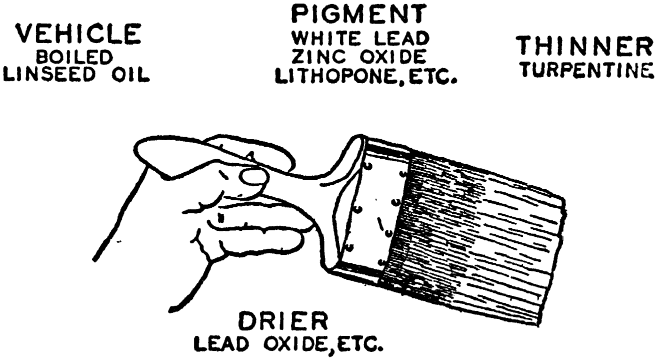
The art of making coloured liquids for protecting or decorating surfaces goes back to Biblical times. It developed slowly for hundreds of years. Then, about twenty-five years ago, chemists suddenly realized that here was a vast field they had been neglecting. A great deal of research was made into the effects of rain, sea water, smoke, fumes, sunlight and friction upon paints and varnishes. New materials and new formulas were sought. Paints and varnishes were greatly improved. They last much longer to-day than they did twenty-five years ago.

WHAT IS PAINT?

A paint consists of a pigment, a vehicle, a drier and a thinner. The pigment is an opaque, finely ground substance to which, except in white paints, a colouring substance is added in small quantities. The pigment must be opaque in order to hide the surface which is to be painted. The greater the hiding power, the less paint is required per square foot of surface. The commonest pigments used for paints are:

White lead (basic lead carbonate)
Zinc oxide
Lithopone (barium sulphate and zinc sulphide)
Blanc fixe (barium sulphate)
Titanox (titanium oxide and barium sulphate)
Rouge (iron oxide)
Red lead (lead oxide)

The vehicle is the liquid in which the base is suspended so that it can be applied to surfaces in a thin layer. The commonest vehicle used in oil paints is "boiled" linseed oil containing a drier. The oil itself does not actually dry; it hardens by the chemical change called oxidation. When spread out in a thin layer, it absorbs oxygen from the air quite rapidly and in a day or so hardens into an unbroken film. The drier speeds this process.



WHAT IS PAINT?

Paint consists of an opaque finely ground substance called a pigment suspended in a vehicle of boiled linseed oil. A colouring substance is added except in white paints. A thinner such as turpentine is added to give the paint spreading and brushing qualities and a drier is included to shorten its drying time.

Driers are usually oxides, resinates, acetates or oleates of the metals lead, cobalt and manganese. They form compounds with the oil and speed its oxidation or "drying" by the atmosphere.

The thinner is present in paint to make it thinner, so that it can be applied in a thin layer with a brush. Turpentine is the usual thinner, but there are other solvents which can be used.

WHAT IS VARNISH?

Varnishes are made by dissolving resins in certain vegetable oils to which a small amount of drier and a thinner are added. They usually dry with a smooth, hard, shining surface.

The oils chiefly used in varnish making are linseed oil, tung oil and perilla oil. Linseed oil, when exposed to the air in a thin film of varnish, "dries" in about a day and a half. Perilla oil "dries" in about the same time as linseed oil but forms a harder film. It comes from Manchuria. A new-comer is oiticica oil, from Brazil.

The natural resins used in varnishes are the exudations formed on trees which have long since decayed and disappeared. They are called fossil gums or copals and are found in the earth. To these must be added rosin and ester gum. Ester gum is made by boiling melted rosin with glycerin. It looks very much like rosin but is less brittle.

Synthetic resins, such as Bakelite resins, are now used in varnishes. They are more resistant to sunlight and chemicals than natural resins and make possible varnishes which dry in four hours.

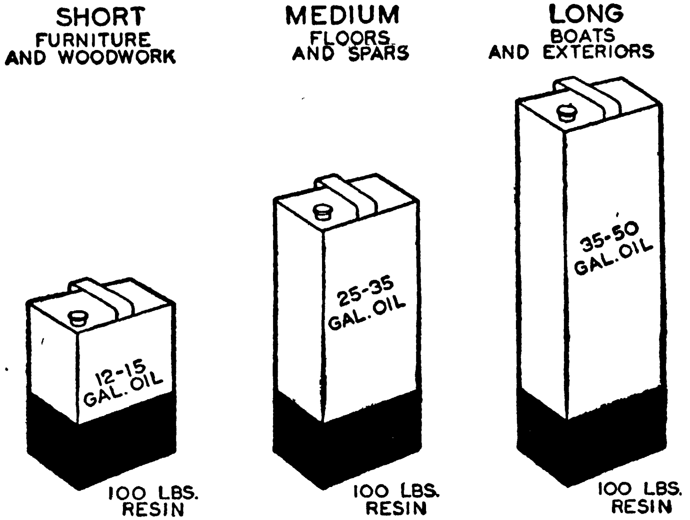
LONG AND SHORT VARNISHES

A varnish suitable for furniture is too hard to use on a floor and also would not endure well under the effects of sunshine and rain if used outdoors. A spar varnish, made for exterior use, would be unsatisfactory on furniture. A floor varnish is suitable for floors and nothing else. In other words, a varnish must be made for the purpose for which it is used.

The several kinds of varnishes are termed "short," "moderately short," medium length," and "long" by the manufacturers, depending upon the relative proportions of oil and resin in their formulas.

A "short" varnish is used for coating furniture and woodwork which are to be rubbed and polished. It contains a much greater percentage of resin than a "long" varnish—usually 100 pounds of resin in 12 to 15 gallons of oil.

"Medium length" varnish is used on floors and spars. It is prepared by dissolving 100 pounds of resin in 25 to 35 gallons of oil.



LONG AND SHORT VARNISHES

A varnish suitable for floors is not suitable for furniture or boats and vice versa. The illustration shows the comparative quantities of oil used with 100 pounds of resin in making varnishes of the short, medium and long types. A varnish containing a small amount of oil in proportion to resin is "short." It is a hard varnish which can be highly polished. A "long" varnish contains a large proportion of oil and is soft and flexible. It is best suited to boats and exterior work.

"Long oil" varnish makes a durable exterior finish and contains 100 pounds of resin in 35 to 50 gallons of oil.

Spar varnish contains tung oil and ester gum and is waterproof.

SHELLAC

Shellac is a "spirit" varnish. Spirit varnishes contain alcohol or a similar solvent and dry by evaporation of the solvent. Gum shellac is a resinous substance produced by an insect on the small twigs of several species of East Indian trees. It is dissolved in alcohol, and when it is spread out in a thin film, the alcohol quickly evaporates, leaving the shellac spread out in a thin film on the surface to which it has been applied.

THE DIFFERENCE BETWEEN LACQUER AND VARNISH

A lacquer is a protective coating which dries rapidly, like a spirit varnish, by the evaporation of the solvents; a standard varnish dries more slowly, partly by evaporation, partly by oxidation.

The lacquers used as a colourful protective coating for automobiles, furniture, refrigerators, etc., contain:

1. Nitrocellulose or pyroxylin.
2. A solvent—usually a mixture of two or more substances.
3. A dye or pigment.
4. A plasticizer which remains in the film and keeps it softer.
5. A thinner.

Lacquers are applied mainly by a spray gun. Within a few hours the coating is dry.

ENAMELS

An enamel is a varnish containing a pigment. It is more glossy than a paint. and since it is harder and more flexible, it chips more easily. It is made by mixing a pigment with linseed oil, followed by further mixing with a varnish. White lead, lithopone, Titanox and blanc fixe are the common pigments. They make a white enamel. Various dyes or colours are added when desirable.

CARBORUNDUM: A GIFT FROM CHEMISTRY WHICH CAME OUT OF A LITTLE IRON POT

In America, practically everyone can enjoy the pleasures and comforts of automobiles, electric lights, radios, telephones, washing-machines, electric refrigerators, vacuum cleaners, phonographs, cameras and numerous other things which give a high standard of living.

We can have these because they are not expensive. They are not expensive because they are made by "quantity production."

Quantity production is founded on the principle of producing quickly a vast number of parts which are exact duplicates and so can be assembled interchangeably. A part is interchangeable when it can be substituted for any other part exactly like it and will fit equally well.

One of the most important processes in the quantity production of some metal parts is *grinding*. Grinding wheels will cut metals and some other materials more accurately and far more quickly than sharp-edged steel tools will. A grinding machine combines quantity production with the utmost accuracy. By grinding, machine parts can be finished by the tens of thousands so accurately that each one varies from the other no more than a fraction of a thousandth of an inch.

In ten hours one grinding wheel will finish 50,000 steel balls one-quarter inch in diameter (such as are used in ball-bearings) and make each ball accurate within one-half of one ten-thousandth of an inch. In other words, no ball will be larger in diameter than one-quarter of an inch plus one-half of one ten-thousandth of an inch or smaller in diameter than one-quarter of an inch less one-half of one ten-thousandth of an inch. One-half of one ten-thousandth of an inch is, popularly speaking, one-twentieth of a hair's breadth.

The cylinders, valves, pistons, piston rods, gears, crankshafts, bearings and other accurately fitting parts of an automobile must be finished to size by grinding if they are to be made cheaply. Take grinding methods away from the automobile industry and the labour cost of building a car would be so great that only a rich man could afford one. The industry would cease to exist on its present lines. This is also true of many other industries.

Suitable grinding wheels or abrasive wheels have been available for less than a generation. Until the turn of the century, they were made of emery, sandstone, corundum and similar natural substances dug out of the ground. They were soft; they would not cut accurately and rapidly. Modern grinding wheels are made of *artificial* abrasives. They are very hard; they cut accurately and rapidly.

By artificial abrasive is meant one which is manufactured. Artificial abrasives are much superior to natural abrasives found ready-made in the earth.

The first artificial abrasive was produced by a chemist in a little shop at Monongahela City, Pennsylvania, in the year 1891. It came out of a little iron pot such as plumbers use for the melting of solder.

Often, the chemist has improved upon Nature. In this instance, the chemist who did so was a young man named Edward Goodrich Acheson.

Acheson had been an assistant in Thomas Edison's laboratory, where he had aided in the perfection of the carbon filament in the original incandescent lamp. Now he was dabbling and puttering with his own ideas. He was trying to create an abrasive or grinding material superior to those made indifferently well by Mother Nature.

Into a small iron pot, ordinarily used for melting solder, Acheson put a small quantity of clay mixed with ground coke. A wire leading from a small electric generator was attached to the pot. Another wire from the miniature power-plant was twisted around one end of a carbon rod and the rod was inserted in the mixture of coke and clay.

When the current was turned on, a very high temperature was generated in this simple little electric furnace. After several hours of anxious waiting, Acheson shut off the power, and when the mass in the pot had cooled, he eagerly pulled out what was left of the carbon rod. The dull greyish mass of fused clay and coke was most disappointing. For a time, the experiment seemed to have been a failure. Then, by sheer chance, he happened to notice some tiny, sparkling, bluish, diamond-like crystals on the end of the carbon rod that had been in the mixture. He placed one of the crystals on the end of a lead pencil and drew it across the surface of a pane of glass. It cut the glass like a diamond.

Acheson was on the right trail. Loading up the pot with a fresh charge of clay and coke, he repeated his experiment and collected enough of the brilliant crystals to test thoroughly their abrasive qualities. With a revolving iron disk coated with the new material, he cut the surface of the diamond in his finger ring.

The next step was to produce the new abrasive in larger quantities. Accordingly, Acheson built a small furnace of bricks, and after much and patient work could produce a few ounces of the crystals per day. Under the impression that the newly discovered material was composed of carbon and corundum, Acheson coined the name "Carborundum" for his product. A company was formed to make Carborundum in larger quantities. There was a good demand, and forty-five tons were produced in a single year. The decision was made to move the plant to Niagara Falls where cheap electrical power was available and manufacture could be carried on in a larger way.

In the huge electric furnaces in the present plant of the Carborundum Company at Niagara Falls, New York, well over

1,500,000 pounds of Carborundum are produced each month.

The beautiful blue and black iridescent crystals of Carborundum are very hard—next to the diamond in hardness. They are an abrasive having just the right characteristics for the grinding of materials of low tensile strength such as cast-iron, brass, bronze and aluminum, for the finishing of leathers, the bevelling of glass, etc.

Materials of great strength, such as steels and their alloys and malleable iron, are ground with fused alumina. This is another product of the electric furnace and is made from bauxite, a clay which contains the purest form of aluminum oxide found in commercial quantities. The fused aluminum oxide is known under the trade name of Aloxite.

With Carborundum and Aloxite a whole range of grinding problems is readily solved.

Thus an iron pot was the cradle of artificial abrasives and the beginning of an important industry.

CHAPTER XIII

Plastics

TO-DAY the world is filled with innumerable articles made of substances called plastics which did not exist a generation ago. They are new collections of chemical atoms, combinations of chemical matter previously unknown in nature which have been put together by those molecule-makers we call chemists.

It is difficult to define "plastics". The word covers a wide range of materials. It includes not only synthetics, but, broadly speaking, also clay, rubber, glass and Portland cement. Probably the first plastic man learned to use was potter's clay.

When a chemist or an engineer speaks of plastics he usually applies the word to those synthetic compounds and mixtures which can be cast, moulded or pressed into an almost unlimited variety of shapes and which will then retain that shape.

There are well over one thousand trade names for plastic materials. The names of some, such as Celluloid, Pyralin, Bakelite, Plaskon, Beetleware, Lustron and Tenite, are probably familiar.

The first man-made plastic was glass.

The first synthetic organic plastic of commercial importance was Celluloid.

The first "modern" plastic was Bakelite.

THE STORY OF CELLULOID

When the natives in the remote jungles of the Dark Continent found that they could obtain coveted rifles and gunpowder from white traders in exchange for elephant tusks, they began to annihilate the elephants.

Among the many things which white men made out of the tusks were billiard balls. As elephants became scarcer the price of ivory mounted and the cost of billiard balls went up. This prompted a New York firm manufacturing billiard balls, Messrs. Phelan and Collander, to offer a handsome prize, ten thousand dollars in gold, for a material which could be substituted for ivory. To-day, three-quarters of a century later, chemists would not find such a problem difficult, but at that time it was a poser.

Among those who attempted to win the reward was a born tinkerer, an ingenious printer named John Wesley Hyatt. At the time he knew as little about chemistry as a Hollywood screen star, but he started mixing all sorts of messes out of paper pulp rags, pulverized wood, rosin, shellac, starch, glue and collodion.

Collodion is cellulose nitrate, or, as some chemists like better to call it, *nitrocellulose*, dissolved in two parts of ether and one of alcohol. A while back, collodion was used in medicine. One of its trade names was Newskin. When applied to a cut or abrasion, the alcohol and ether evaporate, leaving a transparent skin of cellulose nitrate.

After three years, working as a printer in the daytime and as an inventor nights and Sundays, John Wesley Hyatt made billiard balls out of a pressed mixture of paper, collodion and shellac. He did not win the award but he did succeed in selling his formula to the sponsors of the prize contest for a price considerably less than ten thousand dollars.

With the billiard ball problem thus disposed of, back to his mixtures went Hyatt. He was thoroughly interested in this nitrocellulose stuff and somehow or other in his puttering he hit upon the idea of adding camphor and a little alcohol to it, creating Celluloid.

After he had learned to manipulate his new plastic, Hyatt and his brother Isaiah sought capital to produce the material on a large scale. Colonel Marshall Lefferts, a pioneer in establishing telegraph lines between New York, Boston and Buffalo, saw the possibilities of the new compound and backed it liberally with his money.

The Hyatts moved from Albany, where the experimental work had been carried on, and built a plant at Newark, New Jersey. The new Celluloid Company was an enormous success. There had never been such a versatile raw material. It could be softened by heat and pushed into shapes which were retained on cooling. It could be cut and machined with ordinary equipment. It could be made in any colour, to simulate ivory, tortoise-shell, onyx or coral. One of its first uses was for celluloid collars. Later, photographic film became a major use.

The principal objection to Celluloid was its inflammability. It was easily sent off in a flash and puff of smoke.

It has now been displaced in many uses by cellulose acetate which is much less inflammable. Photographic films are now cellulose acetate. So are such moulded products as small radio cabinets, automobile steering-wheels, knobs, chessmen and costume jewelery.

Celluloid was too inflammable to use in moulding switch handles and to use as an insulator in electrical apparatus. It was never able to invade the electrical field. A mixture of shellac with pulverized wood or mica, pushed into hot moulds under heavy pressure, competed for a time with hard rubber as a plastic in electrical industries. But neither hard rubber nor this shellac composition, which had various names such as Electrose, Electrite and Buttonite, was satisfactory.

The search for a synthetic shellac or a substitute for shellac brought a new type of plastic into the world, the plastic called Bakelite.

THE STORY OF BAKELITE

It has long been known by chemists that there are many chemicals which can be used to make substances somewhat similar in appearance to the resin of the pine trees, which we call rosin. During the latter part of the 1800's numerous men tried to produce an artificial resin which would have commercial value. They hoped to find a substitute for shellac. Shellac dissolved in alcohol was in universal use as a varnish. Cast into sticks it was sealing wax; mixed with wood flour it was moulded into phonograph records.

A minute insect is the source of shellac. It is a native of India and sucks the sap out of the twigs of certain types of fig-trees. Twigs and insects become coated with brown resin. It takes 150,000 of these tiny bugs with the big name, *Coccus lacca*, to produce one pound of shellac, and the world consumes about 65,000,000 pounds annually. Sharpen a pencil and figure how many shellac bugs would be put out of business by a good substitute for their product. All attempts to produce a man-made resin yielded resins which were unable to compete with the natural resins in price or were so porous and inferior as to have no industrial worth. One investigator after another had to give up the search without having achieved anything worth while.

Sooner or later the right man turns up to solve almost any problem. Just after the turn of the century, a young chemist whose laboratory was in Yonkers, New York, looked around for "a chemical nut to crack." He was Leo Hendrik Baekeland.

Baekeland was born in the old Flemish city of Ghent, where for a while he was an assistant professor in chemistry at the University of Ghent.

He came to the United States on a sort of combined honeymoon and career hunt. Amateur photography was one of his hobbies and led to his first job in America—chemist in a small plant manufacturing photographic supplies. After two years Baekeland quitted his job and opened his own office and laboratory as a consulting chemist. Clients were few and far between. Baekeland had time and ideas. He puttered with several and then decided to concentrate on a photographic paper that could be printed by artificial light. At that time prints were made on "printing out" papers which required sunlight. Amateurs were anxious to putter with print-making at night when they had more spare time.

The result of Baekeland's work in this direction was Velox, a paper with which prints could be made at night by gaslight or electric light. The Nepera Chemical Company was formed to manufacture the paper. Steadily the sales mounted.

George Eastman, of the Eastman Kodak Company, became interested in Velox. He was bent on dominating the camera field. He would buy this small competitor. Would Baekeland sell? Yes. He would and did. It is reported that Eastman paid one million dollars for the Velox patents and business.

Here now was Baekeland, a young man with a great deal of ability, many ideas and considerable money, looking for a new outlet for his energies. He decided to undertake research which had baffled others. He tackled the problem of making a useful synthetic resin.

He built himself a small laboratory adjoining his home in Yonkers, took off his coat, and went to work. He had plenty of time; he repeated the work of others, then started to carry out his own ideas. For several months, he filled note-books with carefully observed facts. He had not succeeded in producing anything like the substance he was looking for. He was convinced, however, that the path to success lay in the reaction between phenol and formaldehyde. These substances were cheap and plentiful. They produced a resin, a tantalizing substance so far unfit for anything. How could he control the reaction, make it produce what he wanted? It was a long hard job. The next four years were a period of toil and disappointment.

He found the right answer in 1907, and two years later announced the result of his work, a resin called Bakelite. This was the first of the many useful substances called *phenol resinoid plastics*. It looked like amber. It could be produced in the form of a syrupy liquid which could be used in varnish or lacquer. Or it could be hardened by heat to the point where it possessed a strength greatly exceeding the best amber or the hardest copal resin.

It is more than probable that there is a plastic within reach of your hand. The button on a near-by switch, the knobs on a radio, the telephone, parts of a toy locomotive, the barrel of a fountain pen, a table top, umbrella handle, flashlight case, door-knob, ash-tray, clock-case, cigarette holder, ink-well—almost anything may be made of a plastic. An automobile is literally full of plastics. Brake bands, steering wheel, instrument panel, ignition coil, distributor head, switch knobs and gear-shift handle are usually plastics.

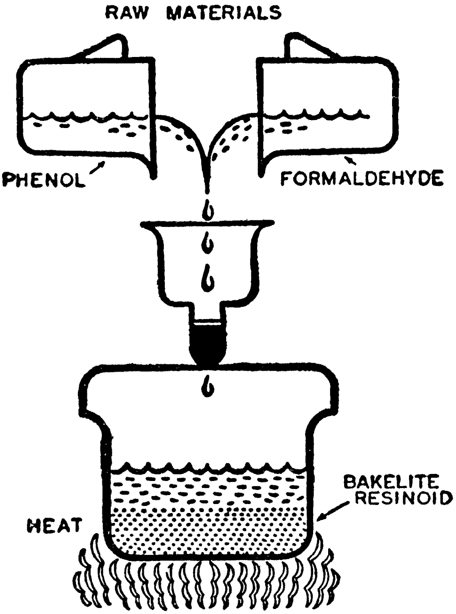
A plastic is not anything that nature put on earth. She supplied the raw materials, but chemists created plastics.

Plastics replace hard rubber, bone, Celluloid, gutta-percha, porcelain, glass, vulcanized fibre, wood, ivory and many other substances. They vary from a clear, transparent glass or amber-like material through all the colours of the rainbow to an opaque black.

HOW BAKELITE IS MADE

Bakelite resinoid is made largely from two raw materials, phenol and formaldehyde. A resinoid is a synthetic or man-made resin, so called to distinguish it from natural resins.

Phenol is the smelly white crystalline solid commonly called carbolic acid and sometimes used as a disinfectant. One of the sources of phenol is coal. The method of obtaining phenol from coal is explained elsewhere in this book. Formaldehyde is one of a group of chemicals called *aldehydes*. It is a gas which, when dissolved in water, is commonly known as formalin. Formalin is also a disinfectant and is just as smelly as phenol. These are certainly two apparently unpromising raw materials from which to produce an odourless, tasteless resinoid for making a set of false teeth.



THE BAKELITE RESINOID PROCESS

The commercial production of Bakelite phenol-formaldehyde resinoid used in making moulding powders, varnishes, etc., is not quite as simple as the process shown in the diagram above. This, however, is the basic principle involved.

Phenol (carbolic acid) and a solution of formaldehyde are heated together under pressure in a steam-jacketed kettle. After several hours, there is a layer of heavy, golden, molten resinoid at the bottom of the kettle, covered by a layer of hot water. The liquid resinoid is drawn off in shallow pans and cooled. In cooling it hardens. To make the common variety of moulding powder, pulverized resinoid is mixed with wood flour and a suitable colouring material.

To make Bakelite resinoid, phenol and a solution of formaldehyde in proper proportions are put into a steam-jacketed kettle and gradually heated. A steam-jacketed kettle is one enclosed in a casing or jacket through which steam or water may be passed.

Soon the two liquids begin to react, and in doing so liberate a great deal of heat. So hot does the mixture become by its own activity that the steam must be shut off from time to time and cold water sent through the jacket of the kettle to keep the contents from boiling over.

It takes about three hours' boiling to make a batch of Bakelite resinoid. When finished, the contents of the kettle consist of two layers, a heavy, melted golden resinoid at the bottom and hot water on top. Large shallow pans are brought in, a cock in the bottom of the kettle is turned, and out runs a syrupy stream of the amber stuff. Pan after pan is filled and set aside to cool.

When the resinoid has cooled it is as brittle as ordinary rosin and like rosin is easily melted or dissolved in a number of solvents, notably alcohol and acetone.

Ordinarily there is nothing remarkable about a resin. Trees and plants have been making resins for millions of years, and man has been using them for no one knows how long. Looking back in history, we find that the early Egyptians used natural resins in linseed oil as varnish for their sarcophagi.

There is, however, something remarkable about this Bakelite resinoid, this man-made resin.

When natural resins are heated, they melt and solidify again on cooling. They may be melted and solidified again and again without much change. They do not set and become permanently hard or infusible. But when Bakelite resinoid is heated to sufficient temperature, it not only melts but further heating causes it to harden, after which it cannot again be softened at any temperature. Furthermore, the resinoid in its now solid form is no longer brittle. It has increased in strength and will no longer dissolve in ordinary solvents.

Since Bakelite resinoid sets or hardens when heated, it is called a *thermosetting plastic.*

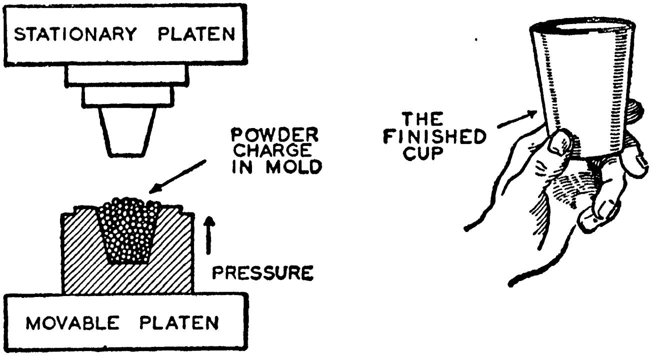
Baekeland soon found that his pure resinoid was not well suited to moulding into various shapes, because it shrank too much on cooling, and the finished product was not as strong as might be desirable. He set out to remedy this, mixing with the pure resinoid every sort of substance that might serve as a suitable filler. Clear, flour-like powdered spruce, brought from the forests of Norway and Sweden, solved the problem. The result was a new material which could be formed into an almost endless number and variety of articles of commerce.

Asbestos, in place of wood flour, is used as a filler whenever Bakelite especially resistant to heat is desired.

HOW BAKELITE IS MOULDED

The moulding of any of the million and one articles made of Bakelite is a simple process when you see it done.

Bakelite moulding is performed in hardened steel moulds set in a sturdy, powerful hydraulic press. The moulds are exact counterparts of the pieces to be made, just as the moulds used to cast lead soldiers are exact counterparts of the soldiers. In moulding lead soldiers, the molten lead is poured into the



PRESTO, CHANGE! A POWDER BECOMES A MOULDED TUMBLER

Bakelite phenolic moulding materials are powders which melt under heat and pressure, then solidify and will not melt again.

The sketch shows the moulding process, in this case the production of a tumbler. A weighed quantity of Bakelite powder is put into a cavity in the lower half of a steel mould. The cavity forms the outside of the tumbler. Pellets or "preforms" of certain size are sometimes pressed and loaded into the mould instead of powder.

The lower half of the mould containing the cavity rests on the movable platen of a hydraulic press. It can be heated by sending steam through its jacket and cooled by shutting off the steam and substituting cold water.

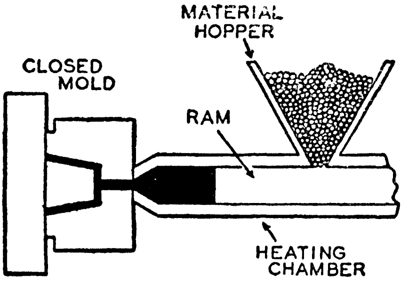
When the press is closed the two halves of the mould come together, and the ram or force (upper part of the mould corresponding to the interior of the tumbler) compresses the Bakelite. The Bakelite melts and fills up all the space in the mould. A moment later it hardens. The press operator shuts off the steam and chills the mould by sending cold water through its jacket. The press is then opened, the mould comes apart and the finished tumbler is removed.

In order to lower costs it is customary to build moulds with several cavities so that several pieces can be moulded in one operation of the press.

mould. In making Bakelite articles the Bakelite is *pushed* into the mould under heavy pressure.

A weighed quantity of Bakelite moulding material is put into the lower half of the mould. The Bakelite may be in the form of a powder or tablets or cakes. The mould is usually jacketed so that it can be heated with steam.

When the mould has been charged or loaded, a valve is opened and the press closes. Steam is sent into the jacket surrounding the mould, and the mould becomes hot. The powerful press compresses the material as it closes the mould. The pressure is usually in the neighbourhood of a ton or more per square inch. Under the heat and pressure a miracle takes place. The Bakelite softens and runs together, completely filling the mould. Then it hardens, never to soften again. The steam is turned off and cooling water sent through the jacket of the mould. Then the pressure is released and the press and mould opened so that the finished pieces can be ejected or "knocked out." Each one is the exact counterpart of the mould which made it.



MOULDING A THERMOPLASTIC

Thermoplastic compounds can be moulded by an "extrusion" process. The moulding powder is placed in a hopper connected to a heating chamber. When the ram or plunger is drawn back some of the moulding material flows into the heating chamber and melts. As the ram moves forward again, under hydraulic pressure, it forces the molten thermoplastic into the mould. Water is then sent through the jacket around the mould, chilling and hardening the moulded piece so that the mould can be opened and the piece removed. The diagram shows a mould for making a thermoplastic cup like the Bakelite cup shown in the previous illustration.

CAST PHENOLIC PLASTICS

To produce these colourful, jewel-like materials, our old friends phenol and formaldehyde are placed in one of the large pressure kettles which a chemist calls an autoclave, together with a suitable catalyst. A catalyst, as we have explained before, takes no part in a process, but without it the process cannot take place properly. A catalyst is like the minister at a wedding.

The result is a resin which may be poured in liquid form into moulds of intricate shape and design, and then hardened in the moulds by baking. The material is produced in all colours in opaque, translucent or transparent effects or as almost perfect imitations of marble, onyx, etc.

Lead is used to make the moulds in which the resin is cast. First, a master pattern is made of highly polished steel. This is immersed in a bath of molten lead kept at an accurately controlled temperature. A layer of lead chills and adheres to the cold steel pattern, which is then withdrawn from the lead pot. When it has cooled the lead shell is removed from the master pattern and becomes the mould in which the resin is cast. The master pattern may be used over and over again to produce thousands of moulds.

An infinite number of articles are made in this way, among them clock cases, radio cabinets, boxes of all sorts, buttons, dice, dominoes, poker chips, costume jewellery, knife handles, gear-shift knobs, buckles, and mah-jong tiles.

UREA PLASTICS

It is a fairly safe bet that any pastel-coloured tumblers, spoons, and sanitary containers for cosmetics and other toiletries you may happen upon were moulded from a urea plastic.

Through the chemical union of urea and formaldehyde, a colourless resin is obtained. This resin, ground and mixed with various fillers and colours, furnishes an unusually strong, slightly flexible moulding material.

Urea is made in quantity by the reaction between ammonia, the gas which, dissolved in ammonia, becomes "household ammonia," and carbon dioxide, the gas of soda water.

Formaldehyde is made from methyl alcohol, made in turn by treating carbon dioxide with hydrogen, the gas used to fill balloons.

The pretty ivory-toned cabinet on your bedside radio may be a urea plastic, and if so was literally made out of three gases.

Or, in other words, here is a charming, hard and solid thing made out of thin air.

THERMOPLASTICS

Ten thousand and one various gadgets which once would have been made of wood, ivory, metal, hard rubber, glass, porcelain, fibre or Celluloid are now made of *thermoplastic* moulding compounds.

Bakelite is a thermosetting material. It can be softened by heating to a putty consistency and forced into intimate contact with a mould. Then, under continued heat and pressure, it hardens *permanently*.

Thermoplastic moulding materials differ from thermosetting in that, after simultaneous heat and pressure forces them into a mould, they remain soft until hardened by cooling. They can be remelted.

The thermosetting phenolic plastics have greater dimensional stability and mechanical strength, but they do not possess the brilliant colours and high lustre of such thermoplastic compounds as cellulose acetate and polystyrene.

CELLULOSE ACETATE

Cellulose acetate is formed by the chemical action of acetic acid on cellulose. The cellulose used is obtained from cotton linters. Parts may be moulded from cellulose acetate in high-speed automatic injection presses, the entire operation taking only a few seconds. Steering-wheels, knobs, escutcheons, horn buttons, combs, bracelets, costume jewellery, hair ornaments, brush handles, door-knobs, drawer-pulls, spectacle and goggle frames, cases and containers, trays, business machine-key buttons and toys are a few of the things made of this pleasing material.

POLYSTYRENE

Polystyrene is a comparatively new plastic which has unique electrical and chemical resistant properties. It is finding new usefulness in scores of industries.

Polystyrene is a compound of carbon and hydrogen. It has been known to chemists for over a hundred years, but only recently has it been perfected as a modern plastic of many uses.

POLYSTYRENE "PIPES" LIGHT

Parts made of polystyrene carry light and in effect pipe it. This light glows only at edges or at points where the surface is disturbed. Polystyrene will carrry light around corners. The up-to-date flashlight which a doctor uses to examine your nose and throat is equipped with a bent rod of transparent polystyrene. The rod "pipes" the light around the bend. His hand and lamp can be held below your chin where they do not interfere with the view of your tonsils.

Perhaps you have seen clear, transparent cowling on airplanes and low-cost powerful magnifying glasses that are carried and handled without breakage, or transparent combs and hair-brush backs. The odds are more than ten to one that these articles were made of polystyrene.

The radio and television industry has long sought an insulating material which could be used as coils, forms, stand-off insulators, socket bases and lead-ins in high-frequency (short wave) service. It has found such a substance in polystyrene.

The sparkle and lustre of clear transparent polystyrene is shared by the coloured forms. A recently developed wall tile consists of individual hollow blocks moulded of this plastic. Walls of this new tile can be designed to serve as a means of illumination, since light from behind gives a soft pleasing glow.

Polystyrene has many remarkable qualities, most startling of which is its resistance to alcohol, water, acids and alkalis. Glass-like but unfragile trays and funnels moulded of polystyrene are not affected by photographic chemicals.

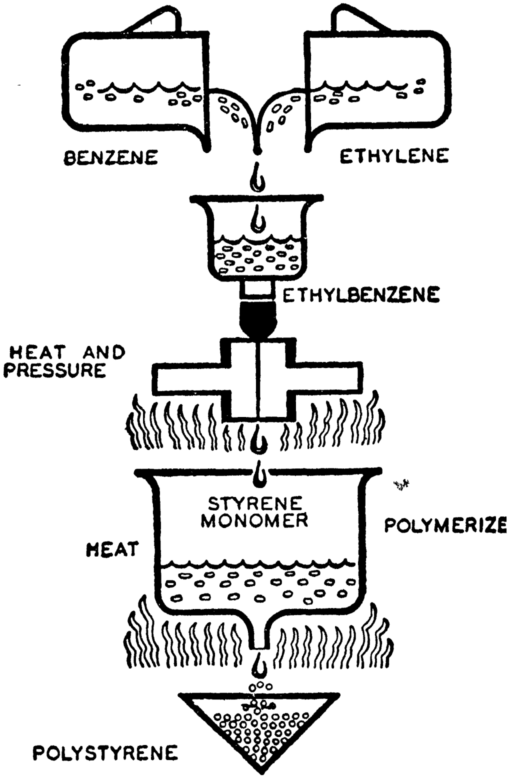
HOW POLYSTYRENE IS MADE

There are several manufactures of polystyrene plastics. They market this product as Lustron, Amphenol, Lucite, etc.

Lustron is the polystyrene plastic made by the Monsanto Chemical Company. It is made by a series of reactions from two organic chemical compounds, benzene and ethylene.

Benzene is one of the liquid by-products obtained in the distillation of coal in making gas, coke, etc. Ethylene is a gas obtained by "cracking" oil or natural gas.

Mixing benzene with ethylene forms *ethyl benzene.* When this is subjected to what the chemist calls a cracking operation under



THE PROCESS WHICH PRODUCES POLYSTYRENE

Polystyrene is a modern plastic of many uses characterized by sparkling transparency or a broad range of colour, resistance to acids, alkalis, alcohols and many solvents.

Lustron, the polystyrene plastic made by Monsanto Chemical Company is made by a series of reactions from two organic chemicals, benzene and ethylene. These are combined in the first step to form ethyl benzene. The ethyl benzene is then heated under pressure, This is called pyrolysis and removes hydrogen from the molecule, the result being styrene monomer, a clear water-white liquid.

Polystyrene is produced from styrene monomer by heating. Polymerization takes place. The individual molecules link together in long chains, converting the liquid to a hard, tough, transparent resin.

Polymerization may be explained by likening molecules to paper clips. Linking the clips together so as to form chains is "polymerization."

high heat and pressure, hydrogen is removed and the result is the clear, water-white liquid, *styrene monomer.*

All that is necessary in order to change this liquid into a hard, tough, transparent resin is to link the individual molecules of styrene together in long chains. This is done by heating. It changes styrene monomer into polystyrene and is called polymerization.

Coloured Lustron is made by working dyes or pigments into clear transparent Lustron on revolving heated rolls which thoroughly knead the plastic and disperse the colour. After rolling, the material is removed in rough, uneven sheets which are allowed to cool and harden. It is then ground into powder of the proper size. From this powder, endless articles can be formed into desired shape under heat and pressure in moulds.

SAFETY GLASS

Plastics have saved humanity countless injuries from flying glass and missiles. They are used in making "safety glass." Laminated safety glass, used as wind-shields and windows in automobiles, is a sheet of plastic between two sheets of glass. The three layers are sandwiched by heat and pressure so that the glass adheres firmly to the plastic. When broken by an impact, the fragments of glass remain attached to the plastic interlayer instead of flying. Before the adoption of safety glass by automobile makers, two out of every three persons injured in an automobile accident were cut by flying glass.

Thirty-odd years ago a French chemist, Edouard Benedictus, was moving some glassware around in his laboratory when a bottle accidentally slipped from his hand and fell to the floor from a considerable height. The glass was shattered and starred like a Bohemian crystal, but the bottle still held together. The bottle had contained a solution of nitrocellulose or collodion from which all the solvents had evaporated, thus lining the interior with a thin layer of nitrocellulose of great strength. So firmly were the fragments of glass held by this layer that not a single piece of any appreciable size became detached or even loosened.

Benedictus saved the bottle as a curiosity, but its significance did not occur to him until some time later when his attention was attracted to an automobile accident. Two young women were badly cut by broken glass in the collision. The next evening, with the aid of an old letter-press, Benedictus succeeded in sandwiching two sheets of glass together with a film of nitrocellulose.

While not the first to visualize safety glass, Benedictus was one of the early inventors in the field.

The first plastic used as the "sandwich" material in the commercial production of safety glass was cellulose nitrate in the form of a Celluloid sheet. It had serious defects: it became loose from the glass, and sunlight discoloured it. We are all familiar with the yellow and brown discolouration of the early safety-glass windshields after they had been in service a year or two.

Two methods of overcoming the objectionable discolouration have been found. One is to use a special glass having a high iron content to filter out the harmful rays in sunlight. The other is to use other plastics in place of cellulose nitrate.

Because cellulose acetate is not discoloured and decomposed by sunlight to the same degree as cellulose nitrate, it has almost completely replaced the nitrate.

SAFER SAFETY GLASS

Along with its good qualities the acetate has some deficiencies. The most important of these is a tendency to lose toughness and strength at low temperatures. Cellulose acetate is not as elastic at winter temperatures as it is in summer. This is equivalent to saying that safety glass made with it as the sandwich layer is not as safe in winter as in summer. High elasticity is desirable property in a plastic material to be used in making safety glass for a windshield. A blow from a man's head will be absorbed gradually if the glass is elastic.

Recently, cellulose acetate has in turn been largely displaced by vinyl plastics. One of these is Vinylite X, a thermoplastic, water-white resin which has its origin in ethylene. Vinylite X is more plastic than either of the cellulose plastics at all temperatures. Another plastic of this type is Butacite. Vinylite X and Butacite make safety glass safer.

CHAPTER XIV

Experiments with Household Chemicals

ACIDS AND ALKALIS

WE commonly speak of anything that has a sharp sour taste as being acid. We use the term quite correctly, for the word *acid* is derived from the Latin word for *sharp*. All acids have a sour taste. That is why rhubarb, lemons and many unripe fruits taste sour; they contain acids. The sour taste of an acid is an interesting but not very usable property.

Acids are one of the three most important classes of chemical compounds. Everybody with a good memory for high-school chemistry will recollect that five acids which the chemists uses frequently are sulphuric, nitric, hydrochloric, acetic and phosphoric acids.

Twelve million tons is a lot of anything. It happens to be the amount of sulphuric aicd which will be consumed in the United States this year. Sulphuric acid is used for so great a variety of purposes and in the preparation of so many compounds that it is called "The King of Chemicals." The industrial prosperity of a nation can be accurately judged by the amount of sulphuric acid it consumes.

There are many acids. Not all are liquids. Some are solids.

It is not an easy matter to define an acid so that a layman knows what an acid is from the chemist's viewpoint. It is simpler to enumerate some of their common characteristics. All acids contain hydrogen. This hydrogen is often replaceable by metals, and this process is used in one of the ways of making hydrogen. Iron was formerly much used with sulphuric acid in producing hydrogen for balloons. Not every metal has the power of replacing hydrogen in every acid.

The compound formed by the replacement of hydrogen in an acid by a metal is called a salt. The salts have names such as sulphates, chlorides, nitrates, acetates, phosphates, chromates, which indicate the acid they were made from. For example, copper sulphate is made by replacing the hydrogen in sulphuric acid by copper. Below is a list of several acids showing the names of the salts which they form.

Acid	*Name of Salt*
Sulphuric	Sulphate
Hydrochloric	Chloride
Nitric	Nitrate
Acetic	Acetate
Phosphoric	Phosphate
Chromic	Chromate
Citric	Citrate
Salicylic	Salicylate
Tartaric	Tartrate
Iodic	Iodate
Carbonic	Carbonate

All acids redden litmus and some other organic colouring matter. This fact is easily proved by an experiment with any of the acids to be found in the kitchen. The following might be called common "household acids": citric acid in lemon juice, acetic acid in vinegar, carbonic acid in soda water, lactic acid in sour milk and boric acid in the medicine cabinet used as an eye-wash.

TESTING FOR ACIDS WITH LITMUS

Dip a piece of blue litmus-paper in vinegar. It will change colour and become red. Vinegar is a dilute solution of acetic acid.

Dip a piece of blue litmus-paper in lemon juice. It will turn red. Lemon juice contains citric acid.

You can try the same experiment with boric acid if you wish. Dissolve a teaspoonful of boric acid in hot water and dip blue litmus-paper in. Again there will be a change in colour from blue to red.

Litmus is a complex vegetable structure extracted from lichens. It is used to dye absorbent paper which then becomes an "indicator" for testing for acids. Some of the common flowers and vegetables contain colouring matter which you can abstract and use as an indicator. Red cabbage is one of these.

MAKING AN INDICATOR FROM CABBAGE

Break up red cabbage leaves until you have almost enough to fill a glass tumbler. Put them in an enamelled saucepan and add a cup of water, boiling hot. Crush and stir the leaf fragments so as to extract the juice. Then let them soak in the water for several hours or until the water has become deep purple in colour.

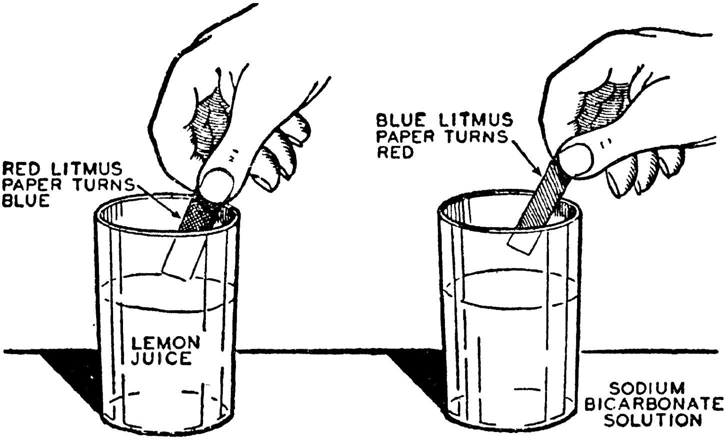
Pour some of the purple liquid into a test-tube and add a lump of sodium bicarbonate about the size of a pea. Shake the tube so as to dissolve the soda and the purple colour will change to green.

If you then slowly add some vinegar, the cabbage indicator will change its colour from green back to red.

The colouring matter of red cabbage is red in the presence of acids and green in the presence of chemicals having an alkaline reaction.

TESTING FOR AN ALKALINE REACTION WITH LITMUS

Dip a piece of blue litmus-paper in a solution prepared by dissolving two or three teaspoonfuls of sodium bicarbonate in a tumblerful of water. It will remain blue. Try a piece of red



TESTING WITH LITMUS AND AN EXPERIMENT IN NEUTRALIZATION

Lemon juice contains citric acid and will turn blue litmus paper red. A solution of sodium bicarbonate has an alkaline reaction and will turn red litmus paper blue. By mixing lemon juice and sodium bicarbonate solution in proper proportions, a neutral solution is formed. A neutral solution has neither an acid nor an alkaline reaction and will not change the colour of either red or blue litmus.

litmus-paper. It will turn blue. A solution of sodium bicarbonate has an alkaline reaction.

You will find this to be true also of household ammonia, milk of magnesia, lime-water and a solution of the cleaning compound called "Gold Dust" in water.

The action of these substances is exactly the reverse of that of an acid. Substances behaving like household ammonia in this respect are said to have an alkaline reaction.

If you mix the proper proportions of an acid with a compound having an alkaline reaction, both lose their characteristic properties. The result is a *neutral* solution, and the process is known as *neutralization.*

Often, in order to bring about the results he wishes, a chemist must cause a solution to be slightly acid, neutral or alkaline as the case may be. He brings about this condition by adding a small amount of the proper acid or alkaline chemical as may be necessary.

AN EXPERIMENT IN NEUTRALIZATION

Squeeze the juice of a lemon into a glass tumbler. Test the lemon juice with blue litmus-paper. It is acid and will turn red as expected.

Prepare a solution of sodium bicarbonate by stirring three or four teaspoonfuls into half a glass of water. This solution will turn red litmus paper blue.

Add three or four teaspoonfuls of the bicarbonate solution to the lemon juice. There will be considerable "fizzing" as the acid and the alkaline salt react and release carbon dioxide. As the fizzing slows down, add one drop of sodium bicarbonate solution at a time. Test the mixture frequently with both red and blue litmus-paper. If you are a careful experimenter, you can adjust the relative proportions of the lemon juice and sodium bicarbonate so that the mixture will not change either red or blue litmus-paper. The solution is then neutral.

The chemical processes which take place in the soil frequently produce acids. The acid condition will show plainly if the soil is mixed with water and tested with blue litmus-paper. An acid soil is unsuitable for certain crops. In order to neutralize it or give it a slightly alkaline reaction, farmers often scatter lime over the field after ploughing. The lime dissolves in the rain and forms lime-water. Lime-water has an alkaline reaction.

SOAPS

When fats or oils are boiled in a solution of an alkali, glycerine is set free, and there is also formed the extremely useful substance which we call soap.

The fats from slaughter-houses and vegetable oils such as olive oil, cocoanut oil, cottonseed oil and palm oil are used. Any of these, or a mixture, is boiled in a solution of sodium hydroxide in the manufacture of hard soaps. Potassium hydroxide is the alkali from which soft soaps are made.

Soap powder is finely ground soap mixed with washing soda (sodium carbonate). Floating soaps contain tiny bubbles of air which render them buoyant. Castile soap is made from olive oil. Laundry soap usually contains a little free alkali to help in removing grease.

Soap-making was once a household art. Now soap is seldom made at home but is made under a chemist's control in huge kettles, holding enough material to make from 150,000 to 1,000,000 pounds in a single batch.

Every year in the United States we consume 25 pounds of soap for every man, woman and child. That is more than is used anywhere else on this earth. If cleanliness can be measured by the use of soap, then we are the cleanest.

THE CLEANSING ACTION OF SOAP

Soapy water helps to remove dirt in three ways.

First, any dirt that is soluble dissolves in the water.

Second, the soap forms an *emulsion* with any grease that is present with the dirt, thus making it possible for the water to wash away both the grease and the dirt.

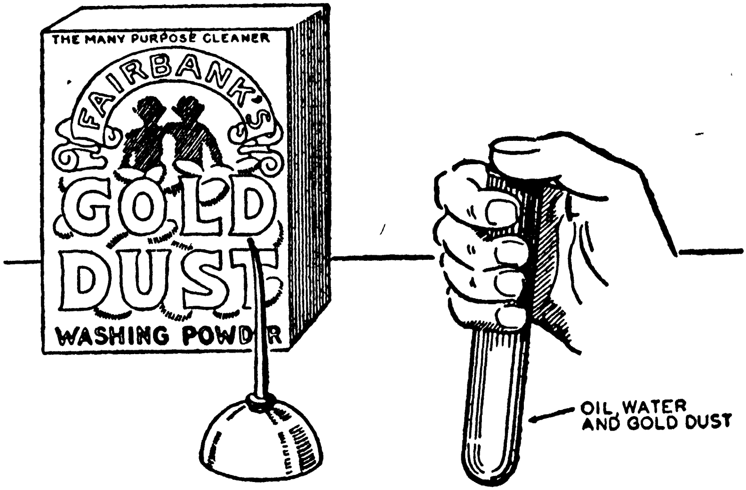
An emulsion is a mixture of two or more liquids which tend to separate slowly. Usually one of the liquids is an oily or fatty substance. A mixture of milk and cream is an emulsion. If you shake up a bottle of milk having a layer of cream at the top, the fatty cream is broken up into tiny globules and scattered through the milk.

AN EXPERIMENT IN MAKING AN EMULSION

Soap aids in making an emulsion.

Put a half-teaspoonful of automobile cylinder oil into a test-tube and add warm water until the tube is two-thirds full. Place your thumb over the open end of the tube and shake the water and oil together thoroughly. The oil will be broken up into small globules scattered throughout the water, but a few seconds after you stop shaking, it will rise to the top of the water. It is plain that oil and water do not mix.

Add half a teaspoonful of strong soap powder such as Gold Dust to the oil and water and shake for a minute or two. The soapy water forms an emulsion with the oil. The oil is broken up into very minute globules and considerable time will elapse before the globules merge and rise to the top of the soapy water.



DO OIL AND WATER MIX?

An old adage proclaims that oil and water do not mix. But they come mighty close to mixing when in the form of an emulsion. An emulsion is a liquid mixture in which oils, fats or resins are suspended in minute globules as butter in milk. The cleansing action of soapy water is partly due to the fact that it forms an emulsion with grease. Water and machine oil will not mix, but if you dissolve soap-powder in the water and shake well an emulsion will be formed. The oil will be broken up into minute globules suspended in the water.

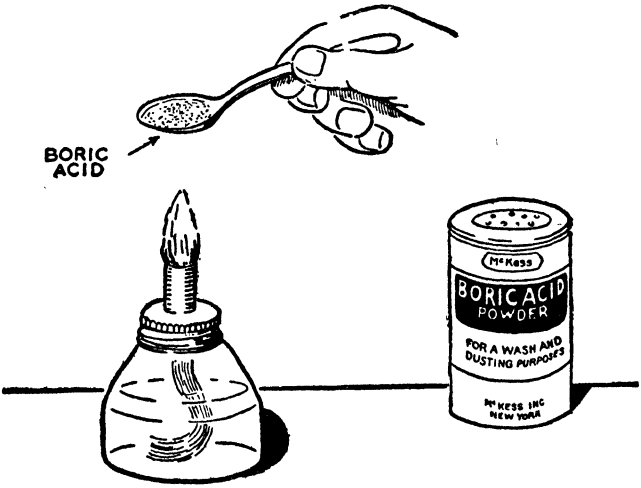
ABSORPTION AND ADSORPTION

Third, soapy water helps to remove dirt by *adsorption.* This word looks and sounds very much like absorption, but it has an entirely different meaning. To absorb dirt is to suck it up as through or into the pores. The dirt that dissolves in water is absorbed. But when soapy water *adsorbs* dirt, it picks it up and holds it on its surface. The particles of dirt are adsorbed on the surface of the soap bubbles and are thus removed. A good lather helps considerably in the cleansing action of soapy water.

WHY WASHING-SODA CRYSTALS CRUMBLE INTO POWDER

Under the name of *boracic acid*, the white powder or crystalline substance which the chemist calls boric acid is used in medicine. Its solution is a mild antiseptic which is especially valuable as an eyewash.

Many crystalline substances contain water which is not apparent at a glance. Boric acid is one of these substances. The water is called water of crystallization and is absorbed from the solution from which the crystals are formed.



AN EXPERIMENT WITH BORIC ACID

Dry, powdered boric acid, the kind you find in the medicine chest, consists of pulverized crystals. It contains hidden water called the *water of crystallization.* Heating in a spoon over a flame will reveal this. The dry powder melts in its own water. Then, as the water is converted into steam and escapes, the boric acid becomes hard, dry, anhydrous (without water) boric acid. Many chemical compounds contain unseen water of crystallization.

Heat some boric acid in an old teaspoon over a flame. The acid will melt first and dissolve in its own water of crystallization. As the heat is continued, the water will change to steam. The molten mass will become pasty and swell up as the steam escapes.

After the water has all been driven off, a clear viscous liquid will remain. This is *anhydrous* boric acid. Anhydrous means without water. Chemists call a compound which contains water of crystallization a *hydrate.*

Although the heat of a flame is necessary to drive the water of crystallization out of boric acid, there are compounds which lose their water of crystallization at ordinary room temperature. This is true of common washing-soda. When you open a package of washing-soda, you will find that this material consists of clear, nearly transparent crystals covered with white powder.

If you leave some of the crystals exposed to the air long enough they will change to powder. The crystals contain water of crystallization. The powder is washing-soda which has lost its water.

If crystals of washing-soda are placed in a test-tube and heated over a flame, the water can be driven out of them in a few minutes. They will first dissolve in their own water of crystallization. Then, if the heating process is continued until all the water is driven off, a white substance which crumbles into a powder will be all that remains.

Crystals which lose their water of crystallization at ordinary room temperature, as does washing-soda, are called "efflorescent."

WHY SALT BECOMES DAMP

Some substances have an action which is just the opposite of this. Instead of giving up the water in their crystals, they absorb water from the air. They are called "deliquescent." Calcium chloride is a common deliquescent substance. It has the property of taking up water from the atmosphere. For this reason it is sometimes sprinkled on country roads to prevent the formation of dust.

Calcium chloride is found in brine, and a small amount of it often contained in salt as a harmless impurity explains why table salt becomes damp and will not "shake" during humid weather.

A GREEN FLAME

Dissolve a small pinch of boric acid in some alcohol contained in a test-tube. Pour a few drops of this solution into an old saucer and light it. Ordinarily, alcohol produces a colourless flame, but this time it will be a beautiful green colour.

The green colour is due to the element boron contained in the boric acid. Sodium colours flame yellow, zinc produces green, and strontium makes a flame red. It is the presence of certain elements in fireworks that makes their colours.

CHAPTER XV

The Building Materials of the Molecule Makers

ABOUT ninety simple substances are the raw materials out of which our world is built. There may be a few more. From these, the chemical elements, Nature has constructed all her varied forms. From these also, the molecule makers build their sulphanilamides, plastics, steels, cola drinks and chewing gums.

A few of the elements—gold, silver, copper, iron, lead, tin, mercury, sulphur and carbon, nine in all—have been known and used since the dawn of history. The rest have been discovered one by one through the ages. The material blessings of the twentieth century have resulted largely from our ever-increasing knowledge of these primeval building materials.

The rich and powerful Roman patrician in a palace of marble, alabaster and porphyry was circumscribed within narrow bounds by lack of chemical knowledge. Dyes were few and costly; anaesthetics were unknown; strong metals were missing; he could not get a safe drink of water. Water that came to him from mountain springs and lakes over miraculous aqueducts was a menace to his health, for he had never heard of the greenish gas chlorine that kills bacteria. If wounded by accident or in battle, he knew of no iodine or other antiseptic to apply. He could not see after sundown without a smoking flame for he did not know of tungsten and that it could be made to glow in the park.

Of course, the ancient conception of an element was quite different from the modern one. Earth, air, water and fire were supposed to be the four simple substances of the universe. We know differently. Fire consists of the glowing embers or incandescent gases of a burning fuel. Water can be decomposed into the two gaseous elements, hydrogen and oxygen; air consists of a number of elements, oxygen, nitrogen, neon, argon, carbon (carbon dioxide), helium, krypton, xenon and hydrogen. Earth is a complex mixture of elements. We find in it calcium, oxygen, silicon, iron, sulphur, silver, phosphorus, sodium, potassium, lithium, copper, etc., in fact, all the elements except a few gases. The elements found in earth vary according to the locality from which it is taken.

The ancient peoples failed to recognize a single element as an element. They were unable to draw any line distinctions. For example, they were acquainted with lead, tin and bismuth, but believed they were all different kinds of lead.

The elements which we know have been discovered, one by one, through the ages, by patient workers in many lands. At the present time, ninety-two have been recognized and named. Two-thirds of these have been discovered during the last 150 years. Chemists believe there are a few others still remaining to be identified. The list which we have is probably not permanent. Some of the rare metals which we think are elements may some day be proved to be compounds.

But since our interest is in practical chemistry, you and I can consider that there are ninety-two elements. Since they are elements, they are a heterogeneous lot. We find among them many gases, one liquid, many metals as different from one another as day is different from night; some are asleep, some are violently active. Here is a description of each of these materials of which you and I, the neighbours, our Lares and Penates, the sidewalk, stars and atmosphere are made. Following the name of each element is the date when it was discovered. Some of these dates are approximate. Those without dates were known to the ancients.

ACTINIUM, 1900

This is an extremely rare radioactive earth discovered in pitchblende by a young chemist in the Curie laboratory named Andrè Debierne. Actinium preparations give off the same rays as radium, but the emanations diminish rapidly. It induces activity in surrounding objects. All efforts to isolate pure actinium from the rare earths with which it is found in mixture have failed.

ALABAMINE, 1931

This is another extremely rare element. A great deal of careful research must be done before much is known about the chemical and physical properties of alabamine.

ALUMINIUM, 1827

Aluminium is the most abundant metal on the earth's surface and one of the most useful ones. It is silvery white in colour and is the lightest of the ordinary metals.

Eight per cent. of the earth's crust is composed of aluminium. It occurs in all common rocks and clays. The metal is obtained chiefly from the mineral bauxite. Pure aluminium oxide obtained from bauxite is dissolved in fused cryolite, and a direct current of electricity sent through it. The pasasge of the electric current results in the production of metallic aluminium.

The aluminium used in casting automobile and vacuum-cleaner parts is an alloy. It contains about 8 per cent. copper and a small amount of zinc. Aluminium is also alloyed with brass, bronze, magnesium, manganese, silicon, zinc and steel to make metals having special properties.

The automobile and aircraft industries are the largest single market for aluminium. When used for such construction, aluminium is more serviceable if it is mixed with other metals. Duralumin used in aircraft is a mixture of aluminium, magnesium and copper.

Aluminium is also used as a foil, replacing tin-foil for wrapping food, candy and other products. In powder form it is used in paint and fireworks.

Its lightness and freedom from tarnish make aluminium an ideal material for pots and pans.

All forms of pottery are made from clay which is an impure aluminium silicate. Various aluminium compounds are used in dyeing and for the purification of water. One of the ingredients of baking-powders is an aluminium compound (sodium aluminium sulphate). Portland cement is prepared by roasting a mixture of limestone and clay. The exact chemical composition of cement is not known, but it is believed to be a complex calcium aluminium silicate.

ANTIMONY

Antimony was known to the ancients but probably only in the form of its sulphide. It is a very brittle, bluish-white metal useful in making alloys, wall-paper, fabrics, paper and paints. Antimony imparts hardness and a smooth surface to soft-metal alloys. Common type metal is composed of 9 parts lead to 1 part antimony. The chief antimony ore is stibnite, found in China, Hungary and Japan.

ARGON, 1894

Argon is a gas which occurs free in the atmosphere to the extent of .96 per cent. by volume. It forms no known compounds. It is used in electric-light bulbs to prevent the vaporization or decomposition of the tungsten filament.

ARSENIC

No one knows who first isolated this poisonous metal. It is soft, steel-grey in colour and brittle. The addition of a small amount of arsenic to the lead used in making shot and to bearing metals hardens them. The poisonous nature of all arsenic compounds renders it useful in making insecticides. It is an ingredient of the valuable medicine known as salvarsan.

BARIUM, 1808

Barium is a silvery-white metallic element of the alkaline earth group obtained by electrolysis. It oxidizes on contact with air and decomposes water at ordinary temperatures. The metal itself is of little importance, but its compounds are very useful. Barium chloride has a number of industrial uses. Among other things it is used for making boiler compounds and heat-treating baths for steel.

Barium nitrate gives a beautiful pale-green flame in burning and is used for green signals, flares and fireworks, It is also used as a source of oxygen. Fourth of July "sparklers," for example, are composed of aluminium powder, iron filings and barium nitrate as a source of oxygen.

Blanc Fixe and Permanent White are trade names for a finely ground compound containing barium sulphate, which is used as a pigment in paints and enamels and as a filler in rubber and paper.

One of the barium compounds, mixed with buttermilk, is used in making X-ray pictures of the stomach and intestines. The mixture is opaque to X-rays and when fed to a patient casts a silhouette of the gastro-intestinal tract on the X-ray film.

BERYLLIUM, 1798

Beryllium is the lightest of all rigid metals. It is hard, brittle and crystalline. It cannot be used by itself, but alloyed with many other metals such as aluminium, iron, copper and silver, it produces metals of great lightness, hardness and resistance to corrosion. Beryllium alloys are used in cameras, scientific instruments and aeroplanes.

BISMUTH, 1753

Bismuth is a lustrous, brittle metal with a rather low melting point. It occurs in small quantities in Canada, England and Sweden. In America, bismuth is obtained as a by-product of refining lead and copper.

Bismuth compounds are used in medicine.

The chief use of the metal is in making alloys. It is valuable in type-metal alloys, where its presence aids in filling the mould and making an accurate impression. Bismuth lowers the melting point of alloys and finds use in fusible plugs for fire-sprinklers and safety plugs for preventing boiler explosions.

BORON, 1808

Boron is one of the non-metallic elements. It resembles carbon and silicon in its chemical properties. Boron is never found in nature in the pure state. When prepared in the laboratory in pure form it consists of hard red crystals or of a brownish-black powder.

The best known compounds of boron are boric acid used in medicine, and borax, used as a cleaning compound and in soldering and welding.

BROMINE, 1826

Bromine is a dark reddish-brown liquid which gives off very irritating fumes and whose name came from a Greek word meaning *stench.*

Bromine is never found free in nature. It occurs in a variety of compounds. Vast beds of magnesium bromide are located in Germany. Ocean water contains considerable quantities of bromine compounds. The American supply comes from salt wells and from a large plant erected at Cape Fear, North Carolina, where over 100,000 tons of sea water are treated every day to produce 7½ tons of bromine.

An important use for bromine is in making tetraethyl lead, a constituent of the ethyl fluid used in gasoline-engine fuel. Bromine is also used in the manufacture of medicines, photographic chemicals and dyes.

CADMIUM, 1817

Cadmium is a silvery-white, crystalline metal whose colour resembles tin. When bent it gives a peculiar crackling sound called a "cry."

Cadmium sulphide is a brilliant yellow colour used as a pigment for either oil or water paints.

The metal is coming into extensive use in alloys. Cadmium bronze is a copper-cadmium alloy containing a small percentage of cadmium, used for trolley wire because it is strong and has high resistance to wear. Solders composed of lead and cadmium have the same uses as tin-lead solders. They are hard. They have low melting points and they cost less than tin solders.

During the past few years cadmium has come into extensive use in electroplating steel tools, screws, bolts, nuts and machine parts where resistance to rust and corrosion is desired. A coating of cadmium is more resistant to corrosion than a coating of tin or zinc. A cadmium plating .0003 is equal in effect to a zinc coating *thirty times* as thick.

CALCIUM, 1808

Next to aluminium and iron, calcium is the most abundant metal, but it has only a very limited commercial use as a free element. However, its compounds are of vast importance. They include such valuable substances as lime, limestone, limewater, marble, chalk, plaster of Paris, Portland cement, calcium phosphate, calcium chloride, bleaching powder and gypsum.

Calcium phosphate, when treated with sulphuric acid to form *superphosphate of lime* is one of our most valuable fertilizers. Calcium chloride absorbs moisture from the air and is employed widely to settle the dust on dirt roads and to attract moisture to the surface of freshly laid concrete.

Calcium is a necessary ingredient in plant and animal food. Bones and teeth both contain a high percentage of calcium.

CARBON

Carbon falls far from the top in order of abundance among the elements, but it is first in importance. In the free state, carbon is found in coal, in graphite and in the diamond. In the form of compounds it is in all animal and vegetable matter such as bone, protein, starch, sugar, fats, oils and cellulose. It is found in petroleum, in all carbonate rocks such as limestone and marble and in the carbon dioxide of the air. It is the chemist's most useful raw material.

CERIUM, 1803

Cerium is an iron-grey metal only slightly harder than lead; it belongs to the rare-earth group. Cerium compounds are used in dyes and for colouring glass.

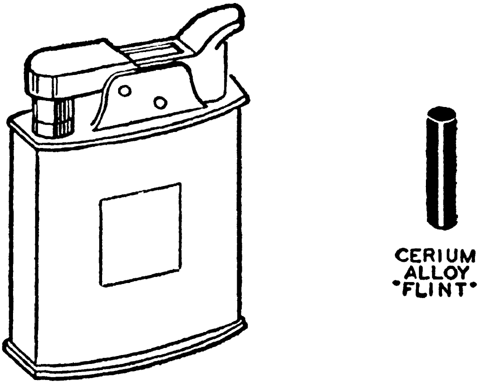
An alloy consisting of 50 per cent. cerium and the rest lanthanum and didymium is used in cigarette and gas-lighters. This is called Misch metal. When Misch metal is alloyed with iron it is Auer metal, named after Auer von Welsbach, the inventor of the incandescent gas-mantle. When Auer metal is struck with steel a shower of sparks is produced. The "flints" in cigarette and gas-lighters are not flint. They are Auer metal.

CESIUM, 1860

Each one of the elements, when heated in a flame, affects differently the colour of the light given by the flame. These effects cannot always be seen with the unaided eye. They are revealed with an instrument called a spectroscope. Each element produces a different set of lines in the spectroscope. Soon after the invention of the spectroscope the instrument was applied to the examination of many substances and as a consequence cesium was discovered. The new element produced blue lines in the spectrum and it was given the name cesium from *caesius*, the word which the Romans used to designate the blue of the sky.

Cesium is a soft, silvery-white metal which oxidizes easily in air and decomposes water. It must be kept in a vacuum. It is rare and costly and no practical use has been found for the metal itself.

Cesium chloride is used in the filaments of radio-tubes and as a light-sensitive coating in photo-electric cells or "electric eyes." The presence of cesium in the filaments of detector and amplifier tubes increases their sensitivity and their life.



THE "FLINTS" IN A CIGARETTE LIGHTER

The "flints" in cigarette and gas-lighters which produce a shower of sparks when rubbed with a rough steel surface are not flint. They are an alloy of iron, cerium, lanthanum and didymium.

CHLORINE

Chlorine is a greenish-yellow, suffocating, corrosive gas which is far too active to exist free in nature. It is found principally as sodium and magnesium chloride in the ocean, salt-beds, salt wells and salt lakes.

Liquid chlorine, prepared commercially by passing an electric current through a salt solution, is an invaluable disinfectant for purifying drinking water.

Hydrochloric acid, the most important chlorine compound made by man, finds extensive use in the chemical industry. Among other things it is used in preparing glucose, various chlorides, glue, gelatine and dyes.

Ordinary salt is a chlorine compound. Its multitudinous uses are described elsewhere in this book.

CHROMIUM, 1798

Chromium occurs in nature only in combination with other elements. Its principal ore is chromite. Metallic chromium is obtained from the ore by reduction and electrolysis. It is a hard, silvery-white metal with a blue tinge, and water does not cling to it. Objects such as automobile head-lights and radiator grilles plated with chromium present a brilliant surface which is much more resistant to corrosion than nickel plating.

The properties of steel are altered to a considerable degree by adding chromium. Chrome steel containing about 3 per cent. of chromium is very hard and resists corrosion. It is used for making ball-bearings, roller-bearings, files and armour plate. Stainless steel contains up to 18 per cent. nickel. It is sold under such trade names as Allegheny metal, Defistain and Duraloy.

Compounds of chromium are used in tanning leather, in dyeing and as a source of colour for paints and enamels.

COBALT, 1735

Cobalt is a white metal with a blue tinge, whose chief use is for alloying with steels, giving great hardness and tenacity. It is an ingredient of the super high-speed steels which retain their cutting edge while red hot. Cobalt oxide is used to colour glass blue and to make blue glaze for pottery.

COLUMBIUM, 1801

Columbium is sometimes used in jewellery and for making watch-cases. Until recently the stock of columbium consisted of museum samples. Now it is obtained in fairly large quantities from an African ore called columbite, which is refined and used for treating stainless steels.

When stainless steels are subjected to heat they become susceptible to corrosive chemicals. By adding a small amount of columbium to the steels they retain their resistance to corrosion when heated.

COPPER

Next to iron, copper is our most useful metal. Alloyed with zinc it forms brass and with tin it forms bronze. Copper was the first metal which primitive man learned to use for making tools and weapons. Next to gold it is the most malleable and ductile of the common metals. Only silver surpasses it as a conductor of electricity. Telephone and telegraph messages and electric power come to us over copper wires. Hundreds of thousands of tons are produced annually for the manufacture of all types of electrical apparatus. Copper is also widely used for tanks, nails, rivets, pipes, gutters and roofing.

Copper compounds are used in dyeing, in purifying water and as fungicides to kill tiny parisitic growths which live on plants.

DYSPROSIUM, 1886

This is a metallic element belonging to the rare-earth group. The salts of this element possess the highest magnetic susceptibility of all salts.

ERBIUM, 1843

Erbium is an extremely rare metallic element which has not yet been isolated. Most erbium salts are rose-coloured. Oxide of erbium glows with a bright green light when heated. It is thought that, when isolated, erbium will prove similar to aluminium.

EUROPIUM, 1901

This is an exceedingly rare metallic element found in small quantity in monazite sand.

FLUORINE, 1771

Fluorine is a poisonous pale-yellow gas. It is the most active of all the elements; it combines vigorously with most of the others, forming fluorides. It occurs abundantly in the earth as calcium fluoride or fluorspar and as cryolite.

The production of aluminum from bauxite by electricity requires cryolite.

Hydrofluoric acid, a compound of fluorine and hydrogen dissolved in water, is the only acid that readily dissolves glass and so is used to etch glass. The glass is coated with a layer of wax and the design is scratched through the wax with a sharp pointed instrument. The prepared surface is treated with the hydrofluoric acid. The wax is then removed, leaving the design etched in the glass. The inside surface of electric light bulbs is "frosted" by etching with hydrofluoric acid.

GADOLINIUM, 1880

This is extremely rare.

GALLIUM, 1875

This metal has not been obtained in appreciable quantities. It is said to stick to glass when heated.

GERMANIUM, 1886

This extremely rare metal was first discovered in silver ore and has no chemical or commercial importance. It crystallizes in octahedra, has a metallic lustre and is of a greyish-white colour.

GOLD

Gold is bright yellow in colour, heavy, soft and the most malleable of metals. It is inert to air and to all common acids. It is so chemically inactive that it is largely found in the native state in the form of nuggets or dust and in gold-bearing quartz. It is employed chiefly for coinage, ornaments, jewellery and for gilding. On account of its softness, gold is almost always alloyed with other metals, usually copper, silver or nickel to give it the necessary hardness.

HAFNIUM, 1923

This metal is far more abundant than gold but has as yet no commercial application or chemical importance.

HELIUM, 1895

Helium is a colourless, odourless, non-inflammable gas. It is the lightest gas, next to hydrogen. Because of this and its non-inflammable quality, it is used for filling balloons and dirigibles. It is also employed in radio tubes and electric lamps. There is a small percentage of helium in the atmosphere. It is extracted on a commercial scale from certain natural gases.

HOLMIUM, 1879

Rare.

HYDROGEN

Hydrogen is a colourless, highly inflammable gas which holds the distinction of being the lightest of all elements. It occurs on the earth in the free state only in minute quantities. In the combined state, however, it exists in great abundance. Water, all acids, petroleum products such as gasoline and kerosene, animal and vegetable substances such as sugars, starch, butter and proteins, contain hydrogen.

Hydrogen is secured easily by the electrolysis of water. It is used for producing the oxy-hydrogen flame for welding, to provide a non-oxidizing atmosphere for heat-treating steels, and for converting cocoanut oil, fish-oil and low-grade coal into highly valuable products. Crisco, for example, is hydrogenated cottonseed oil.

Hydrogen is an essential constituent of all the gaseous and liquid fuels. It occurs in natural gas, is one of the elements in household ammonia and all the various hydroxides.

ILLINIUM, 1926

Rare.

INDIUM, 1863

This rare, white, silver-like metal has as yet no industrial applications. It is not easily oxidized and may become a useful plating metal.

IODINE, 1811

Pure iodine is a crystalline, steel-grey solid which quickly turns to a purplish-black colour when exposed to air. It occurs in sea-water, seaweed, salt deposits and in Chili saltpetre. Iodine is necessary to the health of human beings; a deficiency of iodine results in goitre and cretinism.

The principal commercial use of iodine is in preparing the valuable antiseptic called tincture of iodine (a solution of iodine in alcohol).

Various compounds of iodine are employed in medicine, photography and dyeing.

IRIDIUM, 1804

Iridium is a costly greyish-white metal of extreme hardness. It is insoluble in all acids. It is alloyed with platinum to make electrical contact points, chemical laboratory ware, standard weights and fountain-pen points.

IRON

Iron ranks fourth in abundance among the elements and is the most valuable metal known to man: Steel is a form of iron. Almost every type of industrial activity is dependent upon iron and steel.

The various compounds of iron find widespread use. The red colouring matter in blood is an iron compound. Ink, rouge and the light-sensitive surface of blue-print paper are compounds of iron.

KRYPTON, 1898

Krypton is one of the completely inert gases found in minute quantities in the atmosphere. It has no chemical properties and is of little practical importance.

LANTHANUM, 1839

Lanthanum is a rare metal resembling the element cerium in general properties. It is a white metal which oxidizes rapidly on exposure to air and decomposes water. The name is from a Greek word meaning "concealed." Neither lanthanum nor its salts are of any industrial importance.

LEAD

Lead is the heaviest of the common metals. It is soft and bluish-grey in colour. Its principal use is in making storage-batteries and pigments for paints. Lead alloys easily with tin and other metals and forms many commercial alloys, including type metal, solders and bearing metals. It is used for lining tanks, for sheathing electric wires and cables and for pipes and roofing.

White lead is a basic carbonate of lead used as a pigment in paint. Lead oxides are the active material in the plates of the common storage-battery. The paint pigment generally known as chrome yellow is lead chromate (lead, chromium and oxygen). Lead and its compounds are highly poisonous.

LITHIUM, 1817

Lithium is the lightest of the metallic elements. It is unstable chemically and is of no use as a metal except when alloyed with other metals. The addition of a very small amount of lithium improves iron and copper used for casting. Lithium also hardens aluminum alloys. The metal is also used in making photo-electric cells.

Lithium chloride burns with a crimson flame and is used in fireworks.

LUTECIUM, 1907

This is a rare metallic element of the rare earth group. It has no known uses.

MAGNESIUM, 1808

This light-weight, silvery-white metal is easily tarnished by moist air and burns with a brilliant white light. It is used in making flash-light powders, fireworks and light alloys such as Magnalium and Duralumin.

Magnesium hydroxide is the common "milk of magnesia." Magnesium sulphate (Epsom salts) and magnesium citrate are used in medicine.

MANGANESE, 1774

Manganese is a hard steel-like metal of silvery-white colour with purplish shades. It is used in the steel industry as a hardener and deoxidizer. Nearly all steels contain manganese. It makes excellent alloys. Manganese bronze is used for propeller blades, stuffing boxes and shafts requiring strength, toughness and resistance to the action of sea-water. An alloy of copper, nickel and manganese called manganin is used in electrical work.

An important compound of manganese is manganese dioxide (manganese and oxygen) used in dry cells. Potassium permanganate, a compound of manganese, potassium and oxygen, is used extensively in chemical laboratories as an oxidizing agent.

MASURIUM, 1924

Rare.

MERCURY

Mercury, also called quicksilver, is the only metal that is liquid at ordinary temperatures. Mercury is used for coating mirrors, as an expansive material in thermometers, for separating gold and silver from their ore and in alloys with other metals. The alloys of mercury are called *amalgams*. Silver amalgam is employed in dentistry as a filling for cavities in teeth.

Mercury fulminate, a compound of mercury, carbon, nitrogen and oxygen is used as a detonator to fire high explosives. Mercuric chloride is a poisonous compound used as an antiseptic. Mercurous chloride is non-poisonous and is used for medical purposes.

MOLYBDENUM, 1781

This is a silvery-white metal used as an alloying element in steels and special metals, for grids in radio-tubes and windings in electric furnaces.

NEODYMIUM, 1885

Its properties are much like those of the element cerium.

NEON, 1898

This is one of the gases which occur in minute quantities in the atmosphere. It is chemically inert and does not form any compounds. Neon glows with an orange-red light under the influence of an electric current and is used in advertising signs and aviation beacons. It will give fluctuations in light from total darkness to full brilliancy as many as 100,000 times a second. This property makes it useful for stroboscope lamps. Neon is also used in voltage-regulating tubes for radio apparatus and in starting devices for fluorescent lamps.

NICKEL, 1754

Nickel is a hard, silvery-white metal which is extensively used for protecting other metals. Nickel plating is carried out by an electrolytic process.

Nickel is of great importance in industry because of its many useful alloys. Mixed with gold it forms "white gold." With copper and zinc it forms nickel silver and "German silver" used for tableware and plumbing fixtures.

Alloys of nickel and chromium are employed as the heat-producing elements in electric flat-irons, toasters and other electrical heating apparatus. A small amount of nickel added to cast-iron improves the iron and increases its strength. Nickel added to steel increases the strength, hardness and toughness of steel. The nickel steels are used for automobile parts, armour plate, heavy-duty gears, rails and locomotive parts.

NITROGEN, 1772

Nitrogen is the most abundant constituent of air. It has the highly important function of diluting the oxygen present so that all forms of oxidation including burning and decay are slowed down considerably.

Nitrogen is needed for plant growth. It is a partner of hydrogen in forming ammonia and ammonia compounds. Nitrogen is present in beans, clover, peas, meat and eggs. It is one of the components of nitric acid and the many nitrates and nitrites. It enters into the manufacture of fertilizers, drugs, dyes, explosives, anaesthetics and photographic chemicals.

Ammonium chloride, used in making dry cells, is a nitrogen compound. So are nitroglycerine, dynamite and T.N.T.

Nitrogen is used to fill electric-light bulbs in order to permit the filament to attain a higher temperature and give more light without disintegrating than would be possible in a completely evacuated bulb.

OSMIUM, 1804

Osmium is the heaviest known metal and has the highest melting point. Its principal use is with iridium as a hard-wearing and corrosion-resistant alloy for tipping gold fountain pens.

OXYGEN, 1774

Oxygen is the most abundant element, and to man it is the most important. He breathes it, cooks with it, burns it for warmth and for generating power.

About one-fifth of air by volume is oxygen. Combined with other elements, oxygen is found in tens of thousands of compounds. Enormous quantities are locked up in water, animal and vegetable substances, sand, clay and hundreds of rocks and minerals. Starch, sugar, fat, protein, cellulose—many of the chemicals the chemist employs—are oxygen compounds.

PALLADIUM, 1803

Palladium resembles platinum but has a more beautiful lustre. It is highly resistant to corrosion and to the action of acids. Palladium is frequently alloyed with gold to produce some grades of white gold.

It alloys with platinum. The result is a hard alloy which is easily workable and consequently employed in jewellery and instrument making.

PHOSPHORUS, 1669

Phosphorus is an exceedingly poisonous, light-yellow, wax-like solid. It can be changed into a non-poisonous, reddish-brown powder. Both forms ignite easily in the air. The yellow form is phosphorescent in the dark.

Phosphorus is used in the manufacture of matches, in alloys and in fertilizers.

Phosphorus is widely diffused in nature. It is found in the phosphate rocks, in animal bones, in fish and in soil. Men and animals eat lime and phosphates in order to have the mineral materials for their teeth and bones. It is obtained commercially from phosphate rock.

Phosphorus is highly important in the metallurgical industry because it will deoxidize non-ferrous metals. Phosphor bronze is a bronze which has been deoxidized by adding phosphorus to the molten metal. It is hard, has high tensile strength and is valued as a material for springs, gears, machine bearings and worm wheels.

Superphosphate is a compound containing phosphorus, calcium, hydrogen and oxygen. It is an excellent fertilizer. Trisodium phosphate is a phosphorus compound highly useful for cleaning and as a water-softener and boiler water compound. Monocalcium phosphate is used in considerable quantities as an ingredient of baking-powders.

PLATINUM, 1741

Platinum is a heavy, whitish-grey metal which surpasses gold in value. It is also heavier than gold. It is ductile and malleable, too soft for use alone, and so is almost always alloyed with harder metals such as iridium and osmium. Platinum is inert to most chemicals and has a very high melting point. Consequently, it is used in making crucibles, wires, electrical contact points and other articles used in a chemical laboratory.

In spongy form it is used as a catalytic agent in the manufacture of sulphuric and nitric acid.

POLONIUM, 1898

Polonium is a radioactive element which gives off alpha rays. It loses its radioactivity slowly. No sample of polonium has been obtained that is free or even approximately free of bismuth.

POTASSIUM, 1807

Potassium is a soft, silver-white metal which oxidizes so rapidly in the air that it must be kept in ether or kerosene.

The metal has no commercial applications, but its compounds are extremely useful.

Potassium is essential to plant life and many fertilizers contain it. Common potassium compounds are: potassium nitrate, also known as saltpetre, used as fertilizer, as a meat preservative and in the manufacture of fireworks and gunpowder; potassium chlorate, used in the manufacture of fireworks, matches and explosives; potassium hydroxide, used in making liquid soaps; potassium chloride, used as a fertilizer and in the preparation of other potassium compounds.

PRASEODYMIUM, 1885

Rare.

PROTOACTINIUM, 1917

Rare.

RADIUM, 1898

Radium is the most expensive substance in the world. The most striking fact about this element is that it and its compounds undergo a constant disintegration accompanied by the evolution of three kinds of rays. These rays are used in therapeutic medicine for the treatment of cancer and other diseases.

The rays from radium render certain substances luminous. Minute traces of radium are therefore employed in luminous paints for the hands, pointers and faces of watches and instruments, electric push-buttons and luminous signs.

Radium resembles calcium and barium in its chemical properties. When the name radium is used in referring to the radium employed in medicine it generally means radium bromide.

RADON, 1900

Radon is a gaseous element produced by the disintegration of radium. It is the heaviest of the inert gases. It is unable to form chemical compounds with other elements and therefore may be said to have no chemical properties whatever.

RHENIUM, 1924

Rare.

RHODIUM, 1803

Rhodium is a very hard, white, brittle, rare metal with a high melting point. It alloys with platinum. Rhodium-platinum alloys are used to make the nibs of fountain pens, resistance windings in high-temperature furnaces, chemical apparatus and thermocouples for measuring high temperature.

RUBIDIUM, 1861

Rubidium is a silvery-white metal which takes fire easily in air and, like potassium and sodium, decomposes water. It is found principally in the mineral lepidolite and can be obtained by electrolysis. Tea, coffee, tobacco and certain other plants contain rubidium.

The rarity and instability of this element have limited its use in industry. Rubidium is photo-sensitive and its chief use is for coating photo-electric cells. It is preferred to cesium for this purpose.

RUTHENIUM, 1844

Ruthenium is a hard metal and greylike iron in colour. It further resembles iron in uniting easily with oxygen. Ruthenium has a melting point above 4,400° F. and is used as a hardener in platinum alloys.

SAMARIUM, 1879

This is one of the rare elements belonging to the aluminium family of metals.

SCANDIUM, 1879

This rare metal belongs to the same group as samarium. It forms an oxide and a number of salts.

SELENIUM, 1818

Selenium belongs to the same family of elements as sulphur and tellurium. It assumes two forms, a red amorphous powder and a lead-grey, semi-metallic solid. It changes its resistance when exposed to light and is used in some types of "electric eye."

Most of the commercial selenium is employed in the glass industry. A tiny amount gives the bright-red colour used in automobile tail-lights. It is also used in the manufacture of rubber to speed the vulcanization process and increase the resistance to abrasion.

SILICON, 1823

Next to oxygen, silicon is the most plentiful element. Sand is an oxide of silicon, and this oxide and its compounds are components of many rocks. Pure silicon assumes three different forms. It may be a brown-coloured powder, black needle-like crystals, a dark, steel-grey crystalline mass.

Mica, clay, granite, porphyry, lava, pumice stone and sandstone are common natural compounds of silicon.

The artificial abrasive called Carborundum is silicon carbide. Water-glass used for preserving eggs, for fireproofing and as an adhesive in the manufacture of paper cartons, is a silicon compound (sodium silicate).

All grades of steel contain some silicon. It is used in iron, steel and other metals to give hardness and other characteristics. Silicon-steel sheets are used in the construction of electric motors and transformers. When silicon is alloyed with aluminium it increases the fluidity of the molten metal in pouring castings, decreases the shrinkage and makes sounder castings. A bronze containing silicon possesses great strength and resistance to corrosion.

SILVER

This soft, white, lustrous element is the most common of the precious metals. It is used in coins and jewellery and for plating reflectors and silver-plated ware. Coin silver is an alloy of 90 per cent. silver and 10 per cent. copper—the latter used to harden the silver. An amalgam of silver and mercury is used to fill cavities in teeth.

Because it is used to prepare many other silver compounds, silver nitrate is the most important silver compound. Its solution is used to cauterize wounds.

Silver chloride, silver bromide and silver iodide are all sensitive to light and decomposed by its action. They make photography possible, and each year enormous quantities, particularly of the bromide, are used in photography.

SODIUM, 1807

When pure, sodium is a silvery-white, wax-like metal which oxidizes so rapidly that it must be kept under oil or in air-tight containers. Sodium is lighter than water and floats on its surface. It reacts with water vigorously. Pure sodium has only limited uses. It is an excellent conductor of heat and is used in the valve stems of aeroplane engines to aid in conducting the heat away from the valve heads. It is used in the manufacture of sodium cyanide, a compound which can extract gold from its ores, and of sodium peroxide, a useful oxidizing agent employed in many processes. Sodium also acts as a catalytic agent in making synthetic rubber and as a reducing agent in the production of certain dyes and drugs.

Salt is a sodium compound, being composed of sodium and chlorine, and is one of the most abundant and valuable compounds known to man. Sodium carbonate or soda "ash" is the most important industrial alkali. It is used for softening water, in cleaning compounds and in the manufacture of glass. Other uses for soda ash are found in the wood-pulp industry, with lime as a flux in melting iron, in soaps and for refining oils.

Sodium bicarbonate or baking soda is a familiar sodium compound, also used in medicine. Sodium hydroxide, known commonly as caustic soda and lye, has a wide variety of commercial uses. Most of this alkali is used in the manufacture of hard soap. Some is used in the manufacture of paper, synthetic textiles and gasoline.

Sodium nitrate, known as Chile saltpetre, is used in large quantities in the manufacture of nitric acid, fertilizer and potassium nitrate.

There are many more chemist-made compounds of sodium which are very useful.

STRONTIUM, 1808

Strontium is a pale-yellow metal which has no commercial uses as a metal. Strontium nitrate gives a bright red flame and is used in fireworks, signal stars and railway signal flares.

SULPHUR

Ordinary sulphur is a pale-yellow, brittle, crystalline solid. It is widely distributed over the earth in both the free and the uncombined state. Many of the metallic ores are sulphides (compound of a metal and sulphur). A veritable mountain (nearly 2,000,000 tons) of sulphur is consumed each year in the United States alone.

A large portion goes into the manufacture of sulphuric acid, the most useful of all acids. Nearly every important industry depends upon sulphuric acid. It is sometimes called the "King of Chemicals."

Sulphur has many uses in making sulphur compounds. It is used for making fireworks, matches, dyes, medicines, explosives, and carbon disulphide, and in vulcanizing rubber and bleaching cloth.

SUPER-URANIUM, 1934

Rare.

TANTALUM, 1802

Tantalum is an extremely hard, white, lustrous metal resembling platinum. It is resistant to all acids except hydrofluoric and has found extensive use in making a large variety of chemical apparatus, surgical instruments and tools.

TELLURIUM, 1782

The name tellurium came from the Latin word *tellus*, meaning the earth. Tellurium is a rare metal, obtained in the form of a dark grey or black powder by the reduction of tellurium oxide. It has no commercial applications.

TERBIUM, 1843

Terbium is one of the rare-earth group of elements.

THALLIUM, 1861

Thallium is a soft, heavy, metallic element which resembles lead. It occurs in copper, iron and zinc ores, and the chief source is the flue-dust of smelters of these minerals.

Thallium forms alloys with many other metals. An alloy of lead and thallium is extremely resistant to corrosion and is sometimes used for plating parts of chemical machinery. It is also used for soldering.

Thallium compounds are highly poisonous. Some of them are used as rat and insect poisons.

Thallium oxysulphide is light-sensitive and sensitive also to infra-red rays and is used in photo-electric cells for "dark" signalling.

THORIUM, 1828

Thorium is a rare metal which has never been obtained in a pure state because it has a very high melting point and combines with oxygen easily. Impure thorium is a grey powder. Thorium compounds are used in the manufacture of incandescent gas-mantles and flashlight powders.

THULIUM, 1879

Thulium is a very rare metal of no practical use.

TIN

Tin is a silvery-white metal which is practically unaffected by air. Tin is a constituent of many useful alloys. Some of the most important tin alloys are bronze, solder, type metal, babbit metal and pewter.

Tin is most commonly seen as a protective coating for iron in what are incorrectly called "tin" cans. Tin plate from which cans are made is produced by first cleaning sheet-iron with dilute sulphuric acid and then dipping the metal into a bath of molten tin. The tin sticks to or "wets" the iron, so that the iron, when withdrawn from the molten metal is found to have a very thin coating of tin. Tin is not acted on by fruit and vegetable juices, so that tinned iron makes a satisfactory container for many foods.

Tin-foil is made by rolling the metal in thin sheets.

Tubes for toilet and medical preparations are made of tin.

Block tin, which is tin unalloyed with other metals, is used for the pipes of soda fountains because it is not affected by carbonic acid (solution of carbon dioxide). Metal containers for handling milk, ice-cream, and other foods in bulk are coated with a heavy layer of tin. Nearly all the tin comes from the Malay States and from Bolivia.

TITANIUM, 1791

Titanium is a silvery-white metal, hard enough to scratch glass. It is used for purifying, hardening and strengthening steels. Its compounds are used for dyeing, as a pigment, for colouring pottery yellow and in arc-lamp electrodes.

TUNGSTEN, 1783

Tungsten is a heavy white metal of special interest at the present time because much of our supply comes from China. It has the highest melting point of any of the metals and is used as the filament in the modern electric lamp.

A compound of tungsten called tungsten carbide, when alloyed with cobalt, forms the hardest metallic substance known. It is called Carboloy and is next to the diamond in hardness. Small pieces of Carboloy are brazed to steel bars and used as tools in lathes, boring mills and other machines. They will withstand cutting speeds and feeds from 3 to 10 times those of high-speed steel.

Tungsten is used in the construction of X-ray tubes and for contact points in electrical apparatus and the ignition systems of automobiles.

Tungsten compounds are used for bronze powders and in dyeing.

The chief use of tungsten is in high-speed steels and special alloy steels. Tungsten increases the hardness of steels. Tungsten steels are not suitable for construction but are widely used for tools. Dies for die-casting made of tungsten steel give long life in contact with the molten casting metals. Taps, cutters, chisels, punches and other tools made of tungsten steel are strong and shock resisting. They have a close uniform texture and can be ground to a fine edge.

URANIUM, 1789

Uranium is a hard but malleable metal resembling nickel in colour. It is found principally in pitch-blende, a mineral which is also a source of radium.

It is used to some extent to impart special properties to steel.

Uranium compounds are used for paint pigments, glazes for tiles and pottery and for imparting an opalescent yellow colour to glassware.

VANADIUM, 1830

Vanadium is a pale-grey, brittle metal with a crystalline structure and a silvery lustre.

Vanadium compounds are used in dyeing and to colour glass and pottery.

Small quantities of vanadium added to steel toughen it. It gives to steel the ability to resist breakage under sudden heavy stress. When you ride in an automobile, in all probability your ride is made safer by a frame and springs which contain vanadium, Vanadium steels frequently also contain chromium or tungsten.

VIRGINIUM, 1930

Rare.

XENON, 1898

Xenon is one of the completely inert (totally inactive chemically) rare gases found in the atmosphere.

YTTERBIUM, 1878

This is one of the rare-earth group of metals. It has not as yet been obtained in pure form.

ZINC, 1746

Zinc is a bluish-white metal which finds wide use. It is used for lining tanks, for roofing, in the printing industry, to make plates for illustrations and for making the containers of dry cells. Zinc is used in making several important alloys such as brass, German silver and bronze. Galvanized iron is iron covered with a thin layer of zinc.which acts as a protective coating and prevents rusting.

The alloys used for making pressure die-castings for hardware, automobile and radio parts are about 90 per cent. zinc, the remainder being various proportions of copper, aluminium and tin.

Zinc oxide, commonly known as zinc white and Chinese white, is used in medicine to make zinc ointment and as a white paint pigment and a filler in rubber. Zinc chromate is a beautiful yellow pigment used in paints. Zinc chloride is a poisonous compound used as a flux in soldering.

ZIRCONIUM

This is a silvery-white metal which is very difficult to secure in its metallic form. It is sometimes added to steel to produce uniformity of grain and make it easier to roll into bars and sheets.

The oxide of zirconium called zircite is highly refractory (heat resistant) and is used for lining furnaces.

Index

INDEX

INDEX

INDEX