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INDUSTRIAL SOLVENTS

By

IBERT MELLAN

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حیدرآباد دکن

BOOK DEPARTMENT

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TO MY WIFE

Foreword

The writer has had the pleasure of reviewing the extensive information presented herein on the subject of solvents. This information is bound to be of very great value to all chemists having to do with the use of solvents. It is well prepared and is presented in a logical form.

A. W. Van Heuckeroth

Institute of Paint and Varnish Research
Washington, D. C.

Preface

To realize the remarkable growth of the solvent industry, one need only look back twenty-five years, and compare the very few solvents then in commercial use with the present gigantic industrial development of over a hundred different solvents. The annual production of about 1,600,000,000 pounds of solvents in the United States alone testifies eloquently to the mounting importance of solvents in every industry. The lacquer industry stands first in solvent consumption, but its supremacy is endangered by the new types of coating materials which are made from synthetic resins.

The extensive data on solvents, which have been accumulating for years and have heretofore been unavailable in comprehensive form, have been sifted and correlated into a coherent whole. The large number of graphs and tables has been assembled with the object of affording the user an efficient and rapid means of obtaining specific and comparative information.

Although the data in this book have been carefully selected from reliable sources, there are occasional differences in the values of physical constants. These discrepancies are unavoidable, since the recorded values are influenced both by the human equation of the scientific investigator, and by variations in purity of the materials under examination.

It is necessary to point out that although some of the solvents considered in this book are produced only on a moderate scale or are undergoing development at the present time, these are nevertheless finding wider application every day; and it is entirely possible that some unknown or unheralded solvent may one day bring about far-reaching changes in the industries.

In conclusion the author wishes to express his appreciation and thanks for permission to use data or illustrations supplied by

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IBERT MELLAN.

Philadelphia, Pa.,
June 1, 1939.

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Chapter 1

Solution, Theories and Aggregates

Solution

Solution is everywhere: in the gaseous, the liquid, and the solid state. The air we breathe is a gaseous solution of nitrogen, oxygen, argon, carbon dioxide, water vapor, and so forth. The oceans are gigantic liquid solutions made up of chlorides, carbonates, and sulfates of sodium, magnesium, calcium, etc. They actually contain about 32 of the known elements, and in every 1000 parts of ocean there are 27 parts of sodium chloride. The water we use every day is a dilute solution of sodium, calcium and magnesium carbonates, sulfates and nitrates, dissolved ammonia, and carbon dioxide. The earth's crust consists of thousands of cubic miles of solid solutions. Whole mountain ranges, great hills and uplands of granite rock are solutions of metal, silicon and oxygen: limestone peaks, chalk downs and beautiful marble are solutions of calcium, carbon and oxygen.

There are two phases to every solution: the solvent and the solute. The solvent, usually thought of in terms of a liquid, is the substance in which the solute, the dissolved material, is uniformly distributed in such a fine state of division that the particles cannot be seen and do not separate out on standing.

Theories

It is interesting to contrast the theory of Barr and Bircumshaw [1] with the one presented by Byron.[13] The former claim that the solution of nitrocellulose in a mixture of alcohol and ether is explained by the fact that alcohol in the presence of ether polymerizes and is then a solvent for nitrocellulose. Byron is of the opinion that alcohol is not polymerized but is dissociated, and that ether in this case aids in this dissociation. It is Esselen's [2] theory that the increased solvent action of a mixture of chloroform and alcohol for cellulose acetate is due to the adsorption of the hydroxyl groups within the cotton molecule which leaves the acetate groups covered with alcohol groups. In the opinion of Mardles,[3] solvent liquids are attracted to cellulose esters and form complexes with them. McBain [4] agrees with Mardles in respect to these complexes but goes further in pointing out the fact that, in the solution of cellulose esters in a mixture of solvents, different solvent molecules are attracted to different portions of the solute.

Aggregates

Atoms are made up of aggregates of electrons and protons, units of negative and positive electricity. The number and groupings of these atoms determine the nature of the element. Matter is made up of atomic and molecular aggregates, and its character is governed by the arrangement and number of these. To take polymerized acetone as an example, it can be said to contain aggregate acetone molecules, atomic aggregates, and electron-proton aggregates or, graphically, there are aggregates of aggregates of aggregates. Molecular aggregates are formed by groups of atoms and molecules which attract each other and hold together by borrowing and lending electrons, which are internal electrical forces called secondary valences. These structures are conveniently called "molecular aggregates" and serve as the structural unit for the theory of solvent action.

Postulates

1. A liquid may or may not form molecular aggregates. Any liquid which dissolves and ionizes holds greater possibilities in forming aggregates. This is explained by the fact that the dissociated groups are attracted to each other and are held together by the passage of one or more electrons from one atom to another. These are known as polar compounds. If a substance is a non-polar compound, there is little or no dissociation and therefore aggregates are formed in lesser quantities. These aggregate groups are held together by electrostatic union, that is, a union of two or more groups established by sharing in common one or more pairs of electrons. According to Turner,[5] the tendency to aggregation in organic compounds is due to the presence of certain electro-negative groups. For example:

OH < Alcohols / Phenols

CONH < Amides / Anilides

COOH—Carboxylic Acids

NOH—Oximes

CN—Nitriles

SH—Mercaptans

CSNH—Thioamides

CSOH—Thioacids

NH_2—Primary Amines

NO—Nitrocompounds

CHO—Aldehydes

CO—Ketones

CS—Sulfhydryls

The influence of these groups decreases in the order given. Factors which govern molecular aggregate formation are the mass, its structure, and the groupings in a molecule. The tendency which leads to molecular aggregation decreases with an increase in molecular weight within the homologous series.

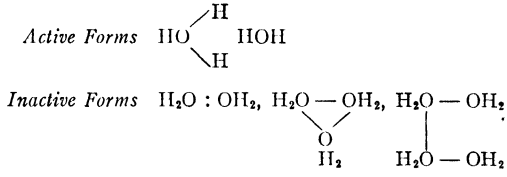
2. A mixture of two or more liquids may or may not form one or more molecular aggregates. When liquids are admixed there is often seen an abnormal change in volume, notably a shrinkage in volume when water

and ethyl alcohol are mixed together. This is explained by the fact that molecular aggregates are formed. The evolution of heat or the adsorption of it when solution takes place indicates aggregate groupings. This heat exchange is the result of forces acting between or among the molecular groups.

Changes in specific gravity are evidences of molecular aggregate formations at different concentrations. These physical changes can be observed when water is mixed with either ethyl alcohol, propyl alcohol, formic, acetic or propionic acids, or acetone. Turner [5] has observed maximum deviations in volume when the following are mixed in the proportions of one molecular weight of ether to one of alcohol; two of benzene to one of ether; and one of ether to two of chloroform.

3. A liquid plus a solid may or may not form one or more molecular aggregates. Turner declares that substances containing the following groups produce the most abnormal results in the order given: hydroxyl, carboxyl, amino, aldo, cyano, ester, nitro, iodide, bromide, and chloride. Worden [6] records certain types of cellulose ethers which are insoluble in both hot and cold water. When water is cooled below the freezing point and permitted gradually to thaw, the liquefied water will then dissolve the cellulose ether. This clearly shows that proper conditions have been brought about for the rearrangement of the molecules into such groupings which exhibit solvency for the particular type of cellulose ether. We can go further and say that liquids which under ordinary conditions exhibit little or no solvent power can be altered by admixture with other solvents or changed by physical means, thus bringing about the formation of molecular groupings which possess specific solvent power.

Armstrong [7] attempted to explain the phenomena of water aggregates by simple molecules, chain and ring formations:



4. If we mix liquid *A* with liquid *B* and no molecular aggregates are formed we say that the two liquids are insoluble in each other or they are immiscible. If a small amount of *A* is taken up by *B* then the molecular aggregates formed are of the type which contains many whole or part molecules of *B* to few of *A*. The structure can be calculated from the size of the molecule, number per cubic centimeters and the degree of solubility. This assumption is true if only one type of molecular aggregate is formed.

But how can we determine if one or more aggregates are formed? This is possible by x-ray diffraction patterns. It is known that liquids of different chemical composition have different diffraction patterns. It has

also been shown that two liquids which are completely miscible show a diffraction pattern different from that of either of the constituents. In the case of two liquids which are not miscible at room temperature, they show individual diffraction patterns.

5. If a larger amount of *A* is taken up by *B*, then the ratio between the *A* and *B* molecules in the aggregate is smaller, and the possibility of forming more than one type of molecular aggregate is greater.

6. Solubility is the formation of molecular aggregates. The degree of solubility will depend upon the type or types and number of molecular aggregates that are formed. Temperature exerts its influence on the type and number of formed aggregates which in turn govern the degree of solubility. For example, if a small quantity of alcohol is taken up by benzene, from a dilute alcoholic solution, the molecular aggregates produced contain many benzene molecules to few alcohol molecules and the number of different resulting aggregates is few. In the case of alcohol and water where there are many types of molecular aggregates formed, the ratio between the alcohol and water molecules and the dissociated groups in the aggregates is of a simple arithmetic relationship.

7. Miscibility, like solubility, depends upon the internal electrical attraction of atoms, molecules, or groups of these, with the formation of molecular aggregates. Complete miscibility means that all the molecules of the different liquids form one or more groups of molecular aggregates. Molecules of liquids that repel each other with an electrical force will not mix or dissolve and are called immiscible liquids. If a mixture contains three or four liquids, the possibility of forming one or more molecular aggregates is consequently greater. Mixed solvents behave like more complex solvents of the ester or alcohol-ether type. In the former, the groups are held together by secondary valences and in the latter, the groups are held together more firmly by primary valences.

Meyer [8] has found that the ionization diffraction curves of two organic solutions change with the concentration. When short-wave radiations were used on mixtures of normal butyl alcohol with orthodiethyl-cyclohexane the diffraction peaks shifted from the peak of one member to the peak of the other as the concentration changed from 100 per cent of one member to 100 per cent of the other and the width of the peak varied in the same manner. It has been shown by a number of workers that the diffraction curves and peaks indicate groupings of the molecules and the spacing is governed by the constituent parts. These spacings can actually be approximated by Bragg's law.

8. A case where large molecular aggregates are formed: If a small amount of *A* is added to *B*, the molecular aggregates formed contain many *B* molecules to few of *A* molecules. This condition results in fewer molecular groups per volume with a corresponding rise in both the freezing point and the vapor pressure temperature. This assumption is verified by the experiments of Wright [9] who has discovered that the addition of a large amount of alcohol to benzene forms alcohol-benzene complexes which

bring about a lowering of the freezing point. This condition is the result of the formation of alcohol, alcohol-benzene, and benzene aggregates. If water is added to this mixture, water-alcohol aggregates are formed. This is explained by the fact that the water and alcohol molecules have greater attraction for each other than do the alcohol and benzene molecules. Thus, in this mixture, most of the benzene molecules are set free from the alcohol-benzene groups. The liberated benzene contains a small amount of benzene-alcohol aggregates which causes a rise in the freezing point of the liberated benzene. Wright's experiments reveal the fact that when a solute, which is more soluble in alcohol, is added to a binary mixture of alcohol and benzene (50%-50%) there is, at first, a rise in the freezing point. Upon adding more of this solute, a depression of the freezing point is brought about. When a solute more soluble in benzene is added to this same mixture a lowering of the freezing point is obtained. Solutes which produce a rise in the freezing point form molecular aggregates which contain large numbers of molecules. Thus, a condition is created in which we have fewer molecular aggregate groups per given volume. In higher concentrations the molecular aggregates are broken down into smaller groups which produce a larger number of molecular aggregate groups per given volume and this consequently produces a lowering of the freezing point. When solutes are added which are more soluble in benzene than in alcohol, many small molecular aggregates are formed which increase the number of groups per given volume and thereby bring about a depression of the freezing point. Following this line of thought, we can mix specific solvents in given proportions to form molecular aggregates in which there are no free molecules of the individual solvents. Such mixtures should possess a constant freezing or boiling point and should exhibit diffraction patterns peculiar to their type. Going further, if an excess of one solvent is added to this constant boiling point mixture, the state of equilibrium is upset and we no longer have the condition of constancy.

In another experiment, Wright added a small amount of water to an alcohol-benzene mixture (50%-50%) until the solution became turbid. The addition of sodium chloride to this turbid mixture caused it to become clear. According to the theory of molecular aggregates, the alcohol molecules in the alcohol-benzene group have a greater attraction for the water molecules than they have for the benzene molecules; they therefore leave the benzene and unite with the water. The liberated benzene is dispersed in this mixture and causes it to become turbid. With the addition of sodium chloride we introduce a substance which possesses greater internal electrical attraction for the water molecules and therefore pulls them away from the alcohol and finally unites with them. The liberated alcohol and the previously liberated benzene are now free to attract each other and form molecular aggregates with the consequent clearing of the solution.

9. The attraction between or among the appropriate groups of solute and solvent results in solution.

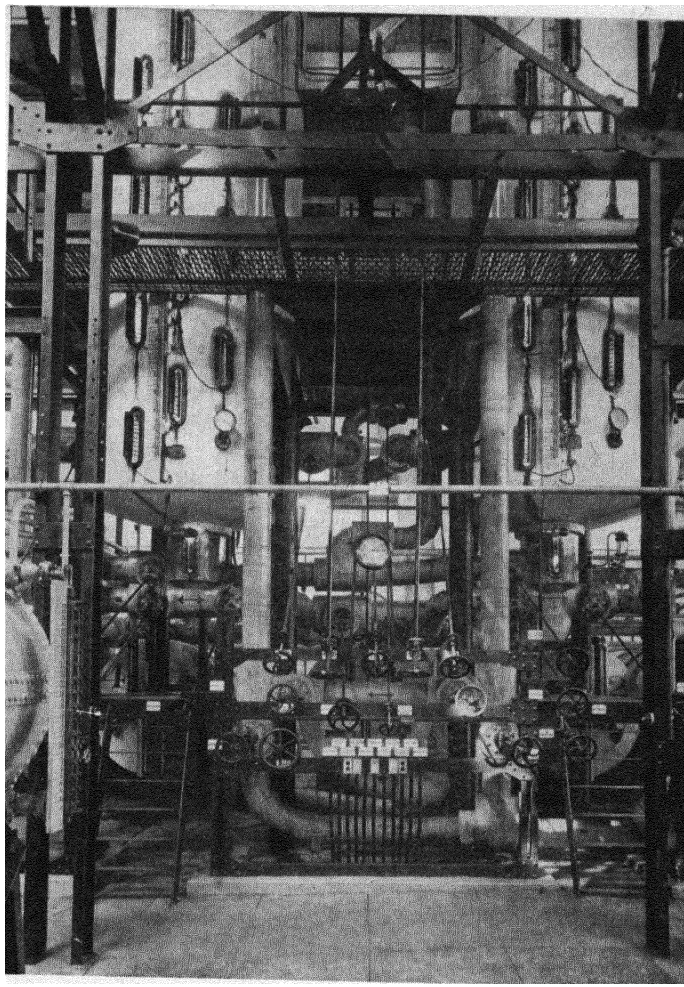
10. Where mixed solvents are concerned the increase in the number of different solvent groups increases the number of solvent-solute aggregates; this results in increased solubility.

11. If, in place of attraction there is repulsion, the condition of insolubility or immiscibility or precipitation is produced.

12. Brown and Bogin [10] have pointed out that the boiling point of a liquid has no relation to its volatility. It therefore bears the assumption that the boiling point is the temperature at which the vapor pressure of molecular aggregates is equal to the atmospheric pressure. On the other hand, volatility depends upon the type of molecular aggregates which are present. These men have also found that though there is only 2° C. difference in boiling points between toluene and isobutyl alcohol, the former will evaporate almost three times as rapidly as the latter. Another example is that of xylene and normal amyl acetate which boil at practically the same temperature; but the hydrocarbon evaporates 1.25 times as rapidly as the ester. Butanol boils 22 degrees below xylene but it evaporates only about 80 per cent as rapidly. These differences in evaporation are owing to molecular aggregation and are governed by the force of the internal attractions or secondary valences. These workers state that vapor pressure curves are a more accurate means of solvent evaluation than is a study of boiling points, but that they are of assistance only insofar as they lead to a better understanding of the principles governing evaporation; and that "the only sectors of vapor pressure curves that are of practical interest are those temperature ranges that represent normal room conditions." Two solvents with identical vapor pressures will evaporate at different rates at a given temperature unless their molecules are of the same weight and their latent heats of evaporation are identical. The solvent with the greater molecular weight will evaporate more rapidly. From the above we can conclude that the latent heat of evaporation is the energy (heat) needed to break the secondary-attraction bonds in the molecular aggregate and to supply the energy in the newly formed aggregates.

Mixtures of solvents may form binary, ternary, quaternary, or polynary vapor pressure mixtures of a complex nature. A state of equilibrium is never reached except for that state of equilibrium which exists at a given temperature. This is accounted for by the fact that as evaporation goes on, energy (heat) is consumed and there is a constant lowering of temperature. For example, the rate of evaporation of a mixture of 30 per cent benzene and 70 per cent ethyl alcohol, at room temperature, is about 25 per cent more rapid than the rate derived from the formula for the evaporation of the "perfect mixture."

In constant-boiling mixtures there is a predominance of one type of molecular aggregate, and the ratio between the constituent parts in the aggregate always remains the same during the process of evaporation. The lacquer imperfections, for example, cotton blush, gum blush, improper drying rate, orange peel, poor flow, water blush and so forth, are believed



Courtesy ***Standard Oil Co. of California.***

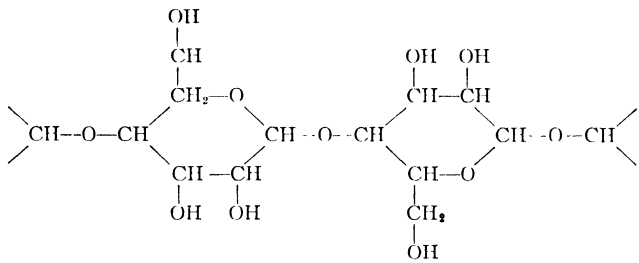
PLATE 1. A Modern Plant for Solvent Recovery.

in the industry to be due to the improper balance of the evaporation rates of the solvents and diluents. These imperfections are in reality due to the formation of undesirable molecular aggregates possessing non-solvent qualities.

The researches of Jean-Jacques Trillat [11] dealing with the change of lattice structure of nitrocellulose prove the presence of crystalline aggregates made up of nitrocellulose (12.9% nitrogen) and acetone. The pres-

ence of these compounds has also been confirmed by means of x-ray spectrography. With this new scientific instrument, it is possible to see the formation of more than one crystalline compound when an acetone solution of nitrocellulose is going through the process of drying. Similar compounds are formed when ethyl acetate is used in place of acetone with corresponding variations in the lattice structure. When dissolvents with less solvent power are used, these phenomena become less clear and almost disappear. Lattice pictures of cellulose show secondary valences as feeble linkage forces and the glucose groupings in the cellulose are bound together by primary valences. Recent work shows that molecular aggregates are formed by the union of cellulose ester, solvent, and plasticizing molecules. It has been shown that the structure of regenerated cellulose ester films varies with the ester, solvent and plasticizer used. This is in accordance with the theory of the formation of molecular aggregates. Further, as a solvent leaves, by evaporation, a molecular grouping, the remaining constituent parts exert their individual force which results in new groupings with different lattice structure. Lacquer films are structurally made up of cellulose molecules randomly oriented with resin and plasticizer which fill in the interstices. This film structure has been formed by energy breaking the solvent bond and leaving the resin-cellulose plasticizer aggregate.

Cellulose is made up of hexose groups linked together by oxygen bridges. The chain, comprised of bundles, is linked together by secondary-valence forces. X-ray measurements confirm the general belief that cellulose is built up of parallel chains of "glucose residues" linked by oxygen atoms.

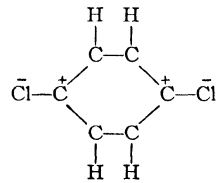


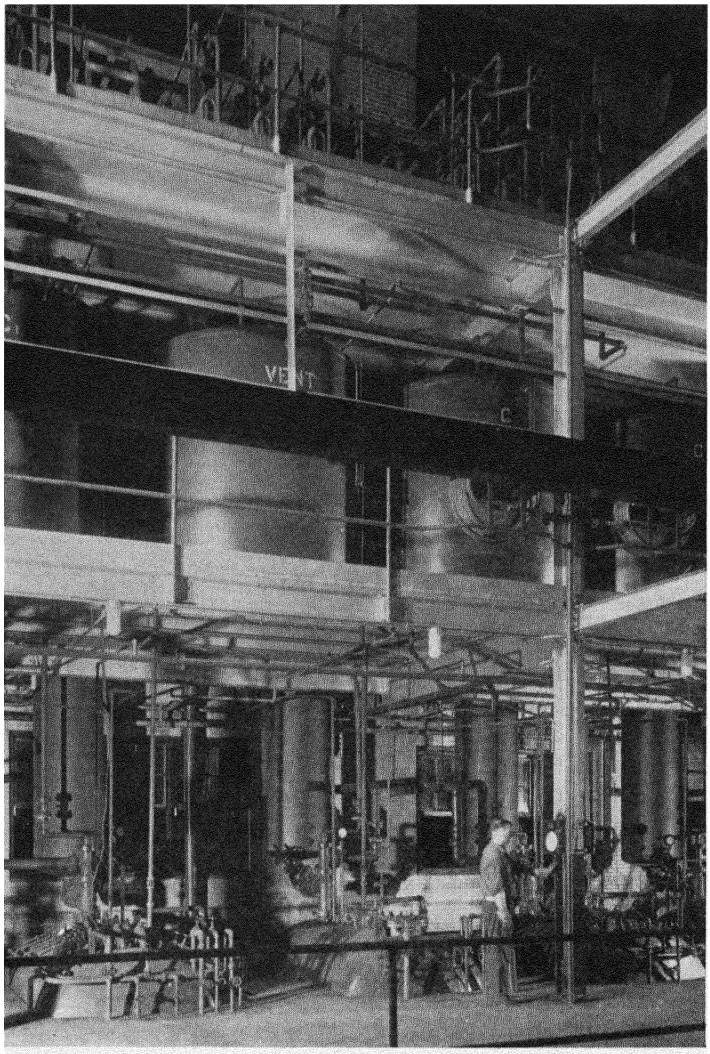
In nitrating cellulose the hydroxyl groups (OH) are attacked and nitrocellulose is formed. When this substance is dissolved in a solvent, molecular groups in chain formation are formed. The length of the chain depends upon the concentration and dissolvent power of the solvent or solvents. Dilute solutions and good solvents yield small chains free to move about in the solvent phase of the solution. Extremely dilute solutions contain the solute subdivided into individual molecules. These chains form molecular aggregates with the solvent, resin and plasticizer, with the provision, of course, that these are of the right type.

Baker [12] believes that the decrease in viscosity of an ether-alcohol solution of collodion is caused by the formation of an ether-alcohol complex and that this complex is responsible for the solvent action of nitrocellulose. Byron [13] has discovered that pyroxylin is not peptized by anhydrous ether but by absolute alcohol at low temperatures which permits his assumption that when alcohol is added to ether it becomes polymerized and is the causative agent in the solution of pyroxylin.

Polar and Non-Polar Compounds

Water is not by any means the only solvent which has electrical conducting properties owing to the dissociation of dissolvent substances. Liquid ammonia, liquid sulfur dioxide, and liquefied hydrocyanic gas possess this property in the same degree as water. Many organic solvents like alcohols, acids, aldehydes, nitriles, amines and so forth, exhibit this conductivity. These substances are chemically active and are referred to as "polar solvents." Compounds which are comparatively inert, such as the hydrocarbons and their derivatives, *e. g.*, benzene, gasoline, kerosene, chloroform and carbon disulfide, are classified as non-polar compounds. Drummond [14] groups solvents as polar and non-polar by their high or low dielectric constants. Solvents like alcohols and ketones, which contain hydroxyl or carbonyl groups, have high dielectric constants and this is evidence of strong polarity. Those of low dielectric constants, like the aliphatic and aromatic hydrocarbons, are classified as non-polar solvents. Solvents in forming molecular aggregates, either within themselves or in combination with other solvents or solutes, exert polar action which is caused either by the dissociated solute or by the molecular aggregate formed. Rule and Mitchell [15] have found that "polar groups" exert an influence on the neighboring molecules which leads to changes in rotatory power. Rule and McLean [15] are of the opinion that the non-polarity of some solvents may be owing to the symmetrical arrangement of the substituent dipoles. Some molecules exhibit non-polar properties with reference to a uniform external field. They may exert, however, a definite force on a point charge or dipole in their immediate neighborhood. In the carbon disulfide molecule the two oriented dipoles are so close to each other $S=C^{++}=S$ that the field exerted by one, at a near-by point, is almost completely neutralized by the other. The polar properties of this compound, if they exist, will be extremely weak. In paradichlorobenzene, the C – Cl poles are separated by two carbon atoms and therefore function individually.





Courtesy Standard Oil Co of California.

PLATE 2. Another View of a Solvent Recovery Plant.

Paradichlorobenzene displays stronger polarity than does the mono-substituted product. Highfield [18] is of the opinion that the polarity of nitrocellulose is due to the presence of the strong hydroxyl polar groups and the weak polar hydrocarbon groups. It is also his belief that there

is a relationship between the hydroxyl content of nitrocellulose and its solubility in a solvent mixture containing a number of hydroxyl groups.

Dilution Ratio

A solution of nitrocellulose containing an active solvent will tolerate a definite quantity of non-solvent, and the maximum amount is called the critical point. A further addition of non-solvent will cause precipitation, or gelling, of the nitrocellulose. The aggregates which are formed between the solvent and the cotton derivative have some secondary-valence forces available for other substances, among which are non-solvents. Some of these added substances will naturally have greater attraction for the solvent molecule or aggregate than has the cotton. If an amount of a non-solvent, like benzene, is added just short of the critical point, it attaches itself to the solvent or solvent-cotton aggregate and is held there by secondary-valence forces. This addition of benzene produces no visible change. If, however, an additional amount of non-solvent is added which will make the volume greater than that which can be tolerated, precipitation will take place. This precipitation of nitrocellulose is owing to the fact that the added non-solvent benzene has a greater attraction for the aggregate than have the molecules of the cotton derivative. This greater attraction ruptures the secondary-valence bonds between solvent and cotton molecules and the benzene forms a new aggregate with the solvent. The critical point, or limit of tolerance in a quantitative significance, is called the "dilution ratio." It is a useful index which expresses the number of cubic centimeters of non-solvent required to gel, or coagulate, some of the "$\frac{1}{2}$-second nitrocellulose cotton" in 1 cubic centimeter of a solution of definite concentration. Factors influencing the results of dilution ratio tests are the types of solvent or solvents used, the types of non-solvent or non-solvents added, the type of nitrocellulose employed, the temperature of testing solutions, and the concentration of the nitrocellulose solution. Solutions of gums and resins in hydrocarbons or alcohols will tolerate only a definite quantity of added non-solvent. Here, the amount of diluent which can be added also depends upon the above-mentioned variables. Dilution ratios can be empirically determined by the "dilution ratio method."

$$\text{Dilution Ratio}^{16} = \frac{Vd}{Vn} \text{ D.R.}$$

Vd refers to volume of diluent
Vn refers to volume of solvent

D. R. corresponds to the solvent-power number of Mardles[3] which is defined as the "volume of liquid (diluent) in cubic centimeters required to begin precipitation from 1-cubic centimeter of a 5/100 concentration sol." Thus, the "solvent-power number" and the "dilution ratio" represent the maximum quantity of a non-solvent or diluent which can be added to a particular solution without producing undesirable effects. It does not, however, tell us anything about other important factors of a good prac-

tical lacquer, such as vapor pressure or rate of evaporation. Dilution ratios are useful in the fabrication of a lacquer or varnish but are of no assistance in making predictions about the balance of solvents, diluents, resins, cellulose derivatives, and plasticizers during the period of drying.

Variation in Evaporation Rate

Liquids vary in their rate of evaporation. Naturally, in a mixture of liquids, some will evaporate more rapidly than others. For example, if the solvent constituent of a lacquer evaporates more rapidly than the diluent, the limit of tolerance entertained by the residual mixture is exceeded and gelling or precipitation occurs. As evaporation goes on gigantic molecular reactions take place. Vast numbers of molecules change places as the new aggregates are formed. Some are replaced and some are repelled, causing immiscibility, precipitation, blushing, or one or more of the many lacquer faults. It follows that dilution ratios do not indicate tolerance during the change of solvent-non-solvent balance which occurs during drying. In the theory of molecular aggregation, higher concentrations of cotton derivatives contain fewer secondary-valence bonds. Consequently, smaller amounts of diluent can be tolerated. This condition occurs during film drying.

Hydroxyl-containing solvents show greater tolerance for toluene than do the simpler esters. In the case of naphtha the condition is reversed. There are, however, exceptions to this statement, among which are butyl lactate and butyl "Cellosolve," which have very high naphtha tolerance. Simple esters will tolerate 50 to 100 per cent more naphtha than will such materials as ethyl lactate, ethyl ether, ethylene glycol, diacetone alcohol, and so forth. Ethers of glycols generally have higher dilution ratios than do the butyl esters with respect to benzene, toluene, and xylene.

Solutions of nitrocellulose will tolerate larger quantities of non-solvents than will solutions of cellulose acetate. The "solvent-power number" is influenced by both the nature of the diluent and the mixing of two or more solvents. Frequently, when two or more non-solvents are mixed, they may exhibit the qualities of a good solvent. This is especially true when one of the ingredients is an alcohol. The ether-alcohol solvent mixture for collodion is an example with which we are most familiar. Another example of acquired solubility is the mixing of butyl acetate with amyl or ethyl alcohol for the less highly polymerized forms of glyceryl phthalate resins. Some of the chlorinated hydrocarbons when mixed with an alcohol will dissolve nitrocellulose. A mixture of benzene and alcohol will dissolve nitrocellulose containing up to 11 per cent nitrogen. A toluene-ethyl alcohol solution of glyceryl phthalate resin will dissolve nitrocellulose. In many cases the solvent property of esters for resins and nitrocellulose is increased by the addition of an alcohol. On the other hand, when active solvents for cellulose esters are mixed with aliphatic or aromatic hydrocarbons the solvent power of these active solvents is decreased.

These facts bring to light reasons why many of the old type solvents have been valued for their impurities. For example, methyl acetone, made from the distillation of wood, had particularly valuable solvent properties. Actually, it is a mixed solvent which consists of methanol, acetone, esters and higher ketones. This mixture has certain desirable properties not obtained by any of its component ingredients when used separately. For this reason the "synthetic methyl acetone" is made to simulate it. For this same reason commercial grades of butyl and amyl acetate contain 85 per cent ester and the remaining portion is the corresponding alcohol. Amyl acetate, containing its characteristic impurities when manufactured from fusel oil, is also valued for its solvent properties. The recent synthetic product is distinct from it because it lacks these impurities. This synthetic product is made from the pentane fraction of gasoline by chlorination, and the chlorpentane is hydrolyzed to form amyl alcohol and finally acetylized to the acetate.

According to Reid,[17] alcohols evaporate at a slower rate than their corresponding esters of higher boiling points. This is due to strong hydroxyl polar groups in the alcohol-containing aggregate. Non-solvents, owing to the fact that they are so loosely held in aggregate groupings, will leave the film, by evaporation, more rapidly than a solvent. Wilson and Wright [19] are of the opinion that water dissolves hydroxylic compounds, that benzene dissolves hydrocarbons, and that alcohols have the intermediate position. They further believe that the solubility of complex solutes in solvents is owing to the action of different groups in the solvent.

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Chapter 2

Solvents, Latent Solvents, Non-Solvents

Solvent Power and Compatibility

The purpose of solvents is to convert substances into a form suitable for a particular use. The importance of the role of solvents is brought out most clearly by the fact that many substances exhibit their usefulness when in solution. Lacquer solvents, for example, are selected to produce homogeneous combinations and calculated to bring about desirable mechanical properties. The physical properties of a fabricated solution can be regulated at will by the proper choice of solvents, thus adapting them for the most varied uses and methods of application. Some of the more important uses for solvents are in lacquers of all kinds, oils, paints, varnishes, polishes, fat extraction and dry cleaning. Many substances will be discussed which may be said to be chemical curiosities, but, should the demand for them arise, these rarities will blossom forth into commercial commodities.

The innumerable possible applications of the cellulose derivatives had lain dormant for many centuries. It was John Wesley Hyatt and his classic celluloid invention which brought to light the vast possibilities of cellulose. It required only the recognition of amyl acetate as a desirable non-hygroscopic, high-boiling solvent to make men solvent-conscious. The modern solvent industry is comparatively new. It was only yesterday, so to speak, that the industrial solvents were comprised of only methyl and ethyl alcohols, acetone, glycerol and aliphatic and aromatic hydrocarbons. The rapid growth and wide use of nitrocellulose created new demands upon this industry. In the World War, the urgent need for acetone was supplied by the development of a new fermentation process for acetone. Butyl alcohol was produced as a by-product and very little use could be found for it. Huxley has said, "Keep a thing long enough and you will find a use for it." As the supply of butanol increased, the activity among research workers was greatly accelerated with the ultimate employment of butyl esters in food, flavoring, solvents and plasticizers. The petroleum industry was impelled by the same fever of activity with the subsequent conversion of butylene, amylene, and hexylene, the olefin fraction of cracked oils, to secondary alcohols like butyl, amyl, and hexyl alcohols. Other industries like the fermentation, petroleum, coal-tar and synthetic organic chemical industries are fully involved in a fevered competition for supremacy by developing new and improved solvents.

Solvents vary in their dissolving power so that the line of demarcation between solvents, latent solvents and non-solvents cannot, with our present knowledge, be clearly defined. Some of the factors which influence solvency are atmospheric conditions, purity and molecular association. Molecular aggregation is the explanation for increased, attenuated, or decreased solvent power or, more concisely, eccentric solvency. Any substance that will dissolve another is called a solvent. Thus, we may have a gas solution when a gas, a liquid or a solid is dissolved in a gas, or a liquid solution when any one of these is dissolved in a liquid, and similarly, a solid solution when any one of them is dissolved in a solid.

In the opinion of Worden [1] and others, solvents for cellulose ethers and esters owe their solvent action to the presence of the ester, ketone and ether groups. The solubility of these solvents decreases with an increase in molecular weight within a homologous series. In accordance with the theory that like dissolves like, Calvert [2] has found that solvent power increases with the increase of the percentage of oxygen within a homologous series of a solvent, within certain limits. This increased solvency is also coupled with a simultaneous decrease in its solubility for unlike materials. In other words, oxygen contained in a ketone group (R – CO – R) or (– CO –), or in an ester group of organic acids (R – CO – OR), is responsible for the strong solvent action for cellulose esters. Chemicals devoid of oxygen in the molecules and those which contain it in the hydroxyl group of higher alcohols are poor or non-solvents. Cellulose ethers, generally, are soluble in hydrocarbons and cellulose acetate is soluble in chlorinated hydrocarbons. Other workers are of the opinion that solvent power for nitrocellulose is associated with the – CO – group found in esters, ethers, and ketones. Alcohols, with the exception of methyl and ethyl alcohols, do not dissolve nitrocellulose. These alcohols do not precipitate this cellulose ester as do the non-solvent hydrocarbons. Sakurado and Kido [3] determined the solvent power of a number of solvents and found them to be as follows: dimethyl acetone, > methyl ethyl acetone, >acetyl ether, > acetyl ethyl ether, >acetyl propyl ether, > pyridine, > acetyl amyl ether, > methyl formate, > acetyl aldehyde, > ethyl carbonate, for nitrocellulose of 13.7 per cent nitrogen, > dimethyl acetone, > methyl ethyl acetone, > pyridine, > acetyl ether, > acetyl ethyl ether, > acetyl amyl ether, > acetyl methyl ether, > methyl formate, > aniline, for 11.6 per cent nitrogen cellulose nitrate.

Pyroxylin solvents, when measured by their tolerance for diluents, show abnormally high effectiveness, but frequently have little or no solvent power for resins. Conversely, many substances which will not dissolve cellulose esters or ethers, *c. g.*, toluene, xylene, and naphtha, are very good solvents for resins such as ester gum, dammar, and so forth. Many non-solvent liquids become active solvents when admixed with active or inactive solvent liquids. Examples of this are mixtures of ether-alcohol, alcohol-benzene, alcohol-toluene, and ether-alcohol-butanol. Often, such mixtures have constant boiling point properties which indicate the for-

mation of molecular aggregates. Davidson [4] records the fact that the solubilities of resins, oils, and gums in glycol ethers increase somewhat with the rise in boiling point. The solubility also increases with an increase in the oxygen content of the glycol radical.

Lacquer materials are not all compatible with each other. The cellulose esters and ethers and some of the synthetic resins require for their solubility solvents which have one or more of the following groups: ketones, keto-alcohols, hydroxy-esters, or ethers. On the other hand, gums and resins, such as dammar, kauri and manila, are soluble in hydrocarbons and alcohols. Lacquer solvent combinations should, therefore, contain dissolvent groups for all of the ingredients which are used to make up a lacquer. There are many instances where a combination of certain solvent groups, such as carboxyl, carbonyl and hydroxyl, exerts a dissolving action which is much superior to that of the constituents separately. Some examples of these are the ethyl alcohol-ethyl ether and ethyl alcohol-ethyl acetate combinations. Likewise, any substance possessing more than one solvent group in its molecule exerts a solvent action superior to that of a solvent containing only one group. It is a known fact that monoethyl ether of glycol and ethyl lactate, which represent two-type solvents, are powerful dissolving agents. Other binary combinations are ester-alcohol, ether-alcohol, ketone-alcohol, ester-ether and so forth. Diacetone alcohol contains both a ketonic group and an alcoholic group and is a powerful solvent for nitrocellulose and ester gum. In making a solution containing both of these substances, they must be dissolved separately. When these solutions are mixed a haze results which persists even in the dry film. This fault can be overcome by the addition of a high boiling solvent like Hexalin or ethyl lactate which contains an ester group and a hydroxyl group. Ethyl lactate is a good solvent for both nitrocellulose and the alcohol-soluble resins like shellac and kauri gum. When solutions of nitrocellulose and alcohol-soluble gums are each separately dissolved in ethyl lactate and then mixed together, a cloudy solution results. This objectionable haze can be corrected by the addition of butanol. Butyl acetate is another solvent for both nitrocellulose and alcohol-soluble resins. The ether-alcohol odorless type of solvent comprising methyl, ethyl and butyl ethers of ethylene and diethylene glycol are high-boiling, powerful solvents for nitrocellulose.

According to Wilson,[5] some of the more commonly used solvents are as follows:* ethyl acetate, butyl acetate, fusel oil acetate, butyl propionate, synthetic amyl acetate from pentane, and "Cellosolve" compounds. In the field of low-boilers, ethyl acetate is in a class by itself due to the fact that acetone and methyl acetate are much too volatile. Ethyl acetate is also used to blend with butyl and higher acetates. Those solvents used in lesser amounts are isopropyl acetate, secondary butyl and amyl acetates, acetone, ethyl propionate, ethyl lactate, ethyl oxybutyrate, acetone oils and so forth. Recently there have appeared on the market mixed esters of

* Arranged in the order of their boiling points.

secondary and iso-amyl acetates and propionates. Esters of lactic acid, such as butyl lactate and others, and the ethers of ethylene glycol possess the unique property of tolerating large quantities of non-solvents and diluents.

Catalytic hydrogenation has brought forth high-boiling liquids of strong solvent power. Some of these are cyclohexanol, cyclohexanone, Tetralin and so forth. By high-pressure, catalytic hydrogenation, mineral spirits of paraffin structure are so altered as to become cyclic bodies with increased solvent power. Naphthas are among the newer substances which have been hydrogenated. The higher-boiling ketones are some of the more recent commercial solvents which are made from the lower ketones; examples of these are: methyl ethyl ketone, methyl isobutyl ketone and so forth. Other recent solvents are the hydroxylated acetals, like glycerol mono-formal, made from the union of aldehydes and polyalcohols, ethers of diacetone alcohol, hydroxy-ethyl-methyl ketone (β-acetone-ethyl alcohol), hydrocetyl-acetone, dichlorethyl ether and so forth.

Most of the solvents for cellulose acetate are methyl compounds, lower ketones, ketone-alcohols, and cyclic ethers like the dioxanes. A valuable property which many of these compounds possess is water-solubility. Although not water-soluble, the chlorinated hydrocarbons possess strong solvent action for cellulose acetate.

TABLE 1.—Solubility of Water in Solvents (by Weight in 100 parts Solvent at 20° C.)

Acetoacetanilide	S. S.	Cyclohexanol	11.8
Acetone	M	Cyclohexanone	8.7
Acetonylacetone	M	Cyclohexanyl acetate	1.4
Acetylene tetrachloride	insol.	Decahydronaphthalene	insol.
Amyl acetate (mixed isomers)	1.15	Diacetin	M
sec-Amyl acetate	0.9	Diacetone alcohol	M
Amyl alcohol (mixed isomers)	9.0	Dibutyl phthalate	0.3 (25° C.)
sec-Amyl alcohol	9.9		
Benzene	insol.	Dichlorethyl ether	0.1
Benzyl alcohol	8.4	Dichlorodiethyl ether	insol.
Benzyl ether of ethylene glycol	18.1	Diethanolamine	M
n-Butyl acetate	1.86	Diethyl carbonate	2.6
sec-Butyl acetate	1.65	Diethyl ether of ethylene glycol	4.5
Butyl acetyl ricinoleate	2.1 (25° C.)	Diethyl ether of ethylene glycol acetate	M
n-Butyl alcohol	19.50	Diethyl ketone	2.1
sec-Butyl alcohol	44.1 (25° C.)	Diethyl sulfate	0.7
		Diethylene glycol	M
Butyl butyrate	0.43	Diglycol diacetate	M
Butyl ether	insol.	Diisobutyl ketone	S. S.
Butyl ether of diethylene glycol	M	Dimethyl ether of ethylene glycol	M
Butyl ether of diethylene glycol acetate	3.4	Dimethyl phthalate	2.2
Butyl ether of ethylene glycol	M	1,4-Dioxane	M
Butyl ether of ethylene glycol acetate	1.9	Dipentene	insol.
		Dipropyl ketone	0.9
Butyl lactate	14.5	Ethyl acetate	11.0
n-Butyl propionate	0.8	Ethyl acetoacetate	2.8
Butyl stearate	0.04 (25° C.)	Ethyl alcohol (anhydrous)	M
		Ethyl alphahydroxyisobutyrate	M
Chloroform	insol.	2-Ethyl butyl acetate	0.6
Cyclohexane	insol.	2-Ethyl butyl alcohol	4.5

TABLE 1.—Solubility of Water in Solvents (by Weight in 100 parts Solvent at 20° C.)—*Continued*

Ethyl butyrate	0.8
Ethyl ether	1.3
Ethyl ether of diethylene glycol	M
Ethyl ether of diethylene glycol acetate	M
Ethyl ether of ethylene glycol	M
Ethyl ether of ethylene glycol acetate	9.4
Ethyl lactate	M
Ethyl propionate	1.2
Ethylene chlorohydrin	M
Ethylenediamine	M
Ethylene dichloride	0 2
Ethylene glycol	M
Ethylene oxide	M
Fenchone	0 5
Furfural	4.8
Furfuryl acetate	insol.
Furfuryl alcohol	M
Glycol diacetate	21.2
Glycol monoacetate	M
Hercosol	insol.
Hi-Flash naphtha	insol.
n-Hexanol	6 5
Hexone (methyl isobutyl ketone)	2 81
Hexyl acetate	0.7
Hexyl (2-ethyl butyl) acetate	0.8
Hexyl (2-ethyl butyl) alcohol	4.6
Isobutyl acetate	1.64
Isobutyl alcohol	16.9 (25° C.)
Isopropyl acetate	2.9
Isopropyl alcohol (anhydrous)	M
Isopropyl ether	0 7
Isopropyl ether of ethylene glycol	M
Isopropyl lactate	M
Mesityl oxide	2 85
Methanol (anhydrous)	M
3-Methoxy butyl acetate	3 7
Methyl acetate	11.0
Methyl acetoacetate	38 0
Methyl acetone	M
Methyl amyl acetate	0.9
Methyl amyl alcohol	6 4
Methyl *n*-amyl ketone	1.4
Methyl *n*-butyl ketone	2.2
Methylcyclohexone	3.0
Methyl ether of diethylene glycol	M
Methyl ether of diethylene glycol acetate	M
Methyl ether of ethylene glycol	M
Methyl ether of ethylene glycol acetate	M
Methyl ethyl ketone	11.8
Methyl *n*-hexyl ketone	0 6
Methyl propyl ketone	3.34
Mineral spirits	insol.
Monoacetin	M
Monochlorobenzene	insol.
Monoethanolamine	M
Octyl acetate	S. S.
Octyl alcohol	S. S.
Octyl (2-ethyl hexyl) acetate	0 4
Octyl (2-ethyl hexyl) alcohol	2 5
o-Dichlorobenzene	insol.
Petroleum naphtha	insol.
Pine oil	1.7
Pine oil (heavy)	2 4
Propylene chlorohydrin	M
Propylene dichloride	0.3
Propylene glycol	M
Propylene oxide	41 0
Safe-T-Esso	insol.
Solvesso No. 1	insol.
Solvesso No. 2	insol.
Solvesso No. 3	insol.
Tetrahydrofurfuryl alcohol	M
Tetrahydronaphthalene	insol.
Toluene	insol.
Turpentine (gum spirits)	insol.
Turpentine (steam distilled)	insol.
V. M. & P. naphtha	insol.
Xylene	insol.

Blushing

Gum, cotton, or other types of blush, are caused by precipitation of one or more of the lacquer ingredients during the stages of drying. Rapid evaporation, one causative factor of this precipitation, lowers the temperature; and this results in condensation of water vapor on the surface. This condensed water forms molecular aggregates with some of the ingredients in the lacquer, thus replacing and precipitating gum or a cellulose derivative. Another cause of blush is the evaporation of the active solvent which leaves the non-volatile constituents of the lacquer in contact with non-solvents, with precipitation as the natural consequence. This blush, or pre-

cipitation, causes a lack of homogeneity giving, as a result, white or opaque films with inferior strength and durability. To prevent blushing and to keep the ingredients in solution and uniformly mixed, the solvent blend should be so adjusted as to contain always sufficient active solvent in the residual mixture. The residual solvent mixture must also be of such a nature as to form molecular aggregates with water and still retain its solvent power for the lacquer constituents. In other words, the active solvent mixture must be of such a nature as to tolerate non-solvents, such as hydrocarbons and water, throughout all the stages of drying. This proper balance of volatile ingredients cannot be too forcibly stressed because of the constant change in ratio between solvent and non-solvent during the drying period.

Diluents and Thinners

In lacquer formulation alcohols and esters of high boiling point are used to hold the nitrocellulose and the resin in solution. If a diluent or blending agent is needed, it too must possess a high boiling point to keep the proper volatility balance. The components of a solvent mixture may comprise such materials as coal-tar hydrocarbons, petroleum distillates, turpentine fractions, alcohols, ethers, esters, and ketones, depending on the kind of solution desired. Some of these substances are added not only to meet the demand for low-cost solvents and thinners, but also because their presence is often very necessary for complete compatibility. These so-called diluents are active solvents for certain resins such as rosin, thus, elemi, mastic, dammar, ester gum, cumar, synthetic resins and so forth, and are of value in blending these resins with cellulose derivative solutions. Their power to reduce the viscosity of a concentrated lacquer gives them the title of thinner. The resinous material added to lacquers imparts depth, adherence and gloss to the film, while the diluent effects flow and vaporization.

Mixing of solvents, diluents and thinners often results in change of solvent properties. Some chlorinated compounds become good solvents for cellulose esters when mixed with an alcohol. On the other hand, some active solvents for esters of cellulose lose some of their solvent power when mixed with hydrocarbons. Alcohols are added to lacquers to improve flow and to prevent blushing, although they vary considerably in these respects. Alcohols are not true or active solvents for nitrocellulose as are the active dissolvents like ethyl lactate or *n*-butyl acetate. The alcohol group, however, cannot be classed as non-solvents like toluene or naphtha. When an alcohol is added to a true solvent, the solvent power of the latter is not reduced but, on the contrary, this active solvent activates the alcohol to such an extent that it too becomes a solvent. Therefore, alcohols are referred to as "latent solvents" whose hidden solvent qualities are brought out by the addition of an active solvent. The presence of a latent solvent increases the tolerance of an active solvent for a non-solvent. This group

of latent solvents can also be called extenders because they increase the volume of a mixture without decreasing the solvent power.

TABLE 2.—Dilution Ratios

Solvent	Diluent: Mineral Spirits	Petroleum Naphtha	Toluene	Xylene	50% Toluene 50% Naphtha	Benzene	Turpentine	Gasoline	Toluene 25% Gasoline 75%	Toluene 50% Gasoline 50%	Toluene 75% Gasoline 25%
Acetone		0.7	5.0	3.7	1.5						
Acetonylacetone				1.8							
Amyl acetate (commercial)		1.5	2.7		1 9				1.7	2.1	2.3
Amyl acetates (isomeric)		1 3	2.5	2.4	1.9						
sec-Amyl acetate		1.1	2.1	2 1	1.5				1.4	1.5	1.7
Amyl lactate		2.5	4.2								
Benzyl ether of ethylene glycol				3.0							
n-Butyl acetate	1 3	1.7	2 9	2.7	2.1	2 6	3.5				
sec-Butyl acetate		1.4	2.8	2.6	1.8	1 5	2.2				
Butyl butyrate		0 9	1 8	1.8							
Butyl ether of ethylene glycol	1.9	2.3	5.3	3.2	2 6	2 6	2.8		2.2	2.4	2.4
Butyl ether of ethylene glycol acetate	1 0			1.9							
Butyl ether of diethylene glycol	1 2		S	4.2							
Butyl ether of diethylene glycol acetate	0 6			1.8							
Butyl ether of propylene glycol		0 6	1 4	1.5		1 2	1.1		0.9	1 0	1.4
Butyl furate			3 8					1.4			
Butyl lactate	2 1	3 0	5.7	5.1	4 0						
Butyl oxybutyrate		2 2		3.8							
n-Butyl propionate	0 7	1.4	2.5	2.3	1 5				1.3	1.4	1.5
Cyclohexanone	1.0			7.5							
Cyclohexanyl acetate		1.4	2.5								
Diacetone alcohol (diacetone)	0.3	0 6	3 5	2.9	1.1			0.5			
Diamyl phthalate		2.0	2.2								
Dibutyl phthalate		1.7	2.7	2.6							
Dibutyl tartrate		1 4	8.0	7.7							
Dichlorethyl ether			S_1								
Diethyl carbonate		0.5	1.1								
Diethyl ether of ethylene glycol	0 2			0.4							
Diethyl ether of diethylene glycol	0 5			1.4							
Diethyl ketone		0.7	3.0								
Diethyl phthalate		0.7	3 8								
Diethylene glycol			S								
Diglycol diacetate				1.3							
Diisobutyl ketone	0.6			1.5							
Dimethyl phthalate			2.9								
Dipropyl ketone	0.3	0 9	3.1	2.7							
Dioxan			S_1								
Ethyl acetate		1.1	3.3		1.9						
2-Ethyl butyl acetate			2.1								
Ethyl butyrate		0.7	1.9								
Ethyl ether			S_1								
Ethyl ether of ethylene glycol	0.7	1.1	5.3	4.3	1.8	4 8	1.9		1.6	2.6	4.5
Ethyl ether of ethylene glycol acetate	0.7	0.9	2 6	2 3	1.4						
Ethyl ether of diethylene glycol			S	1.2							
Ethyl ether of diethylene glycol acetate	0.6		2.2	1.9							
Ethyl ether of propylene glycol		0.8	2.8	2.8		2.7	1.4		1.3	1.9	2.7
Ethyl furate			3.5					0.7			
Ethyl lactate		0.7	5.5	4.7	2.5			0.8			
Ethyl oxybutyrate		1.3	4.5	3.7							
Ethyl propionate		0.8	2.1								
Ethylene dichloride			S_1								
Fenchone	0.8			2.9							
Furfural			2.9	1.6				0.2			
Furfuryl acetate			1.7	1.3				0.5			
Furfuryl alcohol				1.5							
Furfuryl furate			2.7					0.1			
Glycol diacetate				1.4							
Hercosol		0.1	0.4								
sec-Hexyl acetate	0.8			1.8							
Hexyl (2-ethyl butyl) acetate	1.1			2.0							

TABLE 2.—Dilution Ratios—*Continued*

Solvent	Diluent: Mineral Spirits	Petroleum Naphtha	Toluene	Xylene	50% Toluene 50% Naphtha	Benzene	Turpentine	Gasoline	Toluene 25% Gasoline 75%	Toluene 50% Gasoline 50%	Toluene 75% Gasoline 25%
Isoamyl ether of ethylene glycol		1.1	2 4			2.2	2 5		0.5	0.7	0.9
Isoamyl ether of propylene glycol		0 4	1 4	1 4		2 4	0 9		0.6	0 8	0 9
Isoamyl furate			3.2					1 6			
Isobutyl acetate		1.1	2.7								
Isobutyl ether of ethylene glycol		1 6	2 0	2.0		1.5	1 4		1.1	1 3	1.6
Isobutyl ether of propylene glycol		0.3	1.5	1 3		1.2	0 8		0 5	0 7	0.9
Isopropyl acetate		1.3	2.7								
Isopropyl ether of ethylene glycol	1 3	1.6	4.3	3 8		3.2	3 3		1.5	2 3	2.5
Isopropyl lactate		1.2	5.0								
Mesityl oxide		0 9	3.8								
Methanol (anhydrous)		0 3	2 5								
3-Methoxybutyl acetate	0.9			2.1							
Methylacetone		0.7	4.7								
Methyl acetate		0.9	2 3								
Methyl alcohol			2 5								
Methyl amyl acetate	0 8	1.0	1.7	1.6							
Methyl *n*-amyl ketone	1.1	1.2	3 9	3 6							
Methyl *n*-butyl ketone		1.1	3.9								
Methylcyclohexone	1 0			4.5							
Methyl ether of diethylene glycol			2 3	1 0							
Methyl ether of ethylene glycol		0 2	4 7	2 9		4 3	0 4		0 4	0 9	2.7
Methyl ether of ethylene glycol acetate	0 4	0 6	2 3	1 9							
Methyl ether of diethylene glycol acetate	0 3			1.7							
Methyl ether of propylene glycol		0 5	4.4	3 5		3.7	1 5		0 9	1.8	3 5
Methyl ethyl ketone		0 9	4 3	3 1	1 7						
Methyl furate			3 1					0 4			
Methyl *n*-hexyl ketone		0 9	3 6								
Methyl isobutyl ketone (hexone)		1 0	3 5		1 9						
Methyl isopropl ketone		0 9	3 6								
Methyl propyl ketone		1 0	4 0	3 4							
Octyl acetate		0 8	1 3								
Octyl (2-ethyl hexyl) acetate	1 0			1.4							
Phorone	0 7		2.2	2 2							
Propyl acetate	1.2	1 2	3 0	2 0	1.7						
Propyl ether of ethylene glycol		1 3	3 4	3 6		3 0	3 0		2 0	2 4	2 9
Propyl ether of propylene glycol		0 7							1.1	1 3	1 8
Propyl furate			3.9				1.1				
Propylene dichloride			S_1								
Propylene oxide			2 5								
Tetrahydrofurfuryl alcohol			7 8	2 6			0.6				
Tricresyl phosphate		0.7	3 2	3 5							
Triethylene glycol				S							

In general, simple esters and ketones activate alcohols so that they too become solvents and are capable of tolerating various proportions of diluents. This is due to the molecular aggregates formed. Two-type solvents containing both an alcohol and an active solvent group, such as an ester, ether or ketone, activate alcohol to a lesser degree. Unit volumes of a solvent will activate only a limited amount of alcohol, indicating that definite molecular aggregates are formed. A mixture of 50 per cent *n*-butyl acetate and 50 per cent *n*-butyl alcohol will not lose its solvent power until 85 to 95 per cent of the volume is evaporated, contributing further evidence to the validity of the theory of molecular aggregates. Plasticizers, which are the high-boiling solvents, also activate alcohols.

TABLE 3.—Dilution Ratios

Solvent Mixture	% of Mixture	Toluene	Petroleum Naphtha	Toluene 50% Petroleum Naphtha 50%
Acetone	50			
Butyl alcohol	50	4.60		
Acetone	50			
Ethyl alcohol	50	4.60		
Amyl acetates (mixed isomers)	90			
Amyl alcohols (mixed isomers)	10	2.48		
Amyl acetates (mixed isomers)	85			
Amyl alcohols (mixed isomers)	15	2.46		
Amyl acetates (mixed isomers)	80			
Amyl alcohols (mixed isomers)	20	2.45		
Amyl acetates (mixed isomers)	67			
Amyl alcohols (mixed isomers)	33	2.30		
Amyl acetates (mixed isomers)	55			
Amyl alcohols (mixed isomers)	45	2.00		
Amyl acetates (mixed isomers)	45			
Amyl alcohols (mixed isomers)	55	1.60		
Amyl acetates (mixed isomers)	35			
Amyl alcohols (mixed isomers)	65	1.30		
Amyl acetates (mixed isomers)	30			
Amyl alcohols (mixed isomers)	70	0.90		
Amyl acetates (mixed isomers)	25			
Amyl alcohols (mixed isomers)	75	0.70		
sec-Amyl acetate	67			
sec-Amyl alcohol	33	1.70	1.10	1.30
sec-Amyl acetate	50			
Ethyl acetate	50	2.70	0.75	
n-Butyl acetate	50			
sec-Amyl alcohol	50	2 05	1 00	
sec-Butyl acetate	50			
sec-Amyl alcohol	50	1.90	0 80	
n-Butyl acetate	90			
n-Butyl alcohol	10	3 23		
n-Butyl acetate	80			
n-Butyl alcohol	20	3.20		
n-Butyl acetate	67			
n-Butyl alcohol	33	3.15	1.70	2.15
n-Butyl acetate	60			
n-Butyl alcohol	40	3 10		
n-Butyl acetate	50			
n-Butyl alcohol	50	2 90	1 50	1.90
n-Butyl acetate	40			
n-Butyl alcohol	60	2.50		
n-Butyl acetate	30			
n-Butyl alcohol	70	2.10		
n-Butyl acetate	20			
n-Butyl alcohol	80	1.75		
Butyl acetate	50			
sec-Butyl alcohol	50	2 30	1.00	
sec-Butyl acetate	50			
n-Butyl alcohol	50	2.55	1.20	
sec-Butyl acetate	50			
sec-Butyl alcohol	50	2.20	0.90	
n-Butyl acetate	50			
Ethyl acetate	50	2.85	1.30	2.20

TABLE 3.—Dilution Ratios—*Continued*

Solvent Mixture	% of Mixture	Toluene	Petroleum Naphtha	Toluene 50% Petroleum Naphtha 50%
Butyl acetate	50			
Fusel oil (refined)	50	2.50	1.30	
sec-Butyl acetate	50			
Fusel oil (refined)	50	2.15	1.05	
Diacetone	50			
n-Butyl alcohol	50	3.10		
Diacetone	50			
Ethyl alcohol	50	2.75		
Dibutyl phthalate	50			
n-Butyl alcohol	50	2.70		
Dibutyl phthalate	50			
Ethyl alcohol	50	2.95		
Dibutyl tartrate	50			
n-Butyl alcohol	50	2.70		
Dibutyl tartrate	50			
Ethyl alcohol	50	2.95		
Ethyl acetate	50			
n-Butyl alcohol	50	3.00		
Ethyl acetate	50			
sec-Butyl alcohol	50	2 85	0.75	
Ethyl acetate	50			
Ethyl alcohol	50	3.55		
Ethyl acetate	50			
Fusel oil (refined)	50	2.50	0.95	
Ethyl ether of ethylene glycol	50			
n-Butyl alcohol	50	3 00		
Ethyl ether of ethylene glycol	50			
Ethyl alcohol	50	3 40		
Ethyl ether of ethylene glycol acetate	50			
n-Butyl alcohol	50	2 50		
Ethyl ether of ethylene glycol acetate	50			
Ethyl alcohol	50	3.00		
Ethyl lactate	50			
n-Butyl alcohol	50	3.85		
Ethyl lactate	50			
Ethyl alcohol	50	4.25		
Methyl ethyl ketone	85			
Ethyl alcohol	15	4.97		0.87

Classification of Solvents

Owing to the wide differences in physical and chemical properties of solvents and their use in a large variety of products, it is difficult to classify them in order to meet the demands of all. Some advocate a grouping according to evaporation rates while others think dilution ratios are more useful. Like all methods of classification these have their advantages and disadvantages. None gives a complete picture comprising purity, density, stability, evaporation rates, dilution ratios and so forth. The following is a classification according to boiling points:

By Boiling Point

Low Boilers

Those which boil below 100° C. usually have high evaporation rates, dry quickly, many reduce viscosity, many have pleasant odors, and are generally the active solvents or diluents.

Acetone
Acetylene dichloride
Benzene
sec-Butyl alcohol
n-Butylamine
Butyl chloride
Carbon disulfide
Carbon tetrachloride
Cyclohexane
Diethylamine
Diethyl carbonate
Diethyl ketone
Ethyl acetate
Ethyl alcohol
Ethyl alcohol (anhydrous)
Ethyl bromide
Ethyl ether
Ethyl propionate
Ethylene dichloride
Ethylene trichloride
Ethylidene chloride
Ethylidene ether
Isoamylamine
Isoamyl chloride
Isobutyl formate
Isopropyl acetate
Isopropyl alcohol
Methyl acetate
Methyl acetone
Methyl alcohol
Methyl carbonate
Methyl ether
Methyl ethyl ketone
Methyl formate
Methyl propionate
Methyl propyl ketone
Methylene chloride
Petroleum naphtha
Propyl alcohol
Propyl ether
Propyl formate
Propylene dichloride
*Solvesso No. 1

* For the chemical name of this and other trade name products see under their separate treatment in later chapters

Medium Boilers

Those which have boiling points ranging between 100 and 150° C. and usually impart the properties of flow to a lacquer.

n-Amyl acetate
Amyl acetate (mixed isomers)
sec-Amyl acetate
n-Amyl alcohol
Amyl alcohol (mixed isomers)
sec-Amyl alcohol
n-Butyl acetate
sec-Butyl acetate
n-Butyl alcohol
sec-Butyl alcohol
n-Butyl propionate
"Cellosolve"
"Cellosolve" acetate
Cyclohexanone
Diethyl carbonate
Diethyl "Cellosolve"
Dipropyl ketone
Ethyl butyrate
Furfural
sec-Hexyl acetate
Hi-Flash naphtha
Isobutyl acetate
Isobutyl alcohol
Isopropyl "Cellosolve"
Isopropyl lactate
Mesityl oxide
3-Methoxy butyl acetate
Methyl amyl acetate
Methyl amyl alcohol
Methyl *n*-amyl ketone
Methyl *n*-butyl ketone
Methyl "Cellosolve"
Methyl "Cellosolve" acetate
Methyl cyclohexanone
Methyl isobutyl ketone (Hexone)
Petroleum naphtha
Methyl propyl ketone
Monochlorobenzene
Phorone
Solvesso Nos. 1 and 2
Tetrahydrofurfuryl alcohol
Toluene
V. M. & P. Naphtha
Xylene

High Boilers

Those which boil between 150 and 200° C. These are the residual solvents with low evaporation rates and strong solvent power. They prevent blush or precipitation and impart final flow, resulting in smooth and glossy films.

Acetonyl acetone
Benzyl alcohol
Butyl butyrate
Butyl "Cellosolve"
Butyl "Cellosolve" acetate
Butyl lactate
"Carbitol"
Cyclohexanol
Cyclohexanyl acetate
Decahydronaphthalene (Decalin)
Diacetone alcohol
Dichloroethyl ether
Diethyl "Carbitol"
Diethyl oxalate
Diisobutyl ketone
Ethyl acetoacetate
Ethyl benzoate
Ethyl lactate
Fenchone
Furfuryl acetate
Furfuryl alcohol
Glycol diacetate
Hercosol
Hexyl (2-ethyl butyl) acetate
Methyl "Carbitol"
Methyl *n*-hexyl ketone
Mineral spirits
Octyl (2-ethyl hexyl) alcohol
Orthodichlorobenzene
Safe-T-Esso
Solvesso No. 3
Turpentine (gum spirits)
Turpentine (steam distilled)
V. M. & P. Naphtha

Midway Boilers

Those solvents having boiling points ranging between the high boilers and the plasticizers.

Benzyl "Cellosolve"
Butyl "Carbitol"
Butyl "Carbitol" acetate
"Carbitol" acetate
Diglycol diacetate
Levulinic acid esters
Methyl "Carbitol" acetate
Pine oil (heavy)

Plasticizers and Softeners

These solvents have boiling points of 300° C. or over and constitute a permanent part of the film. They impart toughness and flexibility. Refer to the chapter on Plasticizers for a further discussion of this subject.

By Chemical Composition

Aliphatic Hydrocarbons

Cyclohexane
Gasoline
Hi-Flash Naphtha
Mineral spirits
Petroleum benzene
Petroleum naphtha
V. M. & P. Naphtha

Aromatic Hydrocarbons

Benzene
Decahydronaphthalene (Decalin)
1-Methyl-4-isopropyl benzene
p-Cymene
Tetrahydronaphthalene (Tetralin)
Toluene
Xylene

Halogenated Aliphatic and Aromatic Hydrocarbons

Carbon tetrachloride
Dichlorethylene
Dichlorethyl ether
Ethylene chlorhydrin
Ethylene dichloride
Methylene chloride
Monochlorobenzene
o-Dichlorobenzene
Tetrachloroethylene
Trichloroethylene

Alcohols

Amyl alcohol
Benzyl alcohol
Butyl alcohol
Cyclohexanol
Ethyl alcohol
Hexyl alcohol
Hexyl (2-ethyl butyl) alcohol
Methyl alcohol
Methyl amyl alcohol
Octyl alcohol
Octyl (2-ethyl hexyl) alcohol
Propyl alcohol

Ketones

Acetone
Acetonylacetone
Cyclohexanone
Diacetone alcohol
Dibutyl ketone
Diethyl ketone
Dipropyl ketone
Mesityl oxide
Methyl acetone [a]
Methyl amyl ketone
Methyl butyl ketone
Methyl cyclohexanone
Methyl dipropyl ketone
Methyl ethyl ketone
Methyl *n*-hexyl ketone
Methyl isobutyl ketone
Methyl propyl ketone
Phorone

Esters

Acetates
Alkyl formates
Butyrates
Phosphates
Propionates
Stearates

Ethers

Diethyl "Carbitol"
Diethyl "Cellosolve"
Ether
Ethers of dihydroxy alcohols
Ethers from propylene glycol
Glycol ether

Alcohol Esters

Benzyl "Cellosolve"
Butyl "Carbitol"
Butyl "Cellosolve"
Butyl lactate
Diethyl malate
Diethyl tartrate
Ethyl glycollate
Ethyl hydroxypropionate
Ethyl lactate
Ethyl salicylate
Isopropyl "Cellosolve"
Isopropyl lactate
Methyl "Carbitol"
Methyl "Cellosolve"
Triethyl citrate

Ether-Alcohols

"Cellosolve"
"Carbitol"
Diethyl glycerol ether
Diethylene glycol
Glycidol
Monoethyl ether of triethylene glycol

Ketone-Alcohols

Acetonyl methanol
Diacetone alcohol
Dihydroxyl acetone
Pyruvyl alcohol

[a] Methyl acetone is comprised of acetone 48 per cent, methyl acetate 28 per cent, methanol 24 per cent.

Ketone-Esters

Ethyl acetoacetate
Ethyl pyruvate

Ketone-Ethers

Acetal ethyl ether (ethoxy acetone)
Ethyl ether of acetenyl methanol
Methyl ethoxy ethyl ether

Ester-Ethers

Butyl "Carbitol" acetate
Butyl "Cellosolve" acetate
"Carbitol" acetate
"Cellosolve" acetate
Diglycol diacetate
Ethoxy ethyl lactate
Ethyl ether of ethyl glycolate
3-Methoxy butyl acetate
Methyl "Carbitol" acetate
Methyl "Cellosolve" acetate

Ether-Alcohol-Ester

Glycol ether acetate

Requirements of Solvents

1. Lacquer solvents should possess active solvent properties for cellulose esters and ethers, gums and resins, and should be able to dissolve these substances in any desired proportion.
2. They should possess the property of wetting pigments.
3. Rate of evaporation should be uniform, or nearly so, to produce maximum gloss and finish.
4. Colorless or nearly so.
5. Odorless or nearly so (nothing persistent).
6. Neutral in reaction.
7. Stable to chemicals, water, atmospheric conditions and aging. They should not break down in structure.
8. They should tolerate large amounts of non-solvents without blushing or precipitation.
9. Non-toxic to insure the health of user.
10. Free from water.
11. Boiling point or range should indicate purity.
12. The evaporation rate should not produce too great a drop in temperature.
13. Minimum lifting action on varnish and paint films.
14. Good blending properties are essential.
15. The cost should be moderate, and the solvent should be commercially abundant, and have a low specific gravity.

Requirements of Mixed Solvents

1. They should hold the non-volatile ingredients until the film has dried.
2. The active solvent should evaporate at a slower rate than the non-solvent and thus prevent blush or precipitation.

3. The active solvent should be the last to leave the film, but prior to this it should produce a flow resulting in a smooth glossy surface free from gas bubbles.
4. These mixtures should produce uniform blending of all the lacquer ingredients during the stages of drying.
5. When employed as a thinner, they must cut the lacquer base readily.

Requirements of Diluents and Thinners

1. Should possess solvency.
2. Have no harmful physiological effects.
3. Contain no toxic vapors.
4. The active and non-solvents should be in such proportions as to impart maximum solvency.
5. They should approach the perfect mixture in solvent power, thinning qualities, blush resistance, rate of evaporation, low cost and non-lifting action of the under-coat.

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Chapter 3

Plasticity

Properties of Plasticizers

"Plasticity the Servant of Industry," a phrase of Freundlich, adequately sums up the functions and properties of plasticizers. Generally, a plasticizer is a non-volatile, non-separating neutral substance which, when added to another material, imparts plasticity to the mixture. The term plasticizer is a broad one and its significance varies with the industries. What is required of it in the lacquer industry is perhaps not a desirable feature in the molding trade. It follows that plasticity, a desirable property which is imparted by a non-volatile neutral solvent for nitrocellulose in the pyroxylin industry, is an unwanted quality in the artificial leather trade where softness and pliability are necessary. The purpose of the plasticizer is to improve the process of molding and to increase the virtues of a lacquer so as to make it adaptable for various purposes. These desirable properties are brought about by the action of the solvent-plasticizer, or softener, or extender, on the compatible material. The addition of tricresyl phosphate to certain grades of nitrocellulose produces a transparent gel. However, the addition of more plasticizer produces a further dispersion of cellulose derivative with a consequent homogeneous composition. This action is comparable to the process of adding a solvent and a diluent. The greater the solvent power of a plasticizer, the more diluent it will tolerate. Tricresyl phosphate belongs to the group of solvent-plasticizers which exhibits the power to gel. If castor oil is added to this same grade of nitrocellulose it is softened, but no visible change can be observed and the addition of more softener produces no visible effect. Softeners possess the disadvantage of exuding from film or molded masses by changes of pressure or temperature. The gelling-plasticizers, as a rule, do not exude.

Extenders are non-volatile materials and are compatible with cellulose derivatives. They include such materials as the chlorinated derivatives of linseed oil, resinous material and so forth. They do not possess plasticizing properties but, as the term implies, they permit greater dilution with diluents and extend the covering power of a lacquer. There are some natural and synthetic resins like ester gum, dammar, mastic, oils, modified glyptols, phenol-aldehyde resins, vinyl resins, methyl, ethyl, and benzyl abietates, chlorinated diphenyls, toluene-sulfonamide-aldehyde resins, and alkyl resins which act as film-forming materials and are compatible

with cellulose derivatives. They do not plasticize but form clear or homogeneous films. Some of the recently proposed ester ricinoleates and linoleates are on the border line between oils and solvents.

The best plasticizer is the solvent type of a very low volatility, and this very low or non-volatility insures permanent retention. The solvency of this type causes the plasticized film to flow and give without rupture under stress; it allows for film elongation and contraction with changes in temperature; and it permits bending and yielding without fracture under impact. The most important constituent of a lacquer is the plasticizer. The usual quantity of this important constituent should produce the desired and well-balanced relation between increased toughness, flexibility, elasticity and tensile strength. In addition to increased plasticity, these high-boiling solvents add improvement in the flow, smoothness and wearing properties of the film. Gloss or shine in a lacquer film is due to the retarding effect of solvent evaporation which produces a flow just before setting. This flow before setting also prevents blushing and therefore gives a smooth glossy finish, eliminates shrinkage, and fills in rather than bridges over the minute cavities on the surface. This filling in of the porous surface accounts for better adhesion. Cellulose esters and ethers, some synthetic and most natural resins are brittle. This property increases with age. When these substances are used in making coatings which are applied to wood, metal, leather, textiles and so forth, or used in making thermoplastics, their lack of adhesive power causes them to shrink upon drying and aging with consequent cracking and shattering. Any substance which, when added to cellulose derivatives, gums and resins, is able to alter their properties so as to make them more desirable and valuable, is called a plasticizer. For example, acetyl cellulose is brittle, lacking in mechanical strength, and a solution of it lacks adequate plasticity. This is not improved by the addition of gum and pigment which only adds to its brittleness. Should a suitable plasticizer be added, however, a film can be produced which is tough and ductile. The strength, flexibility and clarity of cellulose esters depend upon the type and quantity of plasticizer added.

A more specific and practical example [1] is the mixing of the following which makes an unpigmented enamel base lacquer:

Nitrocellulose (28-second viscosity)	227 grams
Dammar gum	255 grams
Ester gum	57 grams

Dissolved in 3.78 liters of this solvent:

	Per cent
Butyl acetate	25
Butanol	10
Ethyl acetate	15
Xylene	8
Toluene	42

With the addition of 1300 to 1800 grams of Zinc White (ground in) a good white enamel for flat work is produced. This lacquer will, upon aging and when bent, chip and splinter. These faults can be overcome by the addition of 80 per cent dibutyl phthalate on the weight of the nitrocellulose. This film, which is not any softer, can now be bent without consequent marring or loosening from the metal. Similarly, addition of camphor to nitrocellulose makes it possible to mold the mixture at 100° C.

Plasticizers, like all solvents, are able to form molecular aggregates with other substances, like solvents, cellulose derivatives, gums, resins, dyes and so forth, and like other molecular aggregates, some are firmly held together with resulting good, homogeneous, strong, and stable films. Other such aggregates are formed in lesser quantities and held together less tightly and these are sometimes referred to as softeners. Still others form molecular aggregates with one substance in a mixture and repel other substances in that mixture, with a consequent production of all sorts of combinations and results. To form homogeneous films, plasticizers should be solvents for cellulose derivatives, resins and gums and at the same time should be compatible with pigments and dyes.

Requirements of a Plasticizer

1. Good solubility for the material it is used to plasticize, as cellulose derivatives, gums, resins and so forth.
2. Little or no inflammability.
3. Clear, colorless or nearly so. If it contains color, it should not interfere with the finished product.
4. Odorless and tasteless or nearly so, especially when it is used for wrapping food products.
5. Should be unaffected by light, water, chemicals, oils and fats.
6. Stable to atmospheric conditions.
7. Must not crystallize or separate. It must stay in solution permanently.
8. Should possess a high melting point and be non-volatile.
9. Neutral or nearly so.
10. Relatively inexpensive.
11. Must not impair hardness of film, nor plastic mass, nor have bubbling qualities.
12. Should not increase viscosity; if anything, it should decrease it.
13. Should impart ductility, tenacity and adherence.
14. Non-conductor.
15. Compatible with filler, dye, pigments and resins.
16. Must produce highly elastic, non-shrinking and non-scratchable surface.
17. Must produce a homogeneous, tough, flexible and permanent film and should not appreciably reduce film strength.
18. Should be non-injurious to film or plastic mass.
19. Non-hydrolyzing.
20. Resistant to heat, or be heat-proof.

21. Flexibility at all temperatures.
22. High retentivity.
23. Stability on aging.

It is impossible and unnecessary for any substance to meet all the above requirements. To make these requirements adequately workable, it is necessary either to use differing plasticizers to suit the problem or to use combinations of these for the desired results. The purpose and use to which the plasticized material will be subjected will determine both the wisdom of choice and which qualification is of primary or secondary importance and which can be overlooked entirely. For further elucidation of some of the above requirements for an ideal plasticizer, odorless and tasteless plasticizers are absolutely necessary when they will be used to wrap food products. In other substances a slight odor is not objectionable provided it is not noticeable in the fabricated material. Water-resistance is necessary as water will soften, loosen, or disintegrate the material. Liquid gelling agents are preferred to solid, because there is often crystallizing out of the solid. Nevertheless, some solids impart valuable properties, such as combining hardness and elasticity, or a desirable crystallizing out which produces beautiful crystalline effects called "crystal lacquers." To prevent bleeding or separation of dyes, compatibility is necessary, although, in isolated cases, this is not desired. It is also necessary that plasticizers be compatible with resins. The addition of resins improves lustre, adhesion, hardness and durability. Resins, however, do retard drying, reduce mechanical solidity of the film, and increase brittleness which is, however, counteracted by the presence of plasticizer.

Plasticizers came into prominence with the development of pyroxylin and the subsequent growth of the cellulose ester and ether industries. Camphor was the first to be satisfactorily used with nitrocellulose in the making of celluloid and molded pyroxylin articles. In 1883 Graebe [2] used dialkyl phthalate as a plasticizer in pyroxylin and Nobel [3] later advocated the use of dialkyl esters of phthalic acid.

Messer,[4] working on the assumption that acetone, ethyl acetate, and some chlorinated compounds are good solvents, inferred that a good plasticizer could be made should a keto-group, as is found in acetone, or an ester-group, as is present in ethyl acetate, be chemically combined with a high-boiling solvent, and in so doing combine good solvent properties with a high boiling point. Working on these premises he combined sodium salicylate with chloracetone. The free hydroxyl group in the resulting product was then acetylated, producing $OAc \cdot C_6H_4CO_2 \cdot CH_2 \cdot Ac$. The gelatinizing power of this high-boiling, large molecule is attributed both to the ketone and to the two ester groups. When benzoic acid replaced salicylic acid, the inert benzene nucleus reduced the solvent action of the three groups. The replacement of salicylic acid with phthalic acid yielded diacetonyl ester of phthalic acid $C_6H_4(CO_2 \cdot CH_2 \cdot Ac)_2$ with four gelatinizing groups which also possessed high solvent power.

Similar effects were obtained by combining hydroxy or dicarboxylic aromatic acids with ethyl or methyl acetate. Sodium salts of aromatic acids and chloracetic esters were combined and the resulting product was acetylated. Hydroxy acid, like salicylic, yielded $AcO \cdot C_6H_4 \cdot CO_2 \cdot CH_2 \cdot CO_2 \cdot C_2H_5$; from phthalic acid was obtained $C_6H_4(CO_2 \cdot CH_2 \cdot CO_2 \cdot C_2H_5)_2$. These substances are water-insoluble, stable to hydrolysis, and possess excellent softening qualities. Messer[4] has also condensed diacetin and aromatic and aliphatic mono- and dicarboxylic acids, obtaining $AcO \cdot C_6H_4 \cdot CO \cdot CH(CH_2 \cdot OAc)_2$ from salicylic acid and $C_6H_4[CO_2 \cdot CH \cdot (CH_2 \cdot OAc)_2]_2$ from phthalic acid. He has made glyceryl esters by passing a stream of hydrochloric acid gas through a mixture of phthalic anhydride and glycerin. The intermediate chlorohydrins were then treated with sodium acetate and acetic anhydride. These syrupy liquid esters were water-insoluble, non-volatile, and solvents for nitro- and acetylcelluloses and possessed boiling points above 300° C. Other plasticizers proposed by Messer are the acetylated condensation products of aniline and chlorohydrins and the sulfonamides.

Jenkins[5] is of the opinion that the solvent action of ethyl ether of ethylene glycol for nitrocellulose is owing to the combined action of alcohol and ether groups, which is similar to the solvent power of a mixture of ether and alcohol. The solvent properties of "Cellosolve" acetate are similar to the mixture of ethyl acetate and alcohol. By analogy and fact, "Cellosolve" stearate is a good gelatinizer. The analogy is based on both the dissolvent groups present and the boiling point. Other compounds giving evidence of dissolvent power owing to the presence of certain groups are :

1-3 Diamyl ether of glycerol
1-3 Dibutyl ether of glycerol
1-3 Diethyl ether of glycerol
1-3 Dimethyl ether of glycerol

The solvent action of a mixture of benzene or toluene with alcohol for cellulose ethers has been synthesized in the gelatinizing action of:

1-3 Ditolyl ether of glycerol
1-3 Diphenyl ether of glycerol

A review of the plastic industry reveals the following plasticizers which are used in conjunction with nitrocellulose:

Acetanilide	Diphenyl urea
Alkyl phthalates[a]	Esters of phosphates[c]
Butyl stearate[b]	Ethyl acetanilide (Mannol)
Butyl tartrate	Toluene sulfonamide derivatives
Camphor	Triacetin

[a] Diamyl, dibutyl, diethyl, dimethyl phthalates.
[b] Butyl stearate, when used with amyl phthalate, imparts polishing properties.
[c] Tributyl, tricresyl, triphenyl phosphates impart noninflammability.

The plasticizers used in conjunction with cellulose acetate are fewer in number. Some of these are:

Alkyl acetanilides	Methyl mandelate
Benzophenone	Pentaerythrytol tetraacetate[a]
Chloretone	Phenyl carbamate
o-Cresyl-*p*-toluene sulfonate	Resorcinyl diacetate[b]
Cyclohexanone	Triacetin
Dimethyl phthalate	Tributyrin
Ethyl malonate	Tricresyl phosphate
Ethyl succinate	Triphenyl phosphate
Isoamyl carbamate	

Plasticizers used with cellulose ethers are:

Tricresyl phosphate	Diethyl phosphate
Triisobutyl phosphate	

Recently Proposed Plasticizers [6]

A. Ethoxyethyl lactate, alkyl-ether phosphates and adipates and others.
B. Oximes of some high-boiling ketones and aldehydes, such as acetophenone, cyclohexanone and furfural.
C. Alkyl ether acetal with the aid of mercury fluoroborate as a catalyst.
D. Hydroxydiphenyl methanes, such as phenyl cresyl methane.
E. Alkylated derivatives of di- and tetramethylene oxides.
F. Esters of naphthenic acid.
G. Esters of di-, tri-, tetra-, and pentaethylene glycol.
H. Complex bodies made by the action of glycerol on cyclohexanone; for example, pentamethylene-hydroxymethyl-dihydrodioxol.
I. A group of solvents and plasticizers of the methylene ether-ester type, proposed by Frederick Walker. These are made by reacting chloromethyl ethers with sodium salts of organic acids.

$$R - OCH_2Cl + NaOOC - R \longrightarrow NaCl + R - OCH_2OOC - R$$

He has prepared fourteen of these solvents and determined their physical properties.

J. The laboratories of Eastman Kodak [7] have developed the following plasticizers:

Butyl *o*-methoxybenzoate	*p*-Nitrobenzyl
Ethyl *p*-methoxybenzoate	Propyl *p*-hydroxybenzoate
Furfural diacetate	

K. The Commercial Solvents Corporation [8] has recently developed the metal salts of alkyl acid esters of polyhydric alcohols and polybasic acids as plasticizers:

[a] Transparent to ultra-violet light.
[b] Discolors on standing.

Calcium butyl glyceryl phthalate
Cobalt butyl glyceryl phthalate
Sodium butyl glyceryl phthalate
Zinc butyl glyceryl phthalate
Zinc isoamyl glyceryl phthalate

L. Monsanto Chemical Company [9] offers as a new plasticizer:

N-substituted aryl-sulfonamide
(N-ethyl-N-acetyl *p*-toluene sulfonamide)

M. Some of the research workers in the field of plasticizers have shown a renewed interest in castor oil. It has been condensed with polybasic aliphatic and aromatic acids. Examples of these are the condensation products of castor oil with glycerin, succinic, benzoic and tartaric acids, and half-ester of maleic acid. Acetyl butyl ricinoleate is another plasticizer which has been proposed.

N. Aliphatic and aromatic esters of phthalic and hydroaromatic esters:

Benzyl *n*-propyl phthalate
Diethyl ester of di-*n*-butyl monoamid phosphoric acid
Ester of keto-acids
Methyl xylyl hexyl ester of beta-keto butyric acid
Mono-, di-, tri-, tetra-, and hexaoxystearic acid
Xylyl hexyl isoamyl phthalate

Krumbhaar [10] reports that the best plasticizers for chlorinated rubber are the soft alkyls, chlorinated naphthalenes and some synthetic oils.

Krus,[11] in his survey of plasticizers in contemporary publications, concludes that most of them exhibit better solvency for the ester-soluble type of nitrocellulose than for the alcohol-soluble types of low nitrogen content. The best gelatinizers are the aliphatic and aromatic phosphoric acid esters. Dibenzyl tartrate is worthy of special recommendation. Those of weaker plasticizing power are triacetin, dibutyl tartrate, esters of citric acid, and the phthalates. Those of no particular significance as plasticizers are the adipic acid esters, and the acetates of higher fatty alcohols (cetyl and oleyl alcohols). Non-solvency for pyroxylin is shown by the stearates, oleates, ricinoleates and castor and rape oil preparations. The viscosity is increased by both castor and rape oils on one hand and reduced by the aliphatic phosphates on the other. Extensibility is imparted by the addition, in large quantities, of aliphatic phosphates, acetates of higher fatty alcohols, the citrates and triphenyl phosphate. Dibutyl tartrate gives maximum efficiency in high extensibility and high tensile strength, with second place taken by butyl oleate. Castor oil, which is known to impart toughness to films, is outdone in this by the trialkyl phosphates and some phthalates. Films and regenerated cellulose are generally plasticized with glycerin or glycol. These are non-injurious, non-toxic and tasteless.

TABLE 4.—Data on Nitrocellulose Solutions and Exposure of Films.[12]

No.	Organic Compound Added	Condition of Solution	Color of Solution	Color of Unexposed Film	Color of Film After 2 Hours in Sunlight	Days for Complete Failure	Condition of Films Not Failing in 170 Days
1	iso-Allylamine	Clear	Light red	Light yellow	Light yellow	29	
2	Benzylamine	Clear	Red	Light brown	None	32	
3	Piperine	Clear	None	None	Yellow	32	
4	Quinoline	Clear	Light yellow	Light yellow	Light yellow	32	
5	Diphenylguanidine	Clear	Red	Light yellow	Light yellow	39	
6	Piperidine	Clear	Red	Light brown	None	39	
7	*o*-Anisidine	Clear	Red	Light tan	Brown	47	
8	*p*-Toluidine	Clear	Red	Light red	Tan	47	
9	Xylidine	Clear	Red	Light tan	Light tan	47	
10	Acetotoluide	Clear	None	None	None	63	
11	4-Amino-1,3-dimethylbenzene	Clear	Red	Light tan	Light tan	64	
12	Dimethyltoluidine	Clear	None	None	None	64	
13	Hippuric acid	Incomplete*	None	None	None	64	
14	Oxamide	Incomplete*	None	None	Brown spots	64	
15	Pyridine	Clear	None	None	None	64	
16	Aniline	Clear	Light red	Light red	Light tan	79	
17	Diethylaniline	Clear	None	None	Brown-yellow	79	
18	None added (original solution)	Clear	None	None	None	80	
19	Acetanilide	Clear	None	None	None	80	
20	Asparagine	Incomplete	None	None	None	80	
21	Dichloroaniline	Clear	None	None	Light tan	80	
22	Dimethylaniline	Clear	None	Very light green	Green	80	
23	Formanilide	Clear	None	None	None	80	
24	Monoethylaniline	Clear	None	None	Light tan	80	
25	Urea	Incomplete	None	None	None	80	
26	Urethane	Clear	None	None	None	80	
27	Benzamide	Clear	None	None	Light buff	102	
28	Formamide	Clear	Very light yellow	Brown spots	Brown spots	102	
29	Acridine	Clear	Light brown	Light yellow	Yellow	117	
30	Anthranilic acid	Clear	Light brown	Light tan	Brown	117	
31	β-Naphthylamine	Clear	Red	Red	Red	117	
32	Diphenylthiourea	Clear	Very light yellow	None	Light yellow	117	
33	Ethylbenzylaniline	Clear	None	None	Brown-yellow	117	
34	*p*-Amidobenzoic acid	Clear	Light yellow	Light tan	Tan	117	
35	*p*-Bromoaniline	Clear	Light red	Light tan	Tan	117	
36	α-Naphthylamine	Clear	Red	Reddish	Wine red	130	
37	Carbazole	Clear	None	None	Greenish yellow	+ 170	Dull and considerable rust.
38	*m*-Nitroaniline	Clear	Light red	Green-yellow	Yellow-brown	+ 170	Dull and considerable rust
39	Methyldiphenylamine	Clear	None	None	Greenish yellow	+ 170	Dull and considerable rust
40	Phenyl-α-naphthylamine	Clear	Red	Faint tan	Red	+ 170	Dull and considerable rust
41	Diphenylamine	Clear	None	None	Golden-brown	+ 170	Somewhat dull; rust at edges of panel only

*i.e., undissolved crystals

TABLE 5.—Plasticizers

Name	M—Melting Point B—Boiling Point F—Flash-Point ° C.	Specific Gravity at 20° C.	Refractive Index at 20° C	Vapor Pressure (mm. Hg) at 20° C.
Acetamide	M 81 B 222	1.159	1.4274	
Acetanilid	M 114.2 B 303.8	1.2105 (4°)		
Acetonyl acetone	M 9 F 190° F. B 188	0.973	1.4490	2 (30°)
p-Acetophenetidin	M 135.0 B decomp.			
Acetyldiphenylamine	M 93.5			
Acetyl phenyl-β-naphthylamine	M 93.0			
Amyl borate	B 260	0.865	1.4200	
Amyl lactate	B 210.0	0.957– 0.960 (15°)		
Amyl oxalate	B 265.0	0.970		
Amyl tartrate	B 400.0	1.045	1.4500	
Benzanilid	M 161 B 117–9(10)	1.3214		
Benzol monethyl sulfonamid	M 57–58			
Benzyl abietate	B 294			
Benzyl acetate	F 93 B 213.5	1.058	1.5232	
Benzyl alcohol	M 15.3 F 100° F. B 206.9	1.046	1.5394	1(61°)
Benzyl ether of ethylene glycol	F 265° F. B 254	1.070		1 0 (30°)
Benzyl lactate	B 130.0		1.5252 (25°)	
Borneol	M 208.6 B 213.5	1.011		
Butyl acetyl ricinoleate	– 32 to – 65 F 110 B 230	0.940		3
Butyl "Cellosolve" stearate	B 230 (5 mm.)	0.88		
Butyl ether of diethylene glycol	F 230 B 232.1	0.957	1.4258 (27°)	0.2 (50.2°)
Butyl ether of diethylene glycol acetate	F 260° F. B 236	0.987		1.0 (30°)
Butyl ether of ethylene glycol acetate	F 180° F. B 188	0.943		1.0 (30°)
n-Butyl lactate	F 61 B 185–195	0.987– 1.012 (15°)	1.4204	
Butyl phthalyl glycollate	M 35 B 219.0	1.098	1.4897	5
Butyl stearate	M 19–20 B 220.0	0.856– 62	1.4444	20
Butyl tartrate	M 22 B 205.0	1.082	1.4400	20
Camphor	M 179.0 B 209.0	0.990 (25°)		
p-Chloracetanilid	M 172.5	1.385	1.4602	
Cyclohexanol	B 162.3	0.945		0.42
n-Deca alcohol	M 7 B 231.0	0.830	0.1440	

TABLE 5.—Plasticizers—*Continued*

Name	M—Melting Point B—Boiling Point F—Flash-Point ° C.	Specific Gravity at 20° C.	Refractive Index at 20° C.	Vapor Pressure (mm. Hg) at 20° C.
Decahydronaphthalene	F 145° F. B 186	0.885	1.4758	2 (30°)
Diacetin	F 146 B 259.0	1.179 (15°)	1.4395	
Diamyl phthalate	B 340.0	1.023	1.4865	37
Dibenzyl	M 52.5 B 284	0.942 (80.6°)	1.539 (80.6°)	
Dibenzyl succinate (Esterol)	M 45 B 238(14)			
Dibenzyl tartrate	M 50 B 250–70(4)	1.2036 (72.2°)		
Dibutoxy ethyl phthalate	B 233 (5 mm.)	1.06		
Dibutyl phthalate	M 35 B 340.7	1.047	1.4900	0.1 (89°)
Dibutyl sebacate	B 210 (5 mm.)	0.930		
n-Dibutyl sulfone	M 43.5			
Dicyclohexanol phthalate	M 66.0			
Dicyclohexyl adipate	B 212	1.030		12
Diethanolamine	F 280 B 268.0	1.0985		0.1
Diethoxy ethyl phthalate	B 225 (5 mm.)	1.105		
Diethyl diphenyl urea	M 72–73 B 325–30			
Diethyl phthalate	B 290	1.120	1.4952	20
Diethyl sulfate	F 220° F. B 208.0	1.1801		0.1
Diethylene glycol	F 286° F. B 244.5	1.1185		0.1
Diethylene glycol dipropionate	B 165 (4 mm.)	1.075		
Diglycol diacetate	M 43 F 290° F. B 238	1.116		1.0 (30°)
Dihydroxy diphenyl sulfone	M 179			
Diisobutyl ketone	F 145° F. B 164	0.880		4 (30°)
Dimethoxy ethyl phthalate	B 198 (5 mm.)	1.141		
Dimethyl cyclohexyl adipate	B 230	1.091	1.4690	12
Dimethyl cyclohexyl methyl adipate	B 220	1.009	1.4680	12
Dimethyl phthalate	M 0.6 B 283.8	1.193	1.5138	0.3 (82°)
Diphenyl carbonate	M 81.0 B 302.2			
Diphenyl phthalate	M 70 B 250			
Dodeca acetate	B 140–160	0.869	1.434	
Dodeca alcohol	M 24 B 143.0			
Dodeca butyrate	B 174	0.859	1.434	
Dodeca oleate	B 120–130	0.867	1.455	
Ethoxy ethyl phthalate	M 275	0.932		
Ethyl abietate	B 350.0	1.020	1.4980	
Ethyl acetanilide (Mannol)	M 54.5 F 124 B 259.0	0.994 $\frac{60°}{4°}$		20

TABLE 5.—Plasticizers—*Continued*

Name	M—Melting Point B—Boiling Point F—Flash-Point ° C.	Specific Gravity at 20° C.	Refractive Index at 20° C.	Vapor Pressure (mm. Hg) at 20° C.
Ethyl acetoacetate	F 184° F. B 180.0	1.0261		0.7
Ethyl benzoyl benzoate	M 58 B 355.0	1.155		
Ethyl carbamate	M 48 B 180.0	1.11	1.4143 (52)	
Ethyl carbanilate	M 52 B 238.0	1.1063 $\frac{30.4°}{4°}$	1.5376 (30.4)	
Ethyl carbanilid	B 99.0			
Ethyl ether of diethylene glycol	B 196.0	1.023	1.4242 (26°)	0.14
Ethyl ether of diethylene glycol acetate	F 225° F. B 211.0	1.011	1.4230	1.0 (30°)
Ethyl ether of ethylene glycol	F 205° F. B 189.0	1.027		1.0 (30°)
Ethyl ether of ethylene glycol acetate	F 225 B 218.0	1.0125		0.1
Ethyl phthalyl glycollate	M 20 B 190.0	1.180	1.4987	5
n-Ethyl-2,4,6-trichloracetanilid	M 50–1			
Ethylene glycol	F 241° F. B 197.2	1.1155		0.1
Ethylene glycol benzoate	M 73–4 B 360			
Ethylene glycol salicylate	M 106.0			
Fenchone	M 6 B 190	0.948	1.4647 (14.5°)	2 (30°)
Fenchyl alcohol	M 48.0 B 205	0.933 (50°)		
Formanilide	M 47.5 B 271.0	1.112 (60°)	8.70 (55)	39.4 (60)
Formyl diphenylamine	M 72.0 B 190(13)			
Furfuramide	M 121.0 B 250.0			
Furfuryl acetate	F 185° F. B 180	1.119	1.4627	1.0 (30°)
Glycerol tribenzoate (tribenzoin)	M 76.5 B decomp.	1.25		
Glyceryl trisalicylate	M 79			
Glycol diacetate	M 31 F 205° F. B 184	1.107	1.4150	1.0 (30°)
Glycol monoacetate	F 102 B 182.0	1.108		
Hexadeca acetate	B 180–205	0.861	1.440	
Hexadeca alcohol	M 49 B 189.0	0.818		
n-Hexyl alcohol	B 157	0.820	0.1423	
Isobornyl chloride	M 156.5			
Isofenchyl alcohol	M 62–3 B 202–4	0.961 (15°)	1.4801 (15°)	
Isopropyl carbamate	B 75.0			
Isopropyl carbanilate	M 42–3			
Methyl acetanilid	M 102.0 B 254.7			
Methyl carbamate	M 52 B 177.0			

TABLE 5.—Plasticizers—*Continued*

Name	M—Melting Point B—Boiling Point F—Flash-Point ° C.	Specific Gravity at 20° C.	Refractive Index at 20° C.	Vapor Pressure (mm. Hg) at 20° C.
Methyl carbanilate	M 47	1.251 (19°)		
Methyl "Cellosolve" oleate	B 235–65 (5 mm.)	0.900		
Methyl cyclohexanol oxalate	B 200.0	1 035		10
Methyl ether of diethylene glycol acetate	F 200° F. B 190	1.035	1.4244 (26°)	1.0 (30°)
Methyl *n*-hexyl ketone	M 21.6 F 160° F. B 169	0.820	1.4161	3 (30°)
Methyl phthalyl glycollate	M 35 B 189.0	1.220	1.5049	5
Monoglyceryl salicylate	M 76	1.366		
α-Naphthyl acetate	M 44.8			
β-Naphthyl acetate	M 68.5			
Octodeca alcohol	M 59 B 210.0	0.850	1.462	
Octodeca oleate	B 120	0.884	1.465	
Octyl acetate	F 180° F. B 199.0	0.8733		0.3
n-Octyl alcohol	F 185° F. B 184.3	.8344	1.432	0.3
Octyl (2-ethyl hexyl) acetate	F 180° F. B 195.0	0.873	1.4300	1.0 (30°)
Octyl (2-ethyl hexyl) alcohol	F 178° F. B 182	0.834	1.4300	1.0 (30°)
Phenyl benzoate	M 70 0 B 314.0	1 235 (31°)		
Phenyl *p*-toluene sulfonate	M 95			
o-Phthalic acid	M 19	1.593		
o-Phthalic anhydride	M 130.8 B 284.5	1.527 (4°)		
Phthalide	M 65–73 B 290.0	1.1636 (99.1°)	1.53560 (99.1°)	
Pine oil (heavy).	F 200° F. B 211	0.937–0.942		
n-Propyl carbamate	M 53 B 194–6			
n-Propyl carbamilate	M 57–9			
Propylene glycol	F 230° F. B 187.3	1.0381		0.1
Terpenyl acetate	B 220–231	0.961	1.4650	0.1 (37.6°)
Terpineol	B 221.1	0.936	1.4788 (25°)	5.9 (84°)
Tetradeca acetate	B 160–185	0.845	1.437	
Tetradeca alcohol	F 38 B 167			
Tetrahydronaphthalene	M 12.5 F 180° F. B 196	0.972	1.45461	−1 (30°)
Thymol	M 51.5 B 231.8	0.969 (24.4°)	1.52269 (24.4°)	
p-Toluenesulfanilid	M 103.0			
Triacetin	F 133 B 258	1.165	1.4306	
Triamyl borate	B 250–260	0.865 (15°)	1.42	
Tribenzyl phosphate	M 64			

TABLE 5.—Plasticizers—*Continued*

Name	M—Melting Point B—Boiling Point F—Flash-Point ° C.	Specific Gravity at 20° C.	Refractive Index at 20° C.	Vapor Pressure (mm. Hg) at 20° C.
Tributyl phosphate	B 180.0	0.979		20
Tricresyl phosphate	M −20 B 340	1.175	1.556	13
Triethanolamine	F 355° F. B 208	1.1258		0.1
Triethylene glycol	F 331° F. B 288 0	1.1254		0.1
α-Trinaphthyl phosphate	M 145.0			
β-Trinaphthyl phosphate	M 111.0 F 220.0			
Triphenyl phosphate	M 52.0 B 260.0	1.220		20
o-Triphenyl phosphate	M 49.9 B 320			
Urea	M 132.7	1.335		

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Chapter 4

Vapor Pressure, Evaporation Rate, Boiling Point

Matter, in whatever form it may exist, exerts a vapor pressure. We are all familiar with the fact that liquid perfumes, certain solids like camphor, menthol, naphthalene and other substances expel odors, making it evident that their vapor molecules have found the way to our nostrils. We have also observed that ice and snow, at temperatures below the melting point of ice, will gradually disappear owing to evaporation. Even such solids as marble and quartz give off vapors. But these have such extremely low rates of evaporation that it would take countless centuries before a small part would disappear. Instruments available today are much too crude to measure such low rates of evaporation. Should we confine a substance like alcohol in a closed vessel, molecules of alcohol would begin to leave the liquid and accumulate above it. These liberated particles are now typical gas molecules and exert a pressure on all sides of the container. Should we keep external forces constant and allow the alcohol to evaporate, a state of equilibrium would be reached wherein the number of molecules leaving the liquid would equal the number falling back into the liquid. This pressure exerted by the alcohol molecules above the liquid is called the vapor pressure. This expression, in measured terms, indicates the tendency of a substance to pass into a vapor. If a liquid or solid is not confined to a certain area, the vapors are carried away and the rate of evaporation is influenced by:

1. Temperature of the substance.
2. Temperature of surrounding area.
3. Rate of external heat supplied.
4. Conductivity of heat.
5. Specific heat of the substance.
6. Latent heat of evaporation.
7. Number and type of molecular aggregates.
8. Surface tension.
9. Presence of dissolved substances.
10. Atmospheric pressure.
11. Presence of water vapor (humidity).
12. Vapor pressure or pressures of the substance or substances under consideration.
13. Amount and rate of temperature depression.
14. Molecular weight of substances.
15. Method and speed in removal of vapors.

16. Depression of vapor pressure.
17. Viscosity.

Some of the rules for calculating vapor pressure are:

1. Clapeyron equation and modified forms.
2. Trouton's rule.
3. Hildebrandt curves.
4. Raoult's law.
5. Henry's law.

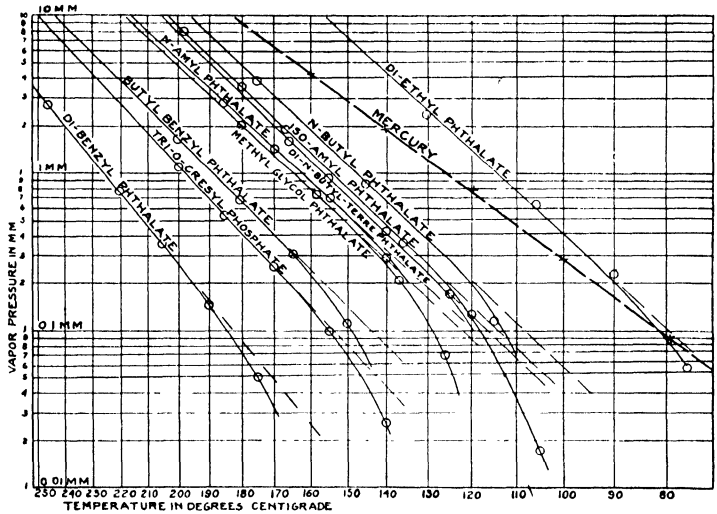


FIGURE 1. Vapor Pressure of Various Solvents at Different Temperatures.[5]

Although the properties of mixtures are not so well understood, there are indications that the vapor pressure, evaporation rates and volatility are interrelated. A knowledge of these factors is essential in the separation of liquids by fractional distillation. This is especially true in the proper use of lacquers, varnishes and protective coatings. In the use of lacquers and other such products, interpretations cannot be made as adequately owing to the insufficient data available in the classification of solvents into low, medium, high, and midway boilers according to their boiling points. Hofmann [1] has found that the rates of evaporation are not proportional to the boiling points and that hydroxyl groups in certain compounds retard the rate of evaporation. Alcohols evaporate more slowly than their corresponding esters of higher boiling points. Esters, ketones, alcohols and hydrocarbons having identical boiling points

will have entirely different rates of evaporation owing to the difference in chemical structure and the type of molecular aggregates that are formed. Hofmann [1] groups mixtures of solvents into two classes.

1. Members of the same homologous series like ethyl, propyl, butyl acetates and so forth, or benzene, toluene, xylene and so forth.

   Hydrocarbons and halogenated derivatives.
   A hydrocarbon and an ester.

In the above cases, the solvents evaporate simultaneously at different rates and have no effect upon each other. When the more rapidly evaporating constituent is gone the remaining one evaporates at a constant rate.

2. The second group consists of constant-boiling mixtures formed by two dissimilar compounds such as an alcohol and a hydrocarbon and these generally form constant-boiling mixtures at higher temperatures.

Certain liquids, when mixed in specific quantities, form constant-boiling mixtures and are said to possess the property of azeotropy. The distillate from such a boiling mixture has also the same composition as the original mixture. The boiling point of an azeotropic mixture is lower than that of either of the constituent parts and the vapor pressure is higher.

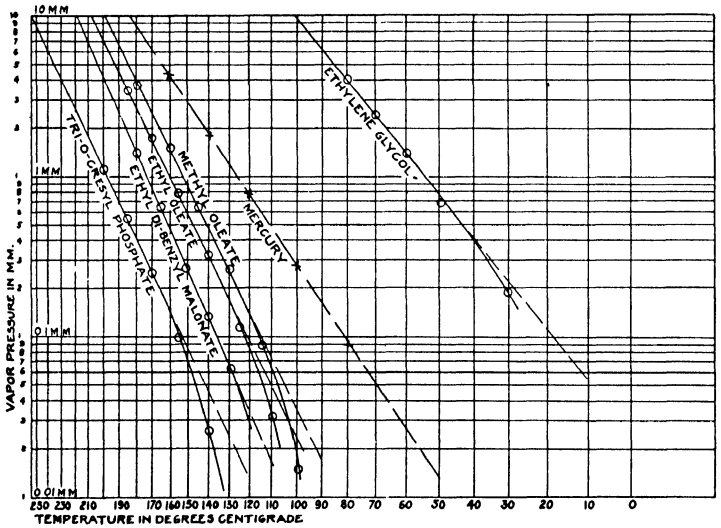


FIGURE 2. Vapor Pressure of Various Solvents at Different Temperatures.[5]

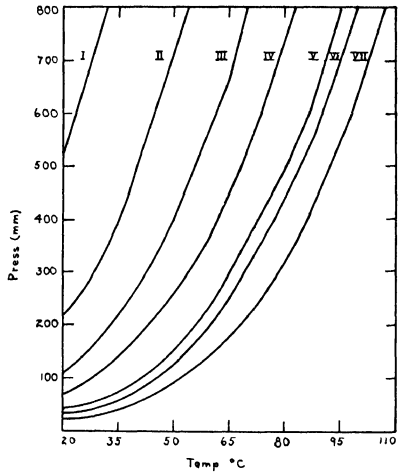


FIGURE 3. Vapor Pressure at Various Temperatures.[9]

I. Methyl Formate.
II. Ethyl Formate.
III. Iso-propyl Formate.
IV. *n*-Propyl Formate.
V. *sec*-Butyl Formate.
VI. Iso-butyl Formate.
VII. *n*-Butyl Formate.

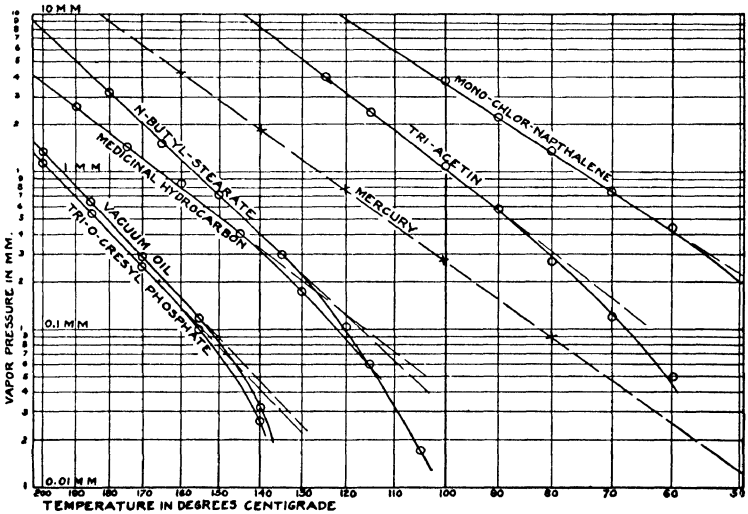


FIGURE 4. Vapor Pressure of Various Solvents at Different Temperatures.

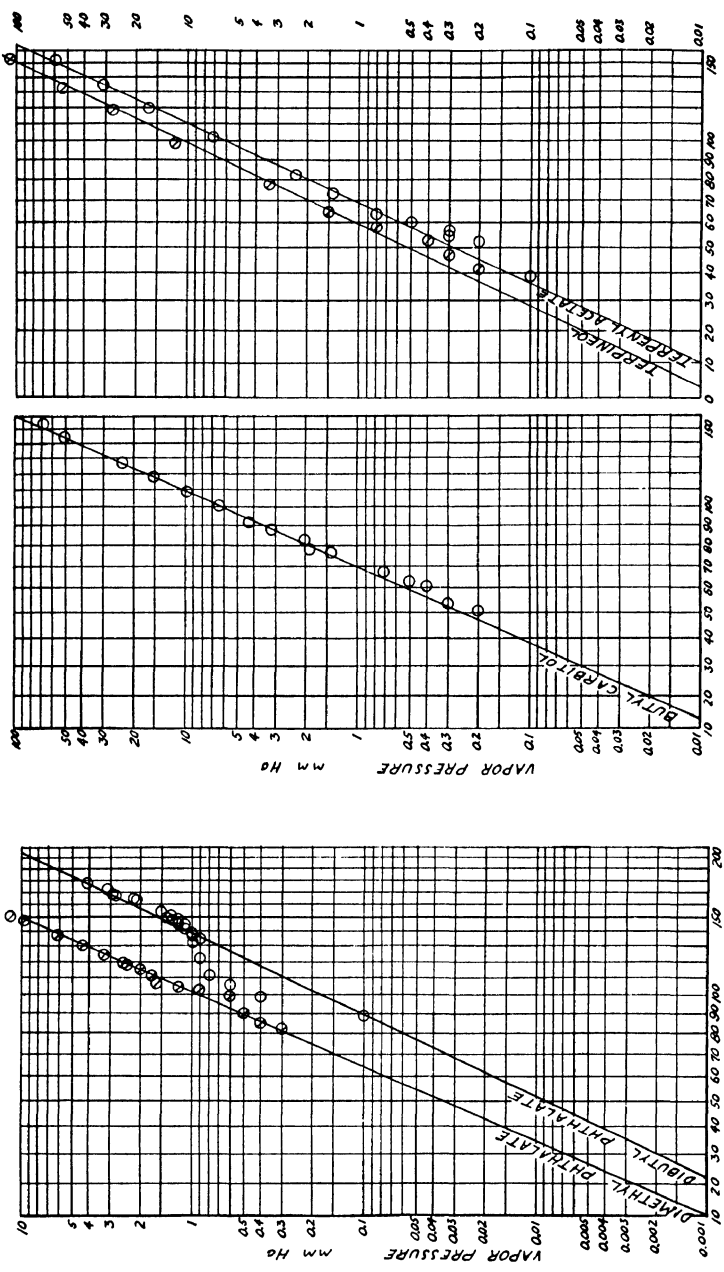


FIGURE 5. Vapor Pressure of Various Solvents at Different Temperatures.[2]

TABLE 6.—Constant-Boiling Mixtures

First Component	% By Weight	Second Component	% By Weight	Boiling Point (° C.)
Acetone	34.0	Carbon disulfide	66.0	39.25
Acetone	20.0	Chloroform	80.0	64.7
Acetone	38.0	Diethylamine	62.0	51.5
Acetone	97.5	Isoamyl acetate	2.5	131.3
Acetone	64.4	Methyl acetate	35.6	56.1
Acetone	86.5	Methyl alcohol	13.5	55.95
n-Amyl alcohol	94.3	Isoamyl acetate	5.7	131.3
n-Amyl alcohol	77.5	Isoamyl propionate	22.5	130.5
n-Amyl formate	57.0	*n*-Amyl alcohol	43.0	130.4
n-Amyl formate	71.6	Water	28.4	91.6
Benzene	55.0	Cyclohexane	45.0	77.8
Benzene	68.0	Ethyl alcohol	32.0	68.2
Benzene	19.0	*n*-Hexane	81.0	68.9
Benzene	91.0	Isobutyl alcohol	9.0	79.8
Benzene	67.0	Isopropyl alcohol	33.0	71.9
Benzene	60.0	Methyl alcohol	40.0	58.3
Benzene	62.0	Methyl ethyl ketone	38.0	78.3
Benzene	83.0	*n*-Propyl alcohol	17.0	77.1
Bromoform	96.6	Ethyl alcohol	3.4	59.3
Bromoform	97.9	Isopropyl alcohol	2.1	60.8
Bromoform	93.6	Methyl alcohol	6.4	53.5
n-Butyl acetate	54.0	*n*-Butyl alcohol	46.0	118.0
n-Butyl acetate	48.0	Isopropyl alcohol	52 0	80.1
n-Butyl acetate	60.0	*n*-Propyl alcohol	40 0	94.2
n-Butyl acetate	71.3	Water	28.7	90.2
n-Butyl alcohol	44.8	*n*-Butyl acetate	55.2	113.5
n-Butyl alcohol	24.0	*n*-Butyl formate	76 0	105.8
n-Butyl alcohol	63.0	Chlorobenzene	37.0	107.2
n-Butyl alcohol	9.8	Cyclohexane	90.2	79.8
n-Butyl alcohol	19.9	Ethyl isobutyrate	80 1	108.5
n-Butyl alcohol	30.8	Methyl isovalerate	69.2	113.0
n-Butyl alcohol	32.0	Perchlorethylene	68 0	110.0
n-Butyl alcohol	33.5	Tetrachlorethylene	66.5	110.0
n-Butyl alcohol	32.1	Toluene	67.9	105.2
n-Butyl alcohol	62.7	Water	37.3	92 3
sec-Butyl alcohol	55.2	Ethyl propionate	44.8	85.5
sec-Butyl alcohol	52.1	*n*-Propyl acetate	47.9	96.5
tert-Butyl alcohol	32.4	Benzene	67.6	74.0
tert-Butyl alcohol	52.0	Ethylbutyrate	48.0	105.5
tert-Butyl alcohol	7.0	*n*-Methyl butyrate	93.0	100.8
tert-Butyl alcohol	9.0	*n*-Propyl acetate	91.0	101.0
Carbon tetrachloride	88.0	Allyl alcohol	12.0	72.32
Carbon tetrachloride	83.5	*tert*-Butyl alcohol	16.5	69.5
Carbon tetrachloride	56.8	Ethyl acetate	43.2	74.75
Carbon tetrachloride	84.1	Ethyl alcohol	15.9	64.95
Carbon tetrachloride	82.0	Isopropyl alcohol	18.0	67.0
Carbon tetrachloride	79.3	Methyl alcohol	20.7	55.7
Carbon tetrachloride	70.9	Methyl ethyl ketone	29.1	73.8
Carbon tetrachloride	59.7	Methyl propionate	40 3	75.5
Carbon tetrachloride	88.4	*n*-Propyl alcohol	11.6	72 8
"Cellosolve"	40.0	Water	60.0	98–99
Chlorbenzene	37.0	*n*-Butyl alcohol	63.0	107.2
Chlorbenzene	64.0	Isoamyl alcohol	36 0	124.3
Chlorbenzene	20.0	*n*-Propyl alcohol	80.0	96.5
Chloroform	80.0	Acetone	20.0	64.7
Chloroform	93.0	Ethyl alcohol	7.0	59 4
Chloroform	72.0	*n*-Hexane	28.0	60.0
Chloroform	22.0	Methyl acetate	78.0	64.5
Chloroform	87.5	Methyl alcohol	12.5	53.5
Cyclohexane	45.0	Benzene	55.0	77.8

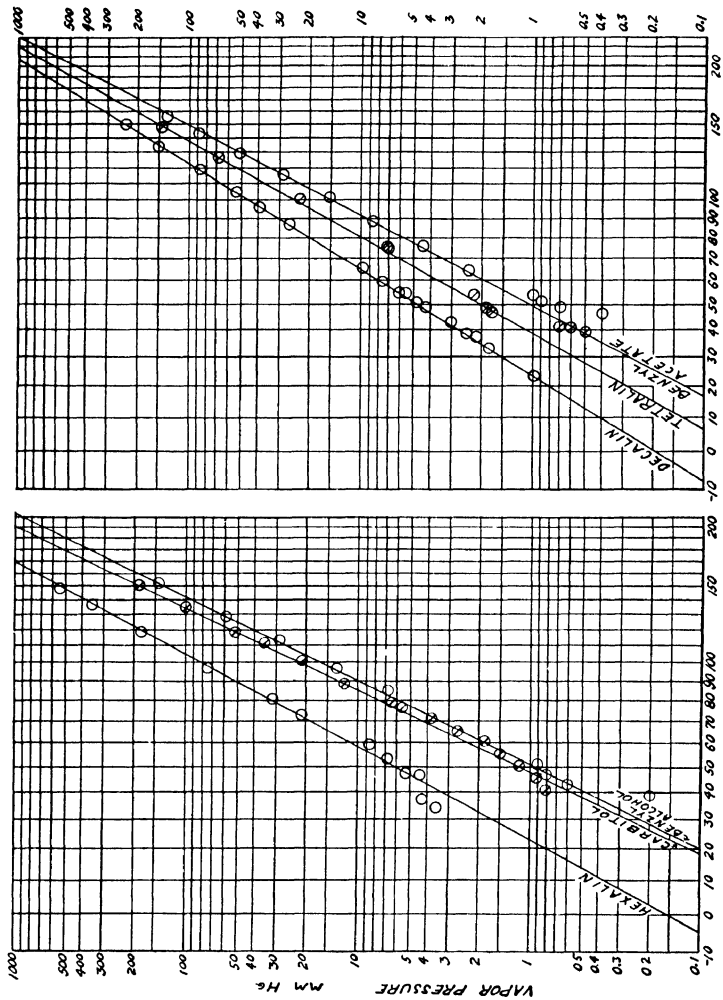


FIGURE 6. Vapor Pressure of Various Solvents at Different Temperatures.[1]

TABLE 6.—Constant-Boiling Mixtures—*Continued*

First Component	% By Weight	Second Component	% By Weight	Boiling Point (° C.)
Cyclohexane	90 0	*n*-Butyl alcohol	10 0	79.8
Cyclohexane	70 0	Ethyl alcohol	30.0	64.9
Cyclohexane	86.0	Isobutyl alcohol	14 0	78.1
Cyclohexane	67 0	Isopropyl alcohol	33.0	68.6
Cyclohexane	63.0	Methyl alcohol	37.0	54.2
Cyclohexane	80.0	*n*-Propyl alcohol	20.0	74 3
Cyclohexanol	41.0	Camphene	59.0	152.0
Cyclohexanol	70.2	Cymene	29.8	159.0
Cyclohexanol	45.0	Furfural	55.0	156.0
Cyclohexanol	18.5	Isoamyl butyrate	81.5	155.0
Cyclohexanol	69.9	Isoamyl propionate	30.1	157.7
Cyclohexanol	36.0	Pentachloroethane	64.0	158.0
Cyclohexanol	35.0	Pinene	65.0	150.0
Cyclohexanol	5.2	*m*-Xylene	94.8	138.9
Cyclohexanone	56.0	Camphor	44.0	151.0
Cyclohexanone	55.0	Tetrachloroethane	45.0	159.0
Cyclohexanone	39.0	Trichlorhydrin	61.0	160.0
Dichlorobromomethane	59.6	Ethyl alcohol	40.4	75.5
Dichlorobromomethane	81.8	Isobutyl alcohol	18.2	89.3
Dichlorobromomethane	50.9	Isopropyl alcohol	49.1	78.0
Dichlorobromomethane	70.1	*n*-Propyl alcohol	29.9	86.4
1,1-Dichloroethane	91.8	Ethyl alcohol	8.2	54.5
Dichlorethylene	82 5	*n*-Propyl alcohol	17.5	80.0
Dimethyl carbonate	77.7	*n*-Propyl alcohol	22 3	88.2
Dimethyl ketone	25 9	*tert*-Amyl ketone	74.1	98.5
Dioxane	2.5	Isoamyl alcohol	97.5	131.3
Dioxane	80 0	Water	20.0	86.8
Dioxane	40.0	*m*-Xylene	60.0	136.0
Epichlorhydrin	30 0	*tert*-Amyl alcohol	70.0	100.1
Epichlorhydrin	57.0	*n*-Butyl alcohol	43 0	112.0
Epichlorhydrin	80.9	Isoamyl alcohol	19.1	115.4
Epichlorhydrin	39.4	Isobutyl alcohol	60 6	105 0
Epichlorhydrin	21 7	*n*-Propyl alcohol	78 3	98.8
Epichlorhydrin	52.0	Tetrachloroethylene	48.0	110.0
Epichlorhydrin	26.1	Toluene	73.9	108.3
Ethanol	32.0	Benzene	68.0	68.2
Ethanol	9.0	Carbon disulfide	91.0	42 4
Ethanol	15.8	Carbon tetrachloride	84.2	64.9
Ethanol	7 0	Chloroform	93 0	59.4
Ethanol	30 5	Cyclohexane	69.5	64.9
Ethanol	31.0	Ethyl acetate	69.0	71.8
Ethanol	3.1	Ethyl bromide	96.9	37.6
Ethanol	48.0	*n*-Heptane	52.0	72.0
Ethanol	21.0	*n*-Hexane	79.0	58.6
Ethanol	34.0	Methyl ethyl ketone	66 0	74.8
Ethanol	52.0	Methyl propionate	48.0	93.2
Ethanol	81.0	Perchlorethylene	19.0	78.0
Ethanol	57.3	*n*-Propyl formate	42.7	73.5
Ethanol	81.0	Tetrachlorethylene	19.0	78.0
Ethanol	68.0	Toluene	32.0	76 6
Ethanol	27.0	Trichlorethylene	73.0	70.9
Ethanol	95.6	Water	4.4	78.2
Ethyl acetate	74.0	*tert*-Butanol	26 0	75.2
Ethyl acetate	3.0	Carbon disulfide	97.0	46.1
Ethyl acetate	43.1	Carbon tetrachloride	56.9	74.8
Ethyl acetate	69.2	Ethanol	30.8	71.8
Ethyl acetate	77.0	Isopropanol	23.0	74.8
Ethyl acetate	20.0	Methanol	80.0	62.3
Ethyl acetate	93.9	Water	6.1	70.4
Ethyl ether	99.0	Carbon disulfide	1.0	34.5

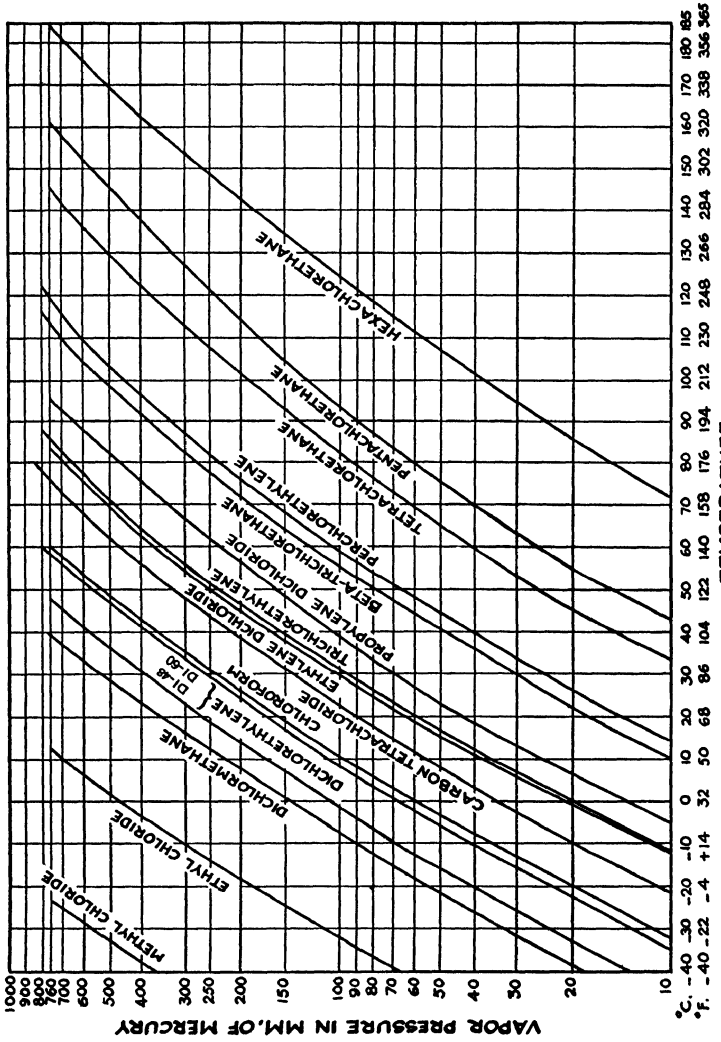


FIGURE 7. Vapor Pressure-Temperature Relationship of Various Chlorinated Hydrocarbons.[8]

TABLE 6.—Constant-Boiling Mixtures—*Continued*

First Component	% By Weight	Second Component	% By Weight	Boiling Point (° C)
Ethyl ether	44.5	Methyl formate	55.5	28.2
Ethyl ether	98.9	Water	1.1	34.1
Ethyl formate	37.0	Carbon disulfide	63.0	39.4
Ethyl formate	84.0	Methyl alcohol	16.0	51.0
Ethylene bromide	44.9	Acetic acid	55.1	114.35
Ethylene bromide	89.9	Ethylbenzene	10.1	131.1
Ethylene bromide	10.1	Isoamyl alcohol	89.9	123.2
Ethylene bromide	41.7	Isobutyl alcohol	58.3	106.2
Ethylene bromide	82.4	Propionic acid	17.6	127.75
Ethylene chlorhydrin	42.0	Water	58.0	96.0
Furfural	40.0	Camphene	60.0	147.0
Furfural	55.0	Cyclohexanol	45.0	156.0
Furfural	38.0	Pinene	62.0	143.0
Isoamyl acetate	50.0	*m*-Xylene	50.0	136.0
Isoamyl alcohol	36.0	Chlorobenzene	64.0	124.3
Isoamyl alcohol	19.0	Epichlorhydrin	81.0	115.4
Isoamyl alcohol	97.5	Isoamyl acetate	2.5	131.3
Isoamyl alcohol	26 0	Isoamyl formate	74.0	123.6
Isoamyl alcohol	19.0	Tetrachlorethylene	81.0	116.0
Isoamyl alcohol	49.3	Ethylbenzene	50.7	125.9
Isoamyl alcohol	53 4	*m*-Xylene	46.6	127.0
Isoamyl alcohol	59.6	*o*-Xylene	40.4	128.0
Isoamyl alcohol	51.3	*p*-Xylene	48.7	126.0
Isoamyl formate	74.0	Isoamyl alcohol	26.0	123.6
Isoamyl formate	79.0	Water	21 0	90.2
Isobutyl acetate	53.0	*n*-Butyl alcohol	47.0	117.2
Isobutyl acetate	55.0	Isobutyl alcohol	45.0	107.4
Isobutyl acetate	71.0	Water	29.0	90.3
Isobutyl alcohol	9.5	Benzene	90.5	79.84
Isobutyl alcohol	14.0	Cyclohexane	86.0	78.1
Isobutyl alcohol	44.5	Toluene	55.5	101.15
Isobutyl alcohol	67.0	Water	33.0	90.0
Isopropyl acetate	47.7	Isopropanol	52.3	80.1
Isopropyl acetate	90.0	Water	10.0	75.0
Isopropyl alcohol	55.0	Acetonitrile	45.0	75.0
Isopropyl alcohol	32.4	Benzene	67.6	71.9
Isopropyl alcohol	8.1	Carbon disulfide	91.9	44.6
Isopropyl alcohol	18.0	Carbon tetrachloride	82.0	67.0
Isopropyl alcohol	4.2	Chloroform	95.8	60.8
Isopropyl alcohol	66.5	Chlorpicrin	33.5	82.0
Isopropyl alcohol	36.0	1-3 Cyclohexadiene	64.0	70.4
Isopropyl alcohol	32.8	Cyclohexane	67.2	68.6
Isopropyl alcohol	36.0	Cyclohexene	64.0	71.0
Isopropyl alcohol	27.6	Dichlorbromomethane	72.4	78.0
Isopropyl alcohol	22.9	Ethyl acetate	77.1	74.8
Isopropyl alcohol	45.0	Ethylene dichloride	55.0	74.0
Isopropyl alcohol	22.2	*n*-Hexane	77.8	61.0
Isopropyl alcohol	33.0	Isobutyl bromide	67.0	75.5
Isopropyl alcohol	17.1	Isobutyl chloride	82.9	63.8
Isopropyl alcohol	76.5	Isobutyl iodide	23 5	81.8
Isopropyl alcohol	52.3	Isopropyl acetate	47.7	80.1
Isopropyl alcohol	10.0	Isopropyl ether	90.0	64.9
Isopropyl alcohol	30.0	Methyl ethyl ketone	70.0	77.3
Isopropyl alcohol	3.1	Methyl iodide	96.9	42.3
Isopropyl alcohol	28.2	Methyl propionate	71.8	77.0
Isopropyl alcohol	16.0	*n*-Propyl bromide	84.0	65.2
Isopropyl alcohol	3.9	*n*-Propyl chloride	96.1	45.8
Isopropyl alcohol	80.6	Tetrachlorethylene	19.4	81.7
Isopropyl alcohol	68.6	Toluene	31.4	80.6
Isopropyl alcohol	28.0	Trichlorethylene	72.0	74.0

TABLE 6.—Constant-Boiling Mixtures—*Continued*

First Component	% By Weight	Second Component	% By Weight	Boiling Point (° C)
Isopropyl alcohol	87.7	Water	12.3	80.4
Isopropyl ether	20 0	Acetone	80.0	53.6
Isopropyl ether	70.0	Chloroform	30.0	68 5–69.5
Isopropyl ether	85–90	Ethyl alcohol	10–15	63.0
Isopropyl ether	90.0	Isopropanol	10.0	64.8–64.9
Methyl acetate	45.0	Acetone	55.0	56.1
Methyl acetate	30.0	Carbon disulfide	70.0	40.2
Methyl acetate	30.0	Isopropyl alcohol	70.0	77.3
Methyl acetate	81.0	Methyl alcohol	19.0	54.0
Methyl alcohol	15.0	Acetone	85 0	55.9
Methyl alcohol	40.0	Benzene	60 0	58 3
Methyl alcohol	20 0	Carbon disulfide	80 0	37.6
Methyl alcohol	37.0	Carbon tetrachloride	63.0	54.2
Methyl alcohol	20.0	Chloroform	80 0	64.7
Methyl alcohol	37.0	Cyclohexane	63.0	54 2
Methyl alcohol	11.4	1,1-Dichloroethane	88.6	49.05
Methyl alcohol	80.0	Ethyl acetate	20.0	62.3
Methyl alcohol	16 0	Ethyl formate	84.0	51.0
Methyl alcohol	62 0	*n*-Heptane	38.0	60.5
Methyl alcohol	27 0	*n*-Hexane	73.0	50.0
Methyl alcohol	19.0	Methyl acetate	81.0	54.0
Methyl alcohol	70.5	Methylcyclohexane	29.5	60.0
Methyl alcohol	91.8	*n*-Propyl formate	8.2	63.7
Methyl alcohol	36.0	Trichlorethylene	64 0	60.2
Methyl alcohol	67.3	Trimethyl borate	32.7	59 0
Methyl ethyl ketone	37.5	Benzene	62.5	78.4
Methyl ethyl ketone	34.0	Carbon disulfide	66.0	39.2
Methyl ethyl ketone	29.0	Carbon tetrachloride	71 0	73.8
Methyl ethyl ketone	40 0	Ethyl alcohol	60.0	74 8
Methyl ethyl ketone	26 0	Isoamyl formate	74 0	123 6
Methyl ethyl ketone	30 0	Isopropyl alcohol	70 0	77.3
Methyl ethyl ketone	86.0	Methyl alcohol	14 0	55 9
Methyl ethyl ketone	52.0	Methyl propionate	48 0	79 25
Methyl ethyl ketone	55 0	Propyl formate	45.0	79.45
Methyl ethyl ketone	88.6	Water	11.4	73.6
Methyl formate	64.1	Ethyl bromide	35.9	29.9
Methyl formate	56.4	Ethyl ether	43.6	28 3
Methyl propyl ketone	39.0	Methyl cyclohexane	61.0	100.6
Methyl propyl ketone	36.5	*n*-Propyl acetate	63.5	101.35
Pentachlorethane	85.0	Clycol	15.0	154 5
Perchlorethylene	48.0	α-Epichlorhydrin	52 0	110.0
Perchlorethylene	19 0	Ethyl alcohol	81.0	78 0
Perchlorethylene	81.0	Isoamyl alcohol	19.0	116 0
Perchlorethylene	60.0	Isobutyl alcohol	40.0	103 0
Perchlorethylene	46.0	*n*-Propyl alcohol	54 0	94.0
n-Propyl acetate	66.8	*tert*-Amyl alcohol	33.2	98.5
n-Propyl acetate	43.0	Carbon tetrachloride	57.0	74.7
n-Propyl acetate	77.0	Isopropyl alcohol	23 0	74.8
n-Propyl acetate	60.0	*n*-Propyl alcohol	50.0	94.2
n-Propyl acetate	86 0	Water	14.0	82.4
n-Propyl alcohol	16.9	Benzene	83.1	77.12
n-Propyl alcohol	11.5	Carbon tetrachloride	88.5	72.8
n-Propyl alcohol	20.0	Cyclohexane	80.0	74.3
n-Propyl alcohol	57.0	Diethyl ketone	43.0	94.9
n-Propyl alcohol	54.0	Tetrachlorethylene	46.0	94.0
n-Propyl alcohol	51.1	Ethyl propionate	48.9	93.4
n-Propyl alcohol	4.0	*n*-Hexane	96.0	65.6
n-Propyl alcohol	71.1	Methyl butyrate	28.9	94.2

TABLE 6.—Constant-Boiling Mixtures—*Continued*

First Component	% By Weight	Second Component	% By Weight	Boiling Point (° C.)
n-Propyl alcohol	24.8	Methyl isobutyrate	75.2	89.3
n-Propyl alcohol	80.0	Monochlorbenzene	20.0	96.5
n-Propyl alcohol	74.0	*n*-Octane	26 0	95.0
n-Propyl alcohol	54.0	Perchlorethylene	46.0	94.0
n-Propyl alcohol	62.6	*n*-Propyl acetate	37.4	94.0
n-Propyl alcohol	9.8	*n*-Propyl formate	90.2	80.6
n-Propyl alcohol	77.4	Toluene	22.6	95.0
n-Propyl alcohol	71.7	Water	28.3	87.7
n-Propyl formate	48.0	Benzene	52.0	72.0
Tetrachlorethane	45.0	Cyclohexanone	55.0	159.0
Tetrachlorethane	91.0	Glycol	9.0	145.0
Tetrachlorethane	68 0	Isoamyl acetate	32 0	150.0
Tetrachlorethylene	66.5	*n*-Butyl alcohol	33.5	110.0
Tetrachlorethylene	74.0	Diethyl carbonate	26.0	118.55
Tetrachlorethylene	18.7	Ethyl alcohol	81 3	77.95
Tetrachlorethylene	80.7	Isoamyl alcohol	19.3	116.0
Tetrachlorethylene	59.8	Isobutyl alcohol	40.2	103.05
Tetrachlorethylene	19.3	Isopropyl alcohol	80.7	81.7
Tetrachlorethylene	46 5	*n*-Propyl alcohol	53.5	94.0
Toluene	68.0	*n*-Butyl alcohol	32.0	105.5
Toluene	74.0	Epichlorhydrin	26.0	108 3
Toluene	32.0	Ethyl alcohol	68.0	76.7
Toluene	56.0	Isobutyl alchol	44.0	101.1
Toluene	31.0	Isopropyl alcohol	69.0	80.6
Toluene	51.0	*n*-Propyl alcohol	49.0	92.6
Trichlorethylene	84.0	Allyl alcohol	16.0	80.9
Trichlorethylene	88.0	*tert*-Amyl alcohol	12 0	84.0
Trichlorethylene	86 0	*tert*-Butyl alcohol	14 0	75.0
Trichlorethylene	73.0	Ethyl alcohol	27 0	70.9
Trichlorethylene	92 0	Isobutyl alcohol	8.0	85.4
Trichlorethylene	73.0	Isopropanol	27.0	74.0
Trichlorethylene	64 0	Methanol	36 0	60.2
Trichlorethylene	83.0	*n*-Propyl alcohol	17 0	81.7
Trichlorethylene	93.0	Water	7.0	71.8
1,1,2-Trichlorethylene	35.2	Ethyl alcohol	64.8	77.3
Water	37.3	*n*-Butyl alcohol	62 7	92.2 5
Water	32.0	*sec*-Butyl alcohol	68 0	88.5
Water	11.7	*tert*-Butyl alcohol	88 3	79.91
Water	6.1	Ethyl acetate	93 9	70 4
Water	4.4	Ethyl alcohol	95.6	78.2
Water	1 3	Ethyl ether	98.7	34.15
Water	27.6	Isoamyl alcohol	72.4	87.0
Water	33 1	Isobutyl alcohol	66.9	89.92
Water	12.3	Isopropyl alcohol	77 8	80.37
Water	10.9	Methyl ethyl ketone	89.1	73.45
Water	28.3	*n*-Propyl alcohol	71.7	87.72
m-Xylene	46.0	Isoamyl acetate	54.0	136 0
m-Xylene	47.0	Isoamyl alcohol	53.0	127.0
o-Xylene	40.0	Isoamyl alcohol	60.0	128 0
p-Xylene	49.0	Isoamyl alcohol	51.0	126.8

Rates of evaporation are accelerated by the corresponding increase in vapor pressure which is brought about by the formation of azeotropic mixtures. A higher rate of evaporation causes excess chilling. In coatings of lacquer, varnish, paint and so forth, where the depth of the solution is small, blush or precipitation may occur. If the azeotropic mixture consists of a solvent and a non-solvent, these two substances, in

evaporating, leave the mixture as one substance. It follows, therefore, that should a larger quantity of the active solvent, in these and other mixtures, leave before the non-solvent, precipitation or blush will occur. To prevent this undesirable occurrence, an excess of non-solvent, of the type that will evaporate at an early stage in the process, should be used in the mixture, or care should be taken not to mix liquids which are

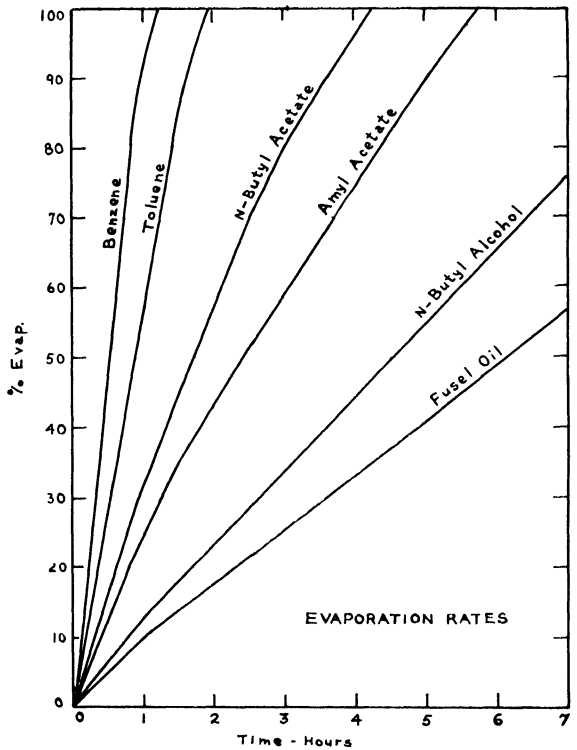


FIGURE 8. Evaporation Rate of Various Solvents at Room Temperature.[1]

likely to form azeotropic mixtures. With the addition of medium- or high-boiling solvents, the vapor pressure of the mixture is reduced and the rate of evaporation is consequently retarded. This reduction in the rate of evaporation is accordingly dependent upon the evaporation rate of each constituent in the mixture, the amounts present, and the molecular aggregates that are formed. The vapor pressure is a function of the size of the molecule and this is shown by the fact that of two substances with the same boiling point, the one with the lower molecular weight will cause a larger reduction in evaporation rates. The function

of a mixture where azeotropic properties are not present is determined by its vapor, and by the amounts of the constituents.

The rate of evaporation of a drying film of varnish, paint or lacquer becomes progressively slower. This is explained by the fact that when the volatile solvent leaves the molecular aggregate, the secondary bonds of attraction are set free momentarily. These momentarily free secondary

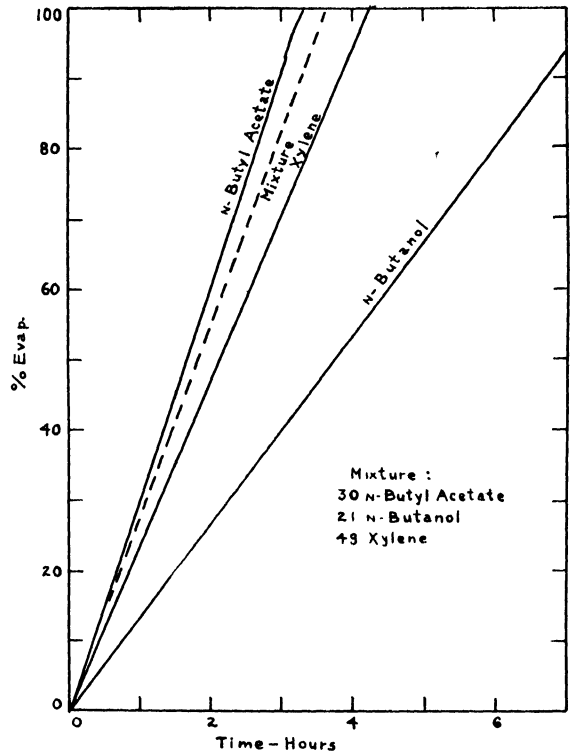


FIGURE 9. Evaporation Rate of Various Solvents at Room Temperature.[1]

valence bonds exert their force on the remaining aggregates and knit the constituent parts closer and more firmly. These stronger bonds of attraction consequently retard the rate of evaporation. Vaporization results in loss of energy with consequent drop in temperature. The rate is governed by the specific heat of the substance, latent heat of evaporation, heat of conductivity, and the rate of heat that is supplied. Wilson [2] tells us that the drop in temperature is a function of the vapor pressure and the latent heat of evaporation when other variables are held constant.

Determinations in blush resistance are similar to dilution ratio values, with the one difference that blush measurements are made with blush producing liquids rather than with precipitants as is found in dilution ratio determinations. Such solvents as ethyl lactate, diacetone, ethyl alcohol, chlorhydrin, and other high-boiling solvents which retain their solubility in the presence of a small quantity of water diminish evaporation rate, prevent or delay blush, precipitation, or chilling. King and

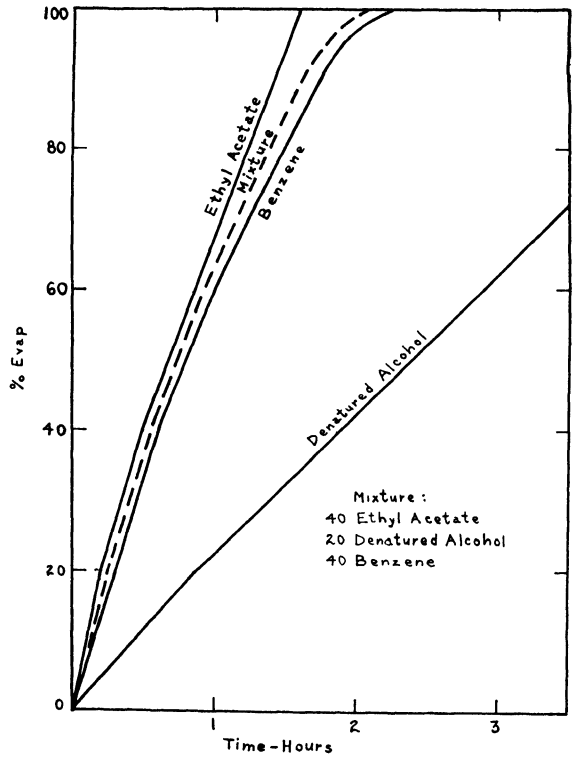


FIGURE 10. Evaporation Rate of Various Solvents at Room Temperature.[1]

Smedley [3] have developed a method for detecting constant evaporating mixtures by means of the Abbé refractometer. They have discovered a mixture of chloroform and alcohol which will evaporate at a constant rate and will evaporate more rapidly than either component. These workers have classified solvent mixtures into two groups, one of which forms an ideal mixture with normal properties and the other exhibits abnormal properties.

Generally the addition of one solvent to another produces a gradual increase in vapor pressure until the maximum is reached when, at this point, there is an accompanying fall. There are many instances, however, where the reverse is true; for example, the gradual addition of acetone to chloroform produces a diminution of vapor pressure until a minimum is reached and then an increase becomes evident. Upper and lower limits are governed by the percentages of constituents in the mixture.

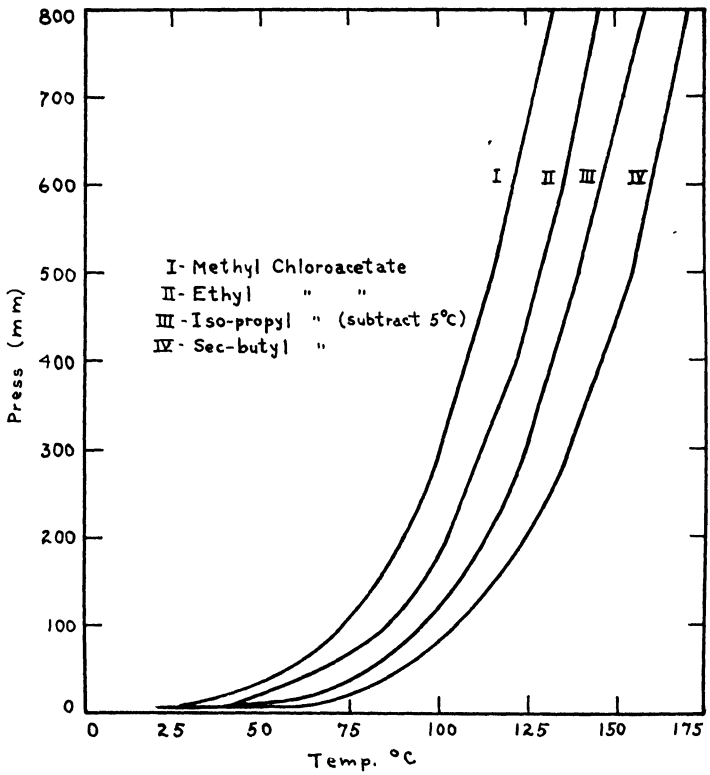


FIGURE 11. Evaporation Rate of Various Solvents at Different Temperatures.[4]

Hofmann [1] has correlated evaporation and distillation curves with the following interpretations:

1. Straight evaporation curves and straight (flat) distillation curves are possible only with pure compounds.
2. Curved evaporation curves and flat distillation curves indicate constant boiling mixtures.

3. Curved evaporation and distillation curves show the behavior of the so-called ideal mixture of similar compounds.
4. Straight evaporation curves and curved distillation curves are indicative of constant-evaporating mixtures.

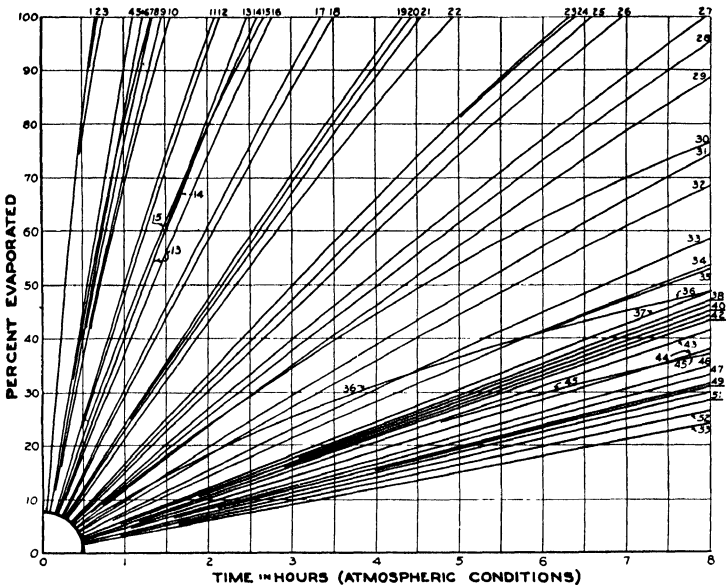


FIGURE 12. Relative Evaporation Rates of Fast to Intermediate Evaporating Liquids at Room Temperature.[6]

1. Methyl acetate 82%
2. Acetone 99
3. Methylacetone (acetone 48 per cent, methyl acetate 28 per cent, methanol 24 per cent) ..... —
4. Cyclohexane ..... —
5. Benzene ..... —
6. Ethylene dichloride 99
7. Ethyl acetate 85
8. Methanol (anhydrous) 99
9. Methyl ethyl ketone 99
10. Isopropyl acetate 95
11. Ethyl propionate 96
12. Ethanol (anhydrous) 99
13. Methyl propyl ketone 99
14. Isopropanol (anhydrous) 99
15. Diethyl ketone 99
16. Petroleum naphtha ..... —
17. Toluene ..... —
18. Solvesso No. 1 ..... —
19. *sec*-Butyl acetate 82
20. Hexone (methyl isobutyl ketone) 99
21. Isobutyl acetate 96
22. Ethyl butyrate 99
23. Diethyl "Cellosolve" 95
24. Diethyl carbonate 91
25. *sec*-Butanol 99
26. Monochlorobenzene ..... —
27. *n*-Butyl acetate 90%
28. Mesityl oxide 86
29. Methyl *n*-butyl ketone 87
30. Xylene ..... —
31. Isobutanol 99
32. *sec*-Amyl acetate 92
33. *sec*-Hexyl acetate 98
34. Amyl acetate, mixed isomers 84
35. *n*-Butyl propionate 99
36. Hi-Flash naphtha ..... —
37. Methyl "Cellosolve" 99
38. Dipropyl ketone 99
39. Methyl amyl acetate 95
40. Steam-distilled turpentine ..... —
41. *n*-Butanol 99
42. *sec*-Amyl alcohol 99
43. Gum spirits of turpentine ..... —
44. Methyl *n*-amyl ketone 98
45. Solvesso No. 2 ..... —
46. Amyl alcohol, mixed isomers 99
47. Methyl amyl alcohol 99
48. "Cellosolve" 99
49. Methyl "Cellosolve" acetate 99
50. Cyclohexanone 67
51. Isopropyl "Cellosolve" 97
52. Hexyl (2-ethyl butyl) acetate 91
53. "Cellosolve" acetate 96

TABLE 7A.—Evaporation Rates

Solvent	Percentage Evaporated / %/hours[a]	Based on *n*-butyl acetate equal to 100.0[a]	Temperature Depression Due to Evaporation (° C.)
Acetone	100/0.72	1365	
Acetonyl acetone	100/200.0		
Amyl acetate			4.35–5
Amyl acetate (mixed isomers)	100/16.0	59	3.9
sec-Amyl acetate		96	
Amyl alcohol (mixed isomers)	100/23.5	35	3.3
sec-Amyl alcohol	100/18.5	47	
Benzene	100/1.26		
Benzyl alcohol	50/500.0		
Benzyl ether of ethylene glycol	hygroscopic		
n-Butyl acetate	100/7.9	100	
sec-Butyl acetate	100/4.35	172–208	8.0
n-Butyl alcohol	100/18.0	38.5	4.8
sec-Butyl alcohol	100/6 6	128	
Butyl butyrate	100/42 0	37.5	
Butyl ether of diethylene glycol	12/500.0 (hygroscopic)		
Butyl ether of diethylene Glycol acetate	5/500.0		
Butyl ether of ethylene glycol	100/130.0	8.0	
Butyl ether of ethylene glycol acetate	100/285.0		
Butyl lactate	100/310 0		
n-Butyl propionate	100/16.0	61.0	4.0
Cyclohexane	100/1.13		
Cyclohexanol	100/225.0		
Cyclohexanone	93/47.0		
Cyclohexanyl acetate	73/60.0		
Decahydronaphthalene	76/60.0		
Diacetone alcohol	100/56 0		
Dichlorethyl ether	84/60.0		
Diethyl carbonate	100/6.4	110	
Diethyl ether of diethylene glycol	94/500.0		
Diethyl ether of ethylene glycol	100/6 3	100	
Diethyl ketone	100/2.7		
Diglycol diacetate	2/500.0		
Diisobutyl ketone	100/44.0		
Dipentene	91/60.0		
Dipropyl ketone	100/17.0		
Ethyl acetate	100/1.4	590	15.6
Ethyl acetoacetate		485	
Ethyl alcohol	100/2.2	308	
Ethyl butyrate	100/4 9		
Ethyl ether of diethylene glycol	51/500.0	51 5	
Ethyl ether of diethylene glycol acetate	34/500.0		
Ethyl ether of ethylene glycol	100/25.0	40	2.8
Ethyl ether of ethylene glycol acetate	100/38.5	25.0	1.9
Ethyl lactate	96/36.5	22 1	
Ethyl propionate	100/2.1	425	
Ethylene dichloride	100/1.4	104.5	
Fenchone	100/103.0		
Furfural	100/49.0		
Furfuryl acetate	99.5/500.0		
Furfuryl alcohol	92/500.0		
Glycol diacetate	100/375		
Hercosol	93/250.0		
Hi-Flash naphtha	100/43 0		
Hexyl acetate	100/16.0	41	
Hexyl (2-ethyl butyl) acetate	100/32.5		
Isobutyl acetate	100/4.6		
Isopropyl acetate	100/1 6	159	

[a]At atmospheric pressure.

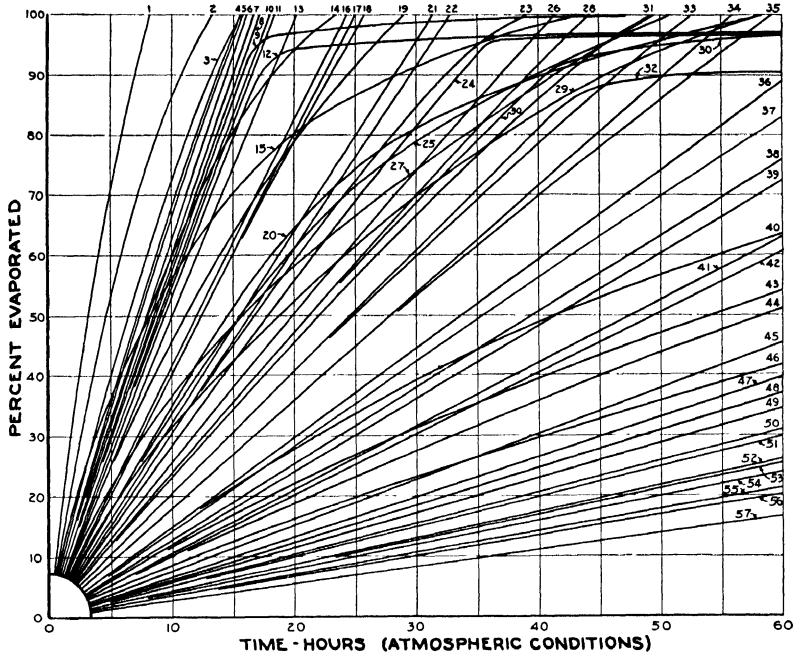


FIGURE 13. Relative Evaporation Rates of Intermediate to Slow Evaporating Liquids.[6]

1	*n*-Butyl acetate	90%	
2	Xylene	--	
3.	*sec*-Hexyl acetate	98	
4	Amyl acetate (mixed isomers)	84	
5.	*n*-Butyl propionate	99	
6.	Methyl "Cellosolve"	99	
7.	Dipropyl ketone	99	
8.	Methyl amyl acetate	95	
9.	Steam-distilled turpentine	—	
10.	*n*-Butanol	99	
11.	*sec*-Amyl alcohol	99	
12.	Gum spirits of turpentine	—	
13.	Methyl *n*-amyl ketone	98	
14.	Amyl alcohol (mixed isomers)	99	
15.	Hi-Flash naphtha	—	
16.	Methyl amyl alcohol	99	
17.	"Cellosolve"	99	
18.	Methyl "Cellosolve" acetate	99	
19.	Solvesso No. 2	—	
20.	Cyclohexanone	67	
21.	Isopropyl "Cellosolve"	97	
22.	Hexyl (2-ethyl butyl) acetate	91	
23.	"Cellosolve" acetate	96	
24.	Ethyl lactate	98	
25.	Methylcyclohexanone	74	
26.	Butyl butyrate	99	
27.	V. M. & P. naphtha	—	
28.	Diisobutyl ketone	95	
29.	Mineral spirits	—	
30.	Isopropyl lactate	99%	
31.	Furfural	98	
32.	Dipentene	—	
33	*o*-Dichlorobenzene	—	
34	Diacetone alcohol	99	
35.	3-Methoxy butyl acetate	99	
36	Methyl *n*-hexyl ketone	96	
37.	Dichloroethyl ether	99	
38	Decahydronaphthalene	—	
39.	Cyclohexanyl acetate	79	
40.	Hercosel	—	
41.	Hexyl (2-ethyl butyl) alcohol	99	
42	Fenchone	—	
43.	Safe-T-Esso	—	
44.	Phorone	—	
45.	Butyl "Cellosolve"	99	
46.	Solvesso No 3	—	
47.	Cyclohexanol	94	
48	Furfuryl acetate	99	
49.	Acetonylacetone	95	
50	Tetrahydrofurfuryl alcohol	99	
51.	Diethyl "Carbitol"	99	
52.	Furfuryl alcohol	98	
53	Tetrahydronaphthalene	—	
54.	Octyl (2-ethyl hexyl) acetate	99	
55.	Butyl "Cellosolve" acetate	99	
56.	Butyl lactate	97	
57.	Glycol diacetate	99	

TABLE 7A.—Evaporation Rates—*Continued*

Solvent	Percentage Evaporated %/hours[a]	Based on *n*-butyl acetate equal to 100.0[a]	Temperature Depression Due to Evaporation (° C.)
Isopropyl alcohol	100/2 6	159	
Isopropyl ether of ethylene glycol	100/32.0		
Isopropyl lactate	97/60.0		
Mesityl oxide		110	
Methanol (anhydrous)	100/1.4		
3-Methoxy butyl acetate	100/58.5		
Methyl acetate	100/0.68	1125	
Methyl acetone	100/0.78		
Methyl amyl acetate	100/17.5		
Methyl amyl alcohol	100/24.0		
Methyl *n*-amyl ketone	100/20.0		
Methyl ethyl ketone		452	
Methylcyclohexone	100/51.0		
Methyl ether of diethylene glycol	55/500 0		
Methyl ether of diethylene glycol acetate	53/500.0		
Methyl ether of ethylene glycol	100/165	56.7	
Methyl ether of ethylene glycol acetate	100/26.0	34.1	
Methyl ethyl ketone	100/1.45		
Methyl *n*-hexyl ketone	88/60.0		
Methyl isobutyl ketone (hexone)	100/4.4		
Methyl propyl ketone	100/2.45	202	
Mineral spirits	100/58 0		
Monochlorobenzene	100/6.9		
Octyl (2-ethyl hexyl) acetate	100/275.0		
Octyl (2-ethyl hexyl alcohol)	80/500		
o-Dichlorobenzene	100/52.5		
Petroleum naphtha	100/2.8		
Phorone	100/125.0		
Pine oil	52/500		
Pine oil (heavy)	45/500.0		
Safe-T-Esso	100/235.0		
Solvesso No. 1	100/3.5		
Solvesso No. 2	100/28 0		
Solvesso No 3	99.5/500.0		
Tetrahydrofurfuryl alcohol	99/500 0		
Tetrahydronaphthalene	96/500.0		
Toluene	100/3.5	266	10.6
Turpentine (gum spirits)	94/185		
Turpentine (steam-distilled)	95/170		47.5
V.M. & P. naphtha	100/49.0		
Xylene	100/13.5		79.0

	Per cent		
Toluene Butyl acetate Ethyl acetate	65 20 15		10.6
Toluene Butyl propionate Ethyl acetate	65 20 15		10.3
Toluene Butyl acetate	65 35		9.6
Toluene Butyl acetate Amyl acetate (mixed isomers)	65 20 15		9.0
Toluene Butyl acetate Butyl propionate	65 20 15		9.2
Toluene Amyl acetate (mixed isomers)	65 35		8.6

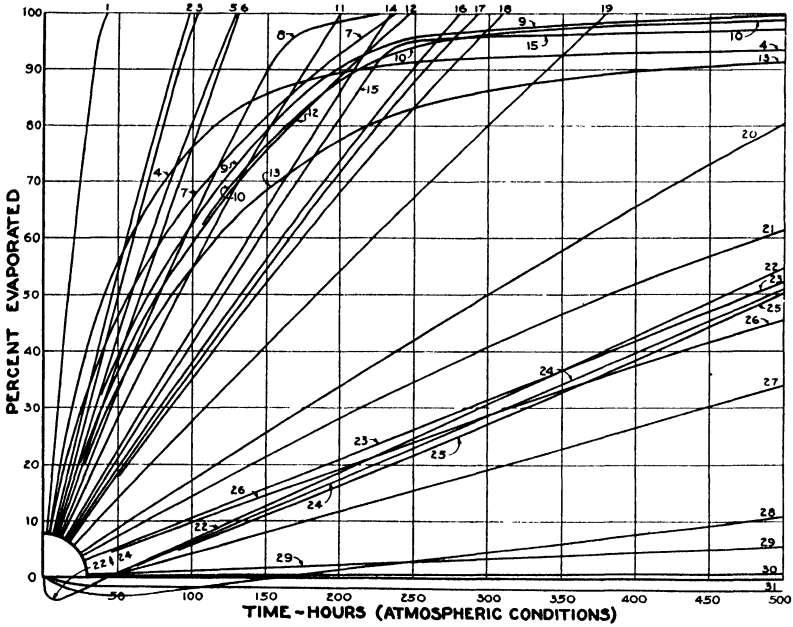


FIGURE 14. Relative Evaporation Rates of Slow to Very Slow Evaporating Liquids at Room Temperature.[6]

1. "Cellosolve" acetate 96%
2. Hexyl (2-ethyl butyl) acetate 99
3. Fenchone ..... —
4. Hercosol ..... —
5. Phorone ..... —
6. Butyl "Cellosolve" 99
7. Safe-T-Esso ..... —
8. Cyclohexanol 94
9. Furfuryl acetate 99
10. Tetrahydrofurfuryl alcohol 99
11. Acetonylacetone 95
12. Solvesso No. 3 ..... —
13. Furfuryl alcohol 98
14. Diethyl "Carbitol" 99
15. Tetrahydronaphthalene ..... —
16. Octyl (2-ethyl hexyl) acetate 99%
17. Butyl "Cellosolve" acetate 99
18. Butyl lactate 97
19. Glycol diacetate 99
20. Octyl (2-ethyl hexyl) alcohol 99
21. Pine oil ..... —
22. Methyl "Carbitol" ..... —
23. Methyl "Carbitol" acetate 99
24. "Carbitol" ..... —
25. Benzyl alcohol 99
26. Heavy pine oil ..... —
27. "Carbitol" acetate 97
28. Butyl "Carbitol" 96
29. Butyl "Carbitol" acetate 99
30. Diglycol diacetate 99
31. Benzyl "Cellosolve" 99

TABLE 7B.—Vapor Pressure (mm. Hg.)

Solvent	20° C.	25° C.	30° C.	35° C.	40° C.	45° C.	50° C.
Benzyl acetate	<0.1	<0.1	<0 1	<0.1	0.1	0.4	0.8
Benzyl alcohol	0.1	0 15	0 2	0.25	0.3	0.7	0 9
Butyl carbitol	<0.1	<0.1	<0.1	<0.1	<0.1	0 1	0.2
sec-Butyl chloroacetate	1.4	1.7	2.0	2.5	3.0	4.5	6.0
n-Butyl formate	22 6	29.4	37 8	48 3	61 3	78.0	98 0
sec-Butyl formate	36.0	48.1	62.5	79.6	102 0	126.0	155.2
"Carbitol"	0.14	0.21	0.29	0.36	0.74	1.02	1.3
Decalin	0.7	1.2	1.5	1.9	2.7	3.7	4.7
Dibutyl phthalate	<0.1	<0.1	<0.1	<0.1	<0 1	<0 1	<0.1
Ethyl chloroacetate	3 7	4 9	6 7	8.9	11.7	15 2	19.5
Ethyl formate	206 5	255 0	312 0	382.0	462.0	558.0	668.0
Isobutyl formate	33 0	43 5	56.0	71 0	88 6	111.0	136.0
Isobutyl chloroacetate	3 0	4.3	5 6	7.5	10.0	12.5	16.5
Isopropyl formate	112 0	138.5	174.2	216.0	267.0	325.1	396.0
Methyl formate	500 2	624 5	720 2				
Methyl chloroacetate	6 7	9.0	11.5	15.2	20.0	26.3	33.5
n-Propyl formate	64.5	85.0	107.0	134 0	166.2	203.5	248.0
Terpenyl acetate	<0.1	<0.1	<0.1	0.1	0.14	0.17	0.2

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Chapter 5

Viscosity

Viscosity is the internal friction which causes the differences in mobility of liquids or their resistance to flow. This property of resistance to flow is of considerable interest and importance to many industries. The character of viscosity in the making of lacquers is determined by such influences as the species of cotton used, the locality where it is grown, its ripeness, the method which is used in making the cellulose derivative, the pressing, the concentration, etc. For many years it had been impossible to make nitrocellulose of low viscosity, which seriously hindered the widespread use of lacquers. Worden [1] lists the following procedures and substances which reduce the viscosity of cellulose ethers and esters.

The addition of solvents or solvent plasticizers such as acetone, chloroform, tricresyl phosphate, diethyl phthalate, dibutyl tartrate and phenyl benzoate.

Heating the dissolved esters or ethers with or without pressure.

Treating the dry, or moist cotton derivative or its solution with dilute acid or the acid gas.

Disintegrating cellulose or subjecting it to ultra-violet light.

Over-ripening.

Addition of ethyl alcohol containing 0.1 per cent acetic acid and then treating with ultra-violet light.

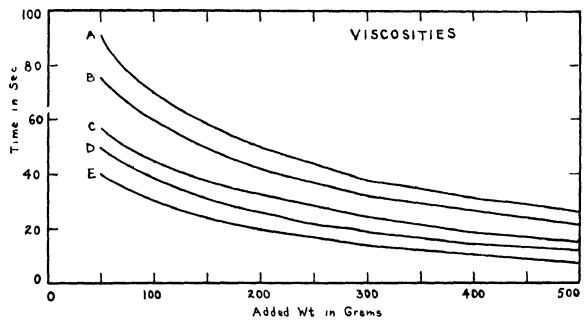


FIGURE 15A. Viscosity[6] at Room Temperature:

A, ½-sec. Cotton
B, ½-sec. Cotton + 10% Turpentine
C, ½-sec. Cotton + 10% Toluene
D, ½-sec. Cotton + 10% Xylene
E, ½-sec. Cotton + 10% Butyl Acetate

Sometimes by the addition of water or acid to the solution of cellulose ethers and esters.

Addition of gall or bile.

With the newer types of low-viscosity cottons, it is possible to load lacquers with such material as resins, pigment and so forth, which give the film body, strength and resistance to wear. Loading also produces quicker setting owing to a quicker rise in consistency which is brought

TABLE 8A.—Effect of Aging on Consistency of Various Lacquers[4]

		Kept in Room — Consistency			Kept in Incubator — Consistency		
No.	Description of Lacquer	May 16, 1927 *Seconds*	August 8, 1927 *Seconds*	Reduction *Per Cent*	May 16, 1927 *Seconds*	August 8, 1927 *Seconds*	Reduction *Per Cent*
1	Blank (10% nitrocellulose in solvents)	124[a]	105	15	124	92	26
2	Blank (10% nitrocellulose in solvents)	124	103	17			
3	Blank 0.1% pyridine	106	67	36			
4	Blank in tin can	131	111	16	134	97	28
5	Blank + 0.2% urea	123	110	11	123	92	26
6	Blank + 0.2% urea	122	110	11	122	92	26
7	Blank + 0.2% urea	122	109	11	122	90	26
8	Blank + 0 2% urea	125	117	7	126	99	22
9	Blank + 5% ZnO	150	105	30			
10	Blank + 5% TiO_2 + $BaSO_4$ pigment	119	107	10			
11	Blank + 2 5% chrome yellow pigment	128	111	12			
12	Blank + 1.2% Prussian blue pigment	121	105	13			
13	Black auto lacquer	118	99	15			
14	10 grams cotton + 40 cc. butyl acetate +40 cc. toluene + 20 cc. butyl alcohol	217	206	4	217	171	21
15	Adherence standard	120	110	8	120	93	23
16	Commercial brushing lacquer 1				79	68	14
17	Commercial brushing lacquer 2				135	103	20
18	Blank + 20% Ester gum	122	80	35			
19	Blank + 20% Dammar	130	110	15			
20	Blank + 5% butyl phenolate	116	101	13			
21	12 grams cotton in 100 cc. butyl acetate	159	135	15			
22	12 grams cotton in 100 cc ethyl acetate	80	69	13			

[a]The original value in each test was taken approximately 1 week after the solutions were made.

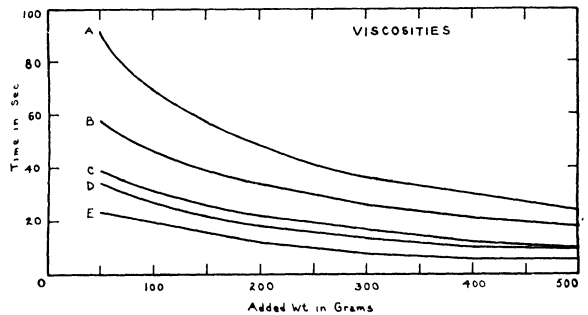


FIGURE 15B. Viscosity[6] at Room Temperature:

A, ½-sec. Cotton
B, ½-sec. Cotton + 20% Turpentine
C, ½-sec. Cotton + 20% Toluene
D, ½-sec. Cotton + 20% Xylene
E, ½ sec. Cotton + 20% Butyl Acetate

about by the evaporation of the solvent mixture. A shorter setting time is effected by increased loading. This establishes an interrelation between the degree of loading, viscosity and setting time. Viscosities in spraying lacquers must not be high since they will require high spraying pressures which produce undesirable behavior in the lacquer.

TABLE 8B

No.	Description of Lacquer	cc.	Series I—45 Days[a] Consistency April 30, 1925 *Seconds*	Consistency June 16, 1925 *Seconds*	Reduction *Per cent*	Series II—125 Days[a] Consistency March 10, 1926 *Seconds*	Consistency July 16, 1296 *Seconds*	Reduction *Per cent*
	24 grams 1/2-second nitrocellulose in:							
1	Butyl acetate	200	100	75	25	273	215	21
2	Ethyl acetate	200	49	37	24	138	112	19
3	Diacetone alcohol	200	253	169	33			
4	Ethyl lactate	200	211	170	20			
5	Butyl acetate + toluene	100 100	126	96	25	409	316	21
6	Butyl acetate + toluene	160 140	140	105	25	748	545	27
7	Butyl acetate + benzene	100 100	134	107	20	433	321	26
8	Butyl acetate + ethyl alcohol	100 100	113	97	14	295	239	22
9	Butyl acetate + butyl alcohol	100 100	168	135	20	476	242	49
10	Butyl acetate + Ester gum, 50%	150 48	203	148	27	688	460	33
11	Butyl acetate + Dammar, 50%	150 48	137	83	40	375	283	25
12	Butyl acetate + tricresyl phosphate	200 12	102	82	20			
13	Butyl acetate Butyl phenolate	200 12	126	101	20	336	246	27
14	Butyl acetate kept in incubator at 97° F. (36° C.)	200	114	76	33	415	186	55
	12 grams 12-second nitrocellulose in:							
15	Butyl acetate	300	125	95	24			
16	Ethyl acetate	300	59	46	22			
17	Diacetone alcohol	300	203	157	23			
18	Ethyl lactate	300	246	209	15			
19	Butyl acetate + toluene	150 150	200	124	38			
20	Butyl acetate + lactic acid, 0.5%	300	120	98	18			
21	Butyl acetate + acetic acid, 0.5%	300	127	83	35			
22	Butyl acetate + nitric acid, 0.5%	300	108	90	17			
23	Butyl acetate + ammonium hydroxide, 0.17%	300	116	46	60			
24	Butyl acetate saturated with urea	300	106	78	26	415	375	5
25	Butyl acetate + tricresyl phosphate, 6 grams	300	155	80	48			
26	Butyl acetate + butyl phenolate, 6 grams	300	133	85	36			
27	Butyl acetate kept in sunlight	300	125	77	42			
28	100 cc. 4-second stock solution + 50 cc. ethyl acetate + 50 cc. benzene		166	148	11			
29	70 cc. 1/2-second nitrocellulose stock + 80 cc. ethyl acetate + 50 cc. benzene		523	520				
30	24 grams. A.S. nitrocellulose in 200 cc. ansol		215	157	26			
31	24 grams 1/2-second nitrocellulose in 200 cc. butyl acetate (80% saturated with H_2O)		101	95	6			
32	12 grams 12-second nitrocellulose in 300 cc. butyl acetate + 5 cc. NaOH in butyl alcohol		84	52	38			
33	24 grams 1/2-second nitrocellulose in 100 cc. butyl acetate + 100 cc. toluene + 0.05 gram pyridine					427	210	51

[a] All tests made in the dark, except where otherwise specified.

TABLE 9.—Viscosity (in Centipoises) of Various Substances*

Acetaldehyde	0.2234(19.2)	Ethylene glycol	[illegible]
Acetamide	1.32(105)	Ethylene trichloride	0.550(25)
Acetic anhydride	0.98(25)	Formanilide	8.70(55)
Acetone	0.316(25)	Formic acid	1.635(24.2)
Aceto-nitrile	0.34(25)	Glycerol	8.3(20.3)
Acetylene dichloride	0.391(25)	Isoamyl acetate	0.79(25)
Acetylene tetrachloride	1.637(25)	Isoamyl alcohol	3.80(25)
Allyl alcohol	1.283(22.8)	Isoamylamine	0.7235(25)
n-Amyl acetate	0.811(25)	Isoamyl ether	1.40(11)
n-Amyl alcohol	4.573(233)	Isoamyl formate	0.794(20)
sec-Amyl alcohol	3.10(25)	Isobutyl alcohol	3.37(25)
tert-Amyl alcohol	3.63(25)	Isobutyl butyrate	0.9766(25)
Amyl butyrate	1.2558(25)	Isobutyl formate	0.6650(20)
Amyl caproate	2.2707(25)	Isobutyl propionate	0.67(25)
Amyl propionate	0.9355(25)	Isomethyl butyl ketone	0.5799(20)
Amyl valerate	0.6227(25)	Isopropyl acetate	0.5247(20)
Aniline	3.70(25)	Isopropyl alcohol	2.15(24.4)
Benzaldehyde	1.40(25)	Isopropyl formate	0.5134(20)
Benzene	0.60(25)	Mesityl oxide	0.879(25)
Benzonitrile	1.25(25)	Methyl acetanilid	0.82(120)
Benzyl acetate	1.423(45)	Methyl acetate	0.3706(22.74)
Benzyl alcohol	5.054(25)	Methyl acetoacetate	1.702(20)
Benzylamine	1.59(25)	Methyl alcohol	0.546(25)
Benzyl benzoate	8.504(25)	*n*-Methyl amyl ketone	0.766(25)
Butyl acetate	0.6714(25)	Methyl benzoate	2.067(20)
n-Butyl alcohol	2.46(25)	*n*-Methyl butyl ketone	0.584(25)
tert-Butyl alcohol	5 887(22.41)	Methyl *n*-butyrate	0.530(25)
n-Butylamine	0.681(25)	Methyl isobutyrate	0.5170(20)
Butyl caproate	1.348(25)	Methyl caproate	0.8096(25)
n-Butyl formate	0.5627(20)	Methyl carbamate	2.28(55.6)
Butyl valerate	1.348(25)	Methyl ethyl ketone	0.497(25)
n-Butyric acid	1.599(20)	Methyl formate	0.3298(25.5)
Carbon disulfide	0.35(20)	Methyl propionate	0.461(20)
Carbon tetrachloride	0.88(25)	*n*-Methyl propyl ketone	0.473(25)
Chloroform	0.54(25)	Methyl valerate	0.6227(25)
Cyclohexanol	20.3(39.1)	Methylene chloride	0 4137(25 6)
Cyclohexanone	2.30(17.3)	Monobromobenzene	0.985(30)
Cyclopentanone	1.07(25)	Monochlorobenzene	1.03(0)
Diethylamine	0 35(25)	Nitrobenzene	2.013(20)
Diethyl oxalate	1.76(25)	Pentachlorethane	2.26(25)
Diethyl phthalate	10.1(25)	Phenetole	1.1158(25)
Diethylene glycol	0.38(20)	β-Phenyl ether alcohol	7.61(25)
Diphenyl ether	3.864(25)	Phenyl methyl ether	1.01(25)
n-Dipropyl ketone	0.685(25)	*n*-Propyl acetate	0.551(25)
α-Epichlorhydrin	1.03(25)	*n*-Propyl alcohol	1.91(25)
Ethyl abietate	6.05(250)	*n*-Propyl benzene	0.793(25)
Ethyl acetate	0.441(25)	*n*-Propyl butyrate	0.8296(20)
Ethyl acetoacetate	1.53(25)	Propyl caproate	1.2864(25)
Ethyl alcohol	1.05(25)	*n*-Propyl formate	0.5134(20)
Ethyl benzene	0.632(25)	*n*-Propyl propionate	0.6722(20)
Ethyl benzoate	2.14(25)	Propyl valerate	0.6227(25)
Ethyl bromide	0.3734(25.3)	Propylene dichloride	0.873(25)
Ethyl butyrate	0.63(25)	Pyridine	0.88(25)
Ethyl caproate	0.9881(25)	Tetrachloroethylene	0.838(25)
Ethyl ether	0.223(25)	Tetralin 1,2,3,4	2.00(25)
Ethyl formate	0.389(25)	Tetralin 5,6,7,8	2 00(25)
Ethyl propionate	0.5045(25)	Toluene	0.552(25)
Ethyl salicylate	1.803(145)	Trichloroethylene	0.550(25)
Ethyl sebacate	5.1(25)	Triethylamine	0.363(25)
Ethyl stearate	3.75(50)	Turpentine (wood)	1.34(25)
Ethyl valerate	0.7623(25)	*m*-Xylene	0.79(12)
Ethylene diamine	1.54(25)	*o*-Xylene	0.95(12)
Ethylene dibromide	1.698(20.6)	*p*-Xylene	0.80(12)

* Figures in parentheses are temperature in °C.

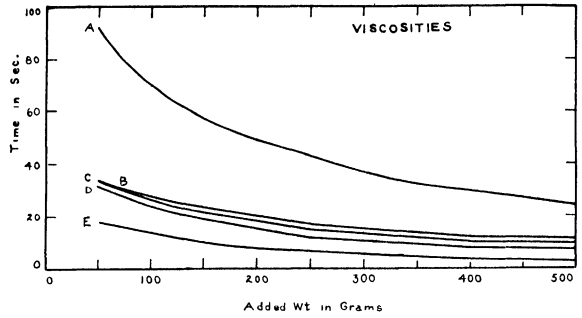


FIGURE 15C. Viscosity[6] at Room Temperature:

A, ½-sec. Cotton
B, ½-sec. Cotton + 30% Turpentine
C, ½ sec. Cotton + 30% Toluene
D, ½-sec. Cotton + 30% Xylene
E, ½ sec. Cotton + 30% Butyl Acetate

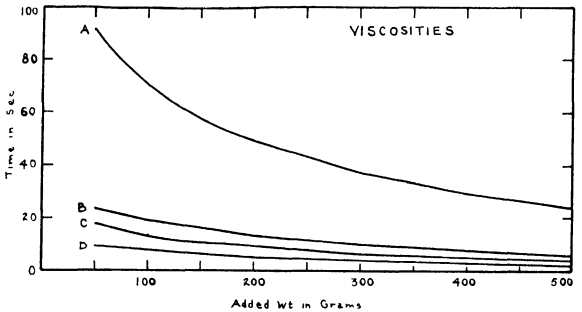


FIGURE 15D. Viscosity[6] at Room Temperature:

A, ½-sec. Cotton
B, ½-sec. Cotton + 40% Toluene
C, ½-sec. Cotton + 40% Xylene
D, ½-sec. Cotton + 40% Butyl Acetate

Mardles[7] has found that there is a relationship between solvent power and viscosity. The optimum solvent mixture dissolves the cellulose ester most rapidly, yields the least viscous solution, and produces a high degree of dispersion. Non-solvents, on the other hand, increase viscosities provided their admixture does not result in increased solvency. The more powerful a solvent the more closely does its solution approach a true solution. In the case of an ether-alcohol mixture containing 4% of nitrocellulose of 12.2% nitrogen content, Gibson and McCall[5] have found that minimum viscosities are obtained when the alcohol content ranges from 40 to 55 per cent and the ether 60 to 45 per cent by volume. It is thus evident that ethyl alcohol materially reduces the viscosity of a nitrocellulose solution. Butyl alcohol behaves in the same manner as ethyl alcohol. A mixture of

alcohol and acetone, or of benzene and acetone, will also reduce viscosities, and maximum results are obtained when the alcohol content is about 14.5 per cent of the alcohol-acetone mixture and the benzene content is about 16.5 per cent of benzene in the benzene-acetone mixture. Esters, owing to their solvent power, yield low viscosity solutions. Fifteen per cent is usually the minimum limit, and any amount less than this will produce only a slight drop in viscosity. However, any amount above 15 per cent will produce a drop in viscosity until the limit is reached. Commercial butyl acetate, as compared with the refined ester, is twice as strong in its power to reduce the viscosity of nitrocellulose solutions. This is attributed to the presence of butyl alcohol in the commercial grade. Benzene in the presence of pure ester merely acts the part of diluent; but when it is mixed with alcohol, it becomes a solvent and acquires the power to reduce viscosity. In general, solvents of low boiling point, low vapor pressure, and high solvency yield solutions of low viscosity, and conversely the increase in vapor pressure, boiling point, and decrease in solvency, produce an increase in viscosity. These facts are of especial significance in the homologous series.

Marling and Purdy [6] have determined the effect of thinners on the consistency of nitrocellulose. The results are reported in the following graphs. The solution consists of 25 per cent nitrocellulose and 75 per cent solvent. The solvent is 50 per cent ethyl alcohol and butyl acetate and 50 per cent toluene by volume. They have found that the consistency of one-half second, four-second, and ten-second nitrocellulose is reduced by increasing the amount of thinner.

TABLE 10.—Viscosity at 25° C. of 5 Per Cent Solutions of Nitrocotton[2]

Butyl Acetal By Vol.	Ethyl Acetate By Vol	Ethyl Alchol By Vol	Benzene By Vol.	Time of Flow Secs.	Time of Flow Secs.	Corrected Viscosity Glycerol = 100
100				71.4	71.4	43.1
90		10		31.6	31.3	18.9
90			10	75.0	75.0	43.3
80		20		24.6	24.2	14.6
80			20	87.0	87.0	52.5
60		40		21.5	20.6	12.4
60			40	36.2	35.8	21.6
40		60		20.0	20.7	12.5
40		30	30	25.8	25 0	15.1
20		80		24.1	22.2	13.4
20		10	70	53.0	47.0	28.4
	100			31.6	31.6	19.0
	90	10		23.4	23.1	13.9
	90		10	36.0	36.0	21.7
	80	20		17.2	16.8	10.5
	80	10	10	21.5	21.5	13.5
	80		20	40.8	40.8	24.7
	60	40		16.0	15.3	9.2
	60		40	64.6	64.4	38.9
	40	60		17.7	16.7	10.1
	40	30	30	19.4	18.8	11.4
	40		60	150.0	149.0	90.0
	20	80		22.8	20.8	12.6

TABLE 11.—Viscosity of Nitrocotton-Dammar Solutions[7]

Butyl Acetate %	Butyl Propionate %	Ethyl Acetate %	Toluene %	0.5-Sec. Cotton %	Dammar	Viscosity (Secs.)
	9.6	22.6	44.7	15.4	7.7	1.5
9.6		22.6	44.7	15.4	7.7	1.3
	7.4	25.8	46.0	15.8	5.0	1.2
7.4		25.8	46.0	15.8	5.0	1.4
	14.8	18.4	46.0	15.8	5.0	1.0
14.8		18.4	46.0	15.8	5.0	1.4
17.0		17.0	45.0	16.0	5.0	1.4
	10.0	24.0	45.0	16.0	5.0	1.4
24.0		10.0	45.0	16.0	5.0	1.8
	14.0	20.0	45.0	16.0	5.0	1.6

The viscosity of resin solutions is practically constant in benzene, toluene and xylene. A higher viscosity is obtained in saturated hydrocarbons than in unsaturated. Viscosities of oleo-varnishes are reduced in proportion to the volume ratios of the thinners used. The more powerful a solvent, the greater is the reduction of viscosity.

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Chapter 6

Volatility, Inflammability, Toxicity

Generally, solvents are liquids which exhibit the power of dissolving other substances and thereby converting them into a fluid state. Solvents which evaporate readily when exposed are called volatile solvents and, should these solvents also have the property of "catching fire," they are called inflammable liquids. The degree of inflammability of a substance is indicated by what is termed its flash-point or explained as the lowest temperature at which the substance will ignite when it gives off sufficient vapor to form an explosive mixture with air. The "ignition point" is the temperature at which this vapor-air mixture will, under favorable conditions, take fire spontaneously. Further, it is the lowest temperature at which there is more heat generated than is lost and therefore combustion becomes self-propellent. The mixture of inflammable vapor or vapors and air is explosive or inflammable only within a limited range of concentration. Should the quantity of any of the ingredients of the explosive mixture lie outside this limited range, ignition will not take place. It has been pointed out that the limit of inflammability in paraffins is inversely proportional to the calorific value of the gas. When two or more inflammable liquids are mixed, the flash-point may be somewhere between the lowest and highest flash-points of the constituent parts or it may even be lower than the lowest flash-point of any of the constituent parts. The lowering of the flash-point, similar to the lowering of the melting-point of eutectic mixtures, is owing to the formation of molecular aggregates. This phenomenon in liquids is referred to as azeotropic combination. Wheeler and Whitaker [1] have observed that the direction of the flame influences inflammability. The upward propagation of the flame requires the lower limit of concentration and the downward or horizontal propagation of the flame requires the upper limit of concentration.

The flash-point of a liquid, or a mixture of liquids, may be raised by replacing the low-boiling liquid, or liquids, in part or wholly, with non-inflammable or higher-boiling liquids or by eliminating such liquids which form constant-boiling mixtures of a low-boiling point.

Some of the physical and chemical properties which influence ignition temperatures are high calorific values, activity of valence forces, and ease of chemical reactions. This is especially true of high calorific values because it makes combustion self-propelling. It has been observed that the simplicity of molecular structure is associated with high ignition.

TABLE 12.—Explosive Properties of Lacquer-Solvent Vapors*[a]

No.	Solvent	Mol. Wt. (Pure)	Distillation Range (A. S. T. M.) ° C.	Flash-Point ° C.	Vapor Pressure (25° C.) mm. Hg	Air Volume (Theor.)	Volume 1 Gram at 25° C. 745 mm. Hg (cc.)	Explosive Range — Low — % by vol.	Low — Gram/liter	High — % by vol.	High — Gram/liter
1	Ether	74.1	35	−40	526	30	324	1.25	0.0386	10.0	0.308
2	U.S.P. acetone	58	56	−20	225	20	414	2.5	0.0605	9.0	0.218
3	Methanol	32	66	12	116	7.5	749	5.5	0.0734	21.0	0.280
4	Ethyl alcohol	46	76–78	13	60	15	546	4.0	0.0733	14.0	0.256
5	Ethyl acetate	88	72–79	3	104	25	273	2.25	0.0824	11.0	0.403
6	Isopropyl alcohol	60	81–83	12	45	22.5	399	2.5	0.0627		
7	Isopropyl acetate	102	84–97	5	68	35	235	2.0	0.0896		
8	Butyl alcohol	74	113–116	29	9	30	324	[a]			
9	Butyl acetate	116	113–140	22	16	40	207	[a]			
10	Butyl propionate	130	124–161	32	15	47.5	183	[a]			
11	Amyl alcohol	88	117–131	33	8	37.5	272	[a]			
12	Amyl acetate	130	129–148	32	10	47.5	184	[a]			
13	Ethyl lactate	118	127–161	43	4	30	203	[a]			
14	Benzene, 90%	78	77–118	−12	97	37.5	308	1.5	0.0487	9.5	0.308
15	Toluene	92	107–125	8	32	45	261	1.3	0.0498	7.0	0.268
16	V.M.P. naphtha		96–154		36				0.0499		

*All work carried out at 25° C. and prevailing atmospheric pressure.

[a]Explosive mixture not formed at 25° C.

TABLE 13.—Ignition Temperatures (° C.)

Solvent	In Air from Surface: Glass	Copper	Steel	Chromium	Auto-Ignition Temperature: In Air	From Surface: Platinum	Glass	Gold	Silver
Acetic acid					599	599	562	599	
Acetone	633–639	649	649	668		727			
Allyl alcohol	393–407	387	392	378					
Amyl acetate (tech.)						563			
Amyl alcohol					519				
Aniline					620	620		592	620
Benzene						656	618	656	649
Benzene (CS_2 0.025%)	580	649	649	668					
Benzyl acetate	460	598	479	610	588	588	503	588	556
Benzyl alcohol	436–444	460	436	428	501	502	443	519	510
Benzyl chloride						627			
Benzyl ethyl ether						496			
Bromobenzene						688			
n-Butaldehyde						408			
n-Butyl acetate	422–426	593	449	562					
n-Butyl acetate (tech.)	383–407	429	376	503					
n-Butyl alcohol	366	356	345	369		503			
Butyl alcohol (tech.)	356–360	323	349	474					
tert-Butyl alcohol	483–487	449	601	604					
n-Butyl bromide						483			
Butyl carbitol (tech.)	229–231	238	234	234					
n-Butyl propionate	428–433	549	447	558					
n-Butyric acid						552			
Carbon disulfide	127	135	133	133	343	149			
Carbon tetrachloride						over 1000			
Chloroform						over 1000			
m-Cresol					626	626			
o-Cresol					599	599		601	573
Cyclohexanone						557			
p-Cymene						466	508		
n-Decane						425			
Diethyl ether (10% alcohol)						487		479	474
Diethyl ketone						608			
Ether (U.S.P.)	193–196	203	196	196					
Ether (C_2H_5OH 0.300%)	188	199	193	189					
Ethyl acetate	484–489	593	547	568		610	569		
Ethyl alcohol (95% U.S.P.)	421–439	524	392	454	566	557	544	523	522
Ethyl aniline						479			
Ethyl benzene					553	553	557		
Ethyl benzoate						644			
Ethyl bromide						588			
Ethyl *n*-butyrate						612			
Ethyl caproate						493			
Ethyl *n*-caproate						582			
Ethyl *n*-caprylate						571			
Ethyl ether					487				
Ethyl formate						577			
Ethyl malonate						541			
Ethyl oleate						353			
Ethyl palmitate						588			
Ethyl pelargonate						524			
Ethyl propionate						602			
Ethyl propyl ketone						575			
Ethyl *n*-valerianate						590			
Ethylene glycol	413–416	518	477	524		522	457		535

TABLE 13.—Ignition Temperatures (° C.)—*Continued*

Solvent	In Air from Surface				Auto-Ignition Temperature				
						From Surface			
	Glass	Copper	Steel	Chro-mium	In Air	Plati-num	Glass	Gold	Silver
Ethylene glycol diacetate						635			
Formic acid					504				
Gasoline (Socony)	258–268	279	288	293					
Glycerol (tech.)	397–402	516	461	500		523	429		
n-Heptane	233–238	249	251	251	451	451	477	474	475
n-Heptanoic acid						523			
α-n-Heptylene						332	338		
Hexane (pract.)	273–297	307	312	313					
n-Hexane	253	266	269	267	520	520	515	538	536
Isoamyl acetate	379	543	461	566					
Isoamyl alcohol	349–356	327	356	458		518	449	513	492
Isoamyl ether						428			
Isobutyl alcohol	438–441	461	483	461	542	542	522	540	511
Isododecane						534	499		
Isooctane						561	537	583	584
Isopropyl acetate	460–468	593	612	618					
Isopropyl alcohol	457	649	634	638	620	620	532	608	619
Mesitylene						621	599		
Methanol	470–475	457	474	508		574	337	548	558
Methone						506			
Methyl acetate	502–512	560	569	606		654			
Methyl alcohol					574				
Methyl cyclohexanone						595			
Methylheptenone						534			
Methyl hexyl ketone						572			
Monoethylaniline					479				
Nitrobenzene					556	556		526	513
n-Octane					458	458	435	482	476
Paraldehyde						541			
n-Pentane (tech.)	309–312	461	313	313	579	579	543	557	564
Propionaldehyde						419			
n-Propionic acid						596			
n-Propyl acetate						662			
n-Propyl alcohol	432–437	481	461	447	540	540	526	537	511
Pulegon						426			
Toluene	552				633	633	604	638	632
m-Toluidine					580	580			
o-Toluidine					537	537			
2,2,4-Trimethylpentane					560				
Turpentine	253	264	262	270					
Varnoline (Socony)	252–256	279	272	273					
Xylene (tech.)	553	649	649	671					
o-Xylene	496–507	635	635						
p-Xylene					618	618	595	623	623

Should non-inflammable liquids be added to a mixture for the purpose of either raising the flash-point or making the mixture non-inflammable, these mixtures do not always remain the same. If, on the other hand, molecular aggregates are so formed as to create a higher flash-point or make the liquid non-inflammable, the mixture will remain the same throughout the entire period of evaporation. Should there be no formation of molecular aggregates, the liquid possessing the highest evaporation rate will leave the mixture sooner; and should this departing liquid be the non-inflammable one, the remaining mixture will no longer carry its pro-

tection. Snell [2] has pointed out some cases wherein a flame-proof mixture becomes an inflammable mixture upon partial evaporation.

TABLE 14.—Effect of Partial Evaporation on Flash-Points of Mixtures[3]

Mixture		Flash-Point	
$(CH_3)_2CO$ (%)	CCl_4 (%)	Of original (° C.)	After 50% evaporation (° C.)
40	60	<0	7
30	70	<0	17
20	80	15	>30
$C_6H_5CH_3$	CCl_4		
80	20	15	5
70	30	24	12
60	40	>30	>30

TABLE 15.—Composition of Mixed Solvents[3]

Mixture	1	2	3	4	5	6	7	8
Benzene	50*	60	20			20		
Toluene			40	60	60	40	30	30
V.M.P. naphtha							30	
Ethyl acetate	50	30	15	15		10		
Butyl acetate			15		15	10		
Butyl propionate				15	15	10	30	40
Ethyl alcohol		10	5	5				
Butyl alcohol			5	5	10	10	10	30
Lower limit for explosive mixture, gram per liter	0.0700	0.0567	0.0714	0.0980	0.0824	0.0620	0.0588	0.0773

*Figures in per cent.

Monroe [4] was the first to recognize inflammable liquids and gases as the cause of mysterious fires. He has attributed these to the phenomenon of static electricity which may develop when liquid solvents flow through pipes, when liquid solvents pass through a gaseous medium like air, when vapors pass into the air, and when a gas passes through a liquid medium.

Static electricity can be eliminated by the addition of a metallic soap. As an example, when 0.05 per cent of magnesium oleate is added to a solvent the electrical conductivity is increased to permit the passing-off of electricity. Well-grounded pipe lines are another means of eliminating static potential. The greatest danger exists at the open end of a pipe, at which point a high state of potential may develop as the liquid leaves the pipe at the opening. To avoid this possible occurrence the liquid should not be permitted to spray, and should a high potential develop it can be neutralized by ionizing the air with ultra-violet light or x-ray. A further aid would be to humidify the air.

Toxicity goes hand in hand with the volatility of solvents. A volatile substance when exposed will escape and find free access to our olfactory systems should we be within the vicinity of its vapors. Broadly, solvent vapors are more or less toxic and their physiologic action can be equally varied. Although people differ widely in their susceptibility, a volatile solvent will find its way into the blood-stream by mixing with the inhaled oxygen and thus ultimately it comes in contact with every body

tissue upon which it exerts toxic action. Larzarev, Brusclavskayo, and Larrav [5] have made experiments upon workmen whose hands were in contact with organic solvents for at least fifteen minutes and they all gave evidence of these toxic substances in the blood-stream. Longer contact gave proof of increased accumulation of these poisons in the blood-stream.

TABLE 16.—Industrial Diseases Among Chemical Workers in England

	1929		1928		1927		1926		1925	
	Chronic	Dead	Chronic	Dead	Chronic	Dead	Chronic	Dead	Chronic	Dead
Carbon disulfide poisoning	6		1				1			
Aniline poisoning	26		41		38	1	33	1		
Benzene poisoning	1						1			
Benzene, benzine, naphtha, petrol	7		7	2	7	2	4	1	3	0
Ether, acetone, nickel carbonyl	36	1	17	2	23	2	17	1	35	3

Wolff [6] has pointed out that benzene and its homologues, acetone, aniline and pyridine derivatives, and chlorinated hydrocarbons are all poisonous in concentrated forms. Benzene runs a close second to lead as the most toxic substance used in coating materials. In a report,[7] the Committee on Volatile Solvents has indicated the danger of even small quantities of benzene and has urged that its use be restricted by substituting for it some of the higher homologues like toluene or xylene, which are less toxic, or petroleum products. Six cases of chronic benzene poisoning were reported in 1927. Nevertheless, benzene is still being used in the manufacture of a large number of products. Steps have been taken in some industries to replace it. Lacquer and coating industries are using substitutes and Stoddard's solvent is used in the dry-cleaning industry.

The following solvents are reported for their poisonous action by Ebert.[8] These are ether, methyl, ethyl, propyl, and amyl alcohols, ketones, esters, turpentine, pine oils, benzine, benzene, toluene, xylene and chlorinated hydrocarbons. This worker is also of the opinion that carbon disulfide is toxically the most dangerous. Smyth and Smyth [9] in their experiments on the inhalation of lacquer solvents determined the progression of increasing toxicity and give the following order: ethyl acetate, amyl acetate, butyl acetate, gasoline, turpentine, xylene, toluene and butyl alcohol. These can be safely used, however, in well-ventilated surroundings. Commercial xylene, which contains a mixture of toluene and benzene, affects young workers in poorly-ventilated rooms by making them nauseous and dizzy. Definitely toxic changes occur in the blood of workmen upon using, over a prolonged period, a mixture of commercial benzene, acetone and methyl alcohol. It has been known that jaundice has occurred among those exposed, by inhalation, to the vapors of tetrachlorethane and trinitrotoluene.

TABLE 17.—Physical and Physiological Properties of Chemicals Used as Stenches[12]

Chemical	Boiling Point (° C.)	Freezing Point (° C)	Character of Odor	Physiological Properties of Vapor	Remarks
Amyl acetate	148	− 75 (thick)	Banana oil	Harmless	Pleasant to most people
Ethyl acetate	77.4	− 83.8	Fruity, pleasant	Harmless	
Amyl alcohol	137.8	.....	Alcoholic	Harmless	
Butyric acid	162.3	− 7.9	Very disagreeable	Harmless	
Valeric acid	186.4	− 58.5	Very disagreeable	Harmless	
Ethyl ether	35	−112.6	Pungent	Soporific	
Phenyl isocyanide	165	.....	Very disagreeable	Unknown	
Allyl isothiocyanate	151	.....	Mustard oil, disagreeable	Lachrymatory and toxic	
Methyl isothiocyanate	119	34	Mustard oil, disagreeable	Lachrymatory and toxic	
Amyl isovalerianate	190	.....	Very disagreeable	Harmless	
Butyl mercaptan	97	.. ...	Very disagreeable	Harmless	
Isobutyl mercaptan	88	.....	Very disagreeable	Unknown	Probably harmless
Ethyl mercaptan	37	−144.4	Very disagreeable	Harmless	
Propyl mercaptan	67	.....	Very disagreeable	Unknown	Probably harmless
Methyl salicylate	222.2	− 8.3	Oil of wintergreen, pleasant	Harmless	
Amyl thioether	95–98	.....	Very disagreeable	Unknown	Probably harmless
Ethyl thioether	92	− 99.5	Very disagreeable	Unknown	Probably harmless
Carbon tetrachloride	76.74	− 19.5	Sweet, unpleasant	Harmless	
Chloroform	62	− 63.2	Sweet, agreeable	Soporific	
Iodoform	Decomposes 119	.... .	Unpleasant	Harmless	
Artificial musk	.....	.... .	Pleasant	Harmless	Unpleasant in higher concentrations
Nitrobenzene	209 4	5 71	Almonds, pleasant	Toxic	
Oil of peppermint	.... .	.....	Pleasant	Harmless	
Pyridine	115.2	− 42	Very disagreeable	Toxic	

TABLE 18.—Results of Measurement of the Intensity of Various Stenches[12]

Chemical	Volumes of the Chemical, as a Perfect Gas, per Million Volumes of Air — Intensity of Odor					Milligrams of Chemical per Cu. Ft. of Air — Intensity of Odor					Milligrams of Chemical per Liter of Air — Intensity of Odor				
	Detectable	Faint	Quite Noticeable	Strong	Very Strong	Detectable	Faint	Quite Noticeable	Strong	Very Strong	Detectable	Faint	Quite Noticeable	Strong	Very Strong
Amyl acetate	7	10	13	90	246	1.1	1.5	2	14	38	0.039	0.053	0.067	0.478	1.326
Ethyl acetate	190	399	615	1236	1753	19.4	34.6	63	126	191	0.686	1.224	2.219	4.457	6.733
Amyl alcohol	63	83	123	439	601	6.4	8.5	13	45	61	0.225	0.300	0.442	1.581	2.167
Butyric acid	2.4	6	18	91	161	0.3	0.6	2	9	16	0.009	0.021	0.066	0.329	0.580
Valeric acid	7	29	125	332	962	0.8	3.4	15	39	114	0.029	0.119	0.523	1.394	4.036
Ethyl ether	1923	3352	4927	5825	19982	165.1	287.7	423	500	1715	5.833	10.167	14.944	17.667	60.600
Butyl mercaptan	6	12	18	38	56	0.5	1.0	2	3	5	0.018	0.037	0.055	0.120	0.177
Isobutyl mercaptan	3.5	5	7	11	16	0.2	0.5	0.7	1	2	0.008	0.018	0.025	0.041	0.060
Ethyl mercaptan	18	35	73	141	198	1.3	2.5	5	10	14	0.046	0.088	0.186	0.357	0.501
Propyl mercaptan	2	7	9	14	17	0.2	0.6	0.8	1.2	1.6	0.006	0.020	0.028	0.043	0.054
Amyl thioether	0.2	1	1.6	1.7	2.2	0 04	0.2	0.3	0.4	0.5	0.001	0.007	0.0115	0.012	0.015
Ethyl thioether	3	12	29	61	74	0.3	1.2	3	6.	8	0.012	0.042	0.107	0.223	0.271
Allyl isothiocyanate	2	3	6	8	50	0.2	0.3	0.7	0.9	6	0.008	0.012	0.024	0.030	0.201
Methyl isothiocyanate	5	13	23	36	48	0.4	1.1	2	3	4	0.015	0.039	0.067	0.108	0.144
Amyl isovalerate	1.7	3	6	10	12	0.4	0.5	1	2	2.3	0.012	0.018	0.039	0.072	0.082
Carbon tetrachloride	718	1461	1588	4964	6091	128	260	283	886	1087	4.533	9.222	10.024	31.333	38.444
Chloroform	674	1389	2600	5887	9528	93	192	360	816	1321	3.300	6.800	12.733	28.833	46.666
Iodoform	1.1(a)	....	....	....	....	0.5(a)	....	....	....	....	0.018(a)	....	....	....	....
Artificial musk	....	....	....	....	....	0.001(a)	....	....	....	....	0.00004(a)	....	....	....	....
Nitrobenzene	29	36	44	114	296	4	5	6	16	42	0.146	0.178	0.222	0.563	1.493
Phenyl isocyanide	0.5	1	3	10	25	0.06	0.1	0.4	1	3	0.002	0.005	0.013	0.042	0.105
Pyridine	10	45	93	700	1764	0.9	4	9	64	162	0.032	0.146	0.301	2.265	5.710
Methyl salicylate	16.1	23	29	244(a)	....	2.8	4	5	43(a)	....	0.100	0.145	0.179	1.526(a)	....
Oil of peppermint	....	....	....	....	....	0.68	0.9	3	9.5	9.9	0.024	0.032	0.109	0.332	0.348

(a) Maximum concentration obtainable.

TABLE 19.—Electrical Conductivity and Dielectric Constants

Solvents	Electrical Conductivity Reciprocal Ohms at 25° C.	Dielectric Constants at 25° C.
Acetal		3.79
Acetic acid	11.20×10^{-9}	6.40
Acetic anhydride	0.48×10^{-6}	20.50
Acetone	5.50×10^{-8}	21.45
Acetonitrile		38.80
Acetophenone	6.43×10^{-9}	18.30
Acetyl acetone		23.00
cis-Acetylene dibromide		7.08
trans-Acetylene dibromide		2.88
Acetylene dichloride (mixture)	$\sim8.50\times10^{-9}$	6.70
cis-Acetylene dichloride		3.67 (16° C.)
trans-Acetylene dichloride		7.55 (16° C.)
Acetylene tetrabromide		7.10
Allyl alcohol		21.00
n-Amyl acetate		5.10
Aniline	2.40×10^{-8}	7.20
Anisole		4.30
Benzaldehyde		18.00
Benzene	4.43×10^{-17} (5.32° C.)	2.2961 (15° C.)
Benzyl alcohol		13.00
Benzyl benzoate	$<1.00\times10^{-9}$	4.85
Benzyl chloride		6.50
Benzyl ethyl ether		3.87 (19.75° C.)
Bromobenzene	1.20×10^{-11}	5.40
Bromoform	$<2.00\times10^{-8}$	4.73
α-Bromonaphthalene		5.17 (19° C.)
p-Bromotoluene		5.10
Butanol		17.80
n-Butyl acetate		5.10
n-Butyl alcohol	3.6×10^{-7}	16.1 (17.2° C.)
Butyric acid		2.90
Carbon disulfide	$<3.70\times10^{-8}$	2.60
Carbon tetrachloride	4.00×10^{-18} (18° C.)	2.40
Chloroacetone		29.00
Chlorobenzene	$<10^{-9}$(0° C.)	5.90
Chloroform	$<10^{-10}$	5.10
Cresol (mixture)		10.30 (17° C.)
m-Cresol	1.397×10^{-8}	13.00
o-Cresol	0.127×10^{-8}	8.00
p-Cresol	1.378×10^{-8}	13.00
m-Cresyl methyl ether		4.08
o-Cresly methyl ether		3.57
p-Cresyl methyl ether		4.03
Cyclohexane		2.10
Cyclohexanol		15.00
Cyclohexanone	$5-8\times10^{-8}$	18.20
p-Cymene	2×10^{-8}	2.249 (17° C.)
Decahydronaphthalene		2.11
n-Decane		1.956
p-Dibrombenzene		4.60
Dichloracetic acid		8.20
o-Dichlorbenzene	$<10^{-9}$(0° C.)	9.82
p-Dichlorbenzene		2.80
α,α-Dichlorhydrin		11.95 (19.6° C.)
Diethyl carbonate	17×10^{-9}	3.10
Diethyl ether	3.7×10^{-13}	4.30
Diethyl malonate		8.40 (20.8° C.)
Diethyl oxalate	7.12×10^{-7}	8.08 (21° C.)
Diisoamyl ether		2.817
Dimethylaniline		4.50
Dimethyl sulfate		55.00
m-Dinitrobenzene		20.70
1·4-Dioxane	$<2\times10^{-8}$	2.235
Diphenyl ether		3.90
Epichlorhydrin	0.54×10^{-7}	23.00
Ethanol		25.70
Ethyl acetate	$<1.0\times10^{-9}$	6.40
Ethyl alcohol	1.35×10^{-9}	25.80
Ethyl benzoate	$<1.0\times10^{-9}$	6.03 (19° C.)
Ethyl bromide	$<2.0\times10^{-8}$	9.31
Ethyl chloride	$<3.0\times10^{-9}$ (0° C.)	6.29 (170° C.)
Ethyl cinnamate		6.45 (19° C.)
Ethyl ether	4×10^{-13}	
Ethyl formate	2.53×10^{-5} (23° C.)	9.10 (14.5° C.)
Ethyl isothiocyanate		19.70
Ethyl propionate	8.33×10^{-4} (17° C.)	5.75
Ethyl salicylate		8.39 (21° C.)
Ethyl thiocyanate		29.00
Ethylene bromide	2.0×10^{-10} (19° C.)	4.865 (18° C.)
Ethylene chlorhydrin		25.80
Ethylene cyanide		66.00
Ethylenediamine		16.00
Ethylene dibromide		4.90
Ethylene dichloride	1×10^{-8}	10.50
Ethylene glycol	1.07×10^{-6}	41.20
Ethylene glycol diacetate	2.8×10^{-2} (20° C.)	
Ethylidene dichloride		10.86 (15.8° C.)
Eugenol		6.00
Formamide	1.98×10^{-6} (20° C.)	84.00
Formanilide		20.50
Formic acid	6.2×10^{-5}	57.00 (21° C.)
Furfural		22.00
Gasoline	2×10^{-12} (15° C.)	
Glycerol	0.9×10^{-7}	43.00
n-Heptane		1.973
n-Hexane		1.910
Isoamyl acetate		5.10
Isoamyl alcohol	$3-5.4\times10^{-9}$	14.70 (18° C.)
Isoamyl benzoate		5.03 (19° C.)
Isoamyl bromide		6.10 (17.6° C.)
Isoamyl *n*-butyrate		3.95
Isoamyl chloride		6.35 (17.7° C.)
Isoamyl isovalerianate		3.62 (19° C.)
Isoamyl propionate		4.25 (19.5° C.)
Isoamyl salicylate		5.40 (19.9° C.)
Isobutyl acetate	2.55×10^{-4} (19° C.)	5.32
Isobutyl alcohol	0.8×10^{-7}	17.95
Isobutyl bromide		6.65 (20.7° C.)
Isobutyl chloride		7.10 (19° C.)
Isopropyl alcohol	0.51×10^{-6}	13.80 (18° C.)
Limonene		2.40
Maleic anhydride		51.00
Methanol		33.70
Methyl acetate	1.923×10^{-4} (17° C.)	8.016 (19.5° C.)
Methylal		2.70
Methyl alcohol	3×10^{-7}	31.20
Methylaniline		6.00
Methyl benzoate	1.37×10^{-6} (22° C.)	6.58 (18° C.)

TABLE 19.—Electrical Conductivity and Dielectric Constants—*Continued*

Solvents	Electrical Conductivity Reciprocal Ohms at 25° C.	Dielectric Constants at 25° C.
Methylcyclohexane		2.071 (24.8° C.)
Methyl ethyl ketone	5.0×10^{-8}	18.4
Methyl formate	1.92×10^{-6} (17° C.)	8.37
Methyl isothiocyanate		19.70
2-Methyl propanol		18.70
Methyl salicylate		9.10 (19.8° C.)
Methyl thiocyanate		35.90
Methylene chloride	4.3×10^{-11}	9.14
Naphthalene	4.35×10^{-10} (81.8° C.)	3.22 (80.5° C.)
α-Naphthyl cyanide		20.00
o-Nitroanisole		24.00
Nitrobenzene	1.22×10^{-8} (23.6° C.)	36.10
Nitromethane		39.00
o-Nitrotoluene		27.40
p-Nitrotoluene		18.70
n-Nonane		1.972
n-Octane		1.962
n-Octyl alcohol		10.34
Oil of turpentine		2.25–2.27 (21° C.)
Oleic acid		2.40
Paraldehyde		14.5
Pentachlorethane		3.60
n-Pentane	2×10^{-10} (19.5° C.)	1 845
Pentanol		5.10
Phenol	$1\text{–}3\times10^{-8}$ (50° C.)	15.00
Phenyl ethyl ether (Phenetole)	1.7×10^{-9}	4.47 (21° C.)
Phenylhydrazine		7.10
Phenyl isocyanate		8.90
Phenyl isothiocyanate		10.70
Phenyl methanol		13.00
Phenyl methyl ether (anisole)	1×10^{-12}	4.35
Phosphorus tribromide		12.40
α-Picoline		10.00
d-*α*-Pinene		2.60
l-*α*-Pinene		2.70
Propanol		21.80
Propanol-2		26.10
Propionic acid		3.20
n-Propyl acetate	$2\ 2\times10^{-4}$ (17° C.)	8.10
n-Propyl alcohol	9.17×10^{-9} (18° C.)	22.20
n-Propyl formate	5.5×10^{-5} (17° C.)	9.01 (23.1° C.)
Pyridine	4.0×10^{-9}	12.50
Quinoline	2.2×10^{-8}	5.00
Salicylaldehyde		14.00
Sulfur monochloride		4 80
Tetrachlorethane		7.83
Tetrachlorethylene		2.50
Tetrahydronaphthalene		2.66
Toluene	1.4×10^{-14}	2.378
o-Toluidine	3.792×10^{-7}	6 03 (19.2° C.)
p-Toluidine	62×10^{-9} (100° C.)	4.88 (58° C.)
Trichlorethylene		3.42 (16° C.)
Xylene (mixture)	$\sim<1\times10^{-8}$	~2.375
m-Xylene		2.40
o-Xylene		2.567 (17° C.)
p-Xylene		2.269 (24.3° C.)
Xylidine		5.00

Flury and Wirth [10] in their study of the toxicity of organic solvents have found that diethyl phthalate, methyl glycol acetate, methyl alcohol, acetone, ethylene glycol and so forth cause irritation of the mucosa of the eye and the respiratory tract, often with considerable inflammation. Their report also disrupts the general belief that esters are not very harmful. Methyl derivatives are especially toxic because the methyl group has a tendency to split off and form methyl alcohol. Other experimenters have reported that the ethers of ethylene glycol produce dryness of the throat, dullness, and a feeling of tightness in the chest.

Bridge [11] has made extensive researches upon the toxic action of some of the more poisonous solvents. Benzene, carbon disulfide, ether, chloroform and tetrachlorethane all produce acute intoxication. They affect the nerve centers in the manner of narcotics thus stupefying the victim. When these are inhaled over a long period, they give rise to jaundice and troubles of the liver. The observed steps in which the toxicity of inhaled vapors affects the individual are, first, a mental excitement followed by a headache and dizziness, and may eventually result in anesthesia. Some of these solvents may also irritate the skin and affect the circulation of the blood. All the chlorinated derivatives like chloroform are narcotic in effect. The following solvents are given in the order of their toxicity, ranging from the least to the most toxic: carbon tetrachloride, <ethylene

perchloride, <ethylene trichloride, <ethylene dichloride, <chloroform, <pentachlorethane, <tetrachlorethane. The chlorinated hydrocarbons have been found to produce various degrees of intoxication, neuritis, gastro-intestinal trouble, and disturbances of the liver. It is understood, however, that idiosyncrasies will play an important part in the reception of the toxic effects of all solvents. People of poor health should not be exposed to an environment containing free toxic vapors. To reduce the toxic dangers of these solvents, they should be handled under a hood or in a room ventilated by forced draught.

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Chapter 7

Solvents and Their Use in the Industries

The amazing growth of the solvent industry can be fairly comprehended when we realize that the few solvents of yesterday, so to speak, such as the aliphatic and aromatic hydrocarbons, methyl and ethyl alcohols, acetone, glycerin and turpentine, have risen to a giant commercial development of over a hundred different solvents. There are many other solvents which are at present produced only on a moderate scale, or are undergoing exploitation, but these are finding wider application every day and are carrying, and may carry, many as yet unknown or unheralded solvents in their wake.

The modern solvent industry produces about 1,600,000,000 pounds of solvents annually in the United States of America. These are no longer limited to the old industrial standbys, such as paint, varnish and lacquer, but have branched out until they are now essential to every industry. At present the lacquer industry claims first place as an outlet for solvents; but this position is in imminent danger of being conceded to the new types of synthetic materials, especially those of synthetic resins. With this new trend the familiar sign "Fresh Paint" will soon be relegated to the past like the wooden Indian of cigar stores.

Lacquer solvents are so blended that the mixture will dissolve cellulose derivatives, natural and synthetic resins and wet pigments; and so that it will be stable, prevent blush, and give any desirable evaporation rate. Solvency is increased by mixing solvents or adding certain ones that possess more than one dissolving group in the molecule. This increased solvent power allows for the addition of diluents and non-solvents, and thus anticipates the never-ceasing demands for lower-cost lacquers. Further demands upon economy will direct research workers to turn to those active solvents which are able to tolerate fairly large quantities of the priceless diluent, water. Wilson[1] suggests the following as the more commonly used solvents: methyl, ethyl, butyl and amyl acetate, secondary esters, acetone, ethyl lactate and the "Cellosolve" compounds. Ethyl acetate is in a class by itself owing to the fact that the lower-boiling solvents, such as acetone and methyl acetate, are much too volatile. The higher esters are used admixed with ethyl acetate and usually constitute the main portion of the solvent mixture. Other good solvents are the secondary esters and the "Cellosolve" compounds. The latter, however, are distinguished by their ability to tolerate fairly large quantities of coal-tar diluents. Lacquer diluents should have a distillation range and an evaporation rate very similar to those of the main solvent in the solvent mixture; they should

also be free of corrosive material, should leave no residue, and should possess solvent power. Thinners for interior gloss paint and enamel should be completely volatile and free of sulfur. It has been pointed out that enamel discoloration is owing to a reaction between sulfur and the constituents of the enamel.

Coal-tar solvents, such as toluene, xylene, and Hi-Flash naphtha, are solvents for alkyd resins and chlorinated rubber (Tornesit type), each of which is used to make corrosion-resistant finishes. They are also added to petroleum naphthas to fortify the solvency of the latter. These solvents will also dissolve rubber resins of the Pliolite type, polymerized cashew shell oil, synthetic drying oils like the divinyl acetylene polymers, and the coumarone and indene resins. Coal-tar solvents are employed in the making of gilsonite wood stains, as dispersion media for aluminum stearate, as flatting agents, for the removal of water from carbon black prior to grinding, and as thinners and dispersion agents for aluminum paints. Toluene and xylene substitutes are usually petroleum products extracted from asphaltic crudes or made by the hydrogenation of cracked petroleum products.

The work of Hofmann and Reid[2] is of special interest to those who wish to apply brushing lacquers to surfaces already coated with varnishes or enamels.

These workers have made the following general conclusions based on lifting tests:[2]

"(a) The various single solvents (and diluents) may be arranged as below in order of increasing lifting tendency:

1. Petroleum hydrocarbons
2. Coal-tar hydrocarbons
3. Alcohols
4. Esters and glycol ethers

(b) Mixtures of two liquids in order of increasing lifting tendency:

1. Petroleum hydrocarbon + alcohol
2. Petroleum hydrocarbon + glycol ether
3. Coal-tar hydrocarbon + ester
4. Ester + alcohol
5. Coal-tar hydrocarbon + alcohol

(c) Typical three-component mixtures listed in order of increasing lifting tendency:

1. Petroleum + alcohol + glycol ether solvent
2. Petroleum + ester + glycol ether solvent
3. Petroleum + ester + alcohol
4. Coal-tar hydrocarbon + alcohol + glycol ether
5. Coal-tar hydrocarbon + alcohol + ester

(d) Other things being equal—that is, in homologous series—the lifting tendency increases with increasing boiling point."

TABLE 20A.—Lifting of Varnishes[2]*

Solvent	Varnish No.** 1	2	3	4	5	6	7	8	9	10	11	12
	Age, Days 16 99	16 99	16 99	16 99	16 99	16 99	16 99	16 99	16 99	16 99	16 99	16 99
⅔ Toluene ⅓ Butanol	x x	x x	x x	x x	x x	x x	x x	x x	x x	0 0	0 0	x x
⅔ Toluene ⅓ Butyl acetate	0 x	x x	x 0	x x	0 0	x x	0 0	x x	x x	0 0	0 0	x 0
⅔ Kemsolene ⅓ Butanol	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
⅔ Kemsolene ⅓ Butyl acetate	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	x 0	0 0	0 0	0 0
½ Butyl acetate ½ Butanol	0 0	x 0	x x	x x	x x	x x	x x	x x	x x	0 0	0 0	x x
½ Ethyl acetate ½ 95% Alcohol	0 0	0	0 x x	0 0	0 x	0 0	x 0	0 0	0 x	0 0	0 0	x x
⅔ Toluene ⅓ "Cellosolve"	0 x	x 0	x x	x x	x 0	x x	x 0	x 0	x x	0 0	0 0	x x
⅔ Toluene ⅓ C.S. acetate	0 x	x x	x x	x x	x x	x x	x x	x x	x x	0 0	0 0	x x
⅔ Denat. alcohol ⅓ "Cellosolve"	0 0	0 0	x x	0 0	x 0	0 0	x x	x 0	0 0	0 0	0 0	x x
⅔ Denat. alcohol ⅓ C.S. acetate	0 0	0 0	x x	0 0	x x	0 0	x x	x 0	0 x	0 0	0 0	x x
50% Toluene 20% Butanol 30% Butyl acetate	x 0	x x	x x	x x	x x	x x	x x	x x	x x	0 0	0 0	x x
50% Kemsolene-T 20% Denat. alcohol 30% "Cellosolve"	0 0	0 0	x x	0 0	x x	0 x	0 x	x 0	x x	0 0	0 0	x x
70% Toluene 15% Ethyl acetate 15% "Cellosolve"	0 x	x x	x x	x x	x x	x x	x x	x x	x x	0 0	0 0	x x
40% Kemsolene-T 20% Denat. alcohol 20% Ethyl acetate 20% Butyl "Cellosolve"	0 0	0 0	0 0	0 0	0 0	0 x	0 x	0 0	0 0	x 0	0 0	0 0	x x
70% Toluene 15% Ethyl acetate 15% C.S. acetate	0 0	x 0	0 0	x 0	0 0	x x	0 0	x x	x x	0 0	0 0	0 0

1. 10-gallon linseed oil—Kauri gum varnish
2. 10-gallon tung oil—Kauri gum varnish
3. 20-gallon linseed oil—Ester gum[a] varnish
4. 20-gallon tung oil—Ester gum varnish
5. 35-gallon linseed oil—Ester gum[a] varnish
6. 35-gallon tung oil—Ester gum[b] varnish
7. 60-gallon linseed oil—Ester gum[a] varnish
8. Same as (3), without driers
9. Same as (4), without driers
10. 20-gallon tung oil—zinc hardened rosin varnish
11. Long oil white enamel, zinc oxide pigment
12. Long oil enamel vehicle, without pigment

*These varnishes were made by mixing a heavy kettle-bodied linseed oil with an Ester gum solution and an appropriate quantity of lead and manganese linoleate driers.

[b]Contained a small amount of free rosin.

*X = Lifted. 0 = Did not lift.

**Varnishes used in Lifting Tests.

TABLE 20B.—Lifting of Varnishes.[2]*—(*Continued*)

	Rubbing Varnish				Floor Varnish				Spar Varnish				White Enamel			
	Age, Days															
Solvent	2	7	28	90	2	7	28	90	2	7	28	90	2	7	28	90
1 Toluene	x	0	0	–	x	0	0	–	x	x	0	–	0	0	0	0
2 Xylene	x	0	0	–	x	0	0	–	x	x	0	–	0	0	0	0
3 Turpentine	0	0	0	–	0	0	0	–	0	0	0	–	0	0	0	0
4 Kemsolene†	0	0	0	–	0	0	0	–	0	0	0	–	0	0	0	0
5 Kemsolene-T‡	0	0	0	–	0	0	0	–	0	0	0	–	0	0	0	0
6 95% Alcohol	x	0	0	–	0	0	0	–	x	0	0	–	0	0	0	0
7 Butanol	x	0	0	–	0	0	0	–	0	0	0	–	0	0	0	0
8 Ethyl acetate	x	0	0	0	0	0	0	0	x	0	x	x	0	0	0	0
9 Butyl acetate	x	x	0	0	x	0	0	0	x	0	x	x	0	0	0	0
10 Pent-acetate	x	0	0	0	0	0	0	0	x	x	x	0	0	0	0	0
11 Butyl propionate	x	0	0	0	x	0	0	0	x	0	x	0	0	0	0	0
12 "Cellosolve"	x	x	0	x	0	0	x	x	0	x	x	x	0	0	0	0
13 "Cellosolve" acetate	x	x	x	x	x	0	0	x	x	0	x	x	0	0	0	0
14 Butyl "Cellosolve"	x	x	x	x	x	x	x	x	x	x	x	x	0	0	0	0
15 1/3 Toluene, 2/3 95% Alcohol	x	x	0	x	x	0	x	x	x	x	x	x	0	0	0	0
16 2/3 Toluene, 1/3 95% Alcohol	x	x	0	x	x	x	x	x	x	x	x	x	0	0	0	0
17 1/3 Toluene, 2/3 Butanol	x	0	x	0	x	0	0	x	x	x	x	x	0	0	0	0
18 2/3 Toluene, 1/3 Butanol	x	x	0	x	x	x	x	0	x	x	x	x	x	0	0	0
19 1/3 Kemsolene, 2/3 Butanol	x	0	0	0	0	0	0	0	x	0	0	0	0	0	0	0
20 2/3 Kemsolene, 1/3 Butanol	x	0	x	0	0	0	0	0	0	0	0	0	0	0	0	0
21 1/2 Turpentine, 1/2 Butanol	x	0	x	x	x	0	0	0	x	0	x	0	0	0	0	0
22 1/2 Turpentine, 1/2 95% Alcohol	x	0	x	0	0	0	0	0	0	0	0	0	0	0	0	0
23 2/3 Xylene, 1/3 Butanol	x	x	0	0	x	x	0	x	x	x	x	x	x	0	0	0
24 1/2 Ethyl acetate, 1/2 95% Alcohol	x	0	0	0	0	0	0	0	0	0	x	0	0	0	0	0
25 1/2 Butyl acetate, 1/2 Butanol	x	x	0	0	x	x	0	0	x	x	x	x	0	0	0	0
26 1/3 Ethyl acetate, 2/3 Toluene	x	0	0	0	0	0	0	0	x	x	x	0	0	0	0	0
27 1/3 Butyl acetate, 2/3 Toluene	x	0	0	0	x	x	0	0	x	x	x	x	0	0	0	0
28 1/3 "Cellosolve", 2/3 Butanol	x	0	x	x	0	0	x	0	0	0	x	0	0	0	0	0
29 1/3 C.S. acetate, 2/3 Butanol	x	0	0	x	x	0	x	0	x	x	x	x	0	0	0	0
30 1/3 "Cellosolve", 2/3 Toluene	x	x	0	x	x	x	x	x	x	x	x	x	0	0	0	0
31 1/3 "Cellosolve", 2/3 Kemsolene	x	0	x	x	x	x	x	x	x	x	x	x	0	0	0	0
32 1/3 C.S. acetate, 2/3 Toluene	x	x	0	x	x	0	x	x	x	x	x	x	0	0	0	0

*X = Lifted. 0 = Did not lift

†Kemsolene is a Petroleum Distillate B.P. 130–160° C. (Approx.)

‡Kemsolene-T is a Petroleum Distillate B.P. 80–130° C. (Approx.)

TABLE 21.—Influence of Thinners on Durability[a]

Paint Designation	Ratio of Lead to Zinc	Comparison Group[c]	Thinner	Weight of Panel[b]	Range of Angle of Grain[c]	Side Painted[d]	Weight of Paint Applied[e]	Durability Based on Integrity	Order of Merit[f]	Moisture Fluctuation[g]	End Checks[h]
				Grams	*Degrees*		*Lb./100 sq. ft.*[i]	*Weeks*		*Grams*	*Inches (cm.)*
			Paints Applied to White Pine								
C1	60 : 30	1	Steam-distilled wood turpentine	341	2–3	B	5.47	21	3	220	1 (2.5)
			Mineral spirits (brand H)	350	0–2	B	5.35	21	1	248	0
			Mineral spirits (brand H)	355	2	B	5.35	21	2	243	0
		2	Gum turpentine	365	5–24	B	5.29	18	2	265	0
			Mineral spirits (brand W)	360	6–24	B	5.65	>21[j]	1	168	0
		3	Steam-distilled wood turpentine	344	16–50	B	5.47	>21	2	135	0
			Destructively distilled wood turpentine	334	19–46	B	5.35	>21	1	132	0
C2	60 : 30	4	Gum turpentine	379	3–17	B	5.29	21	3	183	0
			Gum turpentine	381	6–18	B	5.29	21	2	182	0
			Steam-distilled wood turpentine	374	14–21	B	5.59	>21	1	184	0
			Steam-distilled wood turpentine	382	8–14	B	5.59	21	2	180	4 (10.2)
		5	Destructively distilled wood turpentine	370	19	P	5.11	>21	1	131	0
			Mineral spirits (brand W)	362	16–20	P	5.17	>21	2	148	0
		6	Mineral spirits (brand H)	355	37–62	P	4.99	>21	2	125	0
			Mixture of gum turpentine and H	349	25–57	B	6.20	>21	1	122	0
		7	Destructively distilled wood turpentine	349	56–69	P	5.11	>21	1	124	0
			Mineral spirits (brand W)	341	37–66	B	5.17	>21	2	131	0
D2	75 : 25	8	Gum turpentine	330	4–9	B	6.25	>21	1	104	2 (5.1)
			Mineral spirits (brand W)	345	5–21	B	5.54	20	2	202	2 (5.1)
N	Lithopone-zinc	9	Gum turpentine	327	11–14	P	Not determined	>21	1	114	0
			Steam-distilled wood turpentine	322	2–14	P		>21	2	122	0
			Mineral spirits (brand W)	323	5–13	P		20	3	246	0
		10	Destructively distilled wood turpentine	397	6–26	B	Not determined	>21	1	42	0
			Mineral spirits (brand H)	404	0–18	B		20	2	169	0
		11	Steam-distilled wood turpentine	360	25–45	P	Not determined	>21	2	90	0
			Mineral spirits (brand W)	361	42–55	P		>21	3	92	5 (12.7)
			Mixture of gum turpentine and H	361	30–53	P		>21	1	101	0
C1		12	Mineral spirits (brand W)	366	20–21	P	5.65	>21	1	132	0
C2			Mineral spirits (brand W)	362	16–20	P	5.17	>21	2	148	0
C1	60 : 30	13	Destructively distilled wood turpentine	334	19–46	B	5.35	>21	2	132	0
C2			Destructively distilled wood turpentine	349	56–69	P	5.11	>21	1	124	0
C1		14	Mixture of gum turpentine and H	330	7–15	P	5.59	>21	2	132	0
C2			Mixture of gum turpentine and H	349	5–10	B	6.20	>21	1	220	2 (5.1)

Paints Applied to Yellow Pine

White Lead		15	Destructively distilled wood turpentine	543	50-82	B	7.50	21	3	228	0
			Steam-distilled wood turpentine	542	69-81	B	7.74	>21	2	139	0
			Gum turpentine	605	70-78	B	8.28	>21	1	85	0
			Oxidized turpentine	542	76-80	B	7.47	>21	2	99	0
			Mineral spirits (Midcontinent)	522	49-64	B	7.49	21	2	112	0
			Varnish and paint makers' naphtha	516	59-68	P	7.73	>21	1	99	0
			Mineral spirits (Pa.)	505	34-44	B	7 53	21	2	224	0
			Solvent naphtha	509	40-64	B	7.11	>21	3	165	0
			Mineral spirits (Calif)	506	30-45	B	7.40	>21	2	191	1 (2.5)
			Mineral spirits (Mexico)	501	46-51	B	7.00	>21	3	193	0
White lead		16	Destructively distilled wood turpentine	667	27-43	P	7.50	21	1	295	4 (10.2)
			Steam-distilled wood turpentine	671	30-67	P	7.74	21	1	290	5 (12.7
			Gum turpentine	631	27-52	P	8.28	21	1	345	4 (10.2)
			Oxidized turpentine	641	9-46	P	7.47	21	2	445	4 (10 2)
			Mineral spirits (Midcontinent)	640	14-43	P	7.49	21	5	526	13 (33)
			Varnish and paint makers' naphtha	641	18-37	P	7 73	21	4	528	19 (48)
			Mineral spirits (Pa.)	631	11-26	B	7 53	18	2	570	23 (58)
			Solvent naphtha	616	19-30	P	7.11	21	3	559	26 (66)
			Mineral spirits (Calif)	624	19-24	P	7.40	21	3	582	21 (53)
			Mineral spirits (Mexico)	601	34-37	P	7.00	21	2	550	18 (46)
Lead-zinc	45 : 40	17	Destructively distilled wood turpentine	564	67-69	B	5 25	20	1	276	0
			Steam-distilled wood turpentine	602	58-68	B	5.75	20	2	200	0
			Gum turpentine	605	65-78	B	5 09	20	4	228	0
			Oxidized turpentine	595	67-80	B	5 31	20	1	320	1 (2.5)
			Mineral spirits (Midcontinent)	609	80-85	B	4 91	18	3	280	16 (41)
			Varnish and paint makers' naphtha	588	76-78	P	4 54	18	3	282	15 (38)
			Mineral spirits (Pa.)	612	72-73	B	4 96	18	3	308	12 (31)
			Solvent naphtha	608	72-75	B	4.62	18	3	284	12 (31)
			Mineral spirits (Calif.)	625	62-74	P	4 74	18	3	238	1 (2 5)
			Mineral spirits (Mexico)	675	43-69	B	4 52	14	2	217	2 (5.1)
Lead-zinc	45 : 40	18	Destructively distilled wood turpentine	640	47-70	P	5.25	14	1	89	0
			Steam-distilled wood turpentine	618	34-36	B	5 75	20	3	120	0
			Gum turpentine	590	27-29	B	5.09	20	1	89	2 (5 1)
			Oxidized turpentine	580	50-69	P	5.31	20	1	99	0
			Mineral spirits (Midcontinent)	597	28-65	B	4.91	18	4	99	0
			Varnish and paint makers' naphtha	599	80-83	P	4 54	20	1	111	0
			Mineral spirits (Pa.)	591	64-69	P	4.96	20	2	79	0
			Solvent naphtha	621	79-84	P	4.62	>20	5	101	0
			Mineral spirits (Calif.)	618	69-88	B	4.74	20	1	88	3 (7.6)
			Mineral spirits (Mexico)	579	61-89	B	4.52	18	2	110	0

[a] Each comparison group consisted of panels cut from same long board.
[b] Determined when all panels were of approximately same moisture content.
[c] Angle at which annual rings reached painted surface of panel.
[d] Pitch (P) or bark (B) side.
[e] Average for each group of panels receiving same paint and hence not rigidly applicable to individual panel.
[f] Order of integrity at end of test, value 1 representing best integrity.
[g] Summation of ten fluctuations.
[h] Found to influence moisture-fluctuation values.
[i] One pound per 100 square feet equals 4.9 kg. per 10 square meters.
[j] Greater than 21 weeks; *i. e.*, still sound at end of test.

TABLE 22.—Effect of Different Thinners on the Durability of Paint[4]

Paint and Thinner	At Madison, Wis.				At Washington, D. C.				At Gainesville, Fla.			
		Durability				Durability				Durability		
	Wt. of pigment[a]	Integrity	Protection and integrity	Order of merit at end	Wt. of pigment[a]	Integrity	Protection and integrity	Order of merit at end	Wt. of pigment[a]	Integrity	Protection and integrity	Order of merit at end
	Lbs./100 sq. ft	*Months*			*Lbs./100 sq. ft.*	*Months*			*Lbs./100 sq. ft.*	*Months*		
Paste Paint:												
Turpentine, gum spirits	6.99	22	21	4	6 88	15	13	3	7 08	15	12	5
Turpentine, steam-distilled	7.05	27	23	2	7.57	18	13	2	7.09	15	6	5
Turpentine, destructively distilled	7.43	30	30	2	7 18	18	13	2	7.49	15	12	5
Turpentine, oxidized	7.29	30	24	1	7.54	24	18	1	8.20	35	18	1
Mineral spirits from Pennsylvania crude oil	7 17	24	23	3	6 92	15	13	5	8.37	23	12	3
Mineral spirits from Midcontinent crude oil	7.48	26	23	3	7.47	15	13	4	7 99	18	9	5
Mineral spirits from California crude oil	7 15	26	24	3	6 50	18	11	4	6.67	23	12	3
Mineral spirits from Mexican crude oil	8.08	30	27	1	8 05	18	11	3	8.08	23	12	2
Painters' naphtha from Midcontinent crude oil	7.18	28	26	2	8 14	22	13	3	8.38	23	12	2
Solvent naphtha from coal-tar	7.07	31	28	2	7.36	18	13	4	7.89	15	3	4
Prepared Paint:												
Turpentine, gum spirits	5 23	15	15	3	5.73	13	13	2	4 80	15	15	4
Turpentine, steam-distilled	4 61	14	14	4	5 53	13	13	2	4 99	15	15	2
Turpentine, destructively distilled	4 48	15	15	4	4 64	13	13	2	4.04	15	15	2
Turpentine, oxidized	5.05	16	16	1	5.22	13	13	2	5.17	15	15	1
Mineral spirits from Pennsylvania crude oil	5 02	16	16	3	5.74	13	13	1	4.81	15	15	4
Mineral spirits from Midcontinent crude oil	4.84	16	16	3	4.65	13	13	2	4.05	15	15	5
Mineral spirits from California crude oil	4 53	15	15	5	4 61	13	13	2	4 65	15	15	3
Mineral spirits from Mexican crude oil	4.57	15	15	6	4.73	13	13	1	4.45	15	15	3
Painter's naphtha from Midcontinent crude oil	5.15	16	16	2	5 05	13	13	1	5.12	15	15	3
Solvent naphtha from coal tar	5.60	16	16	2	5.11	13	13	1	5.13	15	15	3

TABLE 22.—Effect of Different Thinners on the Durability of Paint[a]—(*Continued*)

Paint and Thinner	At Fresno, Calif.			At Pittsburgh, Pa.				Weighted Average for All Stations [c]			
		Durability			Durability				Durability		
	Wt. of pigment[a]	Integrity	Protection and integrity	Order of merit at end	Wt. of pigment[a]	Integrity[b]	Protection and integrity[b]	Order of merit at end[b]	Wt. of pigment[a]	Integrity	Protection and integrity	Order of merit at end
	Lbs./100 sq ft.	*Months*			*Lbs./100 sq ft.*	*Months*			*Lbs./100 sq ft.*	*Months*		
Paste Paint:												
Turpentine, gum spirits	6 61	19	19	3	8 28	41	41	1	7.09	21.1	19 9	7
Turpentine, steam-distilled	6.80	19	19	3	7 74	41	41	1	7.23	22.8	18.9	5
Turpentine, destructively distilled	7 50	19	19	2	7 50	41	41	1	7 41	23 4	21.7	4
Turpentine, oxidized	7.78	22	22	1	7 47	41	41	1	7 68	29 6	23.5	1
Mineral spirits from Pennsylvania crude oil	7.02	19	3	4	7 53	41	41	1	7 40	23.2	16.8	7
Mineral spirits from Midcontinent crude oil	7.47	19	19	4	7.49	41	41	1	7 60	22.5	19.6	8
Mineral spirits from California crude oil	7.68	19	3	3	7.40	41	41	1	7 08	24.2	16.6	6
Mineral spirts from Mexican crude oil	7 14	19	3	2	7.00	41	41	1	7.73	25.2	17.2	2
Painters' naphtha from Midcontinent crude oil	7.00	19	19	3	7.73	41	41	1	7.69	25 6	20.7	3
Solvent naphtha from coal-tar	7.04	19	19	2	7.11	41	41	1	7.32	23.6	19.4	5
Prepared Paint:												
Turpentine, gum spirits	4.79	11	11	2	5.09	29	29	2	5 13	15.6	15 6	6
Turpentine, steam-distilled	5.12	17	17	2	5.75	26	26	3	5 16	16.3	16 3	5
Turpentine, destructively distilled	4 72	6	6	2	5.25	35	35	1	4 58	15 4	15.4	3
Turpentine, oxidized	4 83	17	17	2	5.31	29	29	2	5 10	17.2	17 2	1
Mineral spirits from Pennsylvania crude oil	5.06	17	17	2	4 96	26	26	3	5.12	16.7	16.7	5
Mineral spirits from Midcontinent crude oil	4.61	17	17	2	4.91	26	26	4	4.58	16.7	16 7	9
Mineral spirts from California crude oil	4.97	19	19	1	4.74	26	26	5	4.82	16 9	16.9	8
Mineral spirits from Mexican crude oil	4.73	17	17	2	4.52	28	28	2	4.60	16.8	16 8	7
Painters' naphtha from Midcontinent crude oil	5.15	19	19	2	4.54	26	26	2	5.03	17.1	17.1	2
Solvent naphtha from coal-tar	4.99	17	17	2	4.62	26	26	5	5 12	16.7	16 7	4

[a] One pound per 100 square feet equals 4.9 kg. per 10 sq. m

[b] All panels with paste paint at Pittsburgh were still rated "good" in integrity and protection when last inspected, which was 35 months after exposure. The durability was therefore arbitrarily set at 41 months and they were all given the merit rating 1.

[c] In computing the weighted averages the Pittsburgh station was given a weight of two-thirds because the sets of panels were made from two boards instead of three.

TABLE 23.—Indication of the Solubility* of the More Usual Resins[26]

Rosin, Thus, Elemi, Mastic — soluble in: Esters (more readily soluble in esters than in alcohol); Alcohols; Hydrocarbons; Ketones

Dammar, Ester gum, Cumar — soluble in: Esters; Hydrocarbons; Alcohols + hydrocarbons or esters; partly soluble in: Alcohols; Ketones

Shellac, Sandarac — soluble in: Alcohols; Alcohols + esters; Ketones (solubility varies with grade of resin); insoluble in: Esters; Hydrocarbons

Kauri, Pontianac, Soft manilas — soluble in: Alcohols; Alcohols + esters (more soluble than in alcohol alone); Alcohols + hydrocarbons; partly soluble in Ketones; insoluble in: Esters; Hydrocarbons

Hard manilas, Congo, Benguela, Angola, Madagascar, Zanzibar — partly soluble in: Alcohols; Alcohols + esters (esters must be in small amount); insoluble in: Esters; Hydrocarbons; Ketones

*The word "soluble" in this classification means that 95 per cent by weight or more of the resin was soluble in the solvent. Some resins—for example, shellac—have a waxy residue if not "refined." This residue is not considered as part of the resin in this solubility classification.

The higher-boiling esters and the glycol ethers have found a new application in the making of non-aqueous wood stains. The light-colored finishes of the vinyl derivative type are soluble in ketones and esters.

Trease and Pingey [5] are of the opinion that carbon tetrachloride has no advantage over other solvents in the preparation of oleo-resins for pharmaceutical use other than its non-inflammability, and believe it to be of little use in the extraction of alkaloids. It has its usefulness, however, as a reagent in testing for phenols where it will yield color reactions with ortho- and meta-substituted phenols but will not do so with the para compound. For this particular purpose it has, as a reagent, particular advantage over chloroform or iodoform. Hessler [6] has found that chlorinated paraffin wax, called chlorcosane, is a good solvent for the antiseptic dichloramine-T (*p*-toluene sulfodichloramide, $C_6H_4CH_3 \cdot SO_2NCl_2$). Durand [7] reveals that tannins of chestnut wood, acorns and grapevine twigs, which are water-soluble, are also soluble in alcohol and acetone. The researches of Schaffer [8] indicate that methyl alcohol is a better solvent for alkaloids than is ethyl alcohol, when it is used either alone or admixed with benzene, toluene, chloroform, fusel oil, ether, acetone and so forth. Methyl alcohol, or a mixture of methyl alcohol and benzene, or chloroform, are excellent solvents for the morphine alkaloids.

In the following tables Martin and Salmon [9] record the fungicidal properties of spray-fluids containing synthetic solvents.

TABLE 24.—Fungicidal and Other Properties[9]

"In the tables following, in the column recording the action of the spray-fluid, F. designates complete fungicidal action, *i.e.* the depth of all powdery patches of mildew; S.F. super-fungicidal, *i.e.* fungicidal not only for the patches of mildew in the 'powdery' conidial stage, but also for the younger, pre-powdery 'hump' stage, which has been shown to survive a concentration of certain polysulfide washes which is lethal to the 'powdery' stage; N.Q.F. a not quite fungicidal action—the mildew although greatly checked, survives and produces a small number of conidiophores with conidia; N.F. non-fungicidal, with no observable checking action on the mildew patches, which reform densely clustered conidiophores within a few days after the application of the spray-fluid."

Material	Concentrate tested %	Adjuvant	Physical State	Emulsification	Wetting Properties	Fungicidal Properties	Action on leaf
Benzene	1					N.Q.F.	Slight injury on 1 leaf (of 3 sprayed)
"	1.5					F. for older, N.Q.F. for younger, patches	No injury
"	2.0					N.F.	"
"	2.0					F.†	More or less serious 'scorching,' often at margin
Cyclohexane	6.0					N.Q.F. to N.F.	No injury
"	8.0					F.‡	More or less serious 'scorching' on all the 6 leaves sprayed
"	7.0					F., with blackening of patches	Distinct injury, usually at edge of leaf
Methyl cyclohexane	6.0					N. F.	No injury
"	7.0					F.	Distinct injury, usually at edge of leaf
"	8.0					F.	Distinct, though slight, injury
Dekalin	3 0					N.F.	Slight injury at tip of 1 of the 8 leaves sprayed
"	3.5	}				N.Q.F.	More or less serious 'scorching,' often at edge of leaf
"	4.0	}					
Cymene	2	0.25% Agral I		Fair	Oily	F.	More or less serious injury
"	1	"		"	"		" "
"	0.5	"		"	"	F., or rarely N.Q.F.	
"	0.25	"		"	"	N.Q.F.	Occasionally slight injury to tip of leaf
"	0.25	0.13% Na oleate		"	Normal	N.F., with practically no observable actions	No injury
"	0.5	"		"	"		
"	0.5	0.25% Agral I		"	Oily	F. or N.Q.F.*	"
"	0.5	0.13% Na oleate		"	Normal	N.F.*	"
Carvene	1.0	0.25% Agral I		"	Oily	F.	Distinct injury to edge of leaf
"	0.5	"		"	"	N.Q.F.	Occasional slight injury to tip of leaf
"	1.0	0.13% Na oleate		"	Normal	N.F.	No injury
Phellandrene	1.0	0.25% Agral I		"	Oily	F.	Slight or severe injury
"	0.5	"		"	"	N.Q.F.	Some amount of injury
Dipentene	2.0	"		"	"	F.	More or less serious injury
"	1 0	"		"	"	F., or occasionally just breaking down	" "
"	0.5	"		"	"	F.	Slight injury to edges of 4 of the 5 leaves sprayed
"	0.25	"		"	"	N.F., all patches powdery again by seventh day	No injury

†By the tenth day some conidiophores had developed from the 'hump-stage,' *i.e.* the younger, pre-powdery stage of the mildew which has been shown to survive a concentration of certain polysulfide washes which is lethal for the 'powdery' stage.

‡By the second or fourth day all the patches could be seen to have been killed, being more or less blackened and 'picked out.'

*Four leaves were sprayed and the corresponding leaves at the same nodes with 0.5 per cent cymene and 0.13 per cent sodium oleate.

TABLE 24.—Fungicidal and Other Properties[9]—(*Continued*)

Material	Concentrate tested %	Adjuvant	Physical State	Emulsification	Wetting Properties	Fungicidal Properties	Action on leaf
Pinene	1.0	"		"	"	F., or rarely N.Q.F.	Serious injury on 6 of the 7 leaves sprayed
Turpentine	2 0	"		Stable	Normal	F.	More or less serious injury to edge of leaf
"	1 0	"		"	"	N.Q.F.	Slight or serious injury to edge of leaf
Pine oil	2.0	"		"	"	F.	Serious injury, usually at edge of leaf
"	1.0	"		"	"	F.	Slight or serious injury at edge of leaf
"	0.5	"		"	"	N.F., with slight checking action at first	No injury
Geraniol	1.0	"		"	"		Toxic to leaf
"	0.25	"			"	N.F.	No injury
"	0.4	"			"	F., or very rarely N Q F.†	Slight injury at tip or edge of 3 of the 6 leaves sprayed
Eucalyptus oil	1 0	0.25% Agral I		"	"	N.F., with some checking action at first	No injury
"	2.0	"		"	"	F., or occasionally N Q.F.	Very slight 'scorching' injury on 4 of the 6 leaves sprayed
"Lypticide"	1 25	None		Good	"	N.F., no observable action	Possible slight injury
Fenchone	2 0	0 25% Agral I		Stable	"	F.	More or less serious injury
"	1.0	"		"	"	F., or occasionally N.Q.F.	Slight injury to tips of 3 of the 6 leaves sprayed
"	1.5	0.13% Na oleate		"	"	N.F., with some checking action at first	Occasional injury to tip of leaf
Phenol	1	0 5% A				N.F.	No injury
"	2	0.25% A				F., or N.Q F.	Occasional slight injury to tip of leaf
"	1 5	"				N.Q.F.	No injury
"	2.5	"				"	Slight or serious injury to edge of leaf
"	2.0	10% E + 0.25% A				N F.	Very slight injury to edge or tip of leaf
"	2.0	"				"	No injury | The opposite leaves at the same
"	2.0	0.25% A				"	No injury / nodes were used
Cresol	1.0	"				F., or occasionally N Q.F.	No injury
"	1.5	"				N.Q.F.	More or less serious injury to tip
"	0.5	0.5% S				"	No injury
"	1.5	"				N.F.	More or less serious injury
Thymol	0 1	0.25% A				N.F., some checking action at first	No injury
"	1.0	10% E + 0 25% A				—	Lethal, the leaves were killed, within 5 minutes
"	0.5	5% E + 0.25% A				—	Lethal, the leaves were quickly killed
"	0 25	2.5% E + 0.25% A				F.	Some injury*
"	0.20	2% E + 0.25% A					Serious injury‡
"	0.15	1.5% E + 0.25% A				N.F.	No injury
"	0.1	1% E + 0.25% A				N.F., some checking action at first	"

†A marked 'cleansing' action was shown, most of the mildew patches being removed.

*The injury caused was in the form of numerous minute blackish spots (scattered over the lamina) which extended through to the lower surface.

‡In the form of numerous minute 'burnt' spots scattered over the lamina, often accompanied by injury to the edge of the leaf.

Cyclohexanol	2.0	0.5% A	N.F.	No injury
"	4.0	"	"	"
"	8.0	0.25% A	F., or just below fungicidal strength	"
"	10.0	"	F., possibly S.F.‡	"
"	9.0	"	N.F.	Slight 'scorching' injury at edge or tip of leaf
"	8.0	"	F.	More or less serious injury at tip or edge of leaf
Methyl cyclohexanol	6.0	"	N.Q.F.	No injury
"	8.0	"	F.	Serious injury, chiefly at edge
"	7.0	"	—	Lethal injury

A = Agral I. E = Ethyl alcohol. S = Soft soap (B.P.).

Alcohol				
Methyl	60	None	Usually N.F., occasionally N.Q.F.	No injury
"	80	"	N.Q.F.	"
"	90	"	"	"
"	90	"	"	"
"	100	"	N.F.	Slight 'scorching' injury to tips and edges of 2 of the 4 leaves sprayed
Ethyl	60	"	N.F.	No injury
"	80	"	"	"
"	96	"	N.F.*	Serious injury*
Propyl	50	0.25% Agral I	N.F.	No injury
"	70	0.15% Agral I	N.F., with slight checking action at first	Severe 'scorching' of tips of most leaves
Iso-propyl (*a*)	60	0.2% Agral I	N.F.	Occasional slight injury to tip of leaf
"	80	None	"	No injury
"	90	"	"	Serious injury to tip and edge of leaf
"	50	0.25% Agral I	"	No injury
Iso-propyl (*b*)	50	"	"	"
Butyl (primary)	50	"	F.	Severe 'scorching' injury to edge and tip of leaf
"	20	"	N.F., with slight checking action at first	No injury
"	40	"	N.Q.F. to N.F.	Marked injury to edge and tip of leaf
Butyl (secondary)	50	"	N.Q.F.	No injury
"	70	"	N.F. ultimately, marked checking action	Slight injury to edge and tip of leaf
Iso-butyl	20	"	N.F.	No injury
"	40	"	F., or nearly so	Slight injury to edge of leaf
"	30	0.25% Agral I	N.F. ultimately, with checking action at first	No injury
Butyl (tertiary)	50	"	N.F.	"
"	60	0.2% Agral I	N.F., with some checking action	Occasional slight injury to tip of leaf
Amyl	16	0.25% Agral I	F., or occasionally N.Q.F.	More or less serious injury in form of pale brown 'burnt' areas
Diacetone	10	"	N.F.	No injury
"	40	"	N.F., with checking action at first	Slight injury, usually at edge of leaf

‡The mycelial patches remained white.

*Serious injury was caused here and there to the leaf tissue in the form of 'burnt' brown areas, and in the browning and curling of the leaf edge while the mildew patches were uninjured and reformed conidiophores.

TABLE 24.—Fungicidal and Other Properties[9]—(*Continued*)

	Concentrate tested %	Adjuvant	Physical State	Emulsification	Wetting Properties	Fungicidal Properties	Action on leaf
Ethylene glycol	2	"				N.F.	No injury
"	8	"				—	Serious injury, extending inwards from the edge
"	6	"				F., or very nearly so	No injury
"	6	"				F.	More or less serious injury to tip and edge of leaf
"	4	"				N.F.	Injury in form of blackish spots scattered over lamina
Trimethylene glycol	2	"				"	No injury
"	6	"				Apparently F., or nearly so	All the 6 leaves seriously injured at edge or tip
"	4	"				F., or N.Q.F.	Serious injury, chiefly at edge
Ester							
Amyl acetate	1	0.25% A	Stable			N.F.	Slight injury to tip of 1 of the 6 leaves sprayed
"	4	"	"			F., or rarely just below fungicidal strength	Definite injury to edge
Ethylene glycol diacetate	1	"	In solution			N.F.	No injury
"	4	"	"			"	"
"	6	"	"			"	Severe injury
Cyclohexanyl acetate	1	"	Stable			Apparently just below fungicidal strength	More or less serious injury, usually at tip
Methyl cyclohexanyl acetate	1	"	"			F.	Slight injury to tip or edge
Diacetin	2	"	In solution			N.F.	Serious, or even fatal, injury
"	1	"	"			"	More or less serious injury in form of 'burnt' spots
Triacetin	1	"	"			"	Serious injury
Ethyl butyrate	1	"	Stable			"	No injury
"	4	"	"			F., or just below fungicidal strength	"
Isobutyl butyrate	0.5	"	Unstable			N.F.	"
"	1.5	"	"			Below fungicidal strength	Occasional slight 'scorching' injury
"	2.0	"	"			F.(S.F.)	Slight injury to edge and tip
Ethyl oleate	1	"	"			F.*	Serious injury to edge and tip

*Very pronounced action; the mycelium of the patches was disintegrated and more or less completely removed, leaving discolored (blackish-brown) areas of leaf cells where the patches had been.

Ethyl oleate	0.5	0.25% A	Unstable	F.†	More or less serious injury to edge and tip
"	0.25	"	"	N.Q.F.	No injury
"	0.25	0.15% O	Stable	Below fungicidal strength	"
"	0.5	"	"	N.F., with distinct checking action at first	"
"	0.4	0.25% A	Unstable	F. or S.F.	"
"	0.4	0.13% O	Stable	N.Q.F.	"
Methyl cyclohexanyl stearate	0.5	0.25% A	Unstable	F., possibly S.F.‡	"
Dimethyl cyclohexanyl oxalate	1	0.25% A	Unstable	—	Lethal
"	0.5	"	"	F.*	Serious injury, in form of brown areas of dead leaf cells
"	0.25	"	"	F., or perhaps occasionally just below fungicidal strength	Slight injury, in form of brown areas of dead leaf cells
"	0.25	0.13% O	Stable?	Just below fungicidal strength	Slight or severe injury, in form of brown areas of dead leaf cells
"	0.25	0.25% A	Unstable	From fungicidal to well below fungicidal strength	No injury
"	0.25	0.13% O	Stable?	From fungicidal to well below fungicidal strength	Serious 'scorching' at edge of 1 of the 7 leaves sprayed
Ethyl lactate	4	0.25% A	In solution	N.F.	No injury
Amyl lactate	1	"	Stable	"	"
"	4	"	"	F.	Injury in form of dead areas of leaf cells of varying size
Ethyl tartrate	2	"	In solution	N.F.	Lethal
Amyl tartrate	1	"	Unstable	—	No injury
Ethyl benzoate	0.5	"	Stable	Below fungicidal strength	Injury in form of minute brown 'scorched' areas
"	1	"	"	F.(S.F.)	Lethal
Diethyl phthalate	1	"	"	—	Serious 'scorching' injury
"	0.25	"	"	Apparently F.	No injury
"	0.125	"	"	Below fungicidal strength	Serious, or fatal, injury
Dibutyl phthalate	1	"	Unstable	—	Lethal
"	0.5	"	"	—	

A = Agral I. O = Sodium oleate. Stable = Stable emulsion wetting normally. Unstable = Unstable emulsion giving 'oily' wetting.'

†The dead mycelium remained chalk-white, with the underlying leaf cells darkened.

‡Rarely, conidiophores massed in the furrows of the leaf were not wetted and killed.

*The mycelial patches were completely removed, leaving small brown insunken patches of dead leaf cells where they had been.

Gersdorff and Davidson [10] have tabulated the amount of material extracted from pyrethrum with various solvents and have also recorded (see Table 25) the effect of various solvents on cabbages infested with *Myzus persicae* Sulz.

TABLE 25.—Results of Greenhouse Tests with Various Solvents on Cabbages Infested with *Myzus persicae* Sulz[10]

Solvent	Concn. By Volume %	Aphids Used *No.*	Aphids *No.*	Dead %	Injury to Cabbage
		WATER AS DILUENT			
Methyl alcohol	100	179	60	34	Moderate
	10	150	0	0	None
Ethyl alcohol	100	351	57	16	None
Isopropyl alcohol	100	273	256	94	Severe
	10	183	13	7	None
n-Butyl alcohol	100	153	153	100	Severe
	10	159	81	51	None
sec-Butyl alcohol	100	168	166	99	Moderate
	10	81	62	77	None
tert-Butyl alcohol	100	134	127	95	Moderate
	10	150	10	7	None
		95 PER CENT ETHYL ALCOHOL AS DILUENT			
Benzene	10	228	171	75	None
	5	111	64	58	None
Xylene	10	136	136	100	Very severe
	5	124	108	87	Moderate
Carbon tetrachloride	10	190	157	83	Slight
	5	98	49	50	Slight
Chloroform	10	216	52	24	None
	5	112	41	37	None
Ethylene dichloride	10	112	85	76	None
	5	96	52	54	None
Amylene dichloride	10	136	104	76	Severe
	5	115	111	97	Severe
Tetrachloroethylene	10	268	156	93	Severe
	5	114	70	61	None
Diethyl carbonate	10	147	64	44	Moderate
	5	114	85	75	Slight

Pickett,[15] of the Hercules Powder Company, has tabulated and plotted the solubility in a number of solvents of candelilla wax, carnauba wax, montan wax and beeswax. Poole [18] has tabulated data concerning the relative solubilities of wax and oil in several organic solvents. This work has been conducted with the object of encouraging the commercial use of extraction processes for the separation of oils and waxes.

Fitzpatrick [13] tells us that turpentine was the earliest rubber solvent. Other such solvents which followed this early one are carbon disulfide, coal-tar solvents, petroleum solvents, halogenated hydrocarbons and so forth. The ideal rubber solvent for use in cements, varnishes, and lacquers should be chemically stable and non-reactive toward rubber, oxygen, moisture, sulfur chloride and so forth. It should be non-inflammable, must not be too volatile or resist vaporization, and its odor should be both pleasant and non-toxic. Twiss [14] lists the following solvents

which are used in the rubber industry: carbon disulfide, carbon tetrachloride, chloroform, dichlorethylene, cyclohexane, *n*-decane, Dekalin, ethyl ether, ethylene dichloride, *n*-hexane, *n*-heptane, Hexalin, methyl Hexalin, *n*-nonane, *n*-octane, pentachlorethane, *n*-pentane, Tetralin, tetrachlorethane, toluene, trichlorethylene and *m*-xylene. He also classifies their swelling power, which runs parallel to their solvent power, as follows: trichlorethylene, >tetrachlorethane, >pentachlorethane, >carbon tetrachloride, >chloroform, >carbon disulfide, >benzene, >toluene, >xylene, >shale naphtha, >petroleum naphtha, >kerosene, >ethyl ether. The most widely used solvents are the petroleum hydrocarbons comprising those fractions which range from *n*-pentane to *n*-decane. Petroleum naphtha is extensively used when admixed with sulfur chloride in the cold vulcanization of rubber. Benzene, toluene, halogenated hydrocarbons and others are less frequently used because they are either too volatile, or too toxic, or are insufficiently volatile. Some, however, possess excellent solvency. For example, Tetralin is not only a solvent for rubber but will also dissolve resins, waxes and cellulose derivatives, and is miscible with most lacquer solvents and diluents.

Cornish, Archibald, Murphy and Evans [12] have determined the fractional distribution of vitamins in pairs of immiscible liquids.

The petroleum industry, which has for years been a source of supply for solvents to other industries, now turns to the use of selective solvents in order to improve its own products. It is endeavoring, with these selective solvents, to separate the more valuable constituents from a complex mixture in as nearly a pure state as possible. Lazar Edeleanu has the distinction of being the first to use the principle of selective solvents. He treated kerosene with liquid sulfur dioxide and obtained a better burning product. In consequence, other solvents were soon proposed as selective solvents for different petroleum fractions. Ferris [11] tells us that a selective solvent should be non-reactive with the oil, capable of extracting the naphthenic from the paraffinic constituents when used in reasonable amounts, and that at the same time it should be completely separable. He believes there are few liquids which can be compared with nitrobenzene for selective action. These are phenol, cresylic acid, furfural, dichlorethyl ether and a mixture of sulfur dioxide and benzene. He contends, however, that in stability and cost they cannot be classed with nitrobenzene.

Hill [16] believes that, of the host of proposed solvent combinations, liquid propane, acetone-benzene, and trichlorethylene are in a class by themselves. Gohre [17] contributes levulinic acid as an excellent means for separating aromatic from aliphatic substances.

Poole [18] gives us the following solvents as those used in fat and oil extraction: ether, carbon disulfide, acetone, methyl alcohol, benzene, petroleum spirits, coal-tar solvents and halogenated hydrocarbons. The petroleum and coal-tar solvents are used most widely for this purpose. In the opinion of Sieves and McIntyre,[19] since the action of ether, benzene, trichlorethylene and gasoline are all similar, the selection of a vegetable

TABLE 26.—Distribution Ratios of Sterols[12]

Solvents	C. S. T. °C.	Ergosterol: t °C	Ergosterol: Nonpolar layer Grams/liter	Ergosterol: Polar layer Grams/liter	Ergosterol: Ratio	Cholesterol: t °C.	Cholesterol: Nonpolar layer Grams/liter	Cholesterol: Polar layer Grams/liter	Cholesterol: Ratio	Sitosterol: t °C.	Sitosterol: Nonpolar layer Grams/liter	Sitosterol: Polar layer Grams/liter	Sitosterol: Ratio
CS_2, CH_3OH	36.2	0	9.74	7 16	1.36	0	64 0	38.9	1.64	0	69.8	31.6	2.20
		−17	7.82	4.96	1.58	−17	35 4	16.2	2.18	−17	32.9	12.5	2.64
n-C_6H_{12}, CH_3OH	13.2	0			0 76	0	2 61	2.98	0 87	0	2.39	2.60	0.92
		−18	1.39	1 80	0 77	−15	2 83	3.06	0.92	−15	2.76	2.71	1.02
n-C_6H_{14}, CH_3OH	30.1	0			0.95	0	2 16	1.93	1.12	0	6.31	5.06	1.25
		−18	1.54	1.54	1.00	−15	3.37	2.58	1.31	−15	7.10	4 56	1.56
n-C_7H_{16}, CH_3OH	51.5	1	0 89	0 79	1.13	1	1 12	0.80	1.40	1	1.17	0.74	1.58
		−16.5	0.96	0.74	1 29	−16.5	1.27	0.66	1 91	−16.5	1.19	0.58	2.04
Iso-C_8H_{18},[a] CH_3OH	42.5	−19	0.87	0.83	1 05	−19	1.48	1.16	1.27	−19	1.32	0.87	1.52
n-C_7H_{16}, CH_3CN	84 0	25				25 0	1 24	0.17	7.2	25 0	1.35	0.17	8.1
		0	0.44	0.10	4 4	0	1 97	0 19	10.2	0	1.97	0 19	10.2
		−16.5	0.45	0.09	4 9	−15 5	2.04	0 18	11.5	−15 5	1.61	0.17	9.6
Iso-C_8H_{18},[a] CH_3CN	81.0	25.0	0.14	0.06	2 4	25 0	1.10	0.21	5.3	25.0	0.96	0 16	6 0
		0	0.35	0.10	3 5	0	1.96	0.26	7.6	0	1.92	0.24	7.9
		−16.5	0.28	0.07	4.0	−15.5	1.93	0.23	8 4	−15.5	1.91	0.20	9.2
n-C_7H_{16}, C_2H_4ClOH	118.0	0	0.42	0.85	0.49	0	0 99	1.14	0.88	0			
		−18.5	0.27	0.85	0 32	−18.5	0 96	1.29	0.74	−19	0.97	0.94	1.03
Iso-C_8H_{18},[a] C_2H_4ClOH	119.5	0	0.30	0.79	0.39	0	0 77	1.33	0 58	0			
		−18 5	0.15	0.72	0.21	−18.5	0.54	1.49	0.36	−19	0.82	1.26	0.65
n-C_7H_{16}, $CH_3OC_2H_4OH$	47.5	0	0 57	0.97	0.59	0	0.84	1 07	0 78	0	1.01	1.09	0.93
		−18.5	0.47	0.95	0 50	−18.5	0 92	1.25	0.74	−18.5	1.04	1.16	0.90
Iso-C_8H_{18},[a] $CH_3OC_2H_4OH$	45.5	0	0 45	1 10	0 41	0	0 75	1.34	0.56	0	0.90	1 21	0.74
		−18.5	0.37	1.13	0 33	−18 5	0.74	1.26	0.59	−18.5	0.85	1.15	0.73
Iso-C_8H_{18},[a] $C_2H_4(NH_2)_2$	112.0	35.0	0.48	0 83	0 57	35.0	0.61	0 59	1.05	35.0	0.71	0 59	1.20
		35.0	1.07	1.64	0.65	35.0	1.71	1 60	1.07	35.0	1.82	1.44	1.27
Iso-$(C_3H_7)_2O$, $C_2H_4(NH_2)_2$	36.0	8.5	2.1	2 9	0.7[b]	8 5	2 5	0 8	3.0[b]	8 5	1.7	0.5	3.5[b]
n-C_7H_{16}, $C_2H_4(OH)_2$										−18	0.70	0.056	12.5
Iso-C_8H_{18},[a] $C_2H_4(OH)_2$		−18.0	0.064	0 056	1.14								

[a] Iso-C_8H_{18} is 2,2,4-trimethylpentane.

[b] These values are approximate

oil solvent should be based entirely upon cost. Bassel [20] tells us that purified petroleum benzine is, beyond doubt, the best solvent for the commercial extraction of oils and fats. Although it is inflammable and not as safe as the halogenated hydrocarbons, it does not possess their corrosive and toxic properties. In the extraction of flaxseed Täufel and Stondige [21] state that ether and benzine yield light-colored extracts; chloroform, acetone and benzene give yellow to brown extracts; and trichlorethylene gives dark-colored extracts. Since acetone has a specific solvent action for phosphatides it yields extracts high in lecithen.

A mixture of soap and an organic solvent has the property of quickly loosening dirt, oil, fats, greases and waxes from fabric and, at the same time, of dissolving or suspending these substances in the soap-solvent-water mixture. Many of these mixtures have the added properties of wetting and penetration and are, therefore, used in the textile industry.

The following solvents, such as amyl alcohol, phenols, hydrogenated phenols and naphthalenes, pine oil, red oil, high aliphatic acid and their sulfonated products, xylene, triethanolamine and so forth, are used in oil-solvent, soap-solvent, and oil-soap-solvent mixtures in textile processing. Some of these processes comprise bleaching, lubricating, wetting-out, scouring and dyeing, keir boiling, starching, degreasing, mercerizing and finishing. In many of these processes the solvent not only reduces the time of operation but aids in penetration and dispersion.

Freedland [22] records petroleum ether as the best solvent for degreasing wool owing to its comparative cheapness. With modern means of equipment, it is quite safe to handle. Solvent naphtha is used considerably as a solvent for fats and oils, while benzene, on the other hand, is used in the extraction of cotton waxes. Hydrogenated coal-tar solvents, phenols, naphthalenes, and ketones and their sulfonated derivatives are solvents for oils, fats and waxes. These solvents, when they are mixed with soluble oils and soaps, are used as detergents. Benzine soaps dissolved in amyl alcohol, ether, chloroform, carbon tetrachloride and benzine are good fat-solvents and are extensively used in the cleaning industry.

The sartorial cleanliness of modern civilization makes bids for new and better solvents for dry-cleaning. In cleaning dyed garments all dirt, discoloration and stains must be removed, but the dye must not be altered or removed. An ideal dry-cleaning solvent should have the following attributes: it should not affect the garment or the dye; it should be chemically inert, stable, odorless, non-toxic and immiscible with water; its distillation range should be close; it should be volatile but not too volatile; and it should have a high flash-point or be non-inflammable. A warm solution of soap is one of the best of cleaning agents, but its shortcomings of removing dye and shrinking or felting fabric militate against its use. Benzine, benzene, and solvent naphtha have been used in dry-cleaning but are dangerously inflammable. Further, benzine is toxic and affects women more readily than men, producing headaches, giddiness, vomiting and a state of intoxication. Benzene, like benzine, is highly

Industry							
Automotive and Aircraft	Chemical Process	Food Industries	Pharmaceutical and Medicinal	Plastics and Rubber	Surface Coatings	Soaps, Cosmetics	Textile and Leather
			ALCOHOLS				
Anti-freeze, lacquer solvents	Preparation of esters, ethers, acids, aldehydes, solvents, extractants	Extracts, flavors	Preparation of medicinals, tinctures, extracts, manufacture of hypnotics	Formaldehyde manufacture—process solvents, wetting nitrocellulose	Solvents for stains, lacquers, shellac, varnishes, resins	Soap solvents, perfumes, toiletries, extraction of perfumes	Solvent in printing, manufacture of rayon, dyeing
			GLYCOLS				
High-temperature coolants, safety glass, brake fluids	Manufacture of explosives		Vehicles, extractants	Manufacture of resins and plasticizing	Stains, solvent for gums, plasticizers	Perfume solvents, coupling agents, mutual solvents	Dye solvents, printing pastes, conditioners
			ALCOHOL-ETHERS				
Safety glass	Synthesis	Package sealing	Vehicles, extractants	Process solvents	Solvents in lacquers, varnishes, stains	Cleaning compounds, emollients, couplers	Dye solvents
			ESTERS				
Lacquer solvents and plasticizers	Ethylation, dye synthesis	Flavor synthesis, package coating solvents	Manufacture of anti-pyretics, analgesics	Manufacture of film, rayon, cellulose derivatives	Lacquers, varnishes, dopes, inks	Manufacture of perfumes, fixatives	Lacquer solvents, acetic acid concentration
			ACIDS AND ANHYDRIDES				
Cellulose esters for safety glass, dopes	Synthesis	Synthesis of flavors	Manufacture of aspirin and drugs	Cellulose acetate, safety film	Cellulose ester lacquers	Essential oil synthesis	Synthesis dyes and rayon

			ETHERS AND OXIDES				
Manufacture of lube oils	Extractants, solvents, synthesis	Fumigants	Special ointments	Nitrate and acetate cotton solvents	Varnish removers, lacquer solvents	Special detergents, essential oil manufacture	Spotting, scouring, dye solvents
			ALDEHYDES				
	Synthesis acids, alcohols, nitriles	Flavor synthesis	Synthesis	Synthetic resins and rubber accelerators	Resin synthesis	Preparation of essential oils	Synthesis dyes and tanning compounds
			KETONES				
Dewaxing oils, dope solvents	Synthesis	Package coating solvents	Extraction of drugs and capsule cleaning	Artificial leather, film, pyroxylin manufacture	Lacquers, dopes, paint removers	Essential oil synthesis	Manufacture of rayon
			CHLORINATED COMPOUNDS				
Dewaxing oils, metal degreasing	Extraction of fats, oils, waxes, drugs	Fumigation, refrigeration	Vitamin concentration, extraction drugs	Solvents, manufacture of synthetic resins	Lacquer diluents, rubber cements	Cleaning and scouring compounds	Spotting, degumming
			AMINES				
Corrosion inhibitors, cutting oils	Synthesis	Waxing paper for wrapping	Synthesis anesthetics, analgesics	Accelerators, anti-oxidants	Softening, moistening, plasticizing	Manufacture of soaps for emulsion, detergents	Scouring, dyeing, emulsifying

FIG. 16.—The Use of Solvents in Industry[24]

volatile and is by far more toxic. White spirits is a heavier fraction than benzine and is less of a fire hazard. Solvent naphtha is related to benzene in the same manner that white spirits is to benzine. The halogenated non-inflammable hydrocarbons are more widely used in Europe than in America. According to Brown[23] carbon tetrachloride approaches the ideal solvent more nearly than does any other commercially known liquid. It is an excellent solvent for grease, oil, fats, resins and stains with the added virtues of a pleasant odor and not affecting fiber garments. Trichlorethylene and perchlorethylene are other chlorinated compounds which are being used in increasing amounts. The most widely used petroleum product in the dry-cleaning industry is white spirits known as Stoddard Solvent. The following are the required specifications of the U. S. Bureau of Standards for this substance:

STODDARD SOLVENT

(Dry Cleaning)

Material: A petroleum distillate conforming to the requirements given herein.

Appearance: Clear and free from suspended matter and undissolved water.

Color: Water-white or not darker than 21 by Saybolt chromometer.

Odor: Sweet.

Flash-Point: Not lower than 100° F. ("Tag" closed tester.)

Corrosion Test: A clean copper strip shall show not more than extremely slight discoloration when submerged in the solvent for 3 hours at 212° F.

Distillation Range: Not less than 50 per cent shall be recovered in the receiver when the thermometer reads 350° F. The dry or end point shall be not higher than 410° F. No tolerance shall be allowed above 410° F.

Acidity: The residue remaining in the flask after the distillation is completed shall not show an acid reaction.

Doctor Test: Negative.

Sulfuric Acid Absorption Test: Not more than 5 per cent of the solvent shall be absorbed by concentrated "c.p." sulfuric acid (specific gravity, 1.835) (approximately 93.2%).

TABLE 27.—Celanese Spotting Chart (Recommended Practice)[25]

Soap Solution

Soap and water or
Sulfonated oil and water

Digester

Dampen spot with warm water. Sprinkle with Solvase or similar material and work into stain. Let stand 15 minutes. Rinse thoroughly with water.

Dry Spotting Soap

2 parts oleic acid
1 part chloroform
1 part carbon tetrachloride
1 part benzene
⅕ part denatured alcohol
Keep in corked bottle

Dry Spotting Agent

1 part chloroform
1 part carbon tetrachloride
1 part benzene

Lacquer Remover

2 parts amyl acetate
1 part benzene
½ part denatured alcohol

Shellac Remover

1 part butyl "Cellosolve"
1 part oleic acid

Ink Remover

2 parts lactic acid
2 parts denatured alcohol
2 parts Erusticator
10 to 12 parts water

TABLE 27.—Celanese Spotting Chart (Recommended Practice)[25]—(*Continued*)

Stain with Recommended Spotting Agent or Alternative
Animal glue: Soap Solution *or* Digester
Argyrol: Soap solution followed by ammonia *or* Iodine followed by 26° ammonia or Hypo crystals
Asphalt: Dry Spotting Soap
Artists Paint: Dry Spotting Agent followed by Dry Spotting Soap
Balsam: Lacquer Remover followed by Spotting Agent
Beeswax: Warm Lacquer Remover followed by Dry Spotting Agent
Beverage: Soap Solution *or* Digester followed by Acetic Alcohol
Black shoe polish: Dry Spotting Soap *or* Soap Solution
Blood: Soap Solution followed by 26° ammonia *or* Digester
Butter: Dry Spotting Agent followed by Dry Spotting Soap
Candy: Soap Solution
Catsup: Soap Solution
Chewing gum: Dry Spotting Agent
Chocolate: Soap Solution *or* Digester
Coal tar (sometimes permanent): Dry Spotting Agent followed by Dry Spotting Soap
Cocoa butter: Dry Spotting Agent followed by Dry Spotting Soap
Collodion: Lacquer Remover
Color: Soap Solution *or* Hydrosulfite Stripper
Cooking oils: Dry Spotting Agent followed by Dry Spotting Soap
Dextrin: Digester
Discharge: Soap Solution *or* Digester
Drying oils: Dry Spotting Agent followed by Dry Spotting Soap
Egg: Digester
Enamel paint: Dry Spotting Soap *or* Dry Spotting Agent or Lacquer Remover
Fish eggs: Soap Solution followed by salt brine
Fly paper: Soap Solution
Foods: Soap Solution *or* Digester
Furniture polish: Soap Solution *or* Dry Spotting Agent or 3% peroxide or Hydrosulfite Stripper
Gelatin: Soap Solution *or* Digester
Fruit: Soap Solution or Glycerine and 26° ammonia
Graphite: Dry Spotting Soap *or* Soap Solution
Grass: Soap Solution
Hair dye (sometimes permanent): Dry Spotting Soap *or* Soap Solution
Hair oil: Dry Spotting Agent *or* Dry Spotting Agent followed by Dry Spotting Soap
Ice cream: Soap Solution followed by 26° ammonia *or* Digester
Indelible pencil: Soap Solution
Ink, blue black: Soap Solution followed by 3% peroxide over fumes of ammonia *or* Erusticator (25% hydrofluoric acid) may be alternated with amonia
Ink, carbon, (draftsman) (India): Dry Spotting Agent followed by Dry Spotting Soap *or* Soap Solution
Ink, color base: Soap Solution followed by 3% peroxide over ammonia fumes *or* Erusticator, (25% hydrofluoric acid) may be alternated with ammonia. Sometimes use Hydrosulfite Stripper.
Ink, indelible: Soap Solution
Ink, phenol-containing: Fabric affected. If not, use dry spotting agent.
Ink, Printer's: Dry Spotting Agent followed by Dry Spotting Soap *or* Soap Solution or sometimes Hydrosulfite Stripper
Ink, silver nitrate: Soap Solution followed by 26° ammonia
Ink, stamp pad: Soap Solution
Iodine: Hypo Cyrstals
Iron rust: Erusticator, rinse well
Jewelers' rouge: Dry Spotting Agent followed by Dry Spotting Soap *or* Soap Solution
Lacquer: Dry Spotting Agent followed by Dry Spotting Soap *or* Lacquer Remover *or* Shellac Remover
Lamp black: Dry Spotting Agent followed by Dry Spotting Soap *or* Soap Solution
Lead pencil: Dry Spotting Agent followed by Dry Spotting Soap *or* Soap Solution
Linseed oil: Dry Spotting Agent followed by Dry Spotting Soap
Lip stick: Soap Solution *or* Lubrication
Lysol: Fabric affected. If not, use Dry Spotting Soap
Marine glue (vegetable base): Dry Spotting *or* Neutralize with acetic acid and digest
Marine glue (rubber base): Dry Spotting Agent
Meat juice: Dry Spotting Soap *or* Digester
Mercurochrome: Soap Solution
Metal: Soap Solution
Milk: Soap Solution *or* Digester
Mud: Brush Dry *or* Soap Solution
Nail polish: Lacquer Remover
Newskin: Lacquer Remover
Oyster juice: Soap Solution followed by Salt Brine or Digester
Paint: Dry Spotting Agent followed by Dry Spotting Soap
Paraffin wax: Slightly warm Dry Spotting Agent
Perfume: Sometimes alcohol in perfume has run color. Acidulated Alcohol
Perspiration: Soap Solution with a touch of 26° ammonia
Rosin: Dry Spotting Soap
Rubber cement: Dry Spotting Soap
Salad oil: Dry Spotting Agent followed by Dry Spotting Soap
Shellac: Shellac Remover
Shoe polish: Dry Spotting Agent followed by Dry Spotting Soap *or* Soap Solution or possibly Hydrosulfite Stripper
Starch: Soap Solution *or* Digester
Stove polish: Dry Spotting Agent followed by Dry Spotting Soap *or* Soap Solution
Tar (sometimes permanent): Dry Spotting Agent followed by Dry Spotting Soap
Tomato: Soap Solution
Tobacco: Soap Solution
Varnish: Dry Spotting Agent followed by Dry Spotting Soap *or* Lacquer Remover or Shellac Remover
Vomit: Soap Solution followed by Digester

TABLE 28—Spotting Agents[25]

Safe

- Acids
  - 28% Acetic
  - 28% Formic
- Alkalies (dilute)
  - Soap in water
  - Soda
  - Washing soda
- Ammonia (26°)
- Amyl acetate (pure banana oil)
- Benzene
- Carbon disulfide
- Carbon tetrachloride
- Castor oil
- Chlorine bleaches
- Dichlorbutane
- D. C. solvent
- Digestive agents
  - Degomma, Solvase, Takalab, etc.
- Ethyl benzine
- Gasoline
- Glycerin
- Hydrofluoric acid (Erusticator)
- Oleic acid
- Oxalic acid
- Perchlorethylene
- Petroleum ether
- Potassium Permanganate
- Sodium hydrosulfite (Stripper)
- Burmol
- Big Four
- Lykopon
- Paragene, etc.
- Sodium hypochlorite (Javelle water)
- Soluble oils (Monopole, Tetrapole, etc.)
- Toluene
- Trichlorethylene
- Turpentine
- Xylene
- Cyclohexanol (Hexalin)

Semi-safe

- Wood alcohol (methyl)
- Fusel oil (amyl alcohol)
- Butyl "Cellosolve"
- Grain alcohol (ethyl)

Unsafe

- Acetic ether (ethyl acetate)
- Acetone
- Acids
  - Formic (conc.)
  - Glacial acetic
- Alcohol—benzene
- Alcohol—ether
- Aniline oil
- Benzaldehyde
- Chloroform
- Cresol
- Ethylene dichloride—Ethylene, chloro, etc.
- Lactic acid
- Tetrachlorethane, Payzone
- PV solvent, etc.

The Dilution of Unsafe and Semi-Safe Chemicals

If a mixture is to contain such chemicals, the total amount of them should not be more than 30 per cent of the total volume of the mixture. The safe chemicals should evaporate as slowly as or more slowly than the unsafe or semi-safe chemicals. The unsafe and semi-safe chemicals must be soluble in the safe chemicals.

TABLE 29.—Solubility of Miscellaneous Substances

SH Soluble when hot
S Soluble
I Insoluble
P Partly soluble
SC Soluble but cloudy
SS Slightly soluble
G Gelled
OS Has selective solvent action for oil over wax

Solvents	Anthracene	Blown castor oil	Calcium resinate	Carbazol	Castor oil	Essential oils	Fats	Greases	Indene	Inglewood crude petroleum	Lead linoleate	Linseed oil	Manganese resinate	Mineral oil (tech. white)	Pennsylvania oil	Phenanthrene	Texas oil	Tricresyl phosphate	Tung oil	Zinc resinate	Pyrethrum (extract)
Acetal										S											
Acetaldehyde										P											
Acetone	SS			SH	S	S				P		S		I		S			S		
Acetophenone										P											
Amyl acetate			S			S					SS	S	S		OS		S	OS		S	
sec-Amyl acetate		S							S												
Amyl acetate (mixed isomers)		S							S												
Amyl acetate (from fusel oil)		S							S												
n-Amyl alcohol			S			S				S	SS	S	S		OS		S	OS		S	
sec-Amyl alcohol		S							I												
tert-Amyl alcohol										S											
Amyl alcohol (mixed isomers)		S							I												
Amyl alcohol (from fusel oil)		S							I												
Amyl lactate		S							P												
Amylene dichloride																					S
Benzene (nitrated pure)	SS			SS			S	P								SH					S
Benzene (industrial)	SS			SS			S	P								SH					S
Benzene (90% industrial)	SS			SS			S	P								SH					S
Benzene (B-refined)	SS			SS			S	P								SH					S
Butaldehyde										S					OS		OS				
n-Butyl acetate		S	S			S			S		SS	S	S		OS		OS			S	
sec-Butyl acetate		S							S												
n-Butyl alcohol		S	S			S			I		SS	S	SS		OS		OS			S	S
sec-Butyl alcohol		S							I	S											
tert-Butyl alcohol																					S
Butyl butyrate			SS			S					SS	S	SS							S	
Butyl Carbitol												S									
Butyl "Cellosolve"		S							P			S			OS		OS				
Butyl lactate		S							P												
Carbon disulfide	SS			SS												SS					
Carbon tetrachloride	SS			SS						P						S					S
"Cellosolve"		S	S			S			P		SS	S	S		OS		OS			S	
"Cellosolve" acetate		S	S			S			S		I	S	S							S	
Chlorbenzene															OS		OS				
Chloroform	SS			SS						P						S					S

TABLE 29.—Solubility of Miscellaneous Substances—(*Continued*)

Solvents	Anthracene	Blown castor oil	Calcium resinate	Carbazol	Castor oil	Essential oils	Fats	Greases	Indene	Inglewood crude petroleum	Lead linoleate	Linseed oil	Manganese resinate	Mineral oil (tech. white)	Pennsylvania oil	Phenanthrene	Texas oil	Tricresyl phosphate	Tung oil	Zinc resinate	Pyrethrum (extract)
Diacetone alcohol			SS			S				I	SS	S	SS		OS		OS			S	
Dibutyl phthalate												S			OS		OS				
Dichlor ethyl ether			I			S					I	S	SS							S	
Diethylene glycol										I		SS									
Dimethyl phthalate												S									
Dioxane												S									
Ethyl acetate (pure 85%)		S							S	S		S			OS		OS				
Ethyl alcohol			SS			I			I			I	SS							SS	S
Ethyl alcohol (anhydrous)		S	SS			I			I		I	I	SS		OS		OS			SS	S
Ethyl ether	SS		S	SS		S				S	SS	S	SS			S				S	
Ethyl ether of diethylene glycol												S									
Ethyl lactate		S	S			S			P		SS	S	S							S	
Ethyl methyl ketone										S					OS		OS				
Ethylene dichloride			S			S				S	SS	S	S		OS		OS			S	S
Ethylene glycol										P		SS									
Furan										S											
Gasoline	SS			SS												SS					
Glycerin										P											
Glyceryl diacetate										I											
Glycol diacetate			I			S				I	I	I	SS							SS	
Hexalin										S											
n-Hexanol												S									
Hexone		S							S												
2-50-W. Hi-Flash naphtha	SS			SS			S	P								S					
Hi-Flash naphtha (yellow)	SS			SS			S	P								S					
Hydrogenated naphtha	SS			SS			S	P								S					
Isoamyl acetate										S											
Isoamyl alcohol										S											
Isopropyl acetate		S							S			S									
Isopropyl alcohol		S							I	I		S			OS		OS				S
Isopropyl ether												S									
Kerosene															OS		OS				

| | | |

TABLE 30A.—Solubility of Gums

SH Soluble when hot
VS Very soluble
S Soluble

I Insoluble
P Partly soluble
SC Soluble but cloudy
SS Slightly soluble

G Gelled
IG Insoluble-gelled
SSH Slightly soluble when hot

Solvents	Asphalt petroleum	Gum camphor	Gum congo	Gum copal	Gum dammar	Gum dammar (dewaxed)	Gum dammar (whole)	Gum elemi	Gum guaiac	Gum kauri	Gum kauri (chips)	Gum manila	Gum mastic	Gum pontianac (nubs)	Gum rosin	Gum rosin "E"	Gum rosin ester	Gum sandarac	Gum tragacanth	Gum zanzibar
Acetone							P			P	S	S		S		S	P			
Acetophenone																				
Amyl acetate		S		S	I	S		S	SS	S	S	P	S			S	S	S	I	S
sec-Amyl acetate						S				P		S					S	S		
Amyl acetate (mixed isomers)						S				I		P					S	S		
Amyl acetate (from fusel oil)						S				P		P					S	S		
n-Amyl alcohol		S		S	I			SS	I	S		P	S			S	S	I	S	S
sec-Amyl alcohol						P				P		P					P	S		
Amyl alcohol (mixed isomers)						S				I		P					S	S		
Amyl alcohol (from fusel oil)						P				P		P					P	S		
Amyl chloride																				
Amyl lactate						S				I		P					S			
Benzene (nitrated pure)	S		I		I			S		I		I					S			
Benzene (industrial)	S		I		I			S		I		I					S			
Benzene (90% industrial)	S		I		I			S		I		I					S			
Benzene (B-refined)	S		I		I			S		I		I					S			
Brombenzene																				
Butyl acetate, 85%		S		SS	S	S	SC	S	I	S		SC	S			S	S	I	I	I
n-Butyl acetate		S		SS	S	S	SC	S	I	S		SC	S			S	S	I	I	I
sec-Butyl acetate							S			P		P								
n-Butyl alcohol							SC			S		P				S	S			
sec-Butyl alcohol							I			P		P				P	S			
tert-Butyl alcohol																				
Butyl butyrate		S		I	S			S	I	SS			S				S	I	I	I
Butyl "Carbitol"						P				S							S			
Butyl "Cellosolve"						S				P		P					P			
Butyl lactate						SC				P		P					S			
Butyric acid																				
Carbon disulfide																				
Carbon tetrachloride		S		I	I	SC		SS	SS	P		SC	SS			S	S	S	I	S
"Cellosolve"		S		I	I	SC		SS	SS	P		P	SS			S	S	S	I	I
"Cellosolve" acetate																				
Chloroform																				
Cyclochlorohexanes																				

Diacetone alcohol	S		S	I				SS	S				S				S	SS	S	I	SS				
Dibutyl phthalate					S				S								S	S							
Dichlor ethyl ether	S		I	I	I			SS	SS	I			S				S	S	S	I	I	I			
Diethylaniline																									
Diethyl carbinol																									
Diethyl carbonate																									
Diethyl phthalate																									
Diethylene glycol						I				I							S	I							
Dimethylaniline																									
Dimethyl ethyl carbinol																									
Dioxane									S								S	S	S	I	S				
Ethyl acetate (85%)	S		I	SS	S			S	SS	SC			P	SS			S	S	S						
Ethyl acetoacetate					SH											S	S	S							
Ethyl alcohol	S		I	S	P			S	SS	SS			P	SS			S	S	S	I	SS				
Ethyl alcohol (anhydrous)	S		I	S	P			S	SS	I			P	SS			S	S	S	I	SS				
Ethyl ether	S		SS	S	S	P		SS	SS	I	S			SS			S	S	S						
Ethyl ether of diethylene glycol										S							SH	P							
Ethyl ether of propylene glycol																									
Ethyl lactate						SC				P	S							P							
Ethyl methyl ketone																									
Ethyl oxalate																									
Ethyl oxybutyrate																									
Ethyl sulfate																									
Ethylene chlorhydrin																									
Ethylene diacetate	S		SS	S	S			SS	SS	I				SS			S	S	S	I	I				
Ethylene dichloride					I					I							P	I							
Ethylene glycol																									
Formic acid																									
Glycerin																									
Glycol diacetate	S		I	I				SS	I	I				I			S	I	S	I	I				
n-Hexanol					S					S							S	S							
Hexone					S					SC			SC					S							
2-50-W. Hi-Flash naphtha	S			I				S		I			I					S							
Hi-Flash naphtha (yellow)	S			I	S			S		I			I					S							
Hydrogenated naphtha	S			I	S			S		I			I					S							
Isobutyl alcohol																									
Isobutyl "Carbitol"																									
Isobutyl propionate																									
Isopropyl acetate						SC				S			P					S	S						
Isopropyl alcohol						P				S			P					S	S						
Isopropyl ether						P				I								S	S						
Kerosene																									
Lactic acid																									
Mesityl oxide																									
Methanol						P				I			I					P	I						
Methyl acetate						P				I			P					S	S						
Methyl amyl acetate						SC				I			P					S	S						
Methyl amyl alcohol						S				P			P					S	S						
Methyl amyl ketone						S	P			S	S		S				S	SS	S						
Methyl butyl ketone						P	P				S		S				S	S	S						
Methyl "Carbitol"							I			P	S								S						
Methyl "Cellosolve"						P				S									S						

TABLE 30A.—Solubility of Gums—(*Continued*)

Solvents	Asphalt petroleum	Gum camphor	Gum congo	Gum copal	Gum dammar	Gum dammar (dewaxed)	Gum dammar (whole)	Gum elemi	Gum Guaiac	Gum kauri	Gum kauri (chips)	Gum manila	Gum mastic	Gum pontianac (nubs)	Gum rosin	Gum rosin "E"	Gum rosin ester	Gum sandarac	Gum tragacanth	Gum zanzibar
Methyl ether of propylene glycol						S				SC	S	SC		S	S		S			
Methyl ethyl ketone						S	P			P	I	SC		S	S		S			
Methyl isobutyl ketone (hexone)						S	S			P	I	SC		S	S		S			
Methyl propyl ketone						S				P		P								
Methyl salicylate																				
Monoethylaniline																				
Monomethylaniline																				
Naphtha	S		I		S			S		I		I					I			
Naphtha (heavy)	S		I		S			S		I		I					I			
Naphtha (nitrated)	S		I		S			S		I		I					I			
3-BX naphtha	S		I		S			S		I		I					I			
2-10M naphtha	S		I		S			S		I		I					I			
V. M. & P. naphtha	S		I		S	SC		S		I		I					I			
Octyl acetate						S				I		P								
Octyl alcohol										S		P								
Palmitic acid																				
Petroleum ether																				
Pine oil																				
Propionic acid						S				P		P					S			
n-Propyl acetate						P				I							P			
n-Propyl alcohol						S				P							S			
Propylene dichloride						I				S							I			
Propylene glycol						S				S							S			
Propylene oxide																				
Pyridine																				
Solvenol																				
Solvesso No. 1						S				I		I					S			
Sulfonated castor oil																				
Sulfonated caster oil 50%—Pine oil 50%																				
Toluene (nitrated)	S		I		S	S		S		I		I					S			
Toluene (industrial pure)	S		I		S	S		S		I		I					S			
Toluene (90/120)	S		I		S	S		S		I		I					S			
Trichlorethylene																S	S			
Triethylene glycol						S				P						P	I			
Toluol						I				I		I					P			
Turpentine						SC														
Xylene (5 degrees)	S		I		S	S		S		I		I					S			
Xylene (10 degrees)	S		I		S	S		S		I		I					S			
Xylene (industrial)	S		I		S	S		S		I		I					S			

TABLE 30B.—Solubility of Resins and Waxes

SH Soluble when hot
VS Very soluble
S Soluble
I Insoluble
P Partly soluble
SC Soluble but cloudy
SS Slightly soluble
G Gelled
IG Insoluble-gelled
SSH Slightly soluble when hot

Solvents	Shellac	Shellac bleached	Shellac orange	Shellac stik-lac	T. N. shellac	Beeswax	Candelilla wax	Carnauba wax	Ceresin wax	Chinese or insect wax	Japan wax	Montan wax	Ozocerite wax	Paraffin wax	Spermaceti wax
Acetaldehyde		S		S	S										
Acetic acid		S		S	S										
Acetone	P	P		S	SS	SH		SH	I		SH			SH	SH
Acetophenone		SS		SS	SS										
Amyl acetate	SS	I		I	I						I				
sec-Amyl acetate			I												
Amyl acetate (mixed isomers)			I												
Amyl acetate (from fusel oil)			I												
n-Amyl alcohol	I	S		S	S						I				
sec-Amyl alcohol			P												
Amyl alcohol (mixed isomers)			S												
Amyl alcohol (from fusel oil)		S	P	S	S	S		S			S				S
Amyl chloride		I		I	I										
Amyl lactate			SC												
Benzene (nitrated pure)		IG		I	I				S	S	S	S	S		
Benzene (industrial)		IG		I	I				S	S	S	S	S		
Benzene (90% industrial)		IG		I	I				S	S	S	S	S		
Benzene (B-refined)		IG		I	I				S	S	S	S	S		
Brombenzene		IG		I	I										
Butyl acetate, 85%	I	SS		SS	SS						I				
n-Butyl acetate	I	I	I	I	I						I				
sec-Butyl acetate			I												
n-Butyl alcohol	S	S	S	S	S										
sec-Butyl alcohol		S	P	S	S										
tert-Butyl alcohol		S		S	S										
Butyl butyrate											I				
Butyl "Carbitol"	P	S		S	S										
Butyl "Cellosolve"	S	S	SC	S	S										
Butyl lactate			SC												
Butyric acid		SS		S	SS										
Carbon disulfide		I		I	I								S		S
Carbon tetrachloride		I		I	I	S	S	S			S	S		S	S
"Cellosolve"	S	S	SC	S	S						I				
"Cellosolve" acetate	S	SS	I	SS	SS						I				
Chloroform		IG		IG	IG	SH	SH	SH	P		S	S		SH	SH
Cyclochlorohexanes				I											

TABLE 30B.—Solubility of Resins and Waxes—(*Continued*)

Solvents	Shellac	Shellac bleached	Shellac orange	Shellac stik-lac	T. N. shellac	Beeswax	Candelilla wax	Carnauba wax	Ceresin wax	Chinese or insect wax	Japan wax	Montan wax	Ozocerite wax	Paraffin wax	Spermaceti wax
Cyclohexane	S	SS	I	I	SS	HS		HS	I	SS	I	HS	S	HS	S
Diacetone alcohol	S	S	SH	S	S	S									
Dibutyl phthalate	P	S	SH	S	S										
Dichlor ethyl ether	I	I	C	I	I						I				
Diethylaniline		S	SH	S	S										
Diethyl carbonol		I	C	I	I										
Diethyl carbonate		I	SH	I	I										
Diethyl phthalate		I	SH	I	I										
Diethylene glycol	I	S	SH	S	S										
Dimethylaniline		I	SH	I	I										
Dimethyl ethyl carbinol		S	SH	S	S										
Dioxane	S	SS	I	SS	SS	HS	SH	HS	I	SS	SH	SH	I	I	SH
Ethyl acetate (85%)	S	SS	SSH	SS	SS			SSH			SH	SH	I	I	SH
Ethyl acetoacetate	S	SS	SC	S	S			SH			SH	SH	I	HS	SH
Ethyl alcohol (anhydrous)	S	S	SC	S	S	S		SH	I	SS	SH	SH	S	S	S
Ethyl ether	S	SS		SS	SS										
Ethyl ether of diethylene glycol	S	S		S	S										
Ethyl ether of propylene glycol		S		S	S										
Ethyl lactate		S	SC	S	S										
Ethyl methyl ketone		S		S	S										
Ethyl oxalate		S		I	I										
Ethyl oxybutyrate		S		S	S										
Ethyl sulfate		I		I	I										
Ethylene chlorhydrin		S		S	S										
Ethylene diacetate		I		I	I										
Ethylene dichloride	S	IG		IG	IG						SS				
Ethylene glycol	P	I		S	S										
Formic acid		S		I	I										
Glycerin	I	I		I	I						I				
Glycol diacetate	S	S													
n-Hexanol			I												
Hexone															
2-50-W. Hi-Flash naphtha									S		S				
Hi-Flash naphtha (yellow)															
Hydrogenated naphtha		S		S	S										
Isobutyl alcohol		S		S	S										
Isobutyl "Carbitol"		I		I	I										
Isobutyl propionate															

| | | |

TABLE 31.—Solubility of Synthetics

[1] In the presence of alcohol
[2] Nitrocellulose with 35% alcohol
[3] Ethyl cellulose 5% by volume

[4] Ethyl cellulose 16% by volume
S Soluble
I Insoluble
P Partly soluble

SC Soluble but cloudy
SS Slightly soluble
G Gelled

Solvents	Alkyd-resins modified with—Oil	Alkyd-resins modified with—Phenol	Alkyd-resins modified with—Natural resins	Amberlac 94	Amberol 801	S Amberol-type resin	Aroclor	Beckacite 1110	Beckasol 1324	Cellulose acetate	Cellulose nitrate	Copal gum, esterified	Coumarone resin	Ethyl cellulose	Glyptal 2471	S Glyptal-type resin	Lewisol 2	Neville resin	Paraplex RG-2	Rezyl 12	Santicizer B-16	Santolite M-7	Teglac Z-152	Vinyl acetate resin	S Vinylite A	Durez 4032	Paranol CW	S Benzyl cellulose
Acetone				S	S		S	S	S	S	S		S				P	S	S	S	S	S	S	S		S	S	S
Amyl acetate				S	S		S	S	S	I	S		S				S	S	S	S	S	S	S	S		S	S	P
sec-Amyl acetate				S	S		S	S	S	I	S		S				S	S	S	S	S	S	S	S		S	S	P
Amyl acetate (mixed isomers)				S	S		S	S	S	I	S		S				S	S	S	S	S	S	S	S		S	S	P
Amyl acetate (from fusel oil)				S	S		S	S	S	I	S		S				S	S	S	S	S	S	S	S		S	S	P
n-Amyl alcohol				P	I		P	P	P	I	I		P	S₂	P		P	S	P	P	P	P	I	P		P	P	I
sec-Amyl alcohol				P	P		P	P	P	I	I		P	S₂	P		P	S	P	P	P	P	I	P		P	P	I
Amyl alcohol (mixed isomers)				P	I		P	I	S	I	I	S	S	S	P		P	S	P	P	P	P	I	P		P	P	I
Amyl alcohol (from fusel oil)				P	I		P	P	S	I	I	S	S	S	P		P	S	P	P	P	P	I	P		P	P	I
Amyl formate				S	S		S	S	S	I	S	S	S	S	P		S	S	S	S	S	S	S	S		S	S	P
Amyl lactate				S	S		S	S	S	I	S	S	S	S	P		S	S	S	S	S	S	S	S		S	S	P
Amyl propionate				S	S		S	S	S	I	S	S	S	S	P		S	S	S	S	S	S	S	S		S	S	P
Amyl stearate																		S										
Benzene (nitrated pure)		S	S							I	I	I	S	S₂	I		S		S	S	S	S	S	P		S	S	S
Benzene (90% industrial)	S	S	S							I	I	I	S	S	P		S		S	S	S	S	S	P		S	S	S
Benzene (B-refined)	S	S	S							I	I	I	S	S	P		S		S	S	S	S	S	P		S	S	S
Benzyl acetate										S	S	S	S	S	P	S	P		P	P	P	P	I	P		S	S	P
Benzyl alcohol										S	S	S	S	S	P	S	P		P	P	P	P	I	P		S	S	P
Benzyl formate										S	S	S	S	S	P	S	P		P	P	P	P	I	P		S	S	P
Butyl acetate, 85%										S	S	S	S	S	P	S	P		P	P	P	P	I	P	S	P	S	P
n-Butyl acetate				S	S		S	S	S	I	I	S	S	S₂	S		S		S	S	S	S	S	S		S	S	S
sec-Butyl acetate				S	S		S	S	S	I	I	S	S	S₂	S		S		S	S	S	S	S	S		S	S	S
n-Butyl alcohol				S	P		S	P	P	I	I	S	S	S₂	P		P		P	P	P	P	I	P		S	S	I
sec-Butyl alcohol				P	I		P	I	S	I	I	S	S	S	P		P		P	P	P	P	I	P		S	S	I
Butyl butyrate										I	I	SS																
Butyl "Carbitol"				S	S		S	S	S	I	I	S	S	S₂	S		S		S	S	S	S	S	S	S	P	S	P
Butyl "Cellosolve"				S	S		S	S	S	I	I	S	S	S₂	S		S		S	S	S	S	S	S		S	S	S
Butyl formate				S	S		S	S	S	I	I	S	S	S₂	S		S		S	S	SC	S	S	S		S	S	P
Butyl lactate																												
Butyl oxalate										I	S		S		S	I	S	S	S					S				
Butyl propionate													S				S	S										
Carbon disulfide										I	S₂		S	S₂			S	S					I					G
Carbon tetrachloride				S	S		S	S	S	G	S		S	S₂	S		S	S	S	S	S	S		P		S	S	S
"Cellosolve"				S	S		S	S	S	G	S		S	S₂	S		S	S	S	S	S	S	S			S	S	S
"Cellosolve" acetate				S	S		S	S	S	G	S		S	S₂	S		S	S	S	S	S	S	S			S	S	S

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TABLE 31.—Solubility of Synthetics—(*Continued*)

Solvents	Alkyd-resins modified with— Oil	Phenol	Natural resins	Amberlac 94	Amberol 801	Amberol-type resin	Aracior	Beckacite 1110	Beckasol 1324	Cellulose acetate	Cellulose nitrate	Copal gum, esterified	Coumarone resin	Ethyl cellulose	Glyptal 2471	Glyptal-type resin	Lewisol 2	Neville resin	Paraplex RG-2	Rezyl 12	Santicizer B-16	Santolite M-7	Teglac Z-152	Vinyl acetate resin	Vinylite A	Durez 4032	Paranol CW	Benzyl cellulose
Methyl cyclohexanone	S	S		S	S	S	S	S	S	I	I		S	S	S		P	S	S	S	S	S	S	S		S	S	
Methyl cyclohexanyl acetate	S	S		S	S	S	S	S	S	I	I		S	S	S		P	S	S	S	S	S	S	S		S	S	
Methyl ethyl ketone										I	I		S	S	S		P	S	S	S	S	S	S	S		S	S	
Methyl isobutyl ketone (hexone)										I	I		S	S	S		P	S	S	S	S	S	S	S		S	S	
Methyl isopropyl ketone										I	I		S	S	S		P	S	S	S	S	S	S	S		S	S	
Methyl propyl ketone										I	I		S	S	S		P	S	S	S	S	S	S	S		S	S	
Mineral spirits																												
Naphtha	S	S	S								I		S	S	S		P	S	S	S	S	S	S	S	P	S	S	
Naphtha (heavy)	S	S	S								I		S	S	S		P	S	S	S	S	S	S	S		S	S	
Naphtha (nitrated)	S	S	S								I		S	S	S		P	S	S	S	S	S	S	S		S	S	
3-BX naphtha	S	S	S								I		S	S	S		P	S	S	S	S	S	S	S		S	S	
2-10M naphtha	S	S	S								I		S	S	S		P	S	S	S	S	S	S	S		S	S	
V. M. & P. naphtha	S	S	S								I		S	S	S		P	S	S	S	S	S	S	S		S	S	
Octyl acetate				S	S	S	S	S	S	I	I		S		S		P	S	S	S	S	S	S	S		S	S	I
Octyl alcohol				P	P	S	P	P	S	I	I		S		P		P	S	S	I	S	P	P	S		S	S	
Petroleum thinners																												
Pine oil											I		S	S	P		P	S	S	I	S	I	P	S	I	S	S	
n-Propyl acetate				S	S	S	S	S	S	S	S		S	S_2	S		S	S	S	S	S	S	S	S		S	S	
n-Propyl alcohol				S	I	P	I	S	S	I	S_2		S	PS_2	P		P	S	I	S	P	I	I	I		S	S	
Propylene glycol										I	I														I			
Pyridine													S					S										
Rosin oil																												
Solvent naphtha				S	S		S	S	S		I		S		S		S	I	I	S	S	I	S	S		I	S	
Solvesso No. 1													S															
Terpineol											I		S				S	I	I	S	S	S	S	S		S	S	
Tetrahydrofurfuryl alcoho													S															
Tetralin										I	I		S	S_2	S		S	S	S	S	S	S	S	S	S	S	S	P
Toluene (nitrated)	S	S	S	S	S	S	S	S	S	I	I		S	S_2	S	I	S	S	S	S	S	S	S	S		S	S	
Toluene (industrial pure)	S	S	S							I	I																	
Toluene (90/120)	S	S	S							I	I																	
Trichlorethylene										I	I		S	S_2				S						S		S		
Tricresyl phosphate													S															
Triethylene glycol											I														S			
Triphenyl phosphate													S		I		I	S	I	S	S	S	I	I		I	S	I
Toluol				I	I	S	I	I	S		I		S	S_2	S	I	S	S	S	S	S	S	I	S		S	S	
Turpentine													S	S_2	S	I	S	S	S	S	S	S	I	S		S	S	
Xylene (5 degrees)	S	S	S										S	S_2	S	I	S	S	S	S	S	S	I	S		S	S	
Xylene (10 degrees)	S	S	S							I	I		S	S_2	S	I	S	S	S	S	S	S	I	S		S	S	
Xylene (industrial)	S	S	S							I	I																	

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[25] Celanese Research Assoc., Silver Spring, Md.
[26] U. S. Industrial Chemical Co., Inc., New York, N. Y.

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Neville Company, Pittsburgh, Pa.
Sharples Solvents Corporation, Philadelphia, Pa.

Chapter 8

Hydrocarbons and Their Hydrogenated Derivatives

Aliphatic

The uses of the aliphatic hydrocarbons are many. Of the petroleum distillates a large volume is used in the paint, varnish and enamel industries. They are also used as solvents for petroleum-soluble types of synthetic resins, as dissolvents for cellulose ethers, and as diluents in other types of lacquers. This group of solvents is less toxic than most other solvents but they do affect the skin, and their vapors, if present in sufficient concentration, cause nausea, dizziness, and even death. Fractions which are commercially available contain mixtures of hydrocarbons ranging from *n*-hexane to decane.

Petroleum Ether

Petroleum ether (benzinum, light ligroin, benzine) is a colorless liquid consisting mainly of hexane. It is soluble in alcohol, ether, chloroform, benzene, and fixed and volatile oils. It will dissolve some types of cellulose ethers, oils, waxes, soft resins and so forth and is used both in extracting shellac-wax and the volatile oil contained in elemi.

Boiling range	40°–60° C.
Refractive index	1.365–1.376
Specific gravity	0.63–0.67
Flash-point	Below 0° F.
Distillation range	30°–60° C.

Gasoline

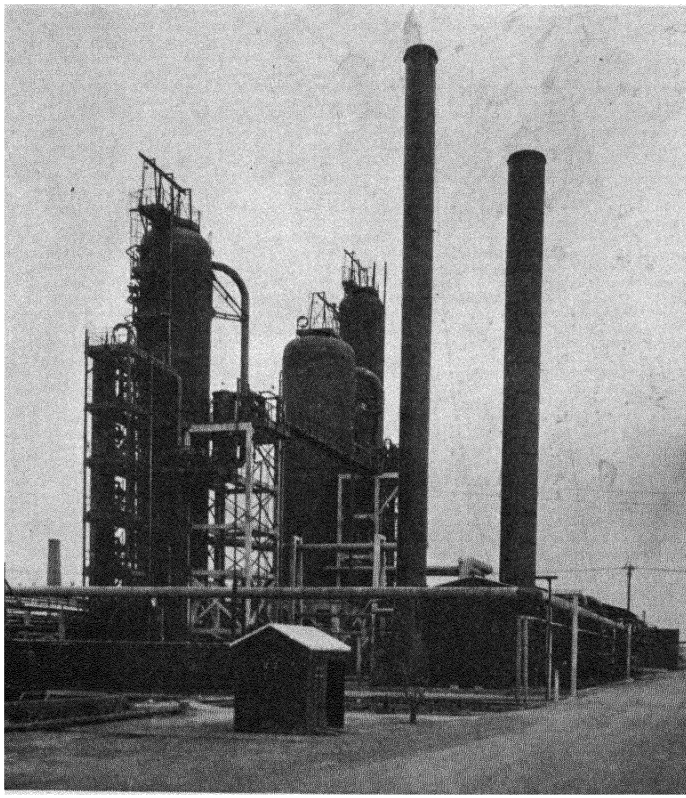
Gasoline (petrol, motor-spirits, petroleum ether, benzine, benzoline) is a colorless, highly volatile liquid of characteristic odor. It is obtained both from natural gas and from the third fraction of the petroleum distillate. It is composed chiefly of hexanes and heptanes with smaller quantities of pentanes and octanes. Gasoline as a solvent is used in dry cleaning, in certain paints in order to secure a quick set, in quick-drying asphaltum varnish, in label varnish, penetrating stains, prepared waxes and metal polishes.

Boiling range	60°–120° C.
Specific gravity	0.66–0.684
Freezing point	−90.6 to −95.4° C.
Refractive index	1.375–1.3877
Flash-point	−10 to 40° F.

Petroleum Spirit

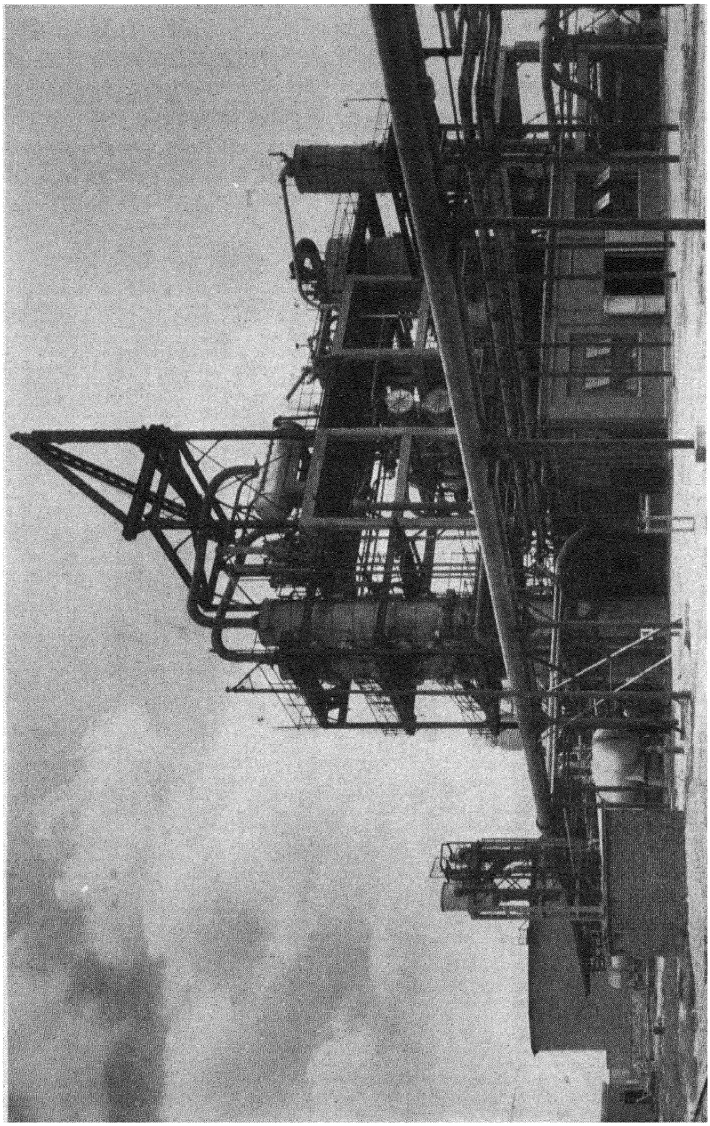
Petroleum spirit (ligroin, benzoline, benzine, petroleum ether, petroleum naphtha) is a colorless, inflammable liquid composed, in the main, of hexanes and heptanes, with small amounts of octanes. It is soluble in alcohol, benzene, chloroform, ether and so forth. It may be used as a solvent in paint and varnish manufacture, in rubber cement, and oil-cloth fabrication. It also finds application as a general solvent, in the extraction of oils, fats and greases, in detergent soaps, and as a detergent and degreasant for textiles, machines and hides.

Boiling range	80°–130° C.
Refractive index	1.407–1.425
Specific gravity	0.730 at 15° C.



Courtesy of Max B. Miller & Co., Inc.

PLATE 3A. Exterior View of a Solvent Extraction Plant (Duo-Sol Process).



Courtesy of Max B. Muller & Co., Inc.

PLATE 3B. Exterior View of a Solvent Extraction Plant (Duo-Sol Process).

V. M. & P. Naphtha

V. M. & P. Naphtha (Varnish Makers' and Painters' Naphtha) as a solvent stands between gasoline and mineral spirit. Its solvency may be accentuated by the addition of coal-tar solvents or turpentine. It is used in paints and varnishes for dipping and spraying purposes, and its presence in these preparations imparts depth and gloss to the films. It is also used in short-oil fossil-gum varnishes, asphalt varnish, gloss furniture varnish, barrel paint, metalware enamels, penetrating stains, prepared waxes, metal and furniture polish, oil type graining compounds and primers.

Refractive index	1.41
Boiling range	100°–160° C.
Specific gravity	0.75–0.770
Flash-point	20°–50° F.

Mineral Spirit

Mineral spirit (petroleum distillate, oleum, heavy naphtha, turpentine substitute) is a colorless petroleum liquid of a sweet pleasant odor. Because it has a high flash-point and evaporates at about 31° C., it is used as a solvent and thinner in the paint and varnish industry, usurping the position long held by turpentine. Mineral spirit is used in brushing preparations where its rate of evaporation does not retard drying but allows for easy working qualities and good flow. Its presence in the vehicle and thinner of mill whites, flat whites, undercoats and primers produces better dispersion of the pigments. It is used to replace turpentine entirely in oleo-resinous products and, in a limited way, in short-oil fossil-gum varnishes and in solutions of blown oils. Pine oil, wood turpentine and dipentene are used with mineral spirit to mask their petroleum characteristic, to increase their solvency and to impart flowing qualities. Mineral spirit will dissolve linoleate driers but will not hold them in solution permanently without the addition of an oil, higher fatty acid, or rosin.

Flash-point	86°–105° F.
Boiling range	90% below 200° C.
Specific gravity	0.770–0.800
Refractive index	1.42

Kerosene

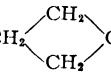
Kerosene (coal oil, astral oil) is a mixture of hydrocarbons, boiling between 150 and 250° C., and constitutes the fifth distillate of petroleum. This material by virtue of its slow-drying properties imparts to paint and varnish mixtures good flow, penetration, easy brushing and working qualities, and it prevents surface skinning. It is used in slow-drying paints, dipping primers, enamels, baking Japans, alkyd resin varnishes, asphalt coatings and plastic and liquid cements. Kerosene also finds application

as a thinner in dammar enamels and in cork-sticking lacquers; when admixed with creosote it is used in shingle stains.

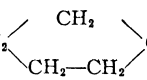
Specific gravity	0.810-0.820
Refractive index	1.45
Flash-point	150° F.
Distillation range	150°–270° C.

Polymethylene Derivatives

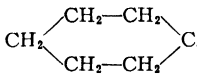
The polymethylene hydrocarbons, such as cyclopropane, cyclobutane, cyclopentane and cyclohexane, and their corresponding alcohols, ketones and esters comprise a series of useful cellulose ether solvents and plasticizers.

Cyclobutane (tetramethylene, ) is a colorless gas which boils at 13° C. In a liquid state, or in combination with other sol vents, it will dissolve a number of cellulose ethers.

Specific gravity	0.7083 at 11° C.

Cyclopentane (pentamethylene, ) is a colorless liquid and will dissolve cellulose ethers.

Boiling point	50.5° C.
Melting point	−93.3
Specific gravity	0.756

Cyclohexane (hexamethylene, hexanaphthene, hexahydrobenzene, ) is a colorless liquid somewhat similar to benzene but less toxic. It is miscible with most lacquer solvents and is a powerful solvent for resins. It is used as a solvent in the molding industry, and in the fabrication of glass substitutes composed of wire mesh coated with synthetic resins. For further data see page 148.

Vapor pressure	76.7 at 20° C.
Refractive index	1.42636
Freezing point	6.4° C.
Boiling point	81° C.
Specific gravity	0.780

Methylcyclohexane (Hexahydrotoluene)

Refractive index	1.42535
Freezing point	− 126.4° C.
Boiling point	100.8

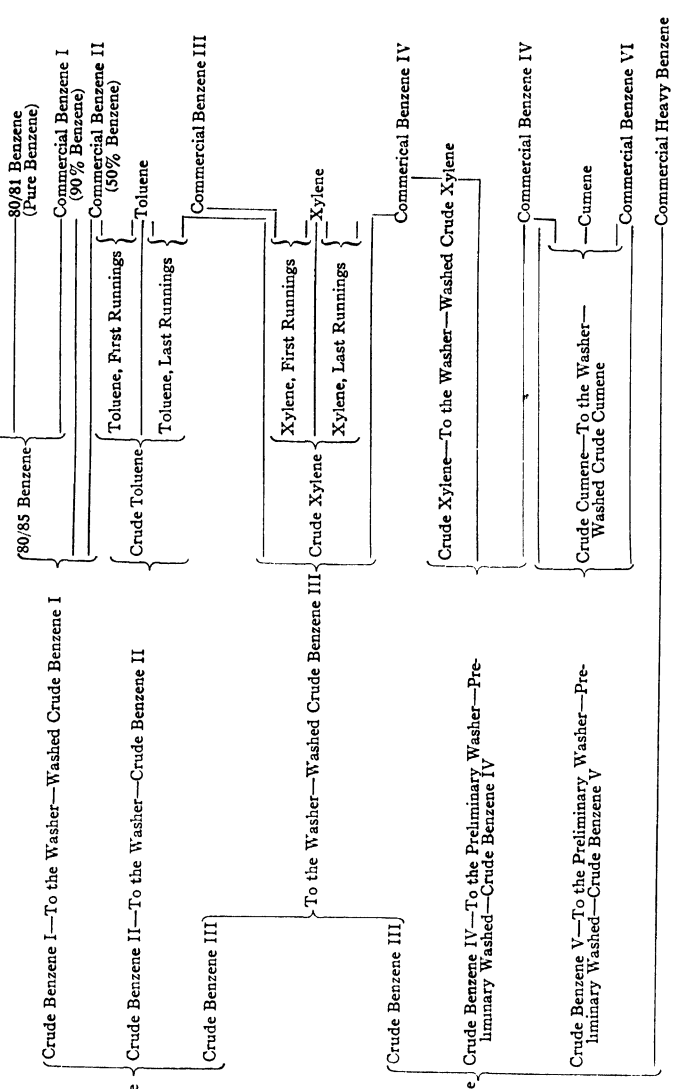


FIG. 17.—Flow Sheet Showing Production of Aromatic Hydrocarbons from Light Oil[1]
From K. B. Lehmann, Archiv. f. Hyg., 75, 5.

TABLE 32.—Physical Properties of Kanotex Petroleum Solvents[2]

	Regular Lacquer Diluent	Special Lacquer Diluent	Special Lacquer Diluent	Special V. M. & P. Naphtha	Special Mineral Spirits	High-Flash Mineral Spirits
Gravity, A.P.I.	62.6	65.8	61.7	57.3	47.5	47.8
Specific gravity	.7290	.7172	.7324	.7495	.7905	.7892
Engler Distillation						
I.B.P.(° F.)	184	171	200	212	260	321
5% over	193	181	206	230	301	332
10%	195	183	207	234	310	334
20%	198	185	209	240	323	337
30%	201	187	211	246	335	341
40%	204	190	213	252	347	345
50%	208	193	215	259	361	349
60%	212	196	218	266	375	354
70%	217	200	221	274	395	359
80%	223	205	226	284	412	367
90%	233	212	234	301	430	377
95%	242	219	242	320	442	386
End Point	263	239	261	367	455	398
Recovery, %	99	99	99	99	99	99
Saybolt, color	30 +	30 +	30 +	30 +	30 +	30 +
Tag. C.C. flash (° F.)	—	—	—	—	—	113
Static vapor pressure (mm. Hg)						
at 70° F.		72				
100		125				
130		214				
Ave. B.P. under vacuum, barometer 29" Hg.						
at 15" vac.		163° F.				
at 22" vac.		122° F.				

TABLE 33.—Physical Properties of Kanotex Petroleum Solvents[2]

	Textile Naphtha	Light Cleaners' Naphtha	Regular V.M. & P. Naphtha	5-A Paint Naphtha	Stoddard Solvent	Mineral Spirits	10-A Naphtha	10-B Naphtha
Gravity, A.P.I.	71.0	57.7	58 4	50.8	50 0	49.0	43.2	43.1
Specific gravity	.6988	.7479	.7451	.7762	.7796	.7839	.8100	.8104
Engler Distillation:								
I.B.P. (° F.)	144	210	205	290	310	312	363	380
5% over	153	226	223	303	319	321	380	392
10%	155	229	228	306	322	325	388	397
20%	157	233	233	310	324	329	396	402
30%	159	237	238	313	327	333	403	406
40%	161	241	244	317	330	337	409	411
50%	164	246	250	321	334	342	414	416
60%	167	251	256	325	338	348	419	421
70%	171	256	262	331	342	355	424	427
80%	176	263	269	337	348	363	429	434
90%	184	271	278	345	357	375	436	444
95%	192	278	287	353	365	385	443	452
End Point	210	297	310	368	378	399	455	462
Recovery, %	99	99	99	99	99	99	99	99
Saybolt, color	30 +	30 +	30 +	30 +	30 +	30 +	25 +	25 +
Tag C.C. flash (° F.)	—	—	—	90	102	105	140 +	150 +
Static vapor pressure (mm. Hg)								
at 70° F.	130							
100	252							
130	494							
Ave. B.P. at 15" Hg vacuum, 29" Baro.	130° F.							
Ave. B.P. at 22" Hg vacuum, 29" Baro.	95° F.							

TABLE 34.—Typical Analyses of Naphthas and Solvents[3]

	Safety Solvent	Stoddard Solvent	Light Pet. Naph.	V.M. & P. Naph.	Spec. Heavy Mineral Spirits	Extraction Naph.	Lacquer Diluent	70/72 Naph.	Special Solvent
Gravity, A.P.I.	44.2	48.7	56.0	54.9	43.0	60.1	59.2	70.7	67.5
Color	+ 30	+ 30	+ 30	+ 30	+ 25	+ 30	+ 30	+ 30	+ 30
Doctor test	O. K.	O. K.	O. K.	O. K.	O. K.	O. K.	O. K.	O. K.	O. K.
Sulfur, %	.026	.017	.017	.017	.007	.009	.011	.008	.012
Corr. (Cu. 122° F.)	O. K.	O. K.	O. K.	O. K.	O. K.	O. K.	O. K.	O. K.	O. K.
Aniline pt.	51.0	53.0	51.8	51.3	60.0	52.0	53.0	56.1	53.9
Kauri butanol solvency	40–43	37–39	37–40	38–40	33.5–36	37–39	37–39	—	—
Corr. (½ hr. at B.P.)	O. K.	—	O. K.	O. K.	O. K.	—	—	—	—
Flash, Tag. C.C. (° F.)	104	103	—	—	154	—	—	—	—
Color stability (16 hrs.)	+ 30 + 30	+ 30 + 30	+ 30 + 30	+ 30 + 30	+ 22 + 21				
H_2SO_4 absorption		1%							
A.S.T.M. distillation:									
I.B. Point, (° F.)	308	307	205	197	374	170	194	104	135
End Point, (° F.)	408	372	320	364	460	300	268	290	234
% at 104									
122								4	
140								16	1
158								32	12
176						1		49	49
194						10		65	80
212			1	2		40	26	79	95
221			4	6		52	54	83	97
230			16	12		65	76	88	98
248			47	36		82	93	93	
266			70	57		91	98	95	
284			87	75		96		97	
302			94	86					
320	5	40	98	93					
338	47	89		96					
356	76	96		97					
374	91								
392	96				20				
410					68				
428					90				
437					94				
446					97				
Recovery	98	98	98	98	98	98	98	98	98
Residue	1	1	1	1	1	1	1	1	1
Loss	1	1	1	1	1	1	1	1	1
A.S.T.M. distillation:									
I.B. Point, (° F.)	308	307	205	197	374	170	194	104	135
End Point, (° F.)	408	372	320	364	460	300	268	290	234
5% at	320	309	222	221	381	185	199	123	149
10	323	311	227	228	385	194	203	132	156
20	328	314	233	237	392	200	209	145	161
30	332	317	238	245	395	206	213	156	166
40	336	320	244	252	398	212	216	166	171
50	340	323	251	260	402	219	219	177	176
60	345	326	258	269	407	226	223	187	182
70	352	329	266	279	412	236	227	199	188
80	359	333	276	292	418	246	233	214	194
90	373	339	292	312	428	264	243	236	204
95	386	352	305	328	438	281	252	264	212

TABLE 35.—The Barrett Company Specifications for Coke Oven Light-Oil Distillates and Coal-Tar Naphthas

	Distillation			Dry Point (or Fixed Point)	Color	Specific Gravity at 15.5° C.	Sulfur Compounds as H_2S or SO_2	Solidifying Point	Flash-point approx. (° F.)
Benzenes	First Drop (or Fixed Point)	Per Cent at Fixed Temperature		Not above					
Thiophene free benzene (8)	Not below 79.2° C.	All within 1° C. including 80.2° C.		81.2° C.	Water white	.882 to .886	(1)	—	10–15
Nitration pure benzene (8)	" " 79.2° C.	" " " " " " "		81.2° C.	" "	.8820 to .8860	None	Not below 4.85° C.	10–15
Industrial pure benzene (8)	" " 78.2° C.	" " 2° " " " "		82.2° C.	" "	.875 to .886	"	—	10–15
Industrial 90% benzene (8)	" " 78 2° C.	At least 90% shall distill at 100° C.		120° C.	" "	.875 to .886	"	—	10–15
Toluenes									
Nitration pure toluene (8)	" " 109 4° C	All within 1° C. including 110 4° C.		111.4° C.	" "	.8690 to .8730	"	—	35–40
Industrial pure toluene (8)	" " 108.4° C.	" " 2° C. " " "		112.4° C.	" "	.864 to .874	"	—	35–40
Xylenes									
Nitration Xylene (8)	" " 137.2° C.	" " 3° C.		140.5° C.	" "	.865 to .870	"	—	80–85
Five degree xylene (8)	" " 137° C.	" " 5° C. including 139.5° C.		143° C.	" "	.860 to .870	"	—	80–85
Ten degree xylene (8)	" " 135° C.	" " 10° C.		145° C.	" "	.860 to .870	"	—	80–85
Industrial xylene (8)	Not above 135° C.	Not over 5% shall distill at 130° C. 90 to 95% shall distill at 145° C.		155° C.	" "	.850 to .870	"	—	80–85
Solvent naphtha	" " " "	" " " " " " "		" "	" "	.850 to .870	"	—	80–85
Industrial Coal-Tar Naphthas									
Cumene	—	95% shall distill between 165.5–175.5° C. 50% point shall be between 169-171° C.		—	" "	—	Not specified	—	Not below 100
Hi-Flash naphtha 185 D P.	Not below 150° C.	—		185° C.	" "	.855 to .890	None	—	" " "
Hi-Flash naphtha 200 D.P.	" " " "	90% shall distill at approx. 180° C.		200° C.	" (7) "	.855 to .890	"	—	" " "
Crude light solvent naphtha	Not above 135° C	Not over 5% shall distill at 130° C. 90–95% shall distill at 160° C.		180° C.	Light amber (7)	.860 to .885	Not specified	—	80–90
Crude heavy solvent naphtha	Not over 5% at 150° C.	Not over 5% shall distill at 150° C. Shall distill at least 5% at 165 and 90% to 200° C.		220° C.	Light amber to dark red	.885 to .970	"	Not over 8% dry salts ($C_{10}H_8$)	Not below 100
Heavy naphtha	Shall distill 10% at not below 160° C.	70% point shall be between 195–203° C.		270° C.	Amber to dark red	.915 to .945	"	(4)	" " "
Heavy naphtha E. W.	Shall distill 10% at not below 160° C	" " " " " " "		270° (5) C.	Straw to dark amber	.915 to .950	"	Not above 10° C. (6)	" " "
Special heavy naphtha	Shall distill 10% at not below 160° C.	—		200° C.	Straw to amber	.880 to .970	"	Below −20° C. —	" " "

(1) No trace of thiophene or carbon disulfide (3) Tar acids not over 3% by volume (5) Residue shall be a liquid (7) Substantially water-white
(2) Using 60° Bé acid and standing 5 minutes (4) Limpid point, (6) No crystals at −20° C (8) Passes Barrett Copper Corrosion Test
All tests shall be performed in accordance with Barrett Testing Methods as given in Specifications for Coke Oven Light-Oil Distillates.

AROMATIC

Benzene

Benzene (C_6H_6, PhH, M.W. 78.05, also known as benzol, phenyl hydride, coal naphtha) is a hydrocarbon discovered by Faraday in 1825 while compressing illuminating gas. It was later prepared by Mitscherlich from benzoic acid and he named it "benzin" or "benzine." It was Liebig who proposed the name of "benzol." Hofmann was the first to discover, in 1834, its presence in coal-tar. At the present time benzene is commercially obtained from coal-tar light oil, illuminating gas and coke-oven gas. The impure grades contain toluene, xylene, and tarry substances. Benzene is a colorless, limpid liquid of a highly refractive nature, having a pleasant and characteristic odor although it is narcotic and toxic. At 0° C. it solidifies into a crystalline state, melts at 5.483° C., and boils at 80.2° C. The vapors of benzene are highly inflammable and a benzene-air mixture containing 1.4 per cent to 4.7 per cent will explode. Benzene vapors burn with a very smoky flame. It dissolves 0.03 per cent of water at 3° C., 0.061 per cent of water at 23° C. and 0.114 per cent at 40° C. Its solubility in water is very slight., It is miscible or soluble in alcohol, ether, formic acid, glacial acetic acid, carbon tetrachloride, chloroform and carbon disulfide. Benzene, which is the parent substance of an enormous number of synthetic compounds, is commercially of exceptional importance. It is an excellent solvent for benzyl abietate, benzyl resins, copal ester, cumar resins, chlornaphthalene resins, cyclohexone resins, glyptol resins, thiourea resins and other natural and synthetic resins, gums, waxes, rubber, oleo-resins, aluminum naphthenate, alkaloids, fats, gases and elements like sulfur, phosphorus and iodine. It will also dissolve such cellulose ethers as methyl, ethyl, butyl, benzyl celluloses and so forth, and such cellulose esters as cellulose dinaphthenate, dilaurate, dipalmitate, distearate, dinitrolaurate, dinitropalmitate and diacetyl-laurate. The solvency of benzene is augmented by the addition of a lower aliphatic alcohol. For example, a mixture of benzene, or toluene, with ethyl alcohol ranging in ratio from 10:90 to 90:10 will dissolve methyl, ethyl and benzyl celluloses. Other solvents used in combination with benzene are acetone, amyl acetate, benzyl alcohol, butyl acetate, carbon tetrachloride, ethyl alcohol, ethylene glycol, methyl alcohol and so forth.

Benzene is used in the manufacture of synthetic dyes and drugs, in photography, in electrotechnics, in artificial leather, linoleum and oil-cloth fabrication, in enriching gases, and as an antidetonant or knock suppressor. Large quantities of benzene are used as a solvent in varnishes, quick-drying asphalt and coal-tar coatings, and as a diluent in the lacquer industry, in airplane dopes and so forth. An even wider use of benzene is prohibited by its narcotic and toxic properties exhibited by totally destroying the leucocytes of the blood. Its use in spraying compounds calls for especially designed booths and exhaust equipment. Its further uses are as a substitute for acetylene in autogenous welding; in the purification of paraffin, waxes and resins; in the process of engraving, litho-

graphing and dry-cleaning; as a constituent part of prepared waxes, traffic paint, rubber cement, tire paint, special textile soaps and motor fuels; and as a preservative in sizings of starch and albumin. It is employed in film manufacture, electric insulation and molded and thermoplastic compounds; for its solvency, in penetrating stains; combined with alcohol, in spirit stains; and admixed with acetone, as a paint, varnish and finish remover. The addition of alcohol to benzene increases the solvency for gums, resins and cellulose ethers.

Toluene

Toluene ($C_6H_5CH_3$, M.W. 92.1, toluol, methyl benzene, phenyl methane) is a colorless mobile liquid of benzene-like odor. It was discovered by Pelletier in 1838, and three years later Sainte-Claire Deville prepared it by the distillation of Balsam of Tolu, whence its name. It is now obtained by the fractional distillation of coal-tar light oils and illuminating gas. Toluene is an important starting point in the manufacture of organic preparations such as intermediates, dyes, perfumes, drugs, explosives (T.N.T.) and so forth. As compared with benzene its vapors are less dangerously toxic, less inflammable, and it has a slower rate of evaporation. As compared with butyl acetate and *n*-butyl alcohol, toluene will evaporate twice as fast as the former and four times as fast as the latter. It is soluble in alcohol, benzene, ether and so forth. It is used to a large extent in the paint and varnish

TABLE 36.—Solubility of Various Dyes in Toluene[5]

Dye	Minimum cc. toluene to dissolve 0.5 gram Dye	Dye	Minimum cc. toluene to dissolve 0.5 gram Dye
Oil Maroon	5	Scarlet RR	15
Scarlet H	5	Naphthol Black	15
Indiana Red	5	Sudan III	16
Butter Yellow	5	Azo Turkey Red	16
Maroon I	5	Sudan R	16
Scarlet M	5	Sudan Brown	16
Chrome Fast Yellow	5	Xylidine Brown M	20
Sudan II	5	Maroon II	20
Sudan VII	5	Maroon III	20
Xylidine Red N	5	Oil Brown	25
Sudan I	6	Benzidine Puce	25
Walnut	6	Alizarin Scarlet	30
Rose	6	Sudan VII	30
Azo Coccine RR	6	Congo Red A	30
Oil Scarlet	7	Cloth Red BB	35
Spirit Yellow	7	Aniline Yellow G	35
Naphthol Brown	7	Cloth Red G	35
Xylidine Brown	7	*p*-Nitroaniline Red	40
Xylidine Red	10	Cardinal	40
Sudan VII	10	Alizarin Yellow GG	50
Sudan IX	10	Sudan G	50
Sudan X	10	Chrysamine G	75
Naphthol Brown II	15	Benzidine Puce A	95
Fast Brown O	15	*m*-Nitroaniline Orange	100
		Benzidine Brown	150 Inc.

industry and it is the most widely used hydrocarbon diluent in the lacquer trade. It is a very efficient solvent for gums, and resins such as benzyl abietate, copals, copal esters, cumar resins, glyptol resins, sandarac and so forth; and it will also dissolve most of the oils, some types of cellulose acetate and many types of cellulose ethers. The solvent power of toluene for cellulose derivatives is much improved by the addition of ethyl or methyl alcohol. It is extensively used as a diluent in cellulose ester lacquers and in combination with such active solvents as will both tolerate its presence and at the same time not impair its solvency. In its use and application in the industries it is similar to benzene.

Xylenes

Xylenes ($CH_3C_6H_4CH_3$, M.W. 106.08, dimethyl benzene, dimethyl benzol) are colorless mobile liquids existing as three isomeric forms in the light oil fraction of coal-tar distillates.

	ORTHO	META	PARA
Specific gravity	0.881	0 8668	0 861
Melting point	− 28° C.	− 54° C.	15° C.
Boiling point	144.2° C	139° C.	138° C.

Xylene is a toxic, inflammable and dangerous liquid but in a lesser degree than either benzene or toluene. The commercial grade is a mixture of the three isomers with the meta-compound predominating. Also present are small quantities of toluene, ethyl benzene, and pseudocumene (trimethyl benzene). The lower-boiling impurities, accordingly, reduce the boiling point while the higher ones retard evaporation. The rate of evaporation of xylene is similar to that of amyl acetate and as compared to benzene or toluene it has a slower rate of evaporation and somewhat

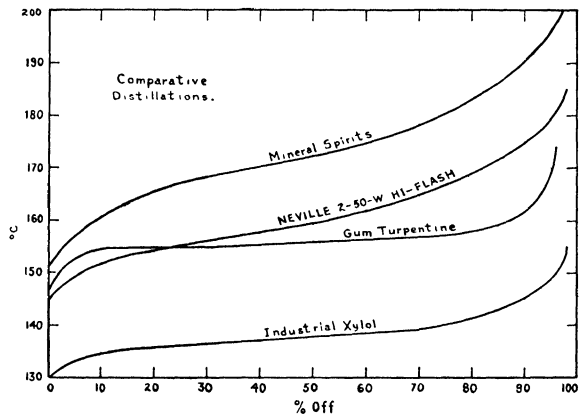


FIGURE 18. Effect of Temperature in Comparative Distillation of Various Solvents.[4]

lower solvent power. In other words, xylene exerts the same solvent action as does benzene or toluene only in a somewhat lesser degree. The solvent property of this homologous series is similar to that of other homologous series, in that, with an increase in molecular weight within the homologous groups, a corresponding decrease in solvency is apparent. Like lower members in this group, the addition of a lower aliphatic alcohol to xylene adds to its solvent power for cellulose esters and ethers. It is soluble in alcohol, ether, hydrocarbons and so forth, and is used in place of benzene or toluene wherever a slower rate of evaporation is desired. It is also used as a solvent for the higher oxidized alkyd resins, phenol-resin-wood oil varnishes, in microscopy, and as a starting point in organic synthesis.

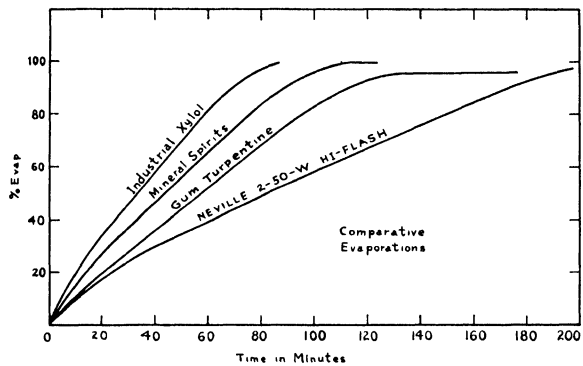


FIGURE 19. Evaporation Rate of Solvents in Fig. 18 at 25° C.

Substitutes

A number of petroleum solvents and diluents with narrow distillation ranges have recently appeared on the market. The following are a few of these:

Benzene substitute consists principally of heptanes and has a distillation range similar to that of 90 per cent benzene.

Specific gravity	0.720
Distillation range	86°–100° C.
Refractive index	1.39 at 20° C.
Flash-point	10° F.

Toluene substitute is composed largely of octanes and will dissolve bitumens and rubber.

Specific gravity	0.743
Distillation range	100°–140° C.
Refractive index	1.40 at 20° C.
Flash-point	30° F.

Xylene substitute has the following characteristics:

Specific gravity	0.760
Distillation range	130°–170° C.
Refractive index	1.41 at 20° C.
Flash-point	45° F.

Coal-Tar Naphtha

Naphtha is an old term referring to the volatile material of *bitumen liquidum candidum* of Pliny. This was a term used by the alchemists to imply volatile, mobile, inflammable liquids, and hence the term coal-tar naphtha refers to the volatile portion of coal-tar. Naphtha (solvent naphtha) appears on the market in several grades. The lighter fractions are composed of mixtures of toluene, xylene isomers, ethyl benzene and propyl benzene; and the heavier mixtures are made up of pseudocumene, isodurene, mesitylene, ethyl-*p*-xylene, hemimellithene, indene, durene, coumarone and naphthalene hydrocarbons.

The light grades have a boiling range of 110° to 160° C. and are solvents for natural and synthetic gums and resins, such as ester gum, copal ester, benzyl abietate and benzyl resins, oils, bitumen, rubber and many cellulose ethers. They are miscible with acetone, amyl alcohol, ethyl alcohol and hydrocarbons. Solvent naphtha has found wide application where strict specifications are not required. However, close-cut fractions whose boiling points are high have made an inroad as lacquer diluents of cellulose ethers and esters. The bulk of naphthas are used in coatings of coal-tar pitch, stearin pitch, petroleum pitch, asphalt and cold-cut East India gum. They are also used in flat varnishes, antifouling paints, synthetic coatings and in plastics and moldable masses. They are solvents for aluminum stearate for waterproofing, thinners in gold and aluminum bronzes, and are used in penetrating stains and in paint, varnish and finish removers. Their addition to phenol resins and Congo varnishes, and in similar mixtures, prevents skinning and gelling. Because of the properties of flood prevention and improved flow, naphtha makes a valuable adjunct to enamel liquids and baking Japans. Their presence in petroleum solvents adds to the solvency of the mixture. Solvent naphtha has been nitrated for the purpose of incorporation into dynamite compositions.

Heavy naphthas (crude heavy solvent naphtha) of commerce are sold as "refined" and "semi-refined" grades, of which there are a number of fractions. Their solvent power is the same as that of the light grades of naphthas but they differ in that their higher boiling points and lower rates of volatility make them unsuitable for lacquer compositions. The following is an approximate analysis of heavy solvent naphthas.

	per cent
Coumarone, indene, styrene, etc.	40
Hi-Flash naphtha components	40
Methyl naphthalene and naphthalene	20

The dark grades are used as solvents in dark-colored paints, bituminous paints and enamels and asphalt road-tars, and in saturating asbestos board, brake lining, fabric transmission felt, pipe coatings, shingle stains and ship-bottom paints. Hi-Flash naphtha is a solvent for oils and natural and synthetic resins such as ester gum, Bakelite resins, Neville resins, alkyd resins, glyptols, benzyl and other resins. This fraction of naphtha is also used as a slow-drying solvent and thinner in varnishes, paints, enamels, lacquers, coatings and in grinding vehicles. Its high boiling point, low rate of evaporation and greater solvent strength impart the desirable qualities of better flow, brushing, leveling, spraying and general working qualities. They also retard thickening and skinning, and reduce viscosity. Still other uses are in sterilizing sutures, in printing inks, shoe polishes, blacking and leather dressing, in oil-cloth and linoleum manufacture; and when admixed with alcohol, as a paint and varnish remover. The yellow Hi-Flash naphthas are used in coatings where off color and moderately pronounced odor are not objectionable. Some fractions of naphthas are especially designed as thinners for enamels which are to be applied to copperware, and in order to secure proper leveling and adhesion of the film at high-temperature baking. Other types are used in cleaning compositions, naphtha soaps, in the process of engraving and lithography and in rubber cement.

Hi-Flash naphtha has a higher distillation range than xylene or ordinary solvent naphtha. Analyses indicate its approximate composition:

	per cent
Ethyl benzene, xylenes, cumene, propyl benzene, and ethyl toluene	10
Trimethyl benzene	45
Tetramethyl benzene	40
Naphthalene	5

The refined Hi-Flash is a non-toxic liquid of mild odor and high solvent power. It is added to many petroleum thinners to fortify their solvency for natural and synthetic resins, and is used in ordinary enamels, house paints, flat wall and interior paints. It has about the same flash-point as turpentine but it differs by having a lower rate of evaporation. Pine oil, turpentine or essential oils are often added to this product to give it a fine odor. It is widely used in the field of alkyd resins.

Ethyl Benzene

Ethyl benzene ($C_6H_5C_2H_5$, M.W. 106.08, phenylethane) is a colorless liquid and is soluble in alcohol, ethers, hydrocarbons and so forth. Ethyl benzene has the same solvent power as, and some of the physical and chemical characteristics of xylene and, like it, is used as a solvent for synthetic resins and as a diluent in lacquers. It is also used in organic synthesis. Some have proposed its admixture with lower aliphatic alcohols or lower alkyl acetates as solvent-mixtures for cellulose ethers.

Boiling point	136° C.
Melting point	−94° C.
Specific gravity	0.867

Cumene

Cumene ($C_6H_5CH(CH_3)_2$, $PhCH(Me)_2$, M.W. 120.15, cumol, trimethyl benzol, isopropyl benzene) occurs as a mixture with pseudocumene and mesitylene in cumin oil. It is a colorless liquid, soluble in alcohol, ether and benzene. Cumene has a narrower distillation range than ordinary Hi-Flash naphtha and is used as a lacquer diluent, in organic synthesis and in sterilizing catgut.

Boiling point	153° C.
Specific gravity	0 862 at 20° C.

Styrol

Styrol ($C_6H_5CHCH_2$, $PhCHCH_2$, M.W. 104.06, styrolene, styrene, phenthylene, vinylbenzene, phenylethylene) is a highly refractive, colorless, aromatic liquid, soluble in alcohol, ether and so forth. It is used in organic synthesis and resin formation, and together with triphenyl phosphate as a plasticizing mixture for nitrocellulose to impart waterproofness.

Boiling point	145°–6° C.
Specific gravity	0.903 at $\frac{20° C.}{40° C.}$

Dibenzyl

Dibenzyl ($C_{14}H_{14}$, M.W. 182.11, bibenzyl) occurs in two forms; one is the asymmetrical form which is a colorless liquid ($MeCHPh_2$) with a boiling point of 209° C., and the other is the symmetrical form which is a white crystalline solid ($PhCH_2CH_2Ph$, diphenyl ethane) with the melting point at 52° C. and the boiling point at 284° C. These compounds are soluble in ether and chloroform and are advocated as solvents for nitrocellulose. The addition of acetone improves their solvency.

Coal-tar Creosote

Coal-tar creosote (creosote oil, liquid pitch oil) is an oily distillate, yellowish to dark green-brown in color, obtained from the high-boiling fractions of crude coal tar. Chemically, it is a mixture of cresols, oxycresols, methyl cresols and other phenols. In specific gravity, these range from 1.03 to 1.10 and distill between 200° and 400° C. They are soluble in alcohol, benzene, toluene, ether, chloroform, volatile oils and so forth. Heavy creosote is used as an absorbent in the recovery of light hydrocarbons from coal-gas.

Its disinfecting properties make it applicable as a preservative for piling, railroad ties and lumber used for the same purpose. It replaces the sap and renders the wood non-absorbent and inhibits germ life. Beechwood creosote is a colorless to yellow oil with a characteristic smoky odor. Its specific gravity is about 1.08 and it boils between 205° and 220° C. It is used as an antiseptic and local anesthetic. The light types of coal-tar creosote oil are used as shingle stain oil, in pipe coatings and in plastic

products formulated from coal-tar pitch. Their behavior is that of a penetrant, wood preservant, and water repellant. By heating with sulfur in the presence of an oxidizing gas, the solvent properties of this oil are increased for coal.

Terpenes

Cymene (M.W. 134.11, *p*-cymene, cymol, methyl-isopropyl benzene, *p*-cymol, 1-methyl-4-isopropyl benzene) is a pleasant-smelling liquid whose odor resembles parsley. It is present in both light resin oil and in spruce turpentine but it is commercially obtained as a by-product in the sulfite-pulp paper industry. It is known here as "spruce turpentine," "black liquor," and "sulfite turpentine."

Isopropyl Toluene Cymene (O), colorless liquid, $CH_3C_6H_4C_3H_7$

Specific gravity	0.858 (18° C.)	insoluble in water;
Melting point	– 182° C.	soluble in alcohol
Boiling point	175° C.	and ether

Isocymene Cymene (M), colorless liquid, $CH_3C_6H_4C_3H_7$

Specific gravity	0.862 (20° C.)	insoluble in water;
Melting point	– 25° C.	soluble in alcohol
Boiling point	175–6° C.	and ether

Cymene Cymene (P), colorless liquid, $CH_3C_6H_4C_3H_7$

Specific gravity	0.857 at $\frac{20° C.}{40° C.}$	insoluble in water;
Melting point	– 73 5° C.	soluble in alcohol
Boiling point	176–7° C.	and ether

Cymene is soluble in acetone, ethyl alcohol, ether, chloroform and most other solvents. It is an excellent solvent for oils, fats, resins, hydrocarbons and many other substances. When this substance is admixed with ethyl alcohol, acetone or *n*-butyl alcohol, the resulting mixture is

TABLE 37.—Solubility of Various Substances in *p*-Cymene

Substance	Grams in/100 cc.	Temp. (° C.)
Acetanilide	7.23	30
	1.72	30
	9.24	100
Anthracene	98.60	176
Antipyrine	2.09	30
	.76	30
Caffeine	15.58	175
deca-Camphoric acid	1.53	100
	2.93	23.5
	16.77	100
Hexachlorobenzene	106.95	176
Naphthalene	14.22	30
β-Naphthylamine	8.63	30
o-Nitroaniline	6.33	30
m-Nitroaniline	1.36	30
p-Nitroaniline	.83	25
Phloroglucinol	.12	175
Strychnine	.71	30

an excellent solvent for paint and varnish and will readily mix with many lacquer solvents. These mixtures are consequently recommended as paint and varnish removers. Para-cymene is the starting point for a number of synthetic products, and is used in metal polish and as a substitute for turpentine. Its high boiling point makes it applicable in such molecular weight determinations where elevated temperatures are required.

Dipentenes

Dipentene ($C_{10}H_{16}$, diamylene, cinene, dipentine, inactive limonene) is a colorless liquid of a pleasant and agreeable lemon-like odor. Commercially, it is obtained both by close fractionation of wood turpentine and as a by-product in synthetic camphor manufacture.

	Max.	Min.
Specific gravity (15.5° C.)	0.854	9.845
Refractive index (20° C.)	1.477	1.472
Residue after polymerization with 3.0 *N*. H_2SO_4	2.5%	
Initial boiling point		170° C.
90% Boiling at	182° C.	177° C.
Dry flask	188° C.	
Color	Water-white	

Dipentene is a strong solvent for oleoresinous products, rosin, ester gum, cumar and alkyd resins, waxes, metallic soap driers and so forth. This terpene is used as a dispersing agent for oils, resins, resin-oil combinations, pigments and driers. It also has the valuable qualities of retarding skinning and gelling and it imparts good flow. Its uniform rate of evaporation both retards initial hardening and exerts levelling action. It has further uses as a thinner for grinding varnishes, as a solvet in chinawood oil varnishes, and as a wetting and dispersing agent in other industries. By adding 15 to 25 per cent of dipentene to petroleum thinners the mixture becomes a solvent for the petroleum-insoluble resinous material.

Should the resinous material, on the other hand, be soluble in a petroleum thinner, the addition of 5 per cent dipentene will impart both excellent working qualities and a pleasant odor. An addition of 5 to 10 per cent dipentene is recommended for air-drying and baking finishes. It is further used to replace turpentine and petroleum solvents in floor waxes and furniture polish.

Solvenol

Solvenol is a refined form of dipentene. Like dipentene, it imparts gloss and adhesion to quick-drying enamels. It has properties similar to those of turpentine with the one difference of having a slower rate of evaporation. It will dissolve resins readily and is used as a solvent in paints and enamels. It is also used in the reclaiming and devulcanizing

of rubber, in textiles and in the synthetic resin industries. Solvenol has the following composition:

	per cent
Dipentene	55
Pinene, terpeneol, and fenchene	15–20
Paramenthane and cymene	5
Terpinolene	20–30

Properties of Solvenol

	Max.	Min.
Specific gravity (15.5° C.)	0.86	0.850
Refractive index (20° C.)	1.478	1.470
Unpolymerized residue	4.0%	.....
Initial boiling point	.....	165.0° C.
Moisture, less than	0.1%	.....
Color, Lovibond tintometer:		
amber	2.75	.....
red	0.75	.....
Odor	Distinctive pine	
Distillation 90%	190° C.	.....
Distillation 95%	200° C.	.....
End point	212° C.	.....
Flash-point, Cleveland open cup	.....	109° F.

TABLE 38.—Solubility Tests[6]

	Bakelite XR 254	Bakelite XR 352	Bakelite XR 302	Nevindene	Paranol Hard No 1	Paranol Ex. Hard No. 1	Amberol BS-1	Rezyl
	(cc of Varsol required to cause precipitation from 100 cc of a 50% solution)							
Solvenol No 1	Insol.	10	135	O K*	O. K.	O. K.	O K	O. K.
Dipentene No 122†	"	5	80	O. K	O. K.	O. K.	500	875
Hercosol No. 80	40	55	220	O K	O. K.	O. K.	O. K.	O. K.
Hercosol No. 80‡	140							
Varsol	Insol.	Insol.	25	O K.	O. K.	O. K.	250	875
Yarmor pine oil	87	150	350	—	- - -	—	300	O. K.
P. W. Turpentine	Insol.	Insol.	53	—	—	—	355	O. K
Pinene No. 111	"	"	57	—	—	—	375	O. K

*O. K. means a dilution with 1000 cc of Varsol without precipitation.
†Refined Dipentene contains Pinene, Terpinene, Terpinolene and Cymene.
‡Steam-distilled wood turpentine used as diluent.

TABLE 39.—Solubility of Synthetic Resins in Hercules Terpene Solvents[6]

Resin	Dipentene No. 122	S D. Wood Turpentine	Solvenol No. 1	Herco Pine Oil	Hercosol No. 80	Pinene No. 111	V M & P. Naphtha
Dulux (varnish type)	Sol.	Sol.	Sol.	Sol.	Sol.	Sol.	Partly sol.
Teglac	"	Partly sol.	"	"	"	Partly sol.	" "
Rezyl No. 11	"	Insol.	"	"	"	Insol.	Insol.
Rezyl No. 12	"	"	"	"	"	"	"
Rezyl No. 17	"	Sol.	"	"	"	Sol.	Partly sol.
Rezyl Balsam No. 33	"	Insol.	"	"	"	Insol.	Insol.
Rezyl Balsam No 53	"	Partly sol	"	"	"	Partly sol.	"
Mowilith-H	Insol.	Insol.	No data	No data	No data	No data	"
Mowilith-N	"	"	"	"	"	"	"
Mowilith-G	"	"	"	"	"	"	"
Kurthoff & Pickhardt Resin E-1	Sol.	Sol.	Sol.	Sol.	Sol.	Sol.	Partly sol.
Kurthoff & Pickhardt Resin 26-M	*Insol.	*Insol.	*Insol.	Sol.	Sol.	*Insol.	Insol.
Kopol No 9	Sol.	Sol.	Sol	"	"	Sol.	"
Bakelite XR-254	*Insol.	*Insol.	*Insol.	"	"	*Insol.	"
Bakelite XR-352	Sol.	*Insol.	Sol.	"	"	*Insol.	"
Bakelite XR-302	"	Sol.	"	"	"	Sol.	Sol.
Nevindene	"	"	"	"	"	"	"
Hard No. 1 Paranol	"	"	"	"	"	"	"
Extra-Hard No. 1 Paranol	"	"	"	"	"	"	"
Amberol BS-1	"	"	"	"	"	"	"
Lewisol No. 2	"	"	"	"	"	"	"

*Resin-drying oil combinations soluble in, and solutions capable of dilution with, petroleum thinners. Thinning tolerance of Solvenol No. 1 and Dipentene No. 122 considerably greater than that of Turpentine or Pinene.

TABLE 40A.—Solubility of Synthetic Resins[6]*

Solvent	Resin No. 1†	Resin No. 2	Resin No. 3	Resin No. 4	Resin No. 5	Resin No. 6	Resin No. 7	Resin No. 8	Resin No. 9
	(cc of Varsol required to cause precipitation)								
Hercules steam-distilled wood turpentine	30	O. K.	33	O. K.	15	12	6	1	19
Hercules dipentene No. 122	38	O K.	43	O. K.	26	16	10	3	23
Yarmor pine oil	115	O. K.	146	O. K.	106	45	38	18	53
Varsol	5	140	11	O. K.	7	3	1	Insol.	8

*These tests were made by dissolving 10 grams of resin in 10 grams of the solvent named and titrating with Varsol (petroleum thinner) until precipitation of the resin occurred. O. K. signifies no precipitation upon dilution to 4 per cent resin concentration.

TABLE 40B.—Solubility of Synthetic Resins[6]*

Solvent	Resin No. 5	Resin No. 6	Resin No. 7	Resin No. 8	Resin No. 9
	(cc. of solvent required to cause precipitation)				
Varsol	18	25	21	Insol.	29
Hercules steam-distilled wood turpentine	O. K.	48	28	26	92
Hercules dipentene No. 122	O. K.	150	63	39	O. K.
Yarmor pine oil	O. K.	O. K.	O. K.	O. K.	O. K.

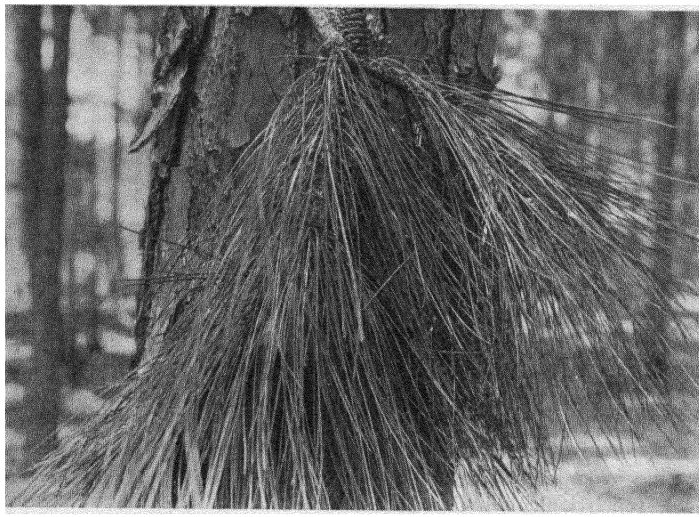
*These tests were made by titrating the resin directly with the solvents named.
†Resin No. 1 = Beckacite No. 1100
Resin No. 2 = Beckacite No. 1102
Resin No. 3 = Beckacite No. 1110
Resin No. 4 = Beckacite No. 1112
Resin No. 5 = Beckasol No. 1
Resin No 6 = No. 1301 P.X. Oil sol.
Resin No. 7 = No. 1304 = A. D.—Oil Solution
Resin No. 8 = No. 1308 = Beck-O-Lac Solution
Resin No. 9 = No. 1310 = A. D. Solution

Turpentines

Gum turpentine, gum spirits, spirit of turpentine, turpentine and oil of turpentine are names given to natural turpentine. This highly mobile, inflammable liquid is obtained by the steam distillation of oleoresins obtained from coniferous trees (pine tree family). Chemically, turpentine is composed of alpha and beta pinene, dipentene, terpinenes, borneol, fenchyl alcohol, limonene and traces of camphor. The natural turpentines have common physical properties which vary within reasonable limits; but their chemical constituents vary with the source of the oleoresin, the method of distillation and the degree of oxidation and polymerization which they have undergone. Spirit of turpentine is an excellent solvent for oils of all kinds, oleoresins, metallic soaps, blown oil, fossil gums and so forth, and is used in surface coatings as primers, flat paints, varnishes and enamels. Its presence imparts penetration to a solution of metallic soaps and to priming coats, and clarity to dammar varnishes. As a solvent turpentine is used in slack-melt varnishes, short-oil varnishes which are made from kauri, manila and so forth. The wetting qualities of turpentine are a desirable property in coating mixtures, thus finding application both in coatings where the pigments are required to be held in suspension and in grinding varnishes. It also imparts brilliancy, flowing qualities and good working properties.

Wood turpentine is made by the steam distillation of dead pine wood. Chemically it is a mixture of 85 per cent alpha pinene with the remaining portion consisting largely of dipentene. This larger amount of dipentene imparts better wetting qualities and greater solvent power than gum tur-

pentine. This predominance of alpha pinene gives it a narrower distillation range than that of the spirit of turpentine, although the rate of evaporation is about the same. For industrial use, however, these two products are interchangeable. Wood turpentine, made by the destructive distillation of pine tree stumps, is a rather crude grade of turpentine and contains more impurities. It is dark in color, stronger in odor and more powerful in solvent action. When this is refined it is used in cruder grades of paints, varnishes and enamels. It also finds use in stains and



Courtesy of Hercules Powder Co.

PLATE 4. Fronds of Long-leaf Pine.

asphalt paints. The wetting and penetrating power of turpentines carries the paint or varnish below the applied surface and in so doing binds it sufficiently to prevent its peeling off. Turpentine vapors will cause nausea, irritate the skin, and will corrode copper, iron and so forth.

"Even more varied, both in sources and in uses than the natural turpentines, are the artificial or synthetic and substituted substances. While these three types differ chemically, all have one important characteristic, namely, that of a common solvent power.

Unlike the substituted turpentines, the artificial or synthetic types have chemical properties somewhat similar to the natural products. Both the artificial and natural turpentines contain chemicals belonging to the terpene group. On the other hand, the substitute materials are entirely different chemically from both the natural and the synthetic. These substitutes are made from petroleum oils and contain their lighter fractions.

Any substance used in place of the natural turpentine whether it is artificial, synthetic or a substitute should have the following physical properties:

Colorless and lustreless or nearly so.
Solvent and thinning powers for varnish and paint equal turpentine.
Odorless or an odor that is not disagreeable.



Courtesy of Hercules Powder Co.

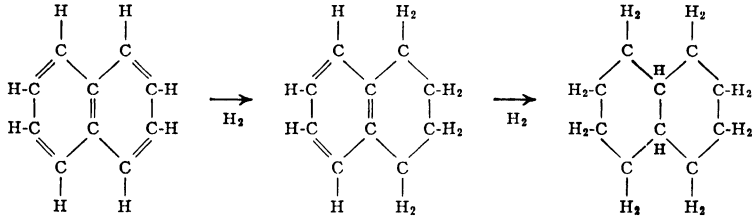
PLATE 5. Pine Stumps—the Raw Material.

Evaporation uniform and not too rapid. It must not begin to distill over 120° C. and the upper limit should not be over 180° C.
Evaporation residue not over 0.5 per cent.
Flash-point, 30° C. or above.
Specific gravity, 0.775 at 15.5° C.
Neutral in chemical reaction.
Clear and free of suspended matter.

"One general type of turpentine substitute is made by the hydrogenation of naphthalene, sold under such trade names as Tetralin and Dekalin. The former represents the partial hydrogenation and the latter the complete hydrogenation of naphthalene. These do not appear on the market as chemically pure products but contain lower or higher hydrogenated naphthalene.

U. S. Patent No. 1,483,739 claims the use of hydrogenated naphthalene with or without the addition of natural turpentine as a diluent in shoe polish.

"The petroleum fraction boiling between 150° C. and 170° C. consisting chiefly of nonanes and decanes is being sold as a turpentine substitute. Other mineral spirits of this same type are made by the special oxidation or distillation of petroleum, gas and tar oils. Some of the other products in this group of substitutes are benzine, benzene and its homologs, solvent naphtha, heavy benzol, and white spirits. British Patent 6643 (1913)



Naphthalene $C_{10}H_8$ — *Tetrahydronaphthalene* (*Tetralin*) — *Decahydronaphthalene* (*Dekalin*)

speaks of a turpentine substitute obtained by the oxidation of petroleum oil with picric acid. The resulting product is then subjected to distillation at a temperature between 200° and 250° C. Another process [British Patent 273,832 (1926)] treats olefinic material with ozone or ozonized air at about 35° C. below the boiling point of the material. The substance obtained is suitable as a turpentine or linseed oil substitute to be used in paint.

"Below is a list of the various key patents on turpentine substitutes made from a petroleum base.

French Patent 354,425. 60 parts of petroleum oil and 40 parts terebinthine are mixed and rectified over lime.

U. S. Patent 1,543,570. Refined petroleum is treated with calcium carbide and an alkali. Pine oil is added to the finished product.

British Patent 126,089 (1918). 100 parts of petroleum, 3 parts of soda, and 300 parts of water are distilled at 95° to 110° C.

U. S. Patent 1,572,902. An acidulated mixture of resin and naphtha is distilled.

British Patent 1927 (1911). A petroleum distillate.

French Patent 661,183 (1928). Benzine and sulfur chloride are mixed and agitated. Calcium chloride or an alkali or alkaline earth hypochloride may be added at the same time.

Danish Patent 2219 (1917). Petroleum is distilled with a suitable alkali or an alkaline salt. This method serves to separate out the heavy oils.

Chemical Abstracts, 1927, page 1,346. Distillation of light oils from Russian petroleum.

"Other products resembling turpentine which find their way into commercial channels are vegetable compounds similar to the terpenes. They are made by the oxidation, dehydration or special distillation of pine oil, rosin oil, pine needle oil, or other members of the terpene group of chemicals. Some are known as "wood turpentine," "sulfite turpentine,"

"Turpenteen," "Terpentix," "Pinex terpentinol," "Teropine," and "Sangojol." "Recovered turpentine" and "regenerated turpentine" are names applied to mixtures of terpenes, often having a peculiar camphor-like odor. These are used as synthetic turpentine and are obtained as by-product in the manufacture of bornyl chloride and artificial camphor. Superturpentine is a spirit of turpentine rectified below 160° C. This eliminates all constituents other than pinene. "Sangojol," sometimes known as crude Borneo naphtha, is a Borneo petroleum distillate containing cyclic hydrocarbons.

"Following are some of the basic patents on synthetic turpentine made from terpene chemicals indicating the character and sources of these materials:

U. S. Patent 1,572,766. Gum of pine, Canada balsam or Peruvian balsam is mixed with 1 to 5 per cent H_3PO_4 and distilled at 310° C.

British Patent 27,024 (1908). Pine oil, resin oil or resin spirit containing 1 per cent acetic acid are steam distilled.

French Patent 394,467 (1908). Pine oil containing 1 per cent acetic acid or resin acid is heated under 5 atmospheres of pressure in the presence of moist ozone. Then 65 per cent of slake lime is added and the mixture distilled.

U. S. Patent 1,463,122. Pine oil is fractionally distilled between the temperatures 225° C. and 350° C. In the process of distillation the vapors are subjected to the action of a catalyst such as cuprous chloride, cupric chloride, aluminum chloride, hydrochloric acid, or other metal chloride.

U. S. Patent 1,772,895. Pine oil is subjected to distillation in the presence of a contact catalyst (Fuller's earth) at a temperature of about 225° C. Instead of argillaceous earth such as Fuller's earth, silicious earth such as kieselguhr may be used. Activated carbon may be used.

Farben Ztg., **17**, 1069-7. Mixing colophony, light rosin oil, and a small amount of essential oils.

French Patent 400,180 (1908). Rosin oil is heated at 400° C. for 5 minutes in the presence of an alkali, then distilled with 0.5 per cent lye.

U. S. Patent 1,691,066. A mixture of pine oil and a halogen is subjected to slow steam distillation. The halogen may be iodine, chlorine or bromine. In addition to a turpentine substitute there is also formed borneol. The substitute has a specific gravity of 0.85 to 0.86, refractive index 1.475 to 1.477 at 20° C., initial boiling point 170° C., and 75 per cent will distill below 185° C.

Another substitute is made by distilling colophony at 270° C. in a vacuum.

U. S. Patent 1,593,030. 1,000 gallons of pine oil, and 50 pounds each of phosphoric acid (85%) and sulfuric acid (66° Bé.) are mixed and heated to 120° C. for two hours. Often this reaction water is drawn off from the bottom of the container. The acid in contact with pine oil is neutralized with soda ash. The altered pine oil is then fractionally distilled. In place of the above acids other dehydrating materials may be used such as zinc chloride, iron chloride and aluminum chloride. The physical properties of the resulting turpentine are as follows: specific gravity 0.8620 to 0.8640 at 15.5° C., refractive index 1.4668 to 1.4673 at 20.0° C., initial boiling point 150° to 154° C., 90 per cent will distill below 170° C., polymerization residue 2 to 3 per cent, flash-point 34 to 35° C., and water-white in color.

German Patent 3420. 100 pounds of colophony, 20 pounds of soda and 50 of water are boiled together, and then mixed with 250 pounds of water and 24 pounds of ammonia. The resulting product is a substitute for turpentine or linseed oil."[7]

Colledge [8] is of the opinion that destructively distilled wood turpentine is superior to all other terpenes for use in the paint and varnish industry. The following is a table of the comparative solvency of some paint and varnish dissolvents as measured by the Kauri-Butanol test.

Lakol	114.8
Turpentine	82.1
Dipentene	105.1
Pine oil	infinite
Gum turpentine	56
Steam distilled turpentine	58
Steam distilled dipentene	60
Steam distilled pine oil	infinite
Toluene	106.7
Xylene	88.2
Solvent naphtha	85.3
Mineral spirit	35.0

Fractions of distillate used in the paint, varnish and lacquer industry are shown in Table 41.

TABLE 41.—Turpentines

	Specific Gravity at 15.5° C.	Optical Rotation	Refractive Index at 20° C.	Boiling Point (° C.)
American turpentine from crude gum of medium quality	0.8670 (20° C.)	− 18.8	1.4690	155.0
American turpentine from crude gum of poor quality	0.8695 (20° C.)	− 21.6	1.4735	155.5
Newport steam-distilled wood turpentine	0.860–0.864		1.4660–1.4675	154.0
Hercules steam-distilled wood turpentine	0.860–0.866		1.465–1.469	150–158
Aleppe pine oil spirits	0.8543–0.8568	+ 46.90–46.6	1.4638–1.464	155–158
Algerian turpentine	0.8543–0.8546	+ 46.2–46.8	1.4636–1.4638	155–156
Austrian turpentine	0.863–0.870	− 36° 30′ to − 39° 10′	1.46905–1.47033	
French turpentine from crude gum of medium quality	0.8700	− 34.1	1.4714	154.8
French turpentine from crude gum of poor quality	0.8730	− 34.2	1.4725	154.8
Greek turpentine	0.8605–0.8660	+ 34–41	1.465–1.474	
Russian turpentine	0.862–0.872	+ 3° to 20°	1.470–1.475	156–171
Sicilian turpentine	0.856–0.863	+ 25°	1.4464–1.4681	
Spanish turpentine	0.865–0.875	− 29 to − 23	1.4805	155–156
Venetian turpentine	0.865–0.878	− 8° 15′ to − 11°	1.46924	



Courtesy of Hercules Powder Co.

PLATE 6. Half a Day's Wood Supply at Brunswick Plant.

Pine Oils

Pine oils are obtained by the distillation of the cones and needles of the various species of pines. These oils are also obtained from the stumps of the long-leaf, yellow pine trees. Steam-distilled pine oils are obtained by the extraction of chipped stumps by means of hot steam and solvents. The destructively-distilled stumps of pine trees yield a pine oil that is known as destructively-distilled pine oil. Pine oil is a powerful solvent for both natural and synthetic gums and resins, oils and many of the cellulose ethers. This oil is miscible with most of the lacquer solvents and is used as an emulsifying agent, solvent, deodorant, germicide and

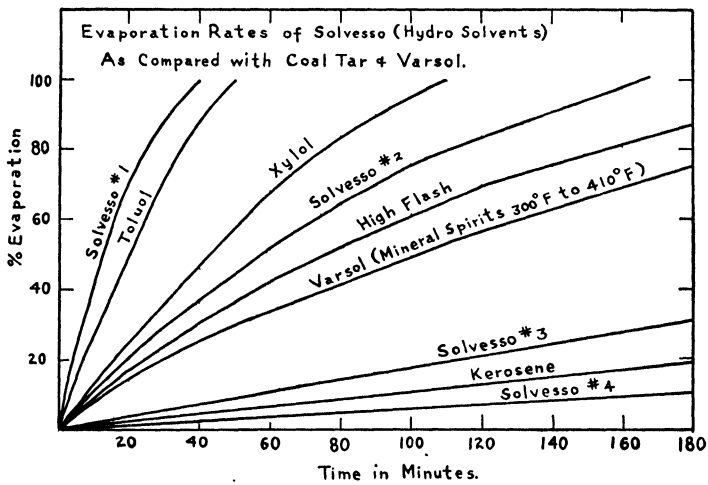


FIGURE 20. Evaporation Rate of Solvesso (Hydrosolvents) as Compared with those of Coal Tar and Varsol.° Room Temperature.

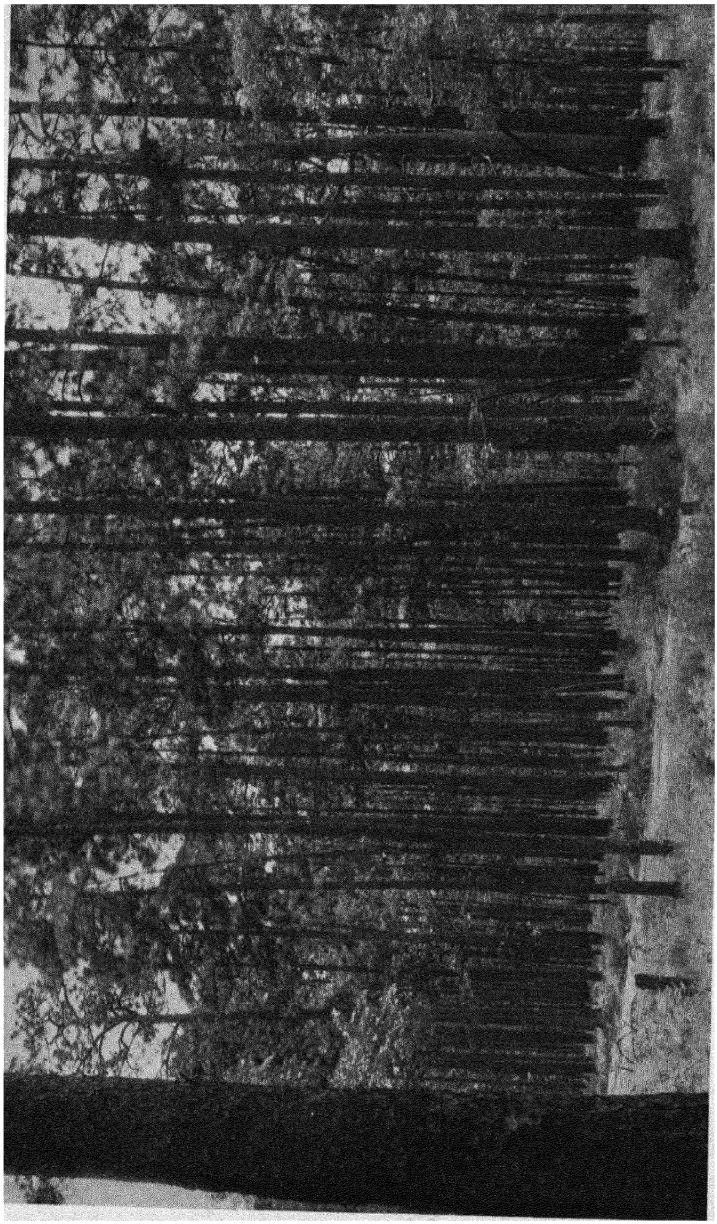
insecticide; as a source of terpineol, terpene hydrate and fenchyl alcohol; and as a denaturant for alcohol. The ore flotation process requires large quantities of pine oil. In dilutions of 1 part in 150,000, it exerts an affinity for the greasy sulfide particles in a mixture of crushed ore and water. It is also used in the separation of metals in the gangue; and because of its powerful emulsifying action it is made a contituent part of metal polishes, cutting oils, liquid soaps and other types of grease, oil and fat-containing emulsions. Pine oil soap is composed approximately of 75 per cent soap (50% soap and 50% water) and 25 per cent pine oil. It is transparent and an excellent emulsifying agent for vegetable and mineral oils. These soaps prohibit the formation of scums and are therefore widely used in laundries, dry-cleaning and in textile processing. It is used in paints and varnishes for its piny odor, solvency, penetration, wetting qualities and so forth.



Courtesy of Hercules Powder Co.

PLATE 7. Shredded Pine Chips Ready for Extractor.

Pine oil is used both in air dried and baked finishes to the extent of 2 per cent in the former and not more than 5 per cent in the latter. In varnishes of the phenol-resin type, the presence of pine oil prevents precipitation, gelling and skinning. Its use is recommended in paints and varnishes owing to its ability to impart wetting, penetrating and good working qualities. Pine oil facilitates easier grinding and holds pigments in suspension. It has further application in ship-bottom and asphalt paints, in fungicides, in prepared waxes, and as an emulsant in dispersing metal soaps.



Courtesy of Hercules Powder Co

PLATE 8. A Pine Forest in the South.

Pine oil is of exceptional merit in the processing of cotton goods, woolens, worsteds, rayons and silks. Cotton can be washed beautifully white with a pine oil soap. Pine oil is an efficient wetting and penetrating agent, qualities which are both exhibited by thorough and rapid removal of dirt and waxy materials, and excellently displayed in dyeing cotton where a level dyeing of good depth is achieved. Its presence also facilitates the washing out of any excess dye. Its dispersing, detergent and neutral properties make it particularly useful in soaps, as a rayon boil-off agent, as a scouring agent for wool, and for degumming silk. The making of pine oil fulling soap is another of its many uses.

Although pine oil is non-toxic and non-caustic, it exhibits disinfectant and insecticidal properties. The following formula attests

	per cent
Pine oil	62½
Rosin soap and water	37½

to a phenol coefficient of 5 (*B. typhosus*—modified Riedeal-Walker test). It has been proved that when pine oil is used in the proper dilution it will kill many of the pathogenic organisms and will repel many insects. Smyth and Smyth [10] have indicated that pine oil has definitely valuable fungicidal action against organisms causing ringworm. Pine oil has been converted into mixtures of terpene hydrocarbons and ketones of lower specific gravity and volatility, which evaporate more rapidly and are less hygroscopic. These new close-cut, lower-boiling fractions are making inroads as solvents for gums and resins such as copal and dammar, ester gum, kauri, manila, metallic soaps, cellulose ethers, and so forth. Further uses are in dipping and brushing lacquers, in reclaiming of rubber, in

TABLE 42A.—Constituents of Pure Steam-Distilled Pine Oil

Terpene Hydrocarbons	Boiling Point (° C.)	Specific Gravty (15.5° C.)	Index of Refraction (20° C.)
α-Pinene	155	.863	1.4664
β-Pinene	166	.865	1.4755
Dipentene	176	.848	1.4719
Limonene	175	.850	1.4746
T-terpinene	178	.848	1.4765
Terpinolene	186	.858	1.4800
Camphene	160	.850	1.4555*
Hydroxy Hydrocarbons			
α-Terpineol	218	.938	1.4827
β-Terpineol	209	.923	1.4747
Fenchyl alcohol	201	.952	Solid
Borneol	212	1.011	Solid
Oxide Hydrocarbons			
Cineol	176	.930	1.4568
Methyl chavicol	216	.971	1.5219
Ketone Hydrocarbon			
Camphor	204	.987	Solid

*Specific gravity and index both at 48° C.

TABLE 42B.—Properties of Steam-Distilled Pine Oil

	Yarmor	Floto	Herco
Specific gravity at 15.5° C.	0.933–0.938	0.905–0.910	0.930–0.940
Refractive index at 20° C., not under	1.479	1.475	1.479
Unpolymerized residue, not over	4%	10%	3.5%
Distillation (typical):			
Distilling below 201° C.	5%	5%	5.0%
Distilling below 228° C.	95%	95%	90.0%
Moisture, not over	1.6%		0.2%
Viscosity, Saybolt, 100° F., close to	47.5	37.5	
Color	Light straw	Dark Straw	yellow 2.0 red .5
Odor	Characteristic Pine		Characteristic Pine
Average weight of a gallon	7.78 lbs.	7.56 lbs.	
Flash-point, Abel closed cup, not under			60° C.

quick-drying and baking enamels, in alkyd resin varnishes, and as wetting agents in grinding liquids. When mixed with alcohols their solvency is very much improved. Solvent mixtures which contain these pine products improve gloss, flow, leveling and wetting properties, and prevent blushing, skinning and rapid surface drying. They are mutual solvents for linseed oil, turpentine, oil varnishes, nitrocellulose lacquers and spirit varnishes. Two of these fractions, known as Hercosol and Solvenol, are manufactured by Hercules Powder Company.

Rosin Spirit

Rosin spirit (pinolin) is the volatile fraction obtained from the distillation of rosin. It is a straw-colored mobile liquid with a strong and penetrating odor. It is a variable mixture containing terpenes of the type $C_{10}H_6$ of which one fraction boils between 154° C. and 157° C. and a second boils between 171° and 173° C. Other constituents are heptene C_7H_{12} (toluene tetrahydride, B.P. 103°-105° C.), amylene, hexylene, xylene, cumene, isobutyric acid, valeric acid and aldehydes. Rosin spirit is a very good solvent for resins and is therefore used to some extent in paints.

Boiling point	150°–300° C.
Refractive index	1.48–1.50
Specific gravity	0.890–0.930
Boiling range	25% between 150°–200° C. 20% between 200°–250° C. 50% between 250°–300° C.

HYDROGENATED ALIPHATIC AND AROMATIC COMPOUNDS

Hydrogenated naphthas are manufactured by the Standard Oil Company of New Jersey. Their work upon these compounds points out that physical properties are changed by hydrogenation. For example, by hydrogenation, the Kauri butanol values and the dimethyl sulfate values and their dilution rates are increased. The same process, on the other hand, will decrease the aniline point. These hydrogenated naphthas are excellent solvents for resins, especially those of the synthetic type. It is

important to note that their solvency is in direct relation to the boiling range; thus, the higher the boiling range, the higher is the solvent power. It means that lighter fractions have a lower solvent power than the higher ones, and consequently in actual application the residual hydrogenated naphthas have greater solvent power.

TABLE 43.—Inspection of Solvesso, etc.[9]

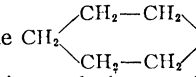
Solvesso	Gravity A.P.I.	Sp. Gr. 60/60 °F.	Aniline Point (°F.)*	Flash °F. Tag Closed Tester	Dimethyl Sulfate Value %	Dilution Ratio	Gum Kauri butanol value	A.S.T.M. Distillation Init. (°F.)	A.S.T.M. Distillation Final (°F.)
Hydrogenated Naphthas									
No. 1 (200–275° F.)	46.1	.797	52	60‡	32.5	1.9	55.2	200	275
No. 2 (275–365° F.)	34.0	.855	– 1	61	62.0	2.8	75.6	275	365
No. 3 (365–419° F.)	26.2	.897	– 10	135	87.0	2.6	77.3†	365	420
No. 4 (419–460° F.)	19.6	.937	– 33	190	100.0	2.4	85.7†	420	540
Coal-Tar Solvents, Commercial Grade									
(1) Toluene	32.0	.865	– 70	50‡	100.0	2.7	90.1†	220	260
(2) High-Flash C.T. naphtha	32.0	.865	– 20	93	100.0	2.5	72.6†	294	390

*All aniline points below 21.2° F. extrapolated from values of three blends in a high aniline point burning-oil.
†Kauris calculated from 50/50 blend of solvent in Kahlbaum benzine of 31 5 Kauri butanol value. Color, Doctor Test, Corrosion, Sulfur for all Solvesso fractions pass standard tests.
‡Less than.

The hydrogenated petroleum solvents have increased solvent power and are used as solvents in protective coatings like alkyd resin finishes, phenol-resin varnishes, short-oil fossil-gum varnishes, peat paints, primers and dipping enamels. Their presence in these preparations prevents skinning and gelling.

Constant minimum boiling mixtures are formed with methanol, ethylene bromide, methyl formate, ethyl alcohol, acetone, ethyl formate, methyl acetate, isopropyl alcohol, methyl ethyl ketone, ter-butyl alcohol and ethyl ether.

Cyclohexane

Cyclohexane  (M.W. 84.09, hexamethylene, hexahydrobenzene) is a colorless, mobile liquid of pungent odor. It is made by the catalytic hydrogenation of benzene and is also found as a constituent part of crude petroleum.

It is a good solvent for oils, fats, waxes, bitumens, resins, and crude rubber. Also, it will hold 9 per cent carnauba wax, or 20 per cent paraffin, or 15 per cent pale crepe rubber in solution. It is used for the extraction of essential oils, and for recrystallization purposes in the chemical industry. It is an efficient paint and varnish remover (see page 122).

Specific gravity	0.779
Refractive index	1.4263
Boiling point	80.7° C.
Freezing point	6.3° C.

TABLE 44.—Hydrocarbons

Hydrocarbon	Formula	Molecular Weight	Physical State	Specific Gravity	Boiling Point Melting Point (°C)	Aniline Equivalent
Methane Series: Normal Paraffins						
Methane (methylhydride, Me H)	CH_4	16.03	gas	0.7168 g/l.	M −184 B −161 6	
Ethane (ethylhydride, Et H)	C_2H_6	30.05	gas	1.357 g/l.	B −88 3 M −172	
Propane (Propylhydride, Pr H)	C_3H_8	44 1	gas	2 014 g/l.	B −44.5 M −189.9	
Butane (butylhydride, Bu H)	C_4H_{10}	58.1	gas		B +0 3 M −139.0	
Isobutane	C_4H_{10}	58 08			B −12.2	
Pentane (amylhydride)	C_5H_{12}	72 09	colorless liquid	0 634	B 36 2 M −129.7	1
Hexane (hexylhydride)	C_6H_{14}	86 11	colorless liquid	0.658	M −94 3 B 69.0	−6
Heptane (heptylhydride)	C_7H_{16}	100 12	colorless liquid	0 687	B 98 4 M −90 5	−14
Octane (octylhydride)	C_8H_{18}	114 14	colorless liquid	0.706	M −56 5 B 125	
Nonane (nonylhydride)	C_9H_{20}	128 16	colorless liquid	0 722	M −51 B 150.7	
Decane (decylhydride)	$C_{10}H_{22}$	142.17	colorless liquid	0.751	M −30 B 174	
Undecane	$C_{11}H_{24}$	156.2	colorless liquid	0.745	M −26 5 B 195.8	
Dodecane	$C_{12}H_{26}$	170 2	colorless liquid	0.772	M −12 B 214 5	
Tridecane	$C_{13}H_{28}$	184.22	colorless liquid	0.761	M −6.2 B 234	
Tetradecane	$C_{14}H_{30}$	198 23	colorless liquid	0.769	M 5.5 B 253	
Pentadecane	$C_{15}H_{32}$	212.3	colorless liquid	0.776	M 10 B 270 5	
Hexadecane	$C_{16}H_{34}$	226.3	colorless liquid	0 779	M 18 B 287.5	
Heptadecane	$C_{17}H_{36}$	240 3	solid	0.778	M 22.5 B 303	
Octadecane	$C_{18}H_{38}$	254 3	colorless liquid	0.7668	M 30 B 317	
Nonadecane	$C_{19}H_{40}$	268 31	solid	0.777	M 32 B 330	
Eicosane	$C_{20}H_{42}$	282 33	solid	0.794	M 36.4 B 205	
Tetracosane	$C_{24}H_{50}$	338 4	crystals	0 805	M 51.5 B 324 1	
Heptacosane	$C_{27}H_{56}$	380 44	crystals	0 804	M 59.5 B 270	
Dotriacontane	$C_{32}H_{66}$	451 0	crystals	0 823	M 70 B 310	
Hexatriacontane	$C_{36}H_{74}$	507 0		0.797		
Branched Paraffins						
2-Methylbutane	C_5H_{12}	72.1	colorless liquid	0.621	M −160.5 B 28	
3-Methylpentane	C_6H_{14}	86.1	colorless liquid	0 673	B 64.0	
4-Methylheptane	C_8H_{18}	114 14	colorless liquid	0.722	B 118	
2-Methylhexane	C_7H_{16}	100.12	colorless liquid	0.6789	B 90 0 M −119.1	
4-Ethylheptane	C_7H_{16}	100 12	colorless liquid	0.741	B 139	
3-Ethylpentane	C_7H_{16}	100.12	colorless liquid	0 6984	M −118.8 B 93.3	4
2,2-Dimethylpentane	C_7H_{16}	100.12	colorless liquid	0.673	B 79 M −125.0	
3,3-Dimethylpentane	C_7H_{16}	100.12	colorless liquid	0.688	B 86.0	
2,4-Dimethylpentane	C_7H_{16}	100.12	colorless liquid	0.6745	B 81 M −123.4	8
3,3-Dimethylpentane	C_7H_{16}	100.12	colorless liquid	0.6934	M −134.9 B 86.0	
2,2,3-Trimethylbutane	C_7H_{16}	100.12	colorless liquid	0.691	M −25.4 B 81.0	19
Isooctane	C_8H_{18}	114.14	colorless liquid	0.704	B 116.0	

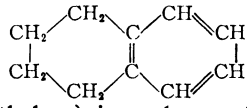
TABLE 44.—Hydrocarbons—(*Continued*)

Hydrocarbon	Formula	Molecular Weight	Physical State	Specific Gravity	Boiling Point Melting Point (°C)	Aniline Equivalent
2,2,4-Trimethylpentane	C_8H_{18}	114.14	colorless liquid	0.7213	M −107.8 B 110.7	16
Hexamethylethane	C_8H_{18}	114.14			M 104 B 106.8	
4-Ethylheptane	C_9H_{20}	128 0	colorless liquid	0.746	B 139	
2-Methylnonane	$C_{10}H_{22}$	142.0		0.743		
		Ethane Series: Aliphatic Olefins				
Ethylene (ethene)	C_2H_4	28.04	gas	1.245 g/l.	M 169.4 B −103.9	
Propylene (propene)	C_3H_6	42.1	gas	1.937 g/l.	M −185.2 B −47.0	
Butylene (butene)	C_4H_8	56.06	gas		M −130 B −5.0	
Amylene (pentene)	C_5H_{10}	70.11	colorless liquid	0.645-4	M −138 B 40	
Trimethylethylene	C_5H_{10}	70.11		0.668	B 38.4 M −124	
Hexylene (hexene)	C_6H_{12}	84.1	colorless liquid	0.683	M −98 B 68	
Heptylene (heptene)	C_7H_{14}	98 2	colorless liquid	0.703	M −10 B 98	
Octylene (octene)	C_8H_{16}	112.17	colorless liquid	0.7217	M 104 B 123	
Diisobutylene	C_8H_{16}	112.17		0.715	B 102.6 M −101.0	
Nonylene (nonene)	C_9H_{18}	126.15	colorless liquid	0.7433	B 149.9	
Decylene (decene)	$C_{10}H_{20}$	140.16	colorless liquid	0.763	M −87 B 172	
2,4-Hexadiene	C_6H_{10}	82.08	colorless liquid	0.718	B 82	29
Dipropargyl	C_6H_6	78.05	colorless liquid	0.805	B 85 M −6.0	
n-Amylacetylene	C_7H_{12}	96.09	colorless liquid	0.7288	M −70.0 B 110 5	
α-Hexadecylene				0.789	B 274	
		Cyclic Olefins				
Cyclobutene	C_4H_6	54 1	gas	0.733	B 2.0	
Cyclopentene	C_5H_8	68.1	colorless liquid	0.772	M −93.3 B 44 0	16
Cyclohexene	C_6H_{10}	82 1	colorless liquid	0.8102	M −103.7 B 83	10
		Cyclic Paraffins				
Cyclopropane	C_3H_6	42.05	colorless liquid	0.72–79	M −126.6 B −34.4	
Cyclobutane	C_4H_8	56.1	gas or liquid	0.703	M −50.0 B 13.0	
Cyclopentane	C_5H_{10}	70.1	colorless liquid	0.756	M −93.3 B 50.5	14
Cyclohexane	C_6H_{12}	84.1	colorless liquid	0.779	M 6 5 B 81.4	7
Methylcyclopentane	C_6H_{12}	84 0		0.750	M −143.0	4
1,2-Dimethylcyclopentane	C_7H_{14}	98.0			M −119.0	
Methylcyclohexane	C_7H_{14}	98.11	colorless liquid	0.769	B 100 3 M −126.9	
Ethylcyclopentane	C_7H_{14}			0 766		1
Cycloheptane	C_7H_{14}	98.1	colorless liquid	0.809	M −12 B 118.1	−6
Methylcyclohexane	C_7H_{14}	98.1	colorless liquid	0 776	M −126 4 B 100.3	
Cyclooctane	C_8H_{16}	112.0	colorless liquid	0.835	M −9.5 B 148	
1,2-Dimethylcyclohexane	C_8H_{16}	112.1	colorless liquid	0.792	M −85 B 121	6
1,3-Dimethylcyclohexane	C_8H_{16}	112.1	colorless liquid	0.776	M −85 B 121	4
1,4-Dimethylcyclohexane	C_8H_{16}	112.1	colorless liquid	0.777	M −86 B 120.5	6
Ethylcyclohexane	C_8H_{16}	112		0.782		
Cyclononane	C_9H_{18}	126.2	colorless liquid	0.769	B 170	
1,2,3-Trimethylcyclohexane	C_9H_{18}	126.1	colorless liquid	0.779	B −136	

TABLE 44.—Hydrocarbons—(*Continued*)

Hydrocarbon	Formula	Molecular Weight	Physical State	Specific Gravity	Boiling Point Melting Point (°C)	Aniline Equivalent
			Aromatics			
Benzene	C_6H_6	78 05	colorless liquid	0.879	M 5.48 B 80.1	10
Toluene	C_7H_8	92.1	colorless liquid	0.871	M −95 1 B 111 0	15
o-Xylene	C_8H_{10}	106.12	colorless liquid	0.881	M −28 B 144.2	17
m-Xylene	C_8H_{10}	106.12	colorless liquid	0.866	M −53 5 B 139	23
p-Xylene	C_8H_{10}	106.12	crystal	0.861	M 13 2 B 135	26
Ethylbenzene	C_8H_{10}	106.1	colorless liquid	0 867	M −93 9 B 136.2	19
Pseudocumene	C_9H_{12}	120.14	liquid	0 879	M −57.4 B 170	20
Naphthalene	$C_{10}H_8$	128.1	solid	1 145	B 218 M 80.2	
Camphene	$C_{10}H_{12}$	136.12	solid	0.879	M 51 B 160	
Durene	$C_{10}H_{14}$	134.11	solid	0.838	M 79.3 B 193	
Isodurene	$C_{10}H_{14}$	134.11	liquid	0.896	M −24.0 B 197	
Prehnitene	$C_{10}H_{14}$	134.11		0.901	B 204 M −7.7	
p-Cymene	$C_{10}H_{14}$	134.11	colorless liquid	0.857	B 176 M −73 5	27
n-Butylbenzene	$C_{10}H_{14}$	134.11	colorless liquid	0.862	M −88.5 B 180	20
tert-Butylbenzene	$C_{10}H_{14}$	134 11	colorless liquid	0.867	M −58.1 B 168.7	25
β-Methylnaphthalene	$C_{11}H_{10}$	142.1	solid	1.029	M 35.1 B 245	
Diphenyl	$C_{12}H_{10}$	154.1	solid	1.180	M 68.6 B 254	
Hexamethylbenzene	$C_{12}H_{18}$	162.14	solid		M 165.5 B 265	
Diphenylmethane	$C_{13}H_{12}$	168.1	solid	1.001	M 25.2 B 264.7	
Anthracene	$C_{14}H_{10}$	178.1		1.25	B 354 M 216.5	
α-Methylanthracene	$C_{15}H_{12}$	192.1	solid	1.101	M 86 B 200	
Phenanthrene	$C_{14}H_{10}$	178.1	solid	1.025	M 96.3 B 340 2	
Tolane	$C_{14}H_{10}$	178.1	solid		M 60 B 300	
Stilbene	$C_{14}H_{12}$	180.1	solid	1.164	M 124 B 307	
Dibenzyl	$C_{14}H_{14}$	182.1	solid	0.984	M 52 5 B 284	

Tetrahydronaphthalene

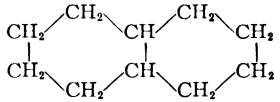
Tetrahydronaphthalene  (M.W. 132.1, Tetralin, 1,2,3,4-tetrahydronaphthalene) is a clear, colorless, pungent liquid made by the catalytic hydrogenation of naphthalene. One ring of this compound is completely hydrogenated while the other is unchanged. This liquid is a powerful solvent for waxes, oleoresins, gums, oils, resins (cumar resin, rosin, mastic, alkyd resins and so forth), rubber, resinates, naphthalene, cellulose ethers, linoxyn, asphalt and so forth. It is fairly stable but will, however, polymerize and oxidize giving rise to discoloration and resinous material. Whether it is toxic or non-toxic, reports are at variance in their decision. The fact that it is a powerful solvent seems to decide in favor of its toxicity since the vapor, when inhaled, cannot help

but affect tissue. It is miscible with most solvents, especially the resinous and petroleum thinners, and is compatible with natural and synthetic vehicles. It is employed as a solvent and thinner in the paint and varnish industry, as a solvent for asphalt in making bituminous emulsions, for tung oil, for liquid driers in surface coatings and for metallic soaps in waterproofing. Tetrahydronaphthalene has a tendency to react with manganese soaps and therewith to form dark-colored compounds. It is further used for removing inks from paper, and for printing type. A printing ink has been proposed which consists of tetrahydronaphthalene with its solvency fortified by the addition of butyl alcohol, toluene and methyl ethyl glycol. This mixture will dissolve cellulose ethers, dyes, pigments and so forth. Tetralin is also used as a turpentine substitute, in purifying gas, in motor fuels, and in paint and varnish removers. Its high solvent power for oils, greases and waxes, and its detergent properties make it very suitable for use in the textile industry. It is used in combination with textile soaps and oils in such processes as open scouring and kier boiling of cotton, piece goods, wetting and cleaning prior to dyeing, removal of oil from rayon and yarn, and the scouring of fabricated silk and wool. The disinfectant and spreading properties of Tetralin are utilized in agricultural sprays.

Tetrahydronaphthalene has the power to absorb large quantities of naphthalene and gums and is used as a solvent medium in the scrubbers for the removal of impurities in gas. Its presence in gas will gradually dissolve and remove deposits of naphthalene in the pipes and will prevent corrosive action. Tetralin has also been recommended both to remove casinghead gasoline from natural gas, and to remove benzene, toluene and naphthalene from coal gas. Further, it is used in shoe creams and floor waxes.

Specific gravity	0.975 (150° C.)
Refractive index	1.540–1.547
Boiling point	206° C.
Flash-point	80° C.
Freezing point	– 25° C.
Color	Water-white
Moisture content	none
Residue on evaporation	none
Solubility in water	insoluble
Acidity	neutral

Decahydronaphthalene

Decahydronaphthalene  (M.W., 138.14, Decalin, Kelalin, bicyclo 0,4,4,-decane) is a clear, colorless liquid considered as non-toxic. It is produced by the complete catalytic hydrogenation of naphthalene.

It is not as powerful a solvent as tetrahydronaphthalene, however, but it is a good solvent for oils, fats, waxes, rubber, resins (like dammar,

mastic, manila), oleoresins, alkyd resins and so forth. Decalin is miscible with most of the organic solvents and is used in the preparation of shoe creams and floor waxes. It imparts to these preparations a better and greater spreading power and softens the consistency of the paste. This solvent has also found application as a turpentine substitute, as a stain remover, and as a constituent part in cleaning fluids, lubricating oils and perfumery. The uses of Decalin are similar to those of Tetralin. When these two hydrogenated solvents are mixed, the solvency of the mixture is more powerful than that of either of its components.

Carbon Disulfide*

Carbon disulfide (CS_2) is a water-white refractive, highly inflammable, toxic liquid of disagreeable odor. It is miscible with alcohols, ketones, ethers, and halogenated hydrocarbons. It is used in organic synthesis, in manufacture of viscose, in cold vulcanization and as a fumigant.

Molecular weight	76.13
Specific gravity	1.263 (25° C.)
Color	Water-white
Odor	pungent-characteristic
Boiling point	46.3° C.
Freezing point	−111.6° C.
Flash-point	−25.5 to −20° C.
Solubility in water	
at 0° C.	0.242%
at 10° C.	0.230
at 20° C.	0.210
at 30° C.	0.185
at 40° C.	0.111

* Although carbon disulfide is not a hydrocarbon compound it is included here for purposes of convenience.

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General Naval Stores, New York, N. Y.
Hercules Powder Company, Wilmington, Del.
Howards and Sons, Ltd., London, England.

Chapter 9

Halogenated Hydrocarbons

Aliphatic

The introduction and use of halogenated aliphatic and aromatic hydrocarbons has helped to relieve all industries of the dreaded fire hazard. These compounds have consequently found natural application in paint and varnish manufacture, in dry-cleaning and in extraction processes. The property of low or non-inflammability of these hydrocarbons is utilized in raising the flash-point of highly volatile solvents by admixture with them. The alkyl and aryl halides usually have a low heat of vaporization and narrow distillation range which accounts for rapid and complete evaporation. These compounds are miscible with most organic solvents and are equally good solvents for oils, fats, resins, waxes, asphalt, rubber, gutta percha and sulfur. They are also efficient wetting agents. Their specific gravities range from 1.68 to 2.97. These high densities are of advantage in that they are used to keep bronze powder and heavy pigments in suspension, and at the same time are a decided disadvantage because the compounds are purchased by weight and sold by volume. The chlorinated hydrocarbons are fairly stable, although there are some that have a tendency to hydrolyze in the presence of moisture, air, heat or light. They are strongly anesthetic and some of them are toxic, which singles out their most prominent fault.

Dichlormethane

Dichlormethane (CH_2Cl_2, methylene dichloride, methylene chloride) is a colorless, highly volatile liquid of ethereal odor with an anesthetic action. It is made by the chlorination of methane and frequently contains traces of methyl chloride and chloroform. Dichlormethane is a solvent for alkaloids, bitumens, caoutchouc, oils, resins, waxes and many organic compounds. It is miscible with many of the lacquer solvents and is also a solvent for cellulose esters and ethers especially when augmented by the addition of an alcohol, ether or an ester. Its uses as a solvent are in surface textile and leather coatings, and in nitro- and acetylcellulose lacquers. It is used in these preparations for its low boiling point and quick evaporation. Other uses for this solvent are in fire extinguishing compositions, in the preparation of hexamethylenetetramine, as a refrigerant in low-pressure ice machines and air-conditioning apparatus, as a local anesthetic in dental work, and in the extraction of oils, fats, perfumes, flavors and drugs. Further, it is used as a spotting agent, a degreasing medium, and

in the dewaxing of lubricating oils. In the manufacture of artificial leather, artificial silk, and in films dichlormethane is used as a low-boiling solvent. As an intermediate it is used in the manufacture of synthetic dyes, drugs and perfumes.

Methyl Bromide

Methyl bromide (CH_3Br, bromomethane) is a colorless, non-inflammable liquid with a sweet odor. It is miscible with alcohols, ethers, ketones, esters, halogenated hydrocarbons and so forth. It is used as a refrigerant, low-boiling solvent, and in organic synthesis.

Molecular weight		94.94
Specific gravity		1.732 (0° C.)
Boiling point		4.6° C.
Vapor pressure		
at	− 30° C.	130 mm.
	− 10	380
	4.6	760
	10	890
	20	1250
	30	1800
	40	2300
Melting point		− 84° C.
Thermal conductivity		0 574 (0° C.)
Heat capacity		1.27 (16° C.)(0.3–0.6 atm.)
Heat of combustion		184 kg. cal/mol (gas)
Critical temperature		173.3° C.
Dieletric constant		0.0068 (100° C.)

Trichlormethane

Trichlormethane ($CHCl_3$, chloroform, formyl trichloride, methenyl trichloride) is a heavy, water-white, sweet-smelling liquid that is strongly anesthetic. It is a low-boiling, stable liquid when dry. Although its vapors have no flash-point, it can catch fire and form explosive mixtures with air. Chloroform is a powerful solvent for fats, fixed, mineral and essential oils, waxes, alkaloids, acetic acid, acetic anhydride, resins, tars, cellulose acetate and nitrate, gutta percha and so forth. It is completely miscible with all halogenated hydrocarbons and most of the common solvents. Trichlormethane will also dissolve methyl cellulose, dimethyl hydrocellulose, cellulose benzoate, dilaurate, dipalmitate and distearate. When trichlormethane is mixed with an alcohol or ester like methyl or ethyl alcohol, or ethyl or methyl acetate, the mixture becomes a solvent for a large number of cellulose esters and ethers.

The anesthetic and toxic properties of chloroform militate against its wider use as a solvent in the industries. Medicinally, trichlormethane is used in rubbing liniments and salves, as an anesthetic, as a preservative for serums and as an insecticide and vermicide. It is used in plastic fabrication and film manufacture, and in the dry-cleaning industry it is used as a cleaning and spotting agent for all textile fabrics except those made from cellulose acetate which it dissolves. It is widely resorted to in

analytical work for alkaloid assay, and as an extractant for oils, waxes, resins, sterols and so forth.

Molecular weight	119.38
Specific gravity	1.499 (15° C.)
Boiling point:	
U. S. P., B. P.	60–62° C.
Technical	61.2° C.
Freezing point	– 63.5° C.
Latent heat of vaporization	59.1 cal./g. 106.4 B.t.u./lb.
Specific heat:	
Cal/g./° C. or B.t.u./lb./° F.	0.233
Viscosity	5.63 millipoises (20° C.) 5.10 millipoises (30° C.)

Carbon Tetrachloride

Carbon tetrachloride (CCl_4, tetrachlormethane, perchlormethane, Pyrene) is a heavy, colorless, non-inflammable, non-explosive liquid of characteristic odor. Upon decomposition it may produce poisonous gases like phosgene, chlorine and hydrochloric acid. It is miscible with acetic anhydride, alcohol, ether, naphtha, halogenated hydrocarbons, and in short, with most solvents. It will dissolve fixed, mineral and essential oils, fats, greases, waxes, gums, camphor, metallic resinates, bitumens, asphalt, rubber, some cellulose ethers and resins like albertols, Bakelite, benzyl abietate, cumar resins, dammar, ester gum, elemi, guaiac, glyptols, mastic, sandarac, rosin, vinyl resins and so forth. The addition of a lower aliphatic alcohol or acetate increases the solvent power of carbon tetrachloride for cellulose esters and ethers. One mixture proposed is made up of carbon tetrachloride and alcohol ranging from 95 per cent : 5 per cent to 5 per cent : 95 per cent. It is extensively used as a solvent and diluent, and in the extraction of oils from their seeds, grease from bones and hides, and alkoloids from plants. Further uses for this compound are as a solvent for bitumens, asphalt, rubber, gums, antimony trichloride, cholesterol and so forth, and extensively as a fire extinguisher for home and industry. Because of its non-inflammable properties and solvency for the impurities found in clothes it is replacing in the industry and home the hazardous solvents for dry-cleaning and spotting.

This non-inflammable solvent finds application as a degreasing agent for textile fabrics, leather goods and metal parts. It is also used in grain fumigation, moth control and as a delousing agent. In the rubber industry carbon tetrachloride has the following uses: as a solvent in rubber cement, as a solvent for rubber for impregnation and as diluent for sulfur chloride. Many of the non-inflammable lacquers contain carbon tetrachloride. Further uses for tetrachlormethane are as a diluent in chlorination, as a solvent in floor waxes and furniture polish, as a type cleaner, as a constituent part in dry-cleaners' soap, as a solvent for cellulose xanthate, and as a solvent in the paint and varnish industry. In organic chemistry carbon tetrachloride serves as the starting point for the synthesis of many organic

chemicals, dyes, drugs and so forth. In the industrial field it is used in the manufacture of leather, lacquers, paints, varnishes, dry colors, printing inks, linoleum, polishes, rubber cement and so forth.

Molecular weight	153.8
Specific gravity	1.5947 (70° F.)
Boiling point	76.74° C. (760 mm. Hg.)
Freezing point	− 23.0° C.
Specific heat of liquid:	
at 68° F.	0.92 } B.t.u./lb./° F.
at 170° F.	0.216}
Specific heat of vapor:	
at 68° F.	0.132} cal./kg./° C.
at 170° F.	0.115}
Heat of fusion	{4.2 cal./kg. {7.6 B.t.u./lb
Heat of vaporization	{46.5 cal./kg. (170° F.) {83.7 B.t.u./lb. (170° F.)
Electrical conductivity	4×10^{-18} recip. ohm
Dielectric constant	2.2 (20° C.)
Thermal expansion of liquid:	
at 158° F.	1.089089 (on basis of volume at 30° F.—1.0)
Refractive index	1.4607 20° C.

TABLE 45.—Vapor Pressure of Carbon Tetrachloride[1]

Temperature (° C.)	Temperature (° F.)	Vapor Pressure mm. Hg.
0	32	33.4
10	50	56.3
20	68	91.3
30	86	141.1
33	91.4	158.
44.3	111.8	250.
62.3	144.2	480.
76.55	169.8	764.5

TABLE 46. Solubility of Water in Carbon Tetrachloride[1]

Temperature (° C.)	Temperature (° F.)	Water in Solution Gram per 100 grams of CCl_4
10	50	0.0071
20	68	0 0084
30	86	0.0109
40	104	0.0152
50	122	0.0237

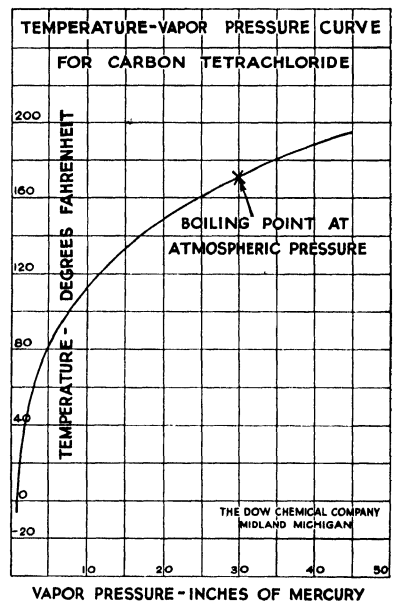
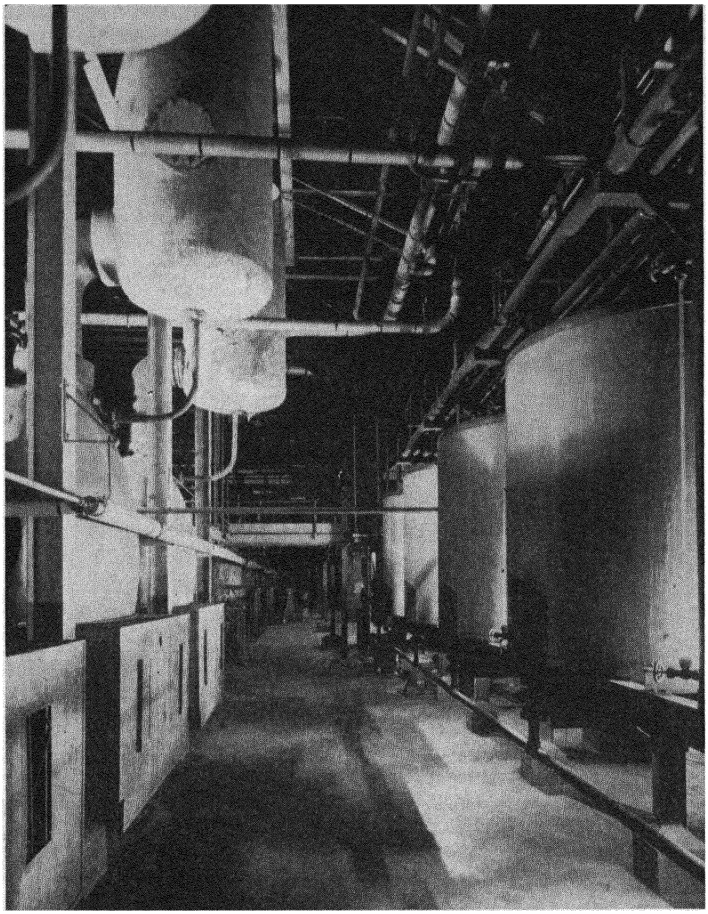


FIGURE 21. Temperature-Vapor Pressure Curve for Carbon Tetrachloride.[2]



Courtesy of Dow Chemical Co.

PLATE 9. A Typical Plant for the Manufacture of Industrial Solvents.

The following data were determined in an investigation of the flash-points of binary mixtures [Snell, F. D., *Ind. Eng. Chem.*, **22**, 893 (1930)]:

	% Inflammable Solvent	% CCl_4	Flash-point (° F.)
Acetone	40	60	Below 32
	30	70	Below 32
	20	80	59
Toluene	80	20	59
	70	30	75
	60	40	Above 86

A mixture of carbon tetrachloride with a higher-boiling flammable solvent tends to become more inflammable during use, as a result of the more rapid evaporation of the lower-boiling protective carbon tetrachloride.

TABLE 47.—Flash-points of Carbon Tetrachloride Mixtures[1]

	% Solvent	% CCl_4	Flash-point (° F.)
Gasoline (Sp. Gr. 0.734 at 60° F.)	50	50	Below 20
	40	60	" 20
	30	70	40
V. M. & P. naphtha	70	30	75
(Sp. Gr. 0.746 at 60° F.)	60	40	100
	50	50	Above 170
	40	60	" 170
	30	70	" 170
Dry cleaners' naphtha	70	30	65
(Sp. Gr. 0.745 at 60° F.)	60	40	90
	50	50	Above 170
	40	60	" 170
	30	70	" 170

TABLE 48.—Decomposition of Carbon Tetrachloride[1]*

Carbon Tetrachloride	Boiling Point	20° C. above b. p.	40° C. above b. p.	60° C. above b. p.
Dry				
In atmosphere of N_2	0	0	0	0
In oxygen	0.2	0	0	0
Saturated with water				
In atmosphere of N_2	0	0	0	0
In air and with soft steel	0	0.2	0.3	6.9
Excess of water				
In atmosphere of N_2	0.5	13.2	61	1066
In air and in presence of soft steel (refluxed)	172			

*Figures represent acidity in cc. of 0.01*N* HCl developed by 25 cc. C.T in 24 hours.

TABLE 49.—Corrosive Action of Carbon Tetrachloride on Soft Steel[1]*

Carbon Tetrachloride	Boiling Point	20° C. above b. p.	40° C. above b. p.	60° C. above b. p.
Saturated with water				
In atmosphere of N_2, with soft steel	0	0 1	0.2	0.6
In air, with soft steel	0.6	0.7	0.6	0.7
Excess of water				
In N_2, with soft steel (refluxed)	48.5			
In air, with soft steel	52.7	89.5	167	136

*Figures show loss of wt. of metal as mg./sq. in /24 hrs.

TABLE 50.—Corrosive Action of Carbon Tetrachloride on Other Metals[1]*

Carbon Tetrachloride	Boiling Point	20° C. above b. p.	40° C. above b. p.	60° C. above b. p.
Saturated with water				
In air, with Aluminum	0.7	0.9	381	358
In air, with Tin	0.9	1.2	1.1	1.0
In air, with Copper	0.9	1.2	1.1	1.0

*Figures show loss of wt. of metal as mg./sq. in./24 hrs.

TABLE 51.—Evaporation of a Carbon Tetrachloride-Naphtha Mixture[1]

% of Sample Evaporated	Composition of Residue by Vol. % CCl_4	Composition of Residue by Vol. % Naphtha	Flash-point of Residue[2]	% of Constituents of Original Mixt. Evaporated CCl_4	% of Constituents of Original Mixt. Evaporated Naphtha
0	43	57	No flash up to incipient boiling.		
37	29	71	104° F.	57.6	21.7
70	5	95	86° F.	96.5	50.0
87	1	99	90° F.	99.7	77.2

TABLE 52.—Evaporation Rate of Carbon Tetrachloride Mixtures[1]

Solvent	Rate of Free Evaporation at Room Temp. (cc. per hour per 100 cm.²)	Rate of Free Evaporation at Room Temp. (Gallon per 24 hrs. per square foot)
Carbon tetrachloride	4.30	0.254
C.T.-Naphtha cleaning fluid		
0–37% evaporated	2.77	0.163
37–70% "	2.06	0.123
70–87% "	0.80	0.047
Weighted average 87% evaporated	2.12	0.125

TABLE 53.—Solubility of Various Dyes in Carbon Tetrachloride[3]

Dye	Min. cc. to Dissolve 0.5 Gram Dye	Dye	Min. cc. to Dissolve 0.5 Gram Dye
Sudan I	5	Sudan III	20
Maroon I	5	Azo turkey red	20
Sudan VIII	5	Cloth red G	20
Chrome fast yellow	5	Sudan G	25
Rose	5	Maroon II	25
Sudan VII	5	Cloth red BB	25
Scarlet H	5	Fast brown O	25
Walnut	5	Maroon III	25
Sudan II	5	Sudan brown	25
Xylidine brown	5	Chrysamine G	25
Indiana red	5	*p*-Nitroaniline red	35
Oil maroon	5	Alizarin yellow R	35
Azo coccine RR	8	Aniline yellow G	35
Xylidine red N	8	Cardinal	35
Xylidine brown M	10	Benzidine puce	35
Sudan IX	10	Benzidine puce A	35
Sudan X	10	Indoine blue	35
Naphthol black	10	Congo red A	60
Oil Scarlet	10	*m*-Nitroaniline orange	60
Sudan R	15	Alizarin yellow GG	60
Fast Red A	15	Benzidine brown	100 Inc.
Oil brown	15	Diazine green	100 Inc.
Spirit yellow	20	Diazine black	100 Inc.

Ethyl Chloride

Ethyl chloride (C_2H_5Cl, chloroethane, muriatic ether) is a volatile inflammable, colorless liquid of ether-like odor. It is stable and non-corrosive when dry but will hydrolyze in the presence of water or alkalies. Ethyl chloride is miscible with most of the commonly-used solvents. It is used as a refrigerant, ethylating agent, local anesthetic and as a solvent.

Carroll[4] proposes a lacquer in which pyroxylin is dissolved in a mixture of ethyl chloride and methyl alcohol to which is added a little benzene. When mixed with methyl acetate in proportions ranging from 90:10 to 10:90 the mixture becomes an excellent solvent for triethylcellulose. The solvent power of monochlorethane and other chlorinated ethanes like the dichlor-, trichlor-, tetrachlor-, and pentachlorethanes, is augmented by the addition of a lower aliphatic alcohol or acetate. Ethyl chloride is a solvent for phosphorus, fats, oils, resins, waxes and so forth.

Molecular weight	64.50
Specific gravity	0.915-0.925 (8° C.)
Boiling point	12.7° C.
Vapor pressure	
at −30° C.	107.4 mm.
at −20	180.3
at −10	289.1
at 0	450
at 10	678
at 20	1000
Critical point	187.2° C. (52 atm.; density 0.33)
Freezing point	−140° C.
Latent heat of vaporization	
at 4.7° C.	389 joules/g.
at 15.0	387 joules/g.
at 25	385 joules/g.
Heat of combustion	316.7 kg. cal./mol. (gas)
Thermal conductivity, gaseous state	0.873 (0° C.)
Thermal conductivity	
compared to K at 0° C.	1.0
compared to K at 100	1.73
compared to K at 184	2.45
compared to K at 212.5	2.76
Dielectric constant of liquid	6.29 at 170° C. under its own pressure

Bromoform

Bromoform ($CHBr_3$, tribromomethane, formyl tribromide, methenyl tribromide) is a colorless liquid of pleasant odor resembling chloroform. It is miscible with alcohols, ethers, esters and so forth. Bromoform is used as an intermediate in organic synthesis, in geological assay and in medicine as a nervine, sedative and local anesthetic.

Molecular weight	252.8
Density	2.884 (25° C.)
Weight per gallon	24 lbs.
Boiling range	150.3–151.2° C.
Freezing point	9° C.
Surface tension	41.53 dynes/cm. (20° C.)
Dielectric constant	4.5 (20° C.)

Forms constant low boiling mixture with butyric acid.

Ethyl Bromide

Ethyl bromide (C_2H_5Br, bromoethane, bromic ether, ethyl hydrobromic) is a low-boiling, volatile liquid of ethereal odor. It is considered non-inflammable because it is ignited only with difficulty. Ethyl bromide is miscible in all proportions with most common solvents.

Molecular weight	108.97
Specific gravity	1.440–1.453 (15° C.)
Weight per gallon	12–12.1 lbs.
Boiling point	38–39° C.
Vapor pressure	
at − 20° C.	59 mm.
at − 10	101
at 0	165
at 10	257
at 20	386
at 30	564
at 40	802
at 50	1113
at 60	1512
Critical temperature	231° C.
Freezing point	− 119° C.
Solubility in water	
at 0° C.	1.055%
at 10	0.956
at 20	0.906
at 30	0.888
Surface tension	
at 10° C.	25.48 dynes/cm.[2]
at 20	24.15
at 40	21.52
Latent heat of vaporization	250.8 joules (34.4° C.)
Heat of combustion	340 kg.cal./mol. (gas)
Dielectric constant, liquid	9.45 (20° C.)
Constant minimum boiling mixture of ethyl alcohol 7 mol. % and ethyl bromide 93 mol. %	37.6° C.

Ethylene Chlorbromide

Ethylene chlorbromide (CH_2ClCH_2Br, sym. chlorbromethane) is a colorless liquid of chloroform-like odor. It is miscible with most solvents and is used both as a solvent and in organic synthesis, and further, it has the distinctive virtue of dissolving both cellulose esters and ethers.

Molecular weight	143.4
Specific gravity	1.790 (0° C.)
Weight per gallon	14.9 lbs. (0° C.)
Boiling point	106.7° C.
Freezing point	− 16.6° C.

Ethylene Dibromide

Ethylene dibromide (CH_2BrCH_2Br, 1,2-dibromoethane, ethylene bromide) is a colorless, stable, non-inflammable liquid of sweetish odor. It is miscible with most solvents and thinners and will dissolve oils, fats, gums, waxes, resins, celluloid and so forth. It is principally used in the

manufacture of "ethyl gasoline." It exerts a powerful dissolvent action upon gums and is therefore used as a constituent part of lubricating gasolines. It is also used as a wax solvent in waterproofing preparations, in celluloid manufacture, and in the organic synthesis of drugs.

Molecular weight		187.86
Specific gravity		2.17–2.18 (20° C.)
Density		
at	10° C.	2.2014
	20	2.1805
	30	2.1594
	40	2.1384
	60	2.0952
	80	2.0538
	100	2.0113
Weight per gallon		18.1 lbs.
Boiling point		131° C.
Vapor pressure		
at	− 10° C.	2.5 mm.
	0	3.9
	10	6.03
	30	17.4
	50	44.3
	70	101.0
	100	295
	120	552
	131	760
Freezing point		9–10° C.
Surface tension		38.71 dynes/cm.² (20° C.)
Latent heat		
of	fusion at 9.55° C.	56.62 joules/g.
	vaporization at 130.8° C.	193.5 joules
Dielectric constant		4.86 (18° C.)

Ethylene Dichloride

Ethylene dichloride (CH_2ClCH_2Cl, 1,2-dichlorethane, sym-dichlorethane, Dutch oil, elayl chloride) was first made by certain Dutch chemists in 1795 and hence we derive the name Dutch oil. It is a colorless, mobile liquid simulating chloroform both in odor and in toxicity. It is manufactured by the chlorination of ethane or ethylene. It is a good solvent for oils, fats, waxes, some alkaloids, rubber, camphor, albertols, Bakelite, benzyl abietate, cumar resins, dammar, glyptols, guaiac resin, Japan wax, mastic, rosin, sandarac, vinyl resins, metallic resinates, gums and so forth, and will also dissolve some cellulose ethers; and when it is mixed with methyl or ethyl alcohols, or ethyl or methyl acetates, the mixture will possess solvent power for a large number of cellulose ethers and esters.

Ethylene dichloride is miscible in all proportions with most common solvents. It is finding wider application as a general solvent because it will not decompose in the presence of water, alkalies, acids or actively-reacting chemicals. It is resistant to oxidation and will not corrode metals. It burns with difficulty and supports combustion. This safe and highly pure solvent is extensively used in the extraction of edible oils from oil-bearing seeds, vitamin D from cod liver oil, residual oil from pressed

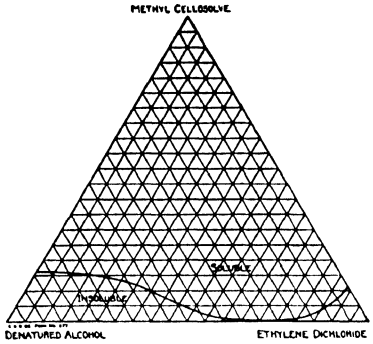


FIGURE 22. Solubility of ½-Second R.S. Nitrocellulose in Mixtures of Methyl Cellosolve, Denatured Alcohol, and Ethylene Dichloride.[6]

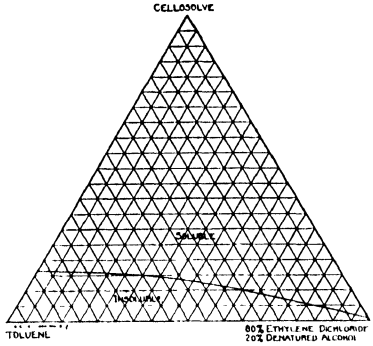


FIGURE 23. Solubility of ½-Second R.S. Nitrocellulose in Mixtures of Cellosolve, Toluene, and 80 Per Cent Ethylene Dichloride-20 Per Cent Denatured Alcohol.[6]

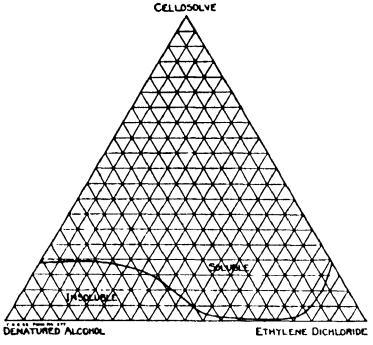


FIGURE 24. Solubility of ½ Second R.S. Nitrocellulose in Mixtures of Cellosolve, Denatured Alcohol, and Ethylene Dichloride.[6]

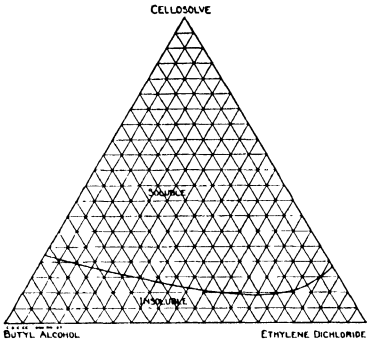


FIGURE 25. Solubility of ½-Second R.S. Nitrocellulose in Mixtures of Cellosolve, Butyl Alcohol, and Ethylene Dichloride.[6]

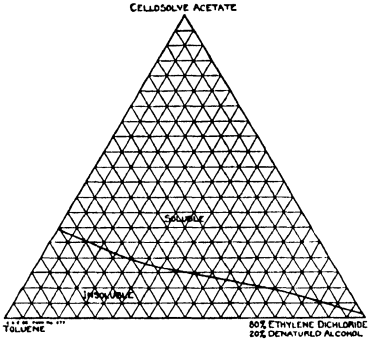


FIGURE 26. Solubility of ½-Second R.S. Nitrocellulose in Mixtures of Cellosolve Acetate, Toluene, and 80 Per Cent Ethylene Dichloride-20 Per Cent Denatured Alcohol.[6]

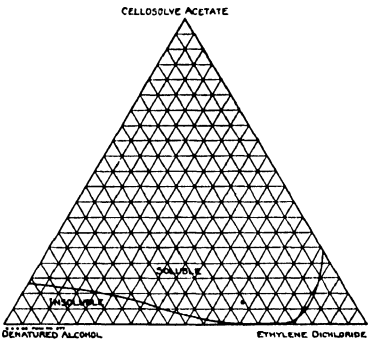


FIGURE 27. Solubility of ½-Second R.S. Nitrocellulose in Mixtures of Cellosolve Acetate, Denatured Alcohol, and Ethylene Dichloride.[6]

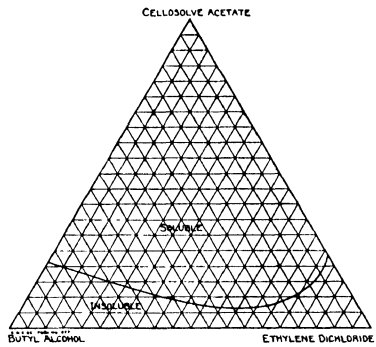


FIGURE 28. Solubility of ½-Second R.S. Nitrocellulose in Mixtures of Cellosolve Acetate, Butyl Alcohol, and Ethylene Dichloride.[6]

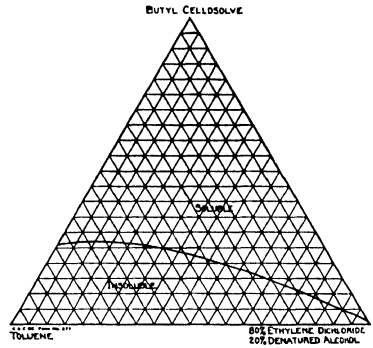


FIGURE 29. Solubility of ½-Second R.S. Nitrocellulose in Mixtures of Butyl Cellosolve, Toluene, and 80 Per Cent Ethylene Dichloride-20 Per Cent Denatured Alcohol.[6]

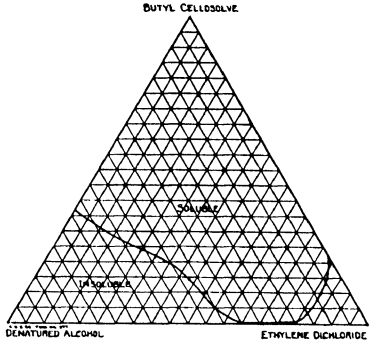


FIGURE 30. Solubility of ½-Second R.S. Nitrocellulose in Mixtures of Butyl Cellosolve, Denatured Alcohol, and Ethylene Dichloride.[6]

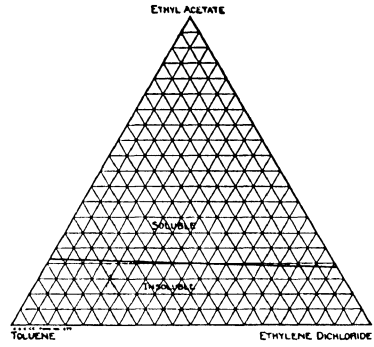


FIGURE 31. Solubility of ½-Second R.S. Nitrocellulose in Mixtures of Ethyl Acetate, Toluene, and Ethylene Dichloride.[6]

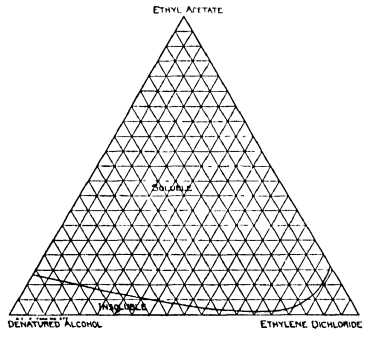


FIGURE 32. Solubility of ½-Second R.S. Nitrocellulose in Mixtures of Ethyl Acetate, Denatured Alcohol, and Ethylene Dichloride.[6]

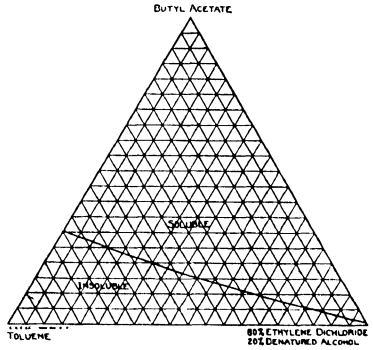


FIGURE 33. Solubility of ½-Second R.S. Nitrocellulose in Mixtures of Butyl Acetate, Toluene, and 80 Per Cent Ethylene Dichloride-20 Per Cent Denatured Alcohol.[6]

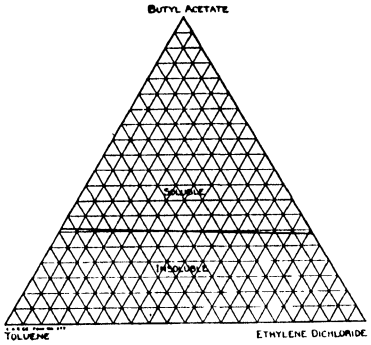


FIGURE 34. Solubility of ½-Second R.S. Nitrocellulose in Mixtures of Butyl Acetate, Toluene, and Ethylene Dichloride.[6]

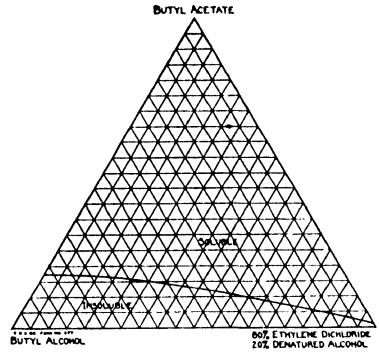


FIGURE 35. Solubility of ½-Second R S Nitrocellulose in Mixtures of Butyl Acetate, Butyl Alcohol, and 80 Per Cent Ethylene Dichloride-20 Per Cent Denatured Alcohol.[6]

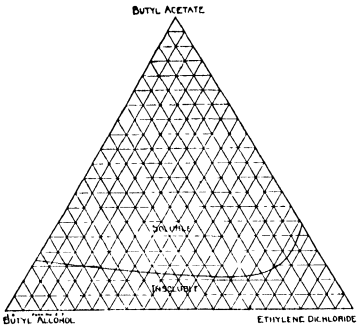


FIGURE 36. Solubility of ½-Second R.S. Nitrocellulose in Mixtures of Butyl Acetate, Butyl Alcohol, and Ethylene Dichloride.[6]

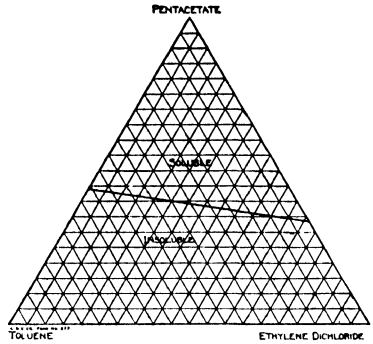


FIGURE 37. Solubility of ½-Second R.S. Nitrocellulose in Mixtures of Pentacetate, Toluene, and Ethylene Dichloride.[6]

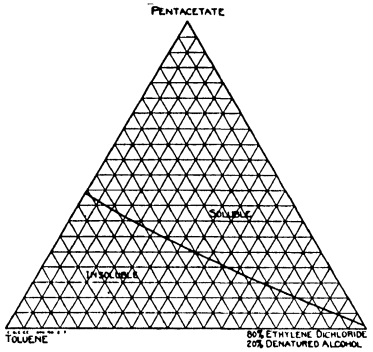


FIGURE 38. Solubility of ½-Second R.S. Nitrocellulose in Mixtures of Pentacetate, Toluene, and 80 Per Cent Ethylene Dichloride-20 Per Cent Denatured Alcohol.[6]

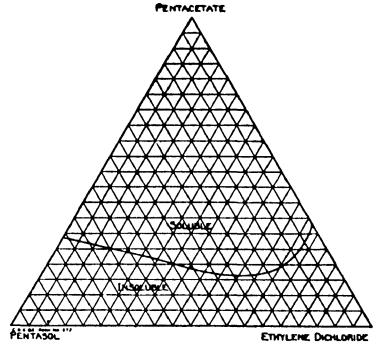


FIGURE 39. Solubility of ½-Second R.S. Nitrocellulose in Mixtures of Pentacetate, Pentasol, and Ethylene Dichloride.[6]

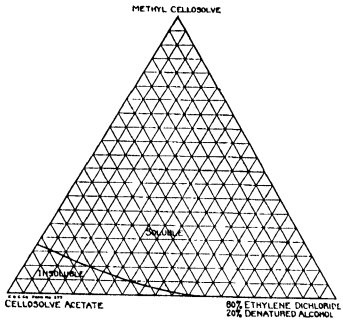


FIGURE 40. Solubility of Low-Viscosity Cellulose Acetate in Mixtures of Methyl Cellosolve, Cellosolve Acetate, and 80 Per Cent Ethylene Dichloride-20 Per Cent Denatured Alcohol.[6]

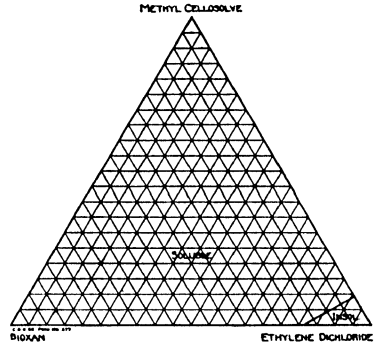


FIGURE 41. Solubility of Low-Viscosity Cellulose Acetate in Mixtures of Methyl Cellosolve, Dioxan, and Ethylene Dichloride.[6]

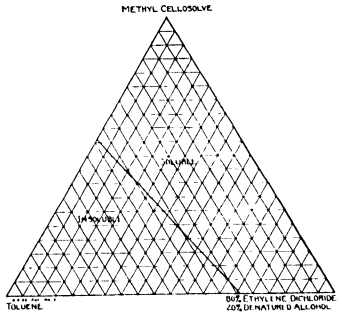


FIGURE 42. Solubility of Low-Viscosity Cellulose Acetate in Mixtures of Methyl Cellosolve, Toluene, and 80 Per Cent Ethylene Dichloride-20 Per Cent Denatured Alcohol.[6]

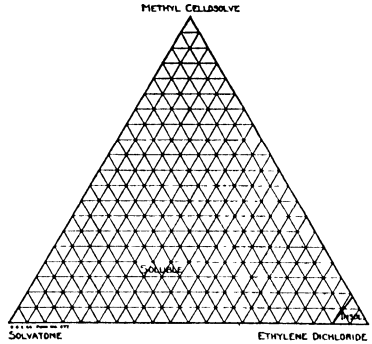


FIGURE 43. Solubility of Low-Viscosity Cellulose Acetate in Mixtures of Methyl Cellosolve, Solvatone, and Ethylene Dichloride.[6]

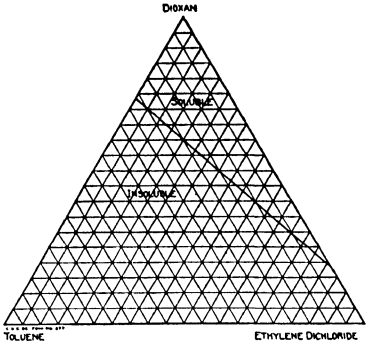


FIGURE 44. Solubility of Low-Viscosity Cellulose Acetate in Mixtures of Dioxan, Toluene, and Ethylene Dichloride.[6]

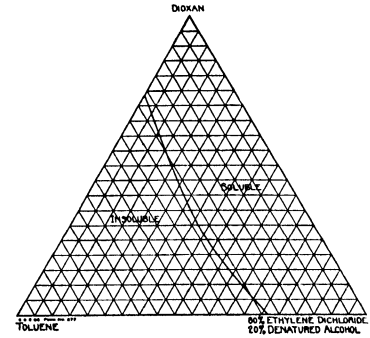


FIGURE 45. Solubility of Low-Viscosity Cellulose Acetate in Mixtures of Dioxan, Toluene, and 80 Per Cent Ethylene Dichloride-20 Per Cent Denatured Alcohol.[6]

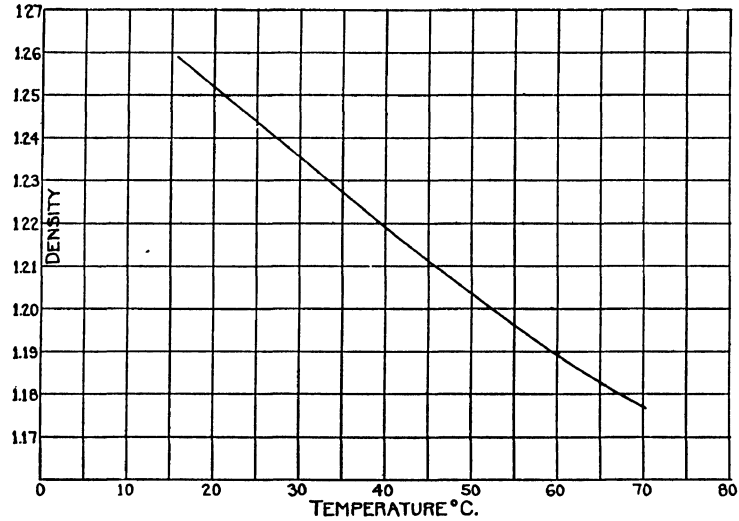


FIGURE 46. Density of Ethylene Dichloride at Various Temperatures.[6]

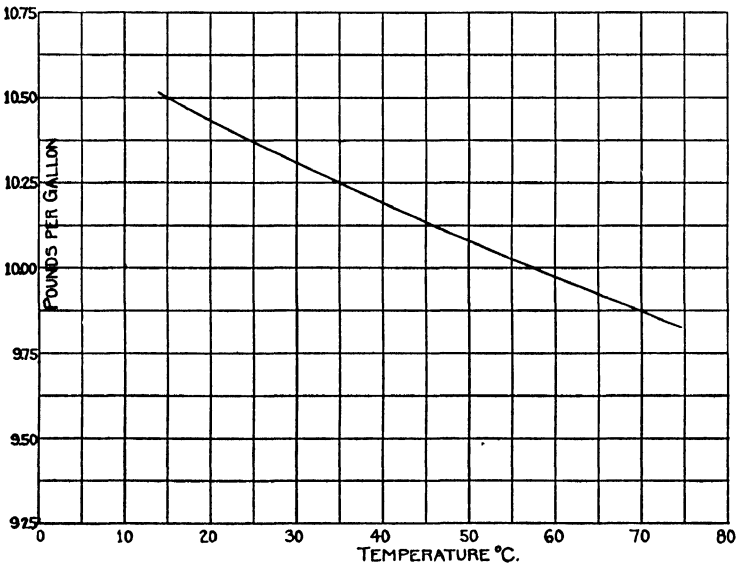


FIGURE 47. Weight per Gallon of Ethylene Dichloride at Various Temperatures.[6]

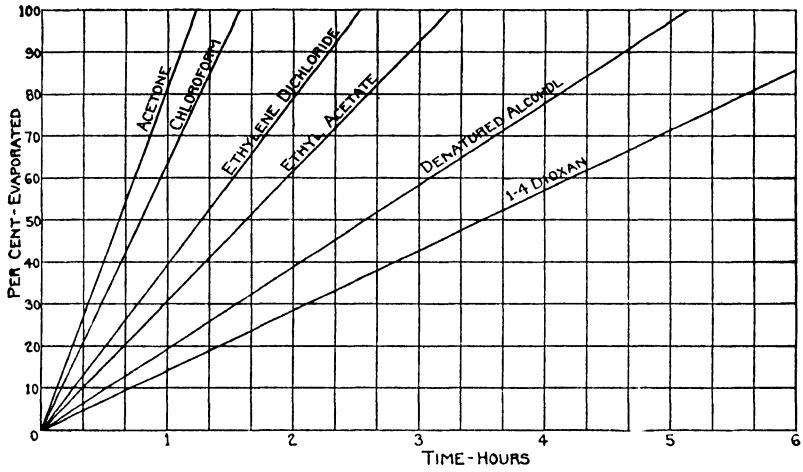


FIGURE 48. Evaporation Rate of Various Solvents at Room Temperature.[6]

oil cakes and so forth. A mixture made up of three parts of ethylene dichloride and one part of carbon tetrachloride is used as a non-explosive, non-injurious fumigant for furniture, furs, cereals, grains, flour, dried fruit, nuts and so forth.

Ethylene dichloride is used as an inert solvent in chlorination and sulfonation processes, in the removal of alkaloids from bark, roots and seeds, pyrethrum and the grease from wool. Ethylene chloride when admixed with carbon tetrachloride is extensively used in the dry-cleaning and spotting industry. It is also used as a lacquer solvent, in paint, varnish and finish removers, in degreasing metals and in chemical synthesis. In the textile industry, ethylene dichloride is used to degrease wool, as a "spotting" agent for the removal of tar, paint and brand marks, in soap and

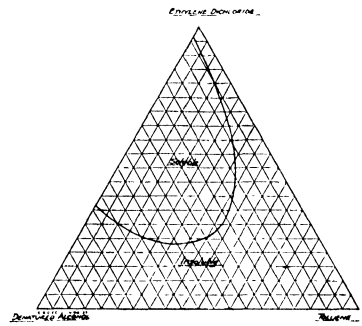


FIGURE 49.

Solubility of Cellulose Acetate in Mixtures of Ethylene Dichloride, Denatured Alcohol, and Toluene.[6]

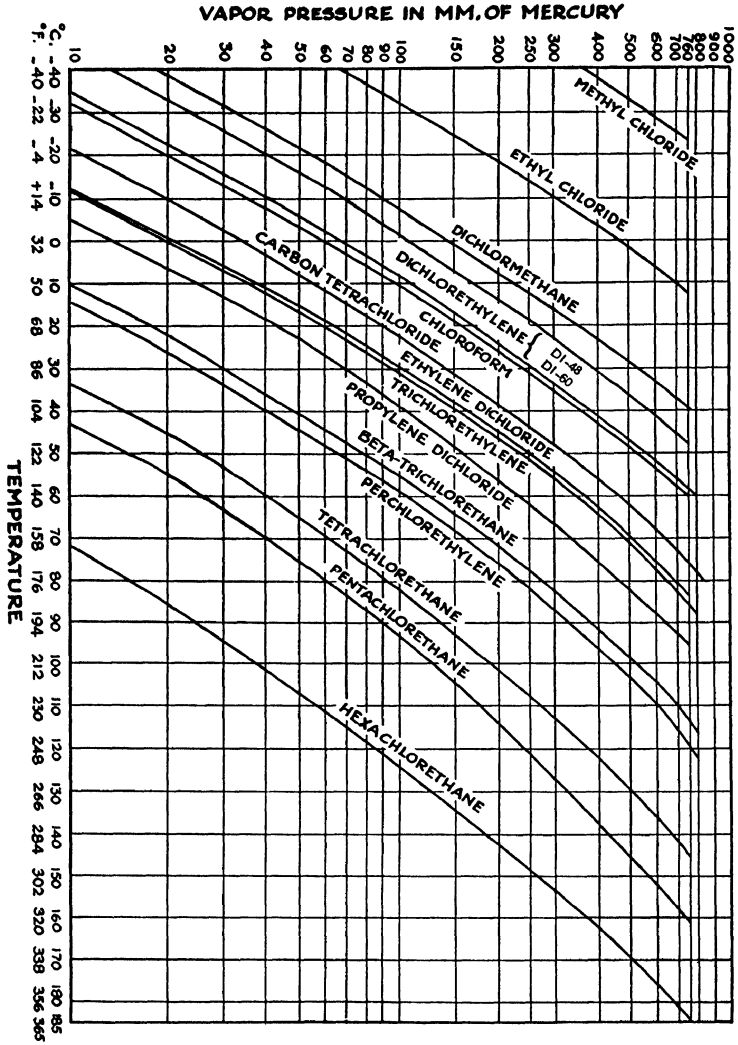


FIGURE 50. Vapor Pressure of Various Solvents at Different Temperatures.[6]

scouring compounds and in wetting out, penetrating and degumming compounds. It is also used for the extraction of nicotine from tobacco.

Molecular weight	98.95
Boiling point	83.5° C.
Freezing point	− 36.0° C.
Specific gravity	$1.2569 \frac{20° C.}{4° C.}$
Weight per gallon	10.53
Refractive index	1.444
Surface tension	37.5 dynes/sq. cm. (25° C.)
Viscosity	0.0078 poise (25° C.)
Vapor pressure	61.6 mm. Hg. (20° C.)
Specific heat	0.3054 (30° C.)
Flash-point	21° C. (70° F.)
Apparent ignition temperature in air	449° C. (841° F.)
Latent heat of evaporation	157.5 B.t.u./lb./0° C.
Electrical conductivity	Less than 1×10^{-8}
Solubility	Insoluble in water. Soluble in most organic compounds.

TABLE 54.—Dilution Ratios[6]

Solvent	Ethylene Dichloride	Toluene	V. M. & P. Naphtha
Acetone	8.6	4.6	0.73
Solvatone[a]	6.8	4.0	0.68
Ethyl acetate	5.4	3.5	1.20
Isopropyl acetate	4.3	3.1	1.25
Methyl "Cellosolve"	9.2	4.3	0.35
Butyl acetate	3.7	2.5	1.35
"Cellosolve"	7.6	4.7	0.95
Butyl propionate	2.7	2.5	1.20
"Cellosolve" acetate	4.2	2.5	0.80
Pentacetate	3.5	1.9	1.27
Butyl "Cellosolve"	4.3	3.0	1.85

[a]Solvatone is a mixture consisting of approximately 80 per cent acetone, 10 per cent isopropyl alcohol and 10 per cent toluene

TABLE 55.—Solubility of Some Gums and Resins[6]

Substance	Ethylene Dichloride	80% Ethylene Dichloride 20% Denatured Alcohol	Substance	Ethylene Dichloride	80% Ethylene Dichloride 20% Denatured Alcohol
Amberol	S	S	Kauri	I	S
Albertol	S	S	Manila	S	S
Bakelite	S	S	Manila ester	S	S
Cumar	S	S	Mastic	SS	S
Camphor	S	S	Rosin	S	S
Dammar	S	PS	Glyptol	S	S
Elemi	SS	S	Sarpee	I	S
Ester gum	S	S	Sandarac	SS	S
Guaiac	SS	S	Shellac	SS	S
Gilsonite	S	S	Vinylite A	S	S
			Vinylite 80	S	I

S = soluble. SS = slightly soluble. PS = partially soluble. I = insoluble.

TABLE 56.—Ethylene Dichloride in Combination with Various Solvents[6]

Cellulose-Acetate Lacquers

Formulae	1	2	3	4	5	6	7	8	9	10
Ethylene dichloride	70	70	70	60	50	50	70	70	40	60
Toluene									20	
Denatured alcohol	20	20	20	10	10	15			10	15
Ethyl acetate				15						
Solvatone							15			
Methyl "Cellosolve"	10			10	30	20	15	20	30	10
1,4-Dioxan						15		10		
Diacetone alcohol					10					
"Cellosolve" acetate				5						15
Ethyl lactate		10								
Butyl "Cellosolve"			10							

Base-Lacquer Solvents

Ethylene dichloride	40	50	75	30	30	70	35	25
Toluene	30	20		30	30		30	40
Denatured alcohol	10	10	15				10	5
Butyl alcohol				15	10	10	5	
Ethyl acetate	10			10	10			15
Butyl acetate		10	10		15		15	
"Cellosolve"	5	5		10		10		10
Pentacetate					5			
"Cellosolve" acetate	5			5		10		
Butyl "Cellosolve"		5					5	5

Thinners

Ethylene dichloride	72	67	45	40	40	35	40
Toluene			30	30	35		30
Xylene						30	
Denatured alcohol	25		10	10	13	15	15
Butyl alcohol		25					
Ethyl acetate	3			10	7	10	5
"Cellosolve"				7	3		5
"Cellosolve" acetate		8			2	10	
Butyl acetate			10				
Pentacetate			5				
Butyl "Cellosolve"				3			5

Tetrabromethane

Tetrabromethane ($CHBr_2CHBr_2$, acetylene tetrabromide, Muthmann's liquid) is a heavy, white to yellow, oily liquid of a pleasant characteristic odor. It is an excellent solvent for oils, fats and waxes and is miscible with most of the common solvents. Its uses are as a solvent, and as a fluid in liquid gauges.

Specific gravity	2.9638
Melting point	0.1° C.
Molecular weight	345.68
Refractive index	1.637955
Boiling point	239–242° C. (decomposes)

Soluble in alcohol, ether and chloroform.

Tetrachlorethane

Tetrachlorethane ($CHCl_2CHCl_2$, acetylene tetrachloride, acetosal, Boroform, Cellon) is a heavy, colorless, mobile, non-inflammable, corrosive, toxic liquid with an odor resembling that of chloroform. It is much more toxic, however, than chloroform for contact with its vapors produces abnormal fatigue and nausea, and if this contact is prolonged jaundice and enlargement of the liver will result. It is made by the chlorination of ethane, or acetylene, or ethylene. Tetrachlorethane is the most powerful of chlorinated hydrocarbon solvents. It dissolves oils, fats, waxes, gums, resins, bitumen, pitch, tarry material, sulfur, phosphorus, halogens, cellulose acetate and nitrate, crude rubber, dyes, camphor, shellac and many organic substances. Its solvency for acetyl- and nitrocellulose is improved by the addition of a lower aliphatic alcohol or acetate. It is miscible with many organic solvents and liquids. Its wider use is greatly hindered by its toxicity. It is used, however, in the paint and varnish industry for the preparation of varnishes and in mixtures for the removal of paint, varnish and finishes; in the manufacture of photographic films, lacquers and imitation pearls; for fabricating airplane wings and preparing artificial celluloid. It has also been used to some extent in the rubber industry as a solvent; as an alcohol denaturant for use in the rayon industry; as an intermediate in dye manufacture; in degreasing; in cleaning compounds and soaps for metal and other surfaces; and as an insecticide. It has only limited use as a solvent for shellac, gum, camphor, sulfur, phosphorus, halogens and many organic compounds.

Beta-Trichlorethane

Beta-trichlorethane ($CH_2ClCHCl_2$) is a colorless, non-inflammable liquid. It is miscible with alcohols, ethers, esters, ketones and so forth. It will dissolve oils, fats, waxes, tar, many natural and synthetic resins, alkaloids, etc. It will dissolve cellulose acetate when it is previously mixed with alcohol.

Molecular weight	133.40
Color	Colorless liquid
Boiling point	114° C.
Latent heat of vaporization	68.7 cal./g. 123.5 B.t.u./lb.
Specific heat	0.270 (20° C.) cal./g/° C.
Specific gravity	1.4406 at $\frac{20° C.}{4° C.}$
Refractive index	1.4458

Vapor Pressures

Temperature (° C.)	Temperature (° F)	Vapor Pressure (mm. Hg)
90	194	369
100	212	505
110	230	680
114	237	764

Pentachlorethane

Pentachlorethane ($CHCl_2CCl_3$) is a heavy, high-boiling, colorless, non-inflammable, toxic liquid. It is made by the chlorination of tetrachlorethane or trichlorethylene and is stable when dry. It is a good solvent for vegetable, mineral and essential oils, gums, such resins as dammar, elemi, mastic and sandarac, cellulose acetate and some types of cellulose ethers. Its solvency and other physical and chemical properties are similar to those of the more toxic tetrachlorethane and pentachlorethane can be used to replace it in nearly all industries. Lindsay [10] suggests solvent mixtures for cellulose acetate made up of some 200 combinations containing pentachlorethane.

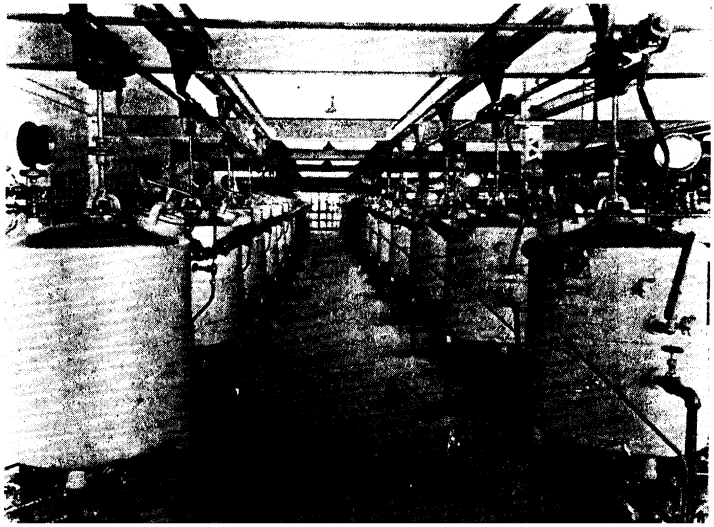
Molecular weight	202.3
Specific gravity	1.582 (25° C.)
Boiling point	161.9
Freezing point	− 22
Flash-point	None
Explosion point	None
Latent heat of vaporization	55.1 cal /g. at B.P.
Specific heat cal. g./° C. B.t.u./lb./° F.	0.27
Refractive index	1.503 (24° C.)

Hexachlorethane

Hexachlorethane (CCl_3CCl_3, carbon trichloride, carbon hexachloride, perchlorethane, tetrachlorethylene dichloride) is a white, crystalline compound of camphor-like odor. It has a specific gravity of 2.091, melting point at 184° C. and sublimes at 185° C. It is soluble in ether, alcohol and oils. It is used in the manufacture of synthetic organic chemicals, as an accelerator, as a camphor substitute in celluloid and as an ingredient in safety explosives.

Propylene Dichloride

Propylene dichloride ($CH_3CHClCH_2Cl$, propylene chloride, 1,2-dichlorpropane) is a colorless, stable liquid of low inflammability with a distinct odor. In odor and in solvent properties it resembles ethylene dichloride. It is a solvent for oils, fats, waxes, gums and resin. The addition of an active solvent like acetone to propylene dichloride imparts solvent properties for cellulose ethers and esters. Its wide range of solvency, and its stability and low specific gravity make it desirable in many industries. It is miscible with most common solvents and is used as an intermediate in the organic synthesis of alcohols, amines, nitriles and acids; as an inactive reaction medium for chlorination and sulfonation; as an ingredient in dry-cleaning fluids, scouring compounds, spotting agents and metal degreasing fluids; and as a fumigant.



Courtesy of Dow Chemical Co

PLATE 10. Chlorinated Hydrocarbon Plant.

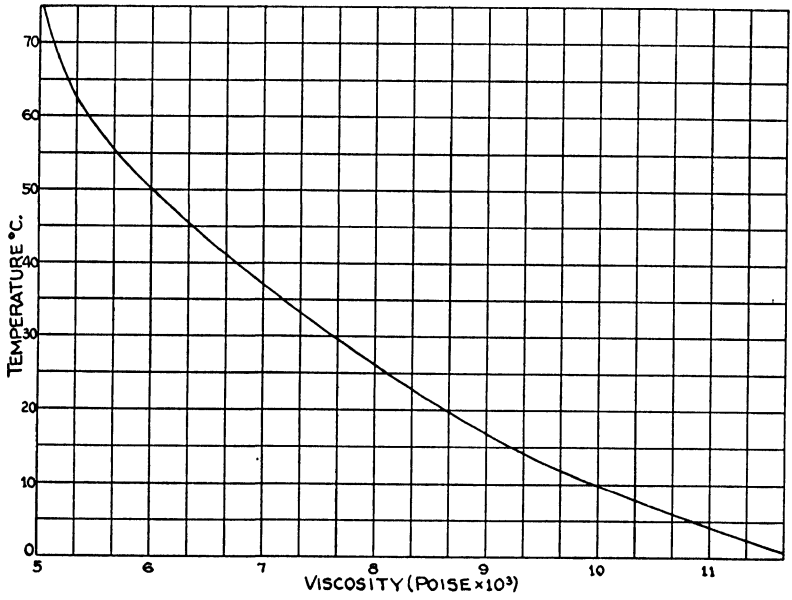
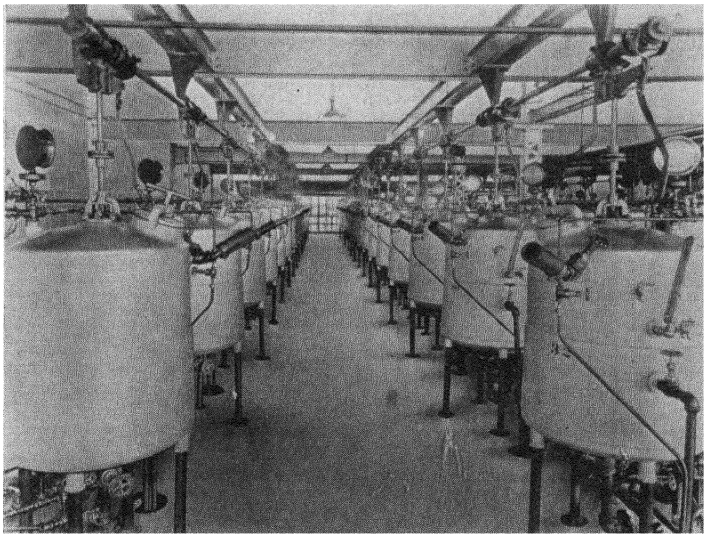


FIGURE 51. Viscosity of Propylene Dichloride at Various Temperatures.[6]



Courtesy of Dow Chemical Co.

PLATE 10. Chlorinated Hydrocarbon Plant.

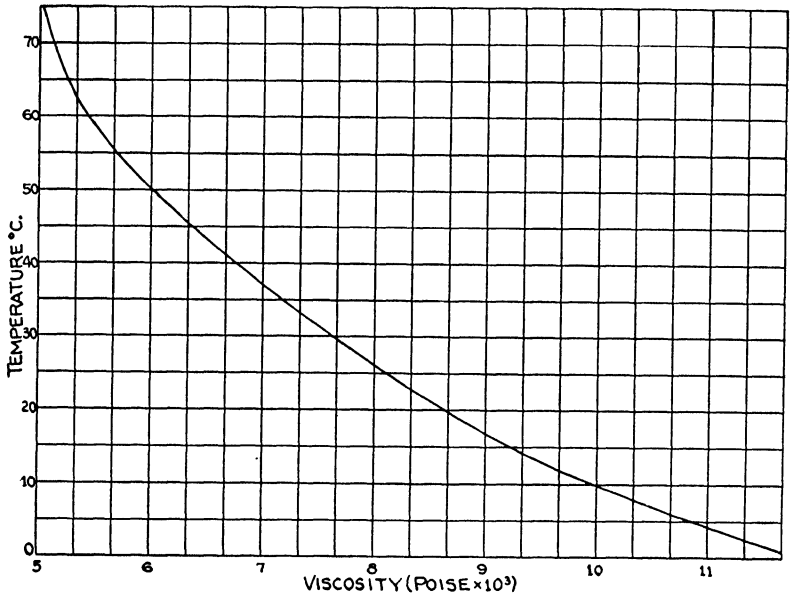


FIGURE 51. Viscosity of Propylene Dichloride at Various Temperatures.[6]

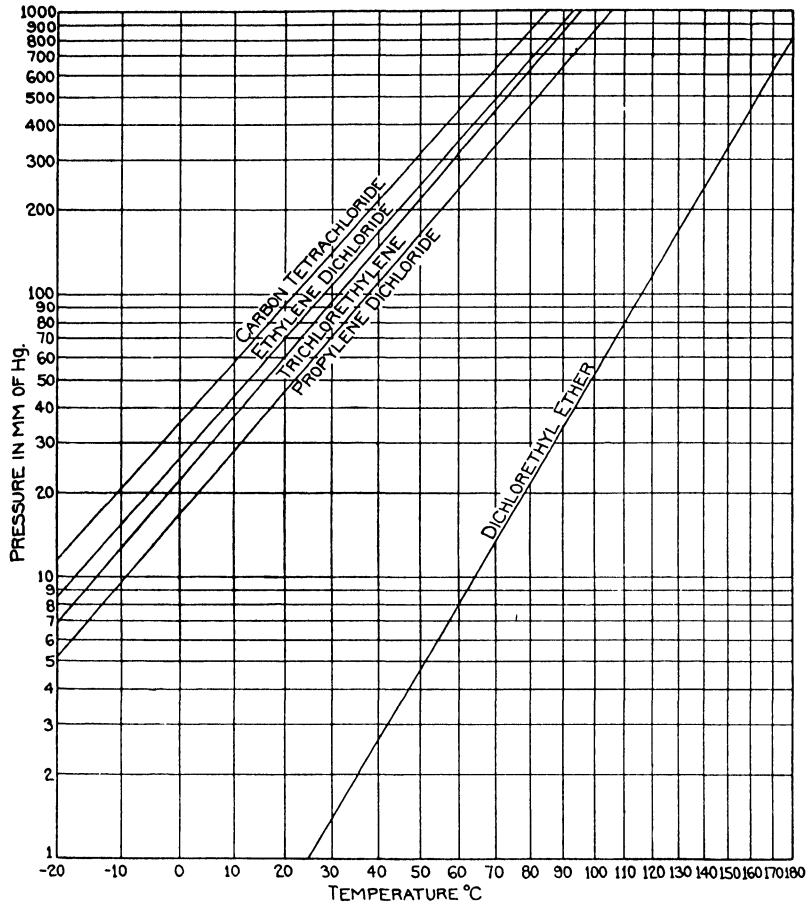


FIGURE 52. Vapor Pressure of Various Chlorinated Solvents at Different Temperatures.[6]

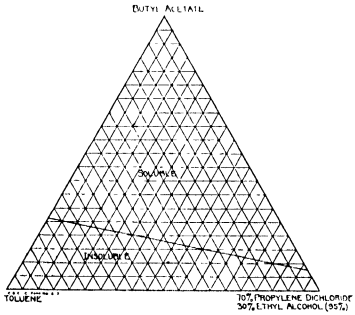


FIGURE 53.

Solubility of ½-Sec. R. S. Nitrocellulose in Mixtures of Butyl Acetate, Toluene and 70-30 Propylene Dichloride-Alcohol.

Properties of Propylene Dichloride

Molecular weight	112.96
Boiling point	95.9° C.
Specific gravity	1.1593 $\frac{20° \text{ C.}}{20° \text{ C.}}$
Weight per gallon	9.65 lb. (20° C.)
Refractive index	1.4068 (20° C.)
Surface tension	31.4 dynes/cm. (25° C.)
Viscosity	0.00865 poise (20° C.)
Vapor pressure	35.8 mm. Hg. (20° C.)
Specific heat	0.334 cal./gm. (25° C.)
Flash-point (A.S.T.M. Open Cup)	21° C. (70° F.)
Latent heat of evaporation	72.2 cal./gm. at B.P.
Solubility in water	0.26% by wt. (20° C.)
Solubility of water in propylene dichloride	0.07% by wt. (20° C.)
Explosive limits in air	
Lower	3.4% by vol. (25° C.)
Upper	14.5% by vol. (100° C.)
Dielectric constant (85.8 kilocycles)	8.925 recip. ohms (26° C.)
Ignition temperature in air	557° C.
Coefficient of expansion (per ° C.)	0.001108 to 20° C. 0.001153 to 55° C.
Freezing point	− 80° C. (− 112° F.)

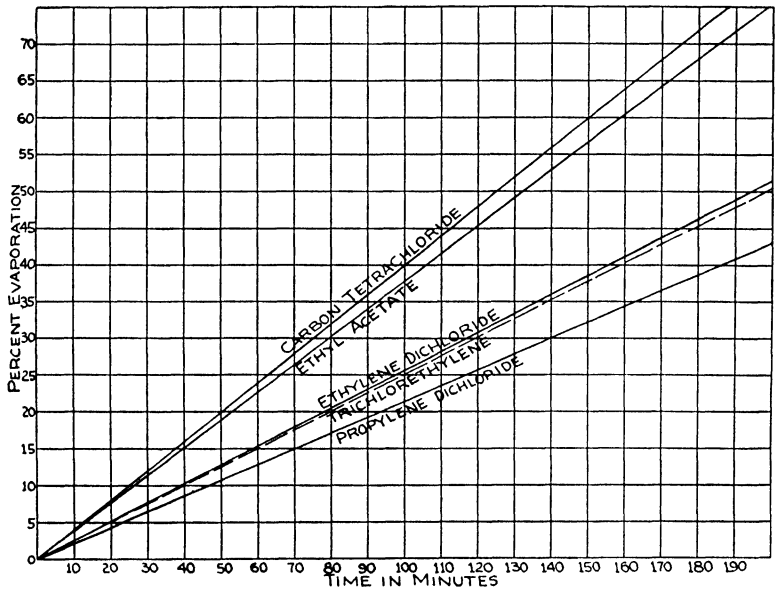


FIGURE 54. Evaporation Rate of Ethyl Acetate and Various Chlorinated Solvents at Room Temperature.[6]

Amyl Chloride

Amyl chloride ($CH_3CH_2CH_2CH_2CH_2Cl$, isoamyl chloride) is a colorless to straw-colored liquid and contains amyl chlorides and amylene as impurities.

Color	Water-white
Specific gravity	0.875 (20° C.)
Free acid as HCl	None
Amylene	Less than 1%
Other hydrocarbons	None
Polychlorides	None
Weight per gallon	7.28 lbs.

Distillation:

95% boils within plus or minus 2 degrees of the true boiling point, 106° C.

Sharples Solvents Corporation manufactures a solvent that is a mixture of all of the monochlorides of pentane and isopentane except tertiary amyl chloride and secondary isoamyl chloride.

Amyl Monochlorides

Color	Water-white
Specific gravity	0.87 (20° C.)
Free acid as HCl	None
Amylene	Less than 3%
Other hydrocarbons	None
Polychlorides	None
Weight per gallon	7.25 lbs.

Distillation:

95% boils within the range of boiling points of the primary and secondary amyl chlorides, from 90° C. to 106° C.

TABLE 57.—Chlorine Content of Various Monochlorides

Formula	Per cent
$CH_2Cl.\ CH_2.\ CH_2.\ CH_2.\ CH_3$	26
$CH_3.\ CHCl.\ CH_2.\ CH_2.\ CH_3$	18
$CH_3.\ CH_2.\ CHCl.\ CH_2.\ CH_3$	8
$CH_3(CH_3)CH.CH_2.\ CH_2Cl$	16
$CH_2Cl(CH_3)CH.CH_2.\ CH_3$	32

TABLE 58.—Formulas and Boiling Point of the Higher Dichlorides

Formula	Boiling Point (° C.)
$CH_2Cl(CH_3)CCl.\ CH_2.\ CH_3$	135
$CH_3(CH_3)CH.\ CHCl.\ CH_2Cl$	143
$CH_3.\ CHCl.\ CHCl.\ CH_2.\ CH_3$	138
$CH_2Cl.\ CHCl.\ CH_2.\ CH_2.\ CH_3$	143

Amyl Dichlorides

Color	Water-white
Specific gravity	1.00–1.04 (20° C.)
Free acid as HCl	None
Monochlorides of pentane	None
Hydrocarbons	None
Weight per gallon	8.5 lbs.

Distillation

100% boils within the range of boiling points of the amylene dichlorides, from 120° C. to 177° C.

These chlorides are miscible with alcohols, ethers, esters, ketones, etc. They are solvents for waxes, oils, fats, resins and so forth, and are used as solvents in pyroxylin and varnish lacquers, in plastics and in organic synthesis like the Friedel-Crafts, Wurtz and Grignard syntheses.

Amylene dichloride (dichloropentane) is a liquid made up of a mixture of isomeric dichlorides of pentanes. This mixture is used as a solvent in the varnish and nitrocellulose lacquers, in plastics, and as a general solvent.

Vinyl chloride is a water-white liquid used as a refrigerant and in organic synthesis.

Color	Water-white and clear.
Boiling range (760 mm.)	Not less than 95% distills over before the temperature of the liquid reaches 10° C.
Acetaldehyde	Not more than 0.5% by weight
Residue	Not more than 0.5% by volume

Dichlorethylene

Dichlorethylene ($CHClCHCl$, sym. dichlorethylene) is a colorless, low-boiling, slightly toxic liquid of pleasant odor. It is made up of two stereo-isomeric compounds made by the partial chlorination of acetylene. The hot vapors of dichlorethylene can be ignited but will not continue to burn unless heat is supplied. In actual practice there is little danger in its use. It is a good solvent for oils, gums, resins, waxes, rubber, shellac and cellulose acetate. When it is used with ethyl or methyl alcohol or alkyl acetates the mixture has a pronounced solvency for the ester and ether derivatives of cellulose. Some of the low-boiling, highly inflammable solvents are destined to be replaced by dichlorethylene because of its excellent solvent powers and non-hazardous properties. It is also used in the extraction of dyes, perfumes and organic material, in lacquers, thermoplastics and as a rubber solvent. The physical properties of this mixture are determined by the percentages of the different isomers present.

Trichlorethylene

Trichlorethylene ($CHClCCl_2$, ethylene trichloride, Westrosol, perchlorethylene, Tri) is a stable, low-boiling, colorless, heavy, mobile, toxic liquid with a pleasant odor reminiscent of chloroform. It is non-inflammable, non-explosive, non-combustible, and will not attack the common metals even in the presence of moisture. It is a solvent for chewing gum, crude rubber, dyes, bitumens, pitch, sulfur, chlorinated hydrocarbons, oils, fats, waxes, grease, tar, gums and resins such as ester gums, rosin, coumarone, mastic, elemi and vinyl resins. It is miscible with acetone, benzene, toluene, pyridine, amyl, butyl, ethyl and methyl acetates or alco-

hols. The mixtures dissolve cellulose ethers and some types of cellulose acetate. This is especially true when it is mixed with cyclohexanol or *p*-toluene-sulfonamid. Trichlorethylene is also miscible with most organic solvents.

Trichlorethylene is called by many the ideal solvent because it so nearly fulfills all the requirements of the perfect solvent; these may be summarized as follows:

High solvent power	Low toxicity
Rapid rate of penetration	Non-inflammability
Ease of separation from extracted matter	Low specific gravity
Economical recovery	Low latent heat of vaporization
High stability	Low specific heat
	Optimum boiling point

"Tri" is widely used as an extraction medium in a number of industries. It is used in the extraction and purification of olive, maise, linseed, soy-bean and other oils from the press cake or native material; of mineral and vegetable waxes, of cocoa butter, fats, nicotine, explosives (like T.N.T.), greases from tankage, bones and leather, and caffeine from coffee. Trichlorethylene is recommended and used in analytical procedures

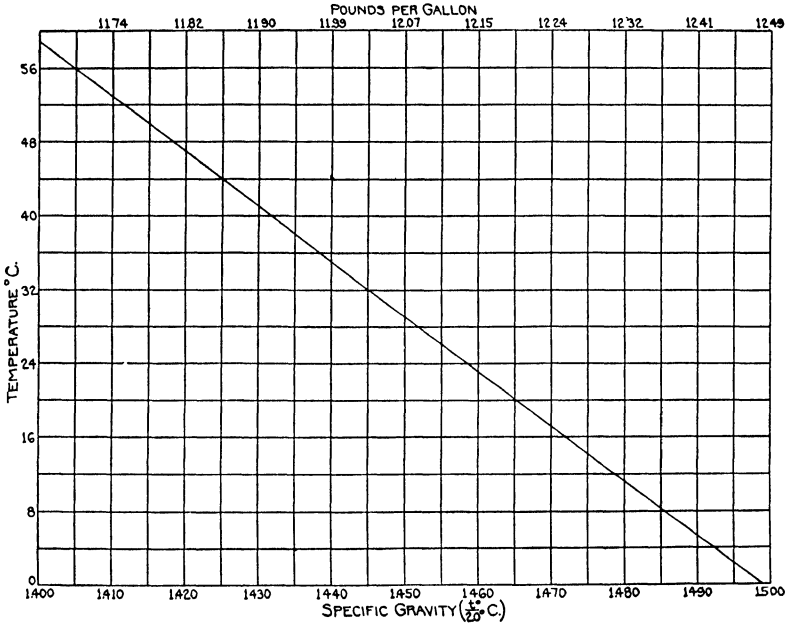


FIGURE 55. Specific Gravity and Weight per Gallon of Trichlorethylene at Various Temperatures.[6]

as a fat solvent. It also serves as a means of separating formic acid from acetic acid and as an intermediate for the making of a number of organic compounds. As an insecticide it is used in conjunction with soap. This mixture destroys the larvae and pupae of stinging and aquatic insects like mosquitoes and grape lice, and is effective as a disinfectant and cleaner of vermin-infested clothes and floors. It is also useful both in the liquid and vapor phase for degreasing metal surfaces, glass, dishes, films, molded articles, leather, textiles and so forth. Further uses are as a cleaning agent in electroplating metal parts; in the printing, painting, automobile, textile and leather industries; in the dry-cleaning industry for its rapid cleaning, unnecessary pre-spotting and freedom from fire hazard; and in making wet-soap.

Trichlorethylene

Extraction	Dry Cleaning	Preparation of Other Products
Edible Oils	Textile Fabrics	Organic Synthesis
Inedible Oils	Furs	Separation of Organic Acids
Drugs		Soaps
Purification of Foodstuffs		Spotting Preparations
Purification of Explosives		Miscellaneous Preparations
Recovery of Grease	**Insecticide Vermicide Fumigant**	
Analytical Work	General Insecticide	
Garbage Grease	Germicidal Soaps	
	Grape Lice	**General Solvent**
	Mosquitoes	Oils
Degreasing		
Metals	Anthelmintic	Fats
Leathers		Greases
		Waxes
Raw Wool	**Refrigerant**	
Textiles	Low Pressure Machines	Tar
Machinery		Rubber
Dewaxing Mineral Oils		Gums
		Resins

FIG. 56.—Principal Industrial Uses and Applications of Trichlorethylene.[1]

There are reports that many cellulose acetate silk dyes are soluble and show bleeding in trichlorethylene. The most affected colors are the yellows, oranges, reds and violets. The blues are less affected, and the blacks practically not at all. The majority of vat dyes are only slightly affected. Indigoid vat dyes bleed more readily than the anthroquinone type. Azoic colors bleed quite badly. The following colors show little or no bleeding: basic cotton dyes, basic, acid, direct and mordant silk dyes, and sulfur viscose silk dyes. Other uses for trichlorethylene are in neutral and liquid soaps, in egg-covering compounds, in degreasing and depitching com-

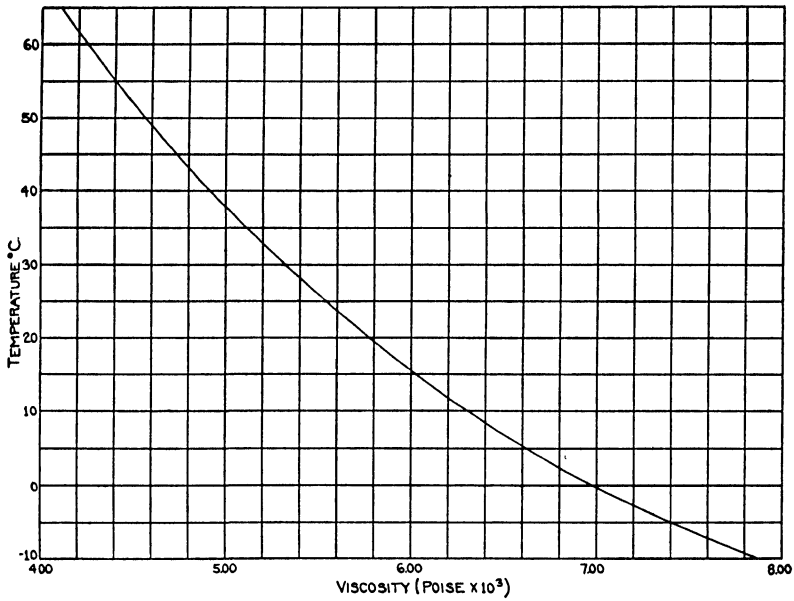


FIGURE 57. Viscosity of Trichlorethylene at Various Temperatures.[6]

pounds; as an ingredient in paint, varnish and tar removers in household cleaning compounds, in rubber cements, in shoe and stove polishes and in fumigation; as an intermediate in the manufacture of dyes, pharmaceuticals, perfumes, and organic chemicals; as a general solvent and a laboratory reagent; in degreasing bones, feathers, leather and wool; as a spotting agent and in dewaxing of oils. It also finds wide application as a volatile thinner for paints, lacquers and thermoplastics.

Molecular weight	131.38
Boiling point	86.7° C.
Freezing point	− 88° C.
Color	Water-white
Specific gravity	
at 0° C.	1.4996
at 15	1.4762 (referred to water at 4° C.)
at 30	1.4514 (referred to water at 4° C.)
at 45	1.4262 (referred to water at 4° C.)
at 59.5	1.3997 (referred to water at 4° C.)
Refractive index	1.4735 (27° C.)
Surface tension	32.0 dynes/cm. (25° C.)
Vapor pressure	60.0 mm.Hg. (20° C.)
Specific heat	0.229 cal./gm. (23° C.)

Flash-point (A.S.T.M. Open Cup)	None at B.P.
Latent heat of evaporation	57.3 cal./g. at B.P.
Coefficient of expansion (per ° C.)	0 00115 to 20° C.
Solubility in water	0.10% by wt. (25° C.)
Solubility of water in trichlorethylene	0.02% by wt. (25° C.)
Vapor Density	0.277 pounds per cu. ft. (90° C.) 3.6 cu. ft. per pound (90° C.)
Viscosity at 25° C.	0.550 centipoise
Viscosity at 50	0.446 "
Viscosity at 75	0.371 "
Heat of vaporization	58 cal./kg. 104 5 B t u /lb.
Dielectric constant	3.42
Heat conductivity (liquid) at 64° F.	0.0672 B.t.u /sq. ft./ft. 0.0718 ° F./hr.

Solubility of Water in Trichlorethylene[3]

Temperature (° C.)	Temperature (° F.)	g. Water per 100 g. Tri
10	50	0.017
18	64	0.025
28	82	0.035

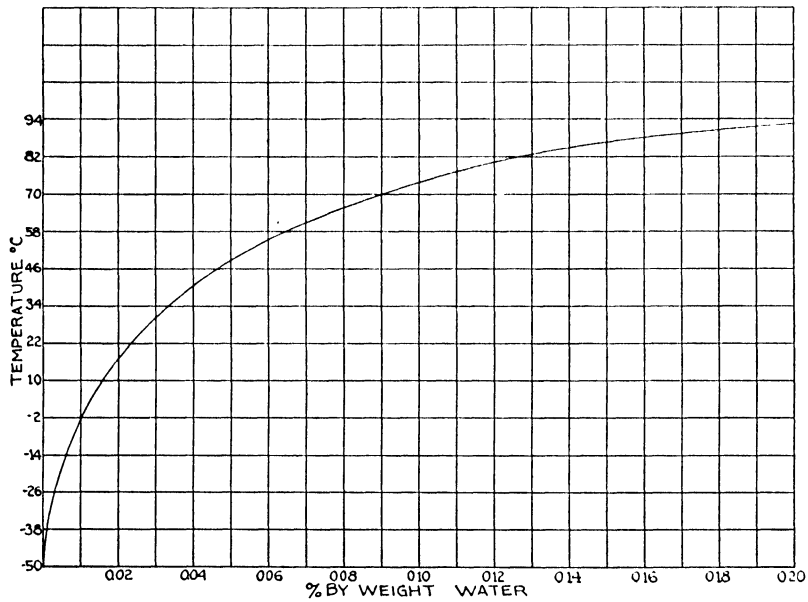


FIGURE 58. Solubility of Water in Trichlorethylene at Various Temperatures.[6]

TABLE 59.—Solubility of Various Substances in Trichlorethylene at 15° C.[1]

(Percentage by Weight as Grams of Substance Dissolved in 100 Grams of Tri)

Material	Per cent by Weight
Benzoic acid	6.9
Boric acid	0.016
Citric acid	0.012
Malic acid	0.01
Salicylic acid	0.28
Tartaric acid	0.005
Adeps suillus	In warm Tri to some degree
Agaricinum	0.014
Aloin	0.013
Amygdalinum	0.029
Anthracene	1.01
Arbutinum	0.011
Asparagin	0.018
Sodium biborate	0.011
Brucine	2.56
Camphor	10 g. dissolve in 5 cc.
Carnauba wax	Well in warm Tri, not so well in cold
Mercuric chloride	0.035
Codeine	12.0
Caffeine	0.76
Colophonium	3 g. dissolve in 5 cc.
Coumarin	1.5 g. dissolve in 5 cc.
Glucose	0.006
Gutta percha	Resinous part easily soluble
Heleninum	1.5 g. easily dissolve in 2 cc.
Codeine hydrochloride	0.014
Mastic	3 g. dissolve in 2 cc.
Nicotine	6.5
Potassium nitrate	0.01
Cocoa butter	Fair
Olive oil	Fair
Piperine	9.83
Saccharine	0.012
Saccharine lactate	0.004
Salicine	0.013
Santonine	2.46
Quinine sulfate	0.07
Sulfur depuratum	1.16
Tannin	0.012
Theobromine	0.008

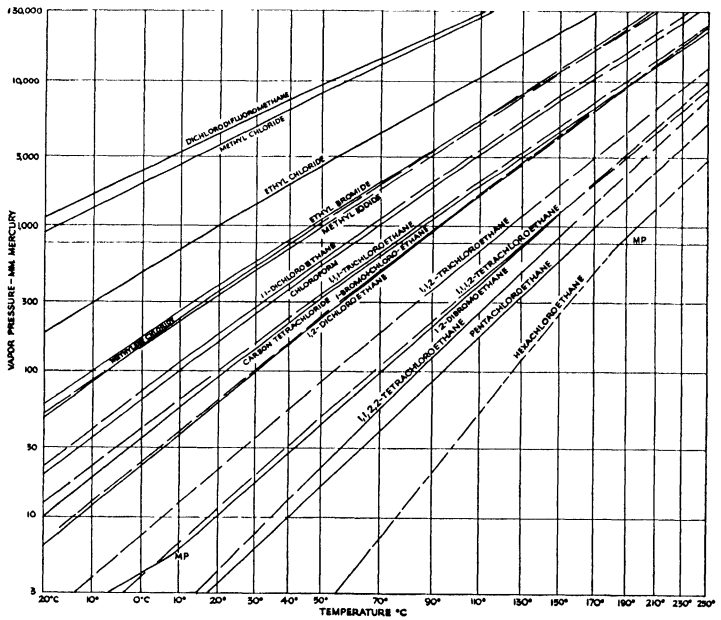


FIGURE 59. Vapor Pressure at Various Temperatures of Some Saturated Halogen Derivatives.

TABLE 60.—Relative Toxicities,* Carbon Tetrachloride Arbitrarily Taken as 1.0[1]

Tetrachlormethane (carbon tetrachloride)	$C Cl_4$	1.0†
Perchlorethylene	C_2Cl_4	1.6†
Trichlorethylene	C_2HCl_3	1.7†
Dichlorethylene	$C_2H_2Cl_2$	1.7†
Trichloromethane (chloroform)	$CHCl_3$	2.2
Pentachlorethane	C_2HCl_5	6.2
Tetrachlorethane	$C_2H_2Cl_4$	9.1

*The information was obtained from various sources in technical and medical literature.
†Non-toxic under most conditions.

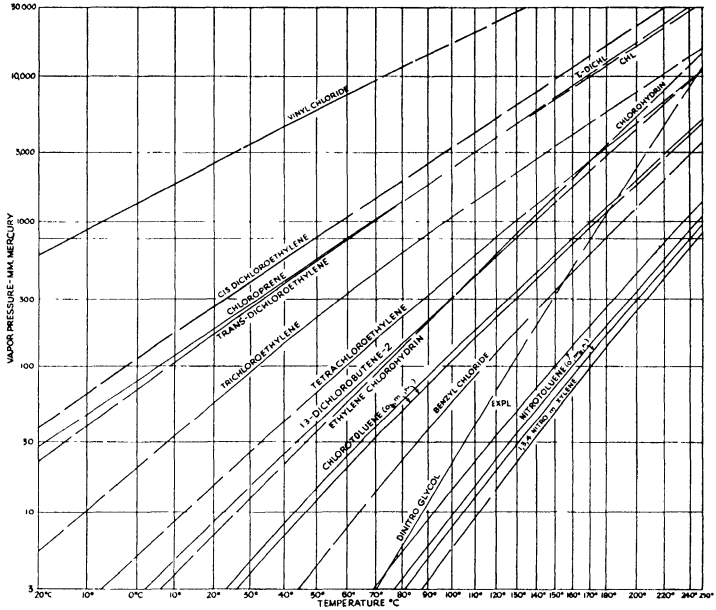


FIGURE 60.* Vapor Pressure at Various Temperatures of Unsaturated Aliphatic Halides and Miscellaneous Inorganic Aliphatic and Aromatic Derivatives.

* Figures 59 and 60 are from a compilation prepared by C. Hadlock, Engineering Dept., E. I. Dupont de Nemours and Company.

TABLE 61.—Effect of Tri on Tensile Strength* of Various Fabrics[1]

Values in pounds per inch width

	Filling		Warp	
	Untreated	Treated with Tri	Untreated	Treated with Tri
Cotton	28.8	27.3	37.2	39.2
Linen	33.3	36.8	39.0	46.2
Silk	22.3	21.2	41.5	43.2
Cellulose acetate Rayon	10.2	10.5	10.8	12.0
Viscose rayon	19.9	20.1	19.3	20.1
Cuprammonium rayon	22.1	21.1	33.2	32.5

*Average of a number of experimental determinations.

TABLE 62.—Flash-points of Various Tri Mixtures[1]

Tri (%)	Inflammable Constituent (%)	Flash-point (° C.)	Flash-point (° F.)
0	100 Stoddard solvent	38	100.4
30	70 " "	67	152.6
50	50 " "	None	
0	100 Kerosene	41	106
50	50 "	90	194
0	100 Naphtha, 72° Grade	21	70
50	50 Naphtha	65.5	150
80	20 "	82	180
0	100 Benzine	30	86
50	50 "	74	165
75	25 "	82	180
83	17 "	86.5	188
0	100 Benzene	27	80
67	33 "	86–88	187–190
0	100 Turpentine	49	120
75	25 }		
80	20 } Turpentine	89–90	192–195
83	17 }		

TABLE 63.—Hazardous Concentrations of Various Solvents[1]

	Rapidly Fatal For Short Exposures p.p.m.	Maximum Amount That Can Be Inhaled for One Hour Without Serious Disturbances p.p.m.	Noxious; Impossible to Breathe Several Minutes p.p.m.	Lethal Dose for Cats in 30 Min. p.p.m.	Lethal Dose for Man in 30 Min. p.p.m.
Carbon disulfide			33000	33000	500–1000
Carbon tetrachloride		4000–6300		63000	48000–63000
Chloroform		5100–6200		25000	
Dichlorethylene				44000	
Gasoline	24300	4300–7100	17000		
Pentachlorethane				9600	
Perchlorethylene				31000	
Tetrachlorethane				7300	
Trichlorethylene				37000	

Tetrachlorethylene

Tetrachlorethylene (CCl_2CCl_2, carbon bichloride, carbon dichloride, perchlorethylene) is a heavy, non-inflammable, toxic, colorless liquid of ether-like odor. It is narcotic, stable and slightly corrosive to metals. The miscibility and solvency of tetrachlorethylene are similar to those of trichlorethylene, and the tetra- compound is used in place of trichlorethylene where a slower rate of evaporation is desired. When either of these compounds is mixed with an active solvent, the mixture will dissolve cellulose ethers and esters.

	Purified	Technical
Molecular weight	165.83	165.83
Specific gravity	1.608	1.614
Boiling range	121–122° C.	118–122° C.
Freezing point	− 19° C.	− 22.4° C.
Flash-point	None	
Explosion point	None	

Solubility in water (25° C.)	0.01%
Solubility of water in C_2Cl_4 at 25° C.	Less than 0.01%
Latent heat of vaporization	{50.2 cal./g. {90.3 B.t.u./lb.
Specific heat cal./g./° C. or B.t.u./lb./° F.	0.216
Viscosity	8.38 millipoises (25° C.)

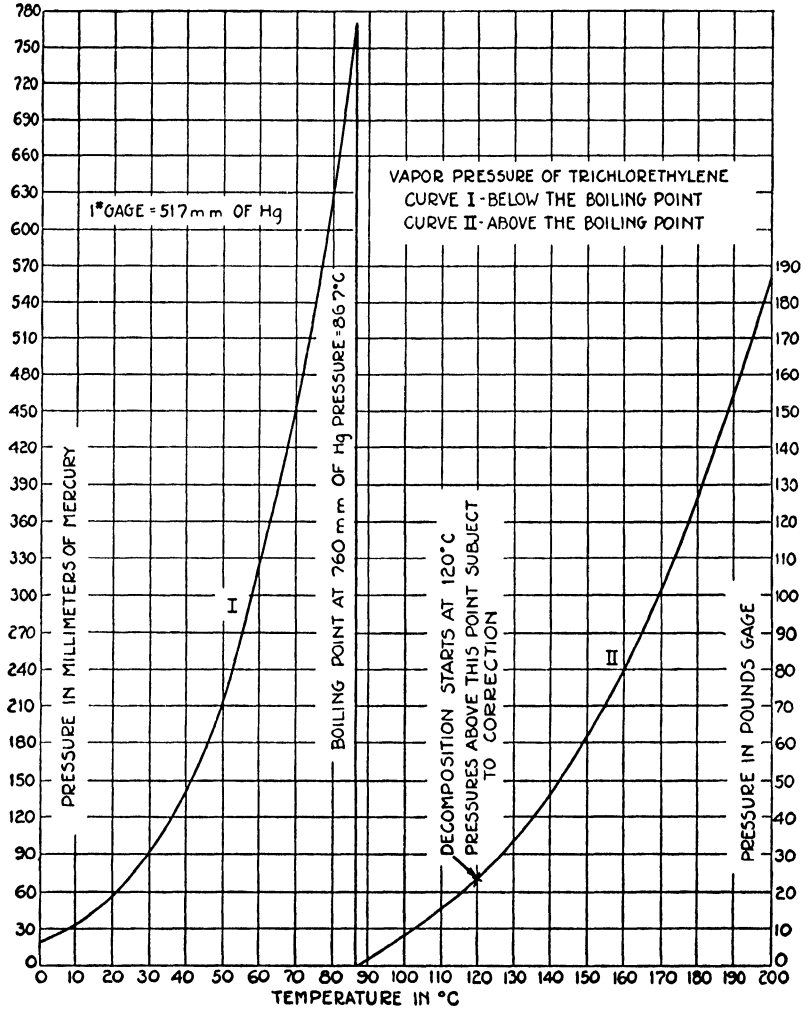


FIGURE 61. Vapor Pressure of Trichlorethylene at Various Temperatures. Curve I, below boiling point. Curve II, above boiling point.[1]

TABLE 64.—Chlorinated Hydrocarbons

Physical Properties

	Methyl Chloride	Methylene Chloride	Chloroform Tech. 98%	Carbon Tetrachloride	Dichlor-ethylene "Di-48"	Dichlor-ethylene "Di-60"	*Dichlor-ethylene "48-60"	Trichlor-ethylene	Perchlor-ethylene
Chemical Formula	CH_3Cl	CH_2Cl_2	$CHCl_3$	CCl_4	HCl C=C ClH	HH C=C ClCl	$CHCl=CHCl$	$CHCl=CCl_2$	$CCl_2=CCl_2$
Molecular Weight	50.48	84 93	119.37	153.83	96.93	96.93	96 93	131.38	165.83
Boiling Point at 760 mm. Hg. (° C.)	−23 7	39.8	61.2	76.7	48.4	60.3	48.4–60.3	86.7	120.8
(° F.)	−10 7	103 6	142.2	170.1	119.1	140.5	119.1–140.5	188.1	249.4
Freezing Point (° C.)	−97.6	−96 7	−63.2	−23.0	−50.0	−80.5	−50.0−−80.5	−88.0	−22.4
(° F.)	−143.7	−142 1	−81.7	− 9.4	−58.0	−112.9	−58.0−−112.9	−126.4	− 8.3
Latent heat of cal./g.	102.4	75 3	59.0	46.5	73.7	73.0	73.3	57.3	50.1
Vaporization (at B.P.) B.t.u./lb.	184.3	135 5	106.1	83.7	132.6	131.3	131.8	103.1	90.1
Specific Heat at 20° C. (Liquid) cal./g./° C. or B.t u./lb./° F.	0.382	0.289	0.234	0.201	0.270	0.270	0.270	0 223	0.216
Specific Gravity at 20/4° C.	1.002 at −23.7° C.	1.336	1.489	1.595	1.257	1.282	1.272	1.462	1.623
Pounds per Gal. at 20° C.	8 34 at −23.7° C.	11 15	12.43	13.31	10.49	10.70	10.61	12.20	13.55
Vapor Density g./liter	2.47	3.32	4.36	5.37	3.67	3.54	—	4.45	5.13
(at B.P. and lb./cu. ft.	0.154	0 206	0 272	0.335	0.230	0.221	—	0.278	0.320
760 mm.) air = 1.00	1.74	2 94	4.13	5 32	3.34	3.35	—	4 53	5.72
Solubility in Water at 25° C. g./100 g.	0.48	2.11	0.88	0 09	0.63	0.77	0.75	0 17	0.04
Refractive Index (20° C.)	—	1.4237	1.4467	1.4607	1.4490 at 15° C.	1.4519 at 15° C.	1.4507 at 15° C.	1.4777	1.5055
Vapor Pressure at 30° C. 760 mm. Hg.	4940	511	246	141	383	255	306	94	33
Inflammable	Mod.	No	No	No	Mod.	Mod.	Mod.	No	No

Specifications‡

	**								
Boiling Range, 760 mm. Hg. (° C.)	−24.6 to −23.6	39.2 to 40 0	60.0 to 61.5	76.2 to 77.0	47.0 to 48.5	57.5 to 61.0	51.0 to 61.0	86 0 to 87.5	120.0 to 122.0
No cloud at:		−24° C.	−10° C.		−15° C.	−15° C.	−15° C.	−10° C.	0° C.
Max. Water, % by wt.	0.008	0 027	0.021		0.004	0.001	0.004	0.002	0.008
Mac. Acid (as HCl), % by wt.	0 001	0 001	0.001	None	0.0005	0.0005	0.0005	None	0.001
Max. Residue, % by wt.	0.01	0 00075	—	0 0015	0.0007	0.0007	0.0007	0 002	0.0007
Specific Gravity, (15/4° C.)		1 333 to 1.336	1.478 to 1 482 at 25/4° C.	1.595 to 1.597 at 20/15.5 ° C.	1.261 to 1.266	1.288 to 1.293	1.279 to 1.285	1.472 to 1.476	1.628 to 1.632
Maximum Color	Water-White	Saybolt No 24	Saybolt No. 24	Clear Colorless	Saybolt No. 24	Saybolt No. 24	Saybolt No. 24	Saybolt No. 24	Saybolt No. 22

*Mixture of 40% by weight of "Di-48" and 60% by weight of "Di-60."

**Methyl Chloride or ARTIC is supplied according to these specifications as well as under two additional formulas, namely, "A" and "N". These products are prepared by adding from 0.3 to 1.3% by weight of a warning agent to the original material. These addition agents produce variations in the properties of the original material, particularly in its odor and color.

‡E. I. Dupont de Nemours & Co.

TABLE 65.—Chlorinated Hydrocarbons

Physical Properties

	Ethyl Chloride	Ethylene Dichloride	Beta-Trichlor-ethane	Tetrachlor-ethane	Pentachlor-ethane	Hexachlor-ethane	Propylene Dichloride
Chemical Formula	CH_3-CH_2Cl	CH_2Cl-CH_2Cl	$CH_2Cl-CHCl_2$	$CHCl_2-CHCl_2$	$CHCl_2-CCl_3$	CCl_3-CCl_3	$CH_3CHCl-CH_2Cl$
Molecular Weight	64 50	98 95	133 40	167.85	202.29	236.75	112.96
Boiling Point at 760 mm. Hg. (° C.)	12 5	83.7	113.5	146 3	161.9	Sublimes	95.9
(° F.)	54.5	182.7	236 3	295.3	323 4	at 185° C.	204.6
Freezing Point (° C.)	−138 7	−35.3	−36.7	−43.8	−22.0	or	−80
(° F.)	−217.7	−31.5	−34 1	−46 8	−7.6	365° F.	−112
Latent Heat of cal./g.	93 0	77.4	68.7	55.2	43 6	46.4	79
Vaporization (at B.P.) B t.u./lb	167 3	139.2	123.6	99.3	78.4	83.5	142
Specific Heat at 20° C. (Liquid) cal./g./° C. or B.t.u./lb./° F.	0.394	0.301	0.266	0.269	0.198	0.174 at 25° C.	0.31
Specific Gravity at 20/4° C.	0.921 at 0° C	1.257	1.441	1.595	1.678	2 091	1.155
Pounds per Gal. at 20° C.	7 69 at 0° C.	10.49	12.04	13.31	14.00	—	9.64
Vapor Density g./liter	2.76	3.88	4.21	4 88	5.68	6.30	3.72
(at B.P. and lb./cu. ft.	0.172	0.211	0.263	0.305	0.355	0.393	0.232
760 mm.) air = 1.00	2 24	3 92	4.61	5.79	7.02	8.20	3.90
Solubility in Water at 25° C. g./100 g.	0 20 at 11° C.	0 89	0.48	0.32	0 05	—	0.27
Refractive Index (20° C.)	1.1179 at 0° C.	1.4443	1.4711	1.4942	1 5035	—	1.4418
Vapor Pressure at 30° C. 760 mm. Hg.	1400	100	35	7	6	0 5	67
Inflammable	Yes	Mod.	No	No	No	No	Mod.

Specifications‡

Boiling Range, 760 mm. Hg. (° C.)	95% 12 0 to 13.0	† 82.1 to 84 6	111.0 to 115 0	—	—	—	† 94.4–97.0
No cloud at:	−15° C.		−15° C.	−10° C.	−10° C.		
Max. Water, % by wt.	0.011	0 092	0 016	0.023	0 001	—	0.038
Max. Acid (as HCl), % by wt.	0.001	—	0 0005	0.0027	0.001	0 05	1.00
Max. Residue, % by wt.	0.01	0 0009	0 0008	0.0007	0.0007	0 15	0.002
Specific Gravity, (15/4° C.)	0.922 to 0 925 at 0/4° C.	1 252 at 20/20° C.	1.446 to 1.452	1.598 to 1 602	1.683 to 1.690		1.161 at 20/20° C.
Maximum Color	Water-White		Saybolt No. 24	Saybolt No. 18	Saybolt No. 18		

†Representative analyses of Ethylene Dichloride and Propylene Dichloride.

‡E. I Dupont de Nemours & Co.

Booth, Mong and Burchfield [7] have fluorinated hexachlorethane and have displaced one to five of the chlorine atoms with fluorine.

TABLE 66.—Solvent Action of Fluorine-Substituted Chlorethylenes[7]

Solute	$C_2Cl_3F_3$	$C_2Cl_4F_2$
Inorganic Compounds		
Ammonium nitrate	Insol.	Insol.
Ammonium fluosilicate	Insol.	Insol.
Ammonium thiocyanate	Insol.	Insol.
Asbestos	Insol.	Insol.
Barium dioxide	Insol.	Insol.
Boric acid	Insol.	Insol.
Cadmium iodide	Insol.	Insol.
Chromium oxalate	Insol.	Insol.
Chromium chloride (violet)	Insol.	Insol.
Iodine	Insol.	Slightly sol.
Potassium antimonyl tartrate	Slightly sol.	Insol.
Potassium chromate	Insol.	Insol.
Potassium permanganate	Insol.	Insol.
Silver nitrate	Insol.	Insol.
Sodium carbonate	Insol.	Insol.
Water	Insol.	Insol.
Organic Acids and Acid Anhydrides		
Anthranilic acid	Very slightly sol.	Insol.
Benzoic acid	Moderately sol.	Very sol.
Malic acid	Very slightly sol.	Insol.
Malonic acid	Insol.	Insol.
Mandelic acid	Insol.	Insol.
Monochloroacetic acid	Insol.	Insol.
Phthalic anhydride	Moderately sol.	Moderately sol.
Salicylic acid	Very slightly sol.	Moderately sol.
Stearic acid	Moderately sol.	Slightly sol.
Succinic acid	Very slightly sol.	Very slightly sol.
Tartaric acid	Very slightly sol.	Very slightly sol.
Resins, Gums, Fats, Oils, etc.		
Amberol F7 light	Slightly sol.	Slightly sol.
Bakelite XR821	Insol.	Insol.
Dammar	Moderately sol.	Very sol.
Ester gum	Moderately sol.	Insol.
Glyptol 1102	Insol.	Insol.
Shellac	Insol.	Insol.
Agar	Insol.	Insol.
Gelatin	Very slightly sol.	Very slightly sol.
Gum arabic	Insol.	Insol.
Gum mastic	Slightly sol.	Insol.
Casein	Insol.	Insol.
Egg albumen	Insol.	Insol.
Cocoa butter	Very sol.	Soluble
Castor oil	Very sol.	Miscible
Cottonseed	Very sol.	Miscible
Anisol	Miscible	Miscible
Citral	Miscible	Miscible
Clove oil	Miscible	Miscible
Aliphatic Solutes		
n-Hexane	Miscible	Miscible
n-Heptane	Miscible	Miscible
Kerosene	Miscible	Miscible

TABLE 66.—Solvent Action of Fluorine-Substituted Chlorethylenes[7]—(*Continued*)

Solute	$C_2Cl_3F_3$	$C_2Cl_4F_2$
Aliphatic Solutes—(Continued)		
Carbon tetrachloride	Miscible	Miscible
Chloroform	Miscible	Miscible
Dichloromethane	Miscible	Miscible
Hexachloroethane	Sol.	Sol.
Bromoform	Miscible	Miscible
Iodoform	Slightly sol.	Slightly sol.
Ethyl bromide	Moderately sol.	Very sol.
Methylene iodide	Insol.	Insol.
Ether	Miscible	Miscible
Ethyl alcohol	Miscible	Miscible
Methanol	Miscible	Miscible
Ethylene glycol monobutyl ether	Miscible	Miscible
Glycerol	Insol.	Insol.
Acetone	Miscible	Miscible
Cane sugar	Insol.	Very slightly sol.
Cellulose acetate	Insol.	Insol.
Nitrocellulose (½ sec.)	Insol.	Insol.
Urea	Slightly sol.	Slightly sol.
Thiourea	Insol.	Insol.
Acetamide	Very slightly sol.	Very slightly sol.
Theobromine	Very sol.	Slightly sol.
Sulfonal	Slightly sol.	Moderately sol.
Trional	Slightly sol.	Very sol.
Dimethylglyoxime	Insol.	Insol.
Aromatic and Ring Compounds		
Benzene	Miscible	Miscible
Diphenyl	Moderately sol.	Very sol.
Naphthalene	Very sol.	Very sol.
Anthracene	Very slightly sol	Very slightly sol.
Xylene	Miscible	Miscible
Chlorobenzene	Miscible	Miscible
Iodobenzene	Miscible	Miscible
α-Chloronaphthalene	Miscible	Miscible
α-Bromonaphthalene	Miscible	Miscible
Tribromophenol	Very sol.	Slightly sol.
Nitrobenzene	Miscible	Miscible
Azobenzene	Very sol.	Very sol.
Aniline	Insol.	Miscible
Acetanilide	Moderately sol.	Very slightly sol.
Antipyrine	Very slightly sol.	Slightly sol.
Diphenylamine	Insol.	Very sol.
Quinaldine	Miscible	Miscible
Methylene blue	Insol.	Insol.
Indigo	Very slightly sol.	Insol.
Phenol	Very slightly sol.	Very slightly sol.
Benzyl alcohol	Miscible	Miscible
Resorcinol	Insol.	Insol.
Benzil	Moderately sol.	Moderately sol.
Diphenyl carbinol	Moderately sol.	Very sol.
Thymol	Very sol.	Very sol.
Camphor	Very sol.	Very sol.
Benzophenone	Very sol.	Very sol.
Anthraquinone	Insol.	Slightly sol.
Phenolphthalein	Insol.	Insol.
p-Nitrobenzoylacetoacetic ester	Moderately sol.	Very sol.

AROMATIC

Monobrombenzene

Monobrombenzene (C_6H_5Br, phenyl bromide, brombenzene) is a heavy, mobile, colorless liquid of pleasant characteristic odor. It is an efficient solvent for many substances and is miscible with both petroleum products and halogenated solvents. Brombenzene is used as an intermediate in organic synthesis. It is added to motor fuels both for its ability to dissolve and remove "gasoline gum" and for the lubricating properties it imparts. Brombenzene is also used as a crystallizing solvent for organic substances.

Molecular weight	156.96
Specific gravity	1.499 (15° C.)
Weight per gallon	12.51 lbs.
Boiling point	156.6° C. 312.9° F.
Freezing point	− 30.5° C. − 22.9° F.
Flash-point	65° C.

Dibrombenzene

Dibrombenzene ($C_6H_4Br_2$, *o*-dibrombenzene) is a heavy liquid of pleasant aromatic odor. It is completely miscible with most solvents and is a particularly good solvent for oils. It is added to gasolines for its ability to dissolve gummy and waxy deposits. Other uses are in organic synthesis and in the separation of ores by flotation.

Monochlorbenzene

Monochlorbenzene (C_6H_5Cl, chlorbenzene, phenyl chloride, monochlorbenzol) is a colorless, mobile, volatile, inflammable liquid of almond-like odor. As a fire hazard it is not considered very dangerous. It is mildly narcotic and is reputed to be less toxic than benzene. It is made by the chlorination of benzene in the presence of a chlorine-carrier. Monochlorbenzene is miscible with most organic solvents and will dissolve ethyl cellulose, many natural and synthetic resins like rosin, dammar, soft copal, vinyl resins Bakelite, acetylcellulose and so forth. Like other halogenated hydrocarbons the solubility power of chlorbenzene is increased by the addition of amyl, butyl, ethyl or methyl alcohols or their acetate esters. Monochlorbenzene is added to lacquers for its unique property of producing a crackle or matt effect. It is used in organic synthesis, in the manufacture of chemicals, perfumes, dyes, drugs and so forth.

Dichlorbenzene

Dichlorbenzene ($C_6H_4Cl_2$, orthene, *o*-dichlorbenzene) is a limpid, volatile, stable liquid of characteristic odor, and although it is considered noninflammable it will burn when ignited. It is a mixture composed, principally, of ortho compounds which contain varying amounts of para and meta isomers. *o*-Dichlorbenzene is miscible with most organic solvents

and is a solvent for the oxides of non-ferrous metal, waxes, sulfur, and organic sulfur derivatives, oils, natural and synthetic resins, acetylcellulose and so forth. It is recommended as an ingredient in metal polish, and as a wax solvent, and is added to lacquer and varnishes for its solvency, penetration, slow evaporation, and its ability to impart easy-working qualities and freedom from orange peel. It is a termite exterminator, repellant and wood preservative which consequently makes it a natural selection as a fungicide and preservative. *o*-Dichlorbenzene is also used in organic synthesis of dyes and drugs, in the removal of sulfur from illuminating gases and as a fumigant. Ehrlich [8] is of the opinion that *o*-dichlorbenzene makes an ideal fat solvent owing to its avidity for fat. He bases his conclusions upon the fact that this solvent works in the presence of water; it extracts fat and oil completely, and can be recovered by direct steam distillation.

	Purified	Technical
Molecular weight	146.95	146.95
Specific gravity (25° C.)	1.305	1.284
Weight per gallon	10.9 lbs.	10.7 lbs.
Chief impurities *p*-dichlorbenzene trichlorbenzene	not over 4%	not over 12%
Boiling range		
°C.	178–180 5	172–179
°F.	352.4–356.9	341.6–354.2
Freezing point		
°C.	not below – 19.3	below – 20
°F.	not below – 2.7	below – 4
Flash-point		
°C.	between 63 and 77	63–77
°F.	145.4	145.4
Burning point		
°C.	103	103
°F.	217 4	217.4
Solubility in water (25° C.)	Less than 0 01%	
Latent heat of vaporization		
cal./g.	66.4	
B.t.u./lb.	119.5	
Specific heat cal./g./° C. or B.t.u./lb /° F.	0.271	

Some other solvents proposed are monoiodobenzene and trichlorbenzene. The following solvents have been proposed as nitrocellulose solvents: nitrobenzyl chloride, nitrochlorbenzene, *p*-chlornitrobenzene, *p*-dibrombenzene, alpha and beta derivatives of mono-, di-, and tetrachlorides of naphthalene. Some 45 solvents were proposed by Carpmael [9] and these were made up of di-, tri-, tetra-, penta-, and hexachlor-, or brom-, or fluorbenzenes, or -toluenes, or -xylenes. When assisting solvents such as amyl, butyl, ethyl, isopropyl or methyl alcohol or their acetic esters are added to halogenated aromatic hydrocarbons, the mixture takes on special solvent properties for ethers and esters of cellulose.

Trichlorbenzene

Trichlorbenzene ($C_6H_3Cl_3$) is a colorless, stable, refractive liquid of an odor simulating *o*-dichlorbenzene. It is miscible with most solvents and oils.

Molecular weight	181.40
Specific gravity	1.45 (20° C.)
Weight per gallon	12.16 lbs.
Chief impurities	1,2,3-Trichlorbenzene not over 12%
Boiling range	213-217° C. 415.4-422.6° F.
Freezing point	8-11° C. 46.1 51.8° F.
Flash-point	None to boiling point

Chlorhydrins

Ethylene Chlorhydrin

Ethylene chlorhydrin ($ClCH_2CH_2OH$, glycol chlorhydrin, 2-chlorethyl alcohol) is a colorless, highly refractive, toxic liquid of ethereal odor. It is made by the action of chlorine water on ethylene. Commercially it appears on the market in an anhydrous condition and in a 38 per cent aqueous solution which contains hydrochloric acid and ethylene dichloride as impurities. Ethylene chlorhydrin is miscible with water, alcohol, benzene and so forth. It has the unusual property of dissolving cellulose acetate and tolerating the addition of water at the same time. When glycol chlorhydrin is admixed with methyl alcohol, the mixture becomes a solvent for ethyl cellulose.

Ethylene, or propylene, or butylene chlorhydrin and water, or water and alcohol, are powerful solvent mixtures for cellulose acetate.

Ethylene chlorhydrin is used in the organic synthesis of such substances as oil of rose, Novocaine and indigo, and for the introduction of the hydroxy-ethyl group. The 38 per cent solution of glycol chlorhydrin is used to activate the sprouting of dormant potatoes.

Acidity	Not more than 0.1% calc. as HCl.
Color	Not more than 2.0 yellow
Purity	Not less than 38% ethylene chlorhydrin
Specific gravity	not less than 1.083 at $\frac{20° C.}{20° C.}$
Weight	9.1 lbs./gal. (15.6° C.)

Monochlorhydrin

Monochlorhydrin ($ClCH_2CH(OH)CH_2OH$) is a colorless, hygroscopic, unstable liquid. It is made by passing hydrochloric acid gas into glycerol containing 2 per cent acetic acid. The commercial grade is a mixture of the two isomers alpha and beta, of which alpha is in a greater proportion.

Monochlorhydrin is a solvent for acetylcellulose, glyceryl phthalate resins, and is able to dissolve partially ester gum, benzyl abietate, shellac, and mastic. It is miscible with water and a number of organic solvents but will not mix with oil and hydrocarbons. A mixture of 40 per cent monochlorhydrin and 60 per cent water will dissolve cellulose acetate. It is used as an intermediate in organic synthesis, and in the manufacture of explosives and Novocaine.

Specific gravity	1.326 (18° C.)
Boiling point	213° C.
Boiling range	213–228° C. (decomposes)

Dichlorhydrin

Dichlorhydrin ($ClCH_2CH(OH)CH_2Cl$, glycerol dichlorhydrin, dichlorisopropyl alcohol, 1,3-dichlor-propanol-2, α-propenyl-dichlorhydrin) is a colorless, slightly viscous, non-inflammable, unstable liquid of a faint chloroform-like odor.

In commerce it is a mixture of the two isomers 1,3-dichlor-2-hydroxypropane and 1,2-dichlor-3-hydroxypropane of which the former is in a dominant amount.

It is a solvent for cellulose acetate, ethyl cellulose and some types of cellulose nitrate, benzyl abietate, soft copal, copal ester, dammar, elemi, cumar resin, ester gum, glyptol resins, manila, mastic, shellac and so forth.

Lilienfeld[5] and others have proposed some 80 solvent mixtures for ethyl cellulose and these are dichlorhydrin and other supplementary dissolvents. The mixture of glycerol dichlorhydrins is miscible with vegetable oils and most organic solvents, and is soluble in water to the extent of 10 per cent. It is used as an intermediate in organic synthesis, as a solvent for resins and cellulose derivatives in lacquers, in celluloid cement, and as a binder for water colors.

Specific gravity	1.36–1.39
Boiling range	174°–176° C. (95%)
Boiling point	(1.3)174° C.-(1.2)183° C.
Refractive index	1.47–1.48
Flash-point	74° C.
Vapor pressure	7 mm. Hg

Epichlorhydrin

Epichlorhydrin (CH_2OCHCH_2Cl, chlorpropylene oxide) is a highly-volatile, unstable, narcotic liquid of chloroform-like odor.

It is immiscible with water and petroleum hydrocarbons, but is miscible with alcohols, ethers, esters, ketones and aliphatic halogen derivatives. It is a powerful solvent for many types of cellulose esters and ethers, synthetic and natural resins and gums, and is used in lacquers and in surface coatings, together with plasticizers.

Specific gravity	1.19–1.20
Boiling point	117° C.

Propylene Chlorhydrin

Propylene chlorhydrin (chlor-isopropyl alcohol) is a colorless liquid soluble in water. It is used in organic synthesis for the introduction of the hydroxy-isopropyl groups.

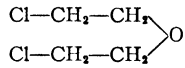
Purity	46 to 54% propylene chlorhydrin by weight
Specific gravity	1.066 to 1.076 at $\frac{20° \text{ C.}}{20° \text{ C.}}$
Acidity	Not more than 0.02% as HCl
Color	Water-white, if shipped in glass
Odor	Mild, non-residual
Solubility in water	Miscible in all proportions
Average weight	8.9 lbs./gal. (20° C.)

Other proposed chlorhydrin solvents and plasticizers are:

Amylene chlorhydrin
Aceto chlorhydrin
Benzo chlorhydrin
Aceto dichlorhydrin
Diaceto chlorhydrin

Dichlorethyl Ether

Dichlorethyl ether ($ClCH_2CH_2OCH_2CH_2Cl$, sym. or β,β-dichlordiethyl ether) is a colorless, stable, non-corrosive liquid with an odor like that of ethylene dichloride. It is an active solvent for oils, fats, waxes, gums, tars, pectins, natural and synthetic resins, insoluble soaps and ethyl cellulose. When symmetrical dichlorethyl ether is mixed with 10 per cent to 30 per cent ethyl alcohol, the mixture will dissolve many types of cellulose esters and ethers. The active solvency of this compound is owing to the combined action of the ethyl ether and ethylene dichloride groups in the molecule



It is miscible with many organic solvents but not with the paraffin hydrocarbons. Because of its detergent action dichlorethyl ether is used to assist soap solutions in such textile processes as kier boiling, scouring, scouring for the removal of paint, tar, oil and grease spots.

It is also used in fulling compounds and in wetting-out agents and penetrants. It also finds application as an intermediate in synthesis and as an activating medium in chemical reactions, as in sulfonation and so forth. It is also used as a diluent in acetyl- and nitrocellulose lacquers, in paint and varnish removers, in spotting agents and cleaning solutions; and it can equally replace ethylene dichloride especially where high temperatures are required. Further uses for dichlorethyl ether are in the textile industry, as a softening and conditioning agent, as a substitute for

caustic alkalies in kier boiling, in peroxide bleaching for penetration, in desizing, and as an aid in mercerizing.

Molecular weight	142.98
Boiling point	178° C.
Specific gravity	$1.22\ \frac{20°\ C.}{20°\ C.}$
Weight per gallon	10.1 lbs. (20° C.)
Refractive index	1.457 (20° C.)
Surface tension	41.8 dynes/sq. cm. (25° C.)
Viscosity	2.0653 centipoises (25° C.)
Vapor pressure	1.2 mm. (20° C.)
Specific heat	0.369 cal. (20–30° C.)
Latent heat of evaporation	64.1 cal./g. (178° C.)
Flash-point (closed cup)	55° C. (131° F.)
Solubility	Insoluble in water Soluble in most organic liquids
Apparent ignition temperature in air	396° C. (745° F.)

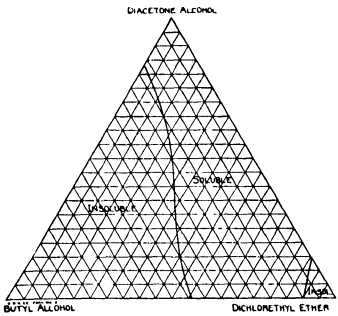


FIGURE 62. Solubility of Low Viscosity Cellulose Acetate in Mixtures of Diacetone Alcohol, Butyl Alcohol and Dichlorethyl Ether.[6]

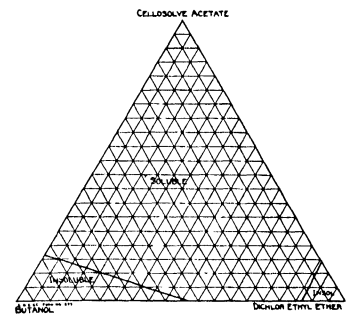


FIGURE 63. Solubility of ½ Second R. S. Nitrocellulose in Mixtures of Cellosolve Acetate, Butanol and Dichlorethyl Ether.[6]

Halowax Oils

Halowax oils are thin, neutral, mobile, almost colorless liquids of a characteristic heavy odor. They are insoluble in alkaline solutions but are soluble in carbon tetrachloride, benzene, and most organic solvents and oils. They dissolve many types of dyes, gutta percha, rubber, mineral and vegetable oils, resins, varnish gums and waxes. Halowax oils are noncorrosive to metals and are high in dielectric strength.

Specific gravity	1.20–1.27 (20° C.)
Liquid at	– 31° C.
Freezing point	– 36° C.
Flash-point	111° C.
Boiling range	(about) 250–288° C.
Specific heat	0.282 (between 30–60° C.)

TABLE 68.—Physical Properties of the Aroclors*

Description (at room temperature)	Aroclor 1242 Practically Water-White Mobile Oil	Aroclor 1248 Practically Water-White Mobile Oil	Aroclor 1254 Pale Yellow Viscous Oil	Aroclor 1262 Light Yellow Soft Sticky Clear Resin	Aroclor 1269 Cream-Colored Opaque Hard Crystalline Solid	Aroclor 4465 Pale Amber Transparent Resin	Aroclor 2565 Brown-Black Opaque Resin
Color (1" depth of Aroclor)—Lovibond yellow No. 510	0.1 to 0.5	0.1 to 0.6	0.5 to 1.0	0.5 to 1.2		4.3 to 6.4	
Pour point (° C.) (A. S. T. M. method)	−17.7 to −20.7	−9	8.0 to 12.6	34.9 to 38.0			
Softening point (° C.) (A. S. T. M.)						60 to 66	68 to 72
Condition at 0° C.	Viscous Liquid	Viscous Liquid	Soft Sticky Resin	Hard Brittle Resin	Same as at Room Temperature	Same as at Room Temperature	Same as at Room Temperature
Distillation range (° C., A. S. T. M. method)	311 to 356	330 to 350	352 to 381	373 to 404	Too High	Too High	Too High
Specific gravity at 25° C./25° C.	1.374 to 1.393	1.445 to 1.456	1.543 to 1.550	1.646 to 1.653	1.870 to 1.876	1.712 to 1.723	1.723 to 1.740
Per cent increase in volume upon heating from from 25° C. to temperature specified	2.71 25° to 65° C.	25° to 65° C. —2.82% 25° to 250° C. —18.56%	2.64 25° to 65° C.	4.16 25° to 90° C.		2.45 25° to 65° C.	2.62 25° to 65° C.
Approximate average coefficient of expansion over range specified (cc./cc./° C.)	0.000678 25° to 65° C.	0 000702 25° to 65° C.	0.000661 25° to 65° C.	0.000640 25° to 90° C.		0.000611 25° to 65° C.	0.000656 25° to 65° C.
Pounds per gallon at 25° C. (average)	11.50	12.06	12.86	13.71	15.60	14.28	14.41
Decimal part of gallon bulked by one pound	0.0869	0.0829	0.0778	0.0729	.0641	0.0700	0.0693
Viscosity (seconds Saybolt) at 210° F.	34.0 to 34.6	36.0 to 37.0	46.0 to 47.7	90.0 to 103.0	Solid	Too Viscous	Too Viscous
Viscosity (seconds Saybolt) at 100° F.	81.1 to 93.1	200.0 to 210.0	1800 to 2400		Solid		
Flash-point (° C.) (Cleveland Open Cup)	176 to 180	196	None	None	None	None	None
Fire point (° C.) (Cleveland Open Cup)	334 to None at Boiling Point of Liquid	None	None	None	None	None	None
Refractive index for D-line at 20° C.	1.627 to 1.629	1.630 to 1.631	1.6407 to 1.6410	1.6501 to 1.6517		1.664 to 1.667	
Maximum acidity (milligrams KOH per gram)	0.01	0.01	0.01	0.02		0.02	1.26
Per cent loss on heating (A.S.T.M.)	3.04 to 3.64	3.0 to 4.0	1.06 to 1.28	0.48 to 0.56	0.10 to 0.20	0.23 to 0.29	0.21 to 0.24

*Courtesy of Swann Chemical Co.

TABLE 69.—Solubility of the Aroclors In Various Solvents*

(Figures Represent Grams of Aroclor per 100 cc. Solvent)

Solvent	Aroclor 1242		Aroclor 1254	
	Cold	Hot	Cold	Hot
Mineral spirits	S	S	S	S
Gasoline	S	S	S	S
Kerosene	S	S	S	S
Paraffin	—	S (50° C.)	—	S (50° C.)
Benzene	S	S	S	S
Toluene	S	S	S	S
Xylene	S	S	S	S
Turpentine	S	S	S	S
Pine oil	S	S	S	S
Methyl alcohol	42.5 (29° C.)	88.5 (60° C.)	15 (26° C.)	22.2 (65° C.)
Ethyl alcohol	23.3 (29° C.)	80.0 (70° C.)	10 (27° C.)	28 (75° C.)
Normal butyl alcohol	S	S	S	S
Amyl alcohol	S	S	S	S
Glycerin	I	I	I	I
90% Phenol	194 (30° C.)	S (99° C.)	P.S.	Slowly soluble
Ethyl ether	S	S	S	S
"Cellosolve" acetate	S	S	S	S
"Cellosolve"	S	S	S	S
"Carbitol"	224 (31° C.)	307 (99° C.)	173 (26° C.)	259 (98° C.)
p-p' Dihydroxy ethyl ether	16.9 (23° C.)	19 (99° C.)	8 (30° C.)	10 (100° C.)
Castor oil	S	S	S	S
Methyl acetate	S	S	S	S
Ethyl acetate	S	S	S	S
Butyl acetate	S	S	S	S
Amyl acetate	S	S	S	S
Ethyl lactate	S	S	S	S
Diethyl phthalate	S	S	S	S
Dibutyl phthalate	S	S	S	S
Tricresyl phosphate	S	S	S	S
Cottonseed oil	S	S	S	S
Ethylene glycol diacetate	S	S	S	S

*Courtesy of Swann Chemical Company

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Chapter 10

Alcohols

In the opinion of Worden the solvent power of the aliphatic alcohol groups for cellulose derivatives increases with an increase in molecular weight within the homologous series. By adding an aromatic hydrocarbon an increased solvency is imparted for ethyl and benzyl cellulose.

Methyl Alcohol

Methyl alcohol (CH_3OH, methanol, wood alcohol, Columbian spirits) is a limpid, mobile, toxic, inflammable, hygroscopic, volatile liquid of spiritous odor. Boyle in 1661 was the first to obtain it in a crude state from the distillation of hardwood and he named it adiaphorous spirit. It was first refined on a small scale by Pollack in 1865. Wood alcohol until recently was made by the destructive distillation of wood. At present, the bulk of methyl alcohol is made synthetically by combining carbon monoxide and hydrogen under pressure by the aid of a catalyst.

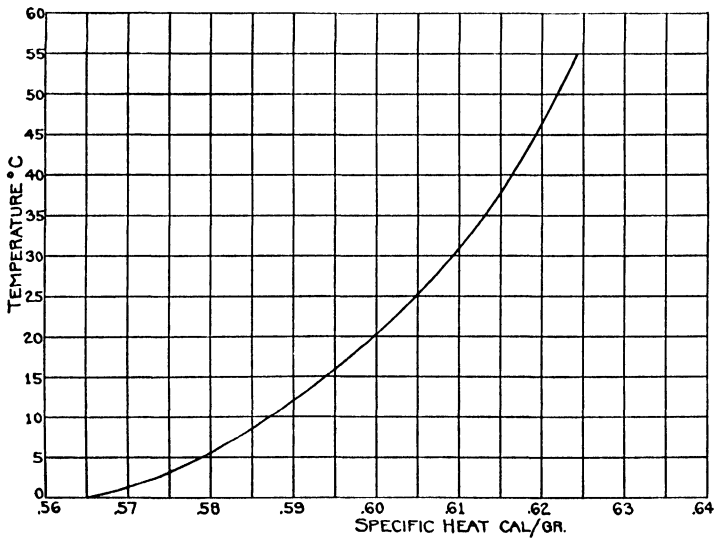


FIGURE 64. Specific Heat of Methanol at Various Temperatures.[2]

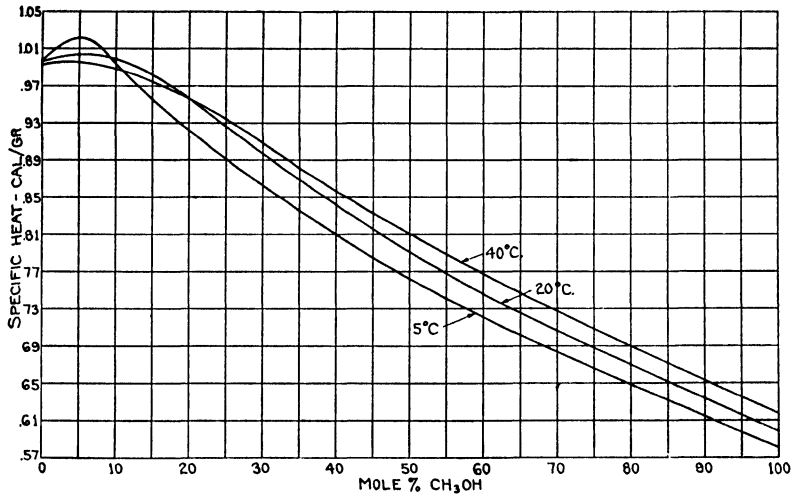


FIGURE 65. Specific Heat of Aqueous Solutions of Methanol.[2]

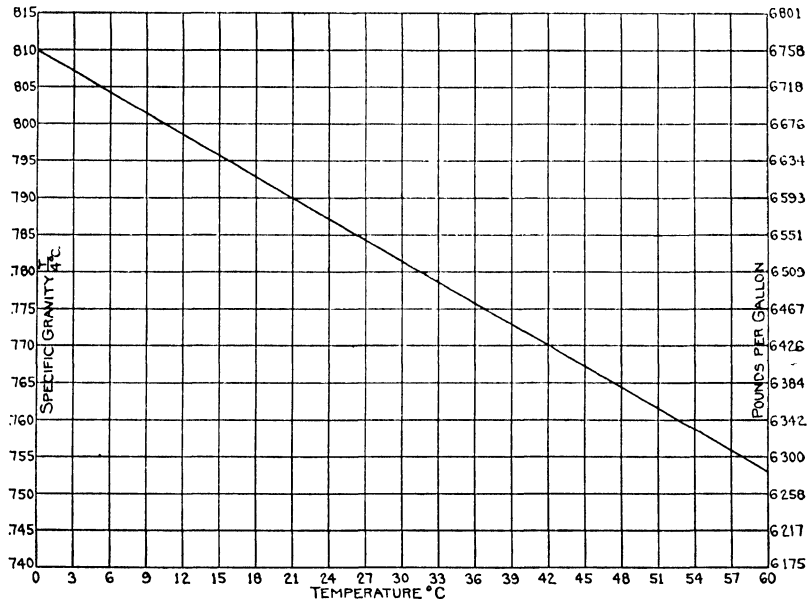


FIGURE 66. Specific Gravity and Weight per Gallon of Methanol at Various Temperatures.[2]

The commercial grade of methanol, made from the distillation of wood and containing such impurities as methyl acetone, methyl acetate and various oils, is a more powerful solvent than the chemically pure synthetic product. Methyl alcohol will dissolve low-viscosity nitrocellulose, ethyl cellulose, acetylene, alkaloids, insoluble soaps, natural and synthetic resins, oils, fats, gums, shellac, castor and croton oils. By adding acetone, ethyl acetate, or benzene to methanol its solvent power is augmented for a wider range of substances including such materials as the esters and ethers of cellulose. It is entirely miscible with water, alcohols, ketones, esters, halogenated hydrocarbons and many other organic solvents. Methyl alcohol is also partly miscible with benzene. Methyl alcohol is used extensively as an industrial solvent, in the lacquer industry, in the preparation of celluloid, films, plastics, textile soaps, wood stains, artificial leather and non-scatterable glass. Owing to its solvency for gums and resins it is used in the paint and varnish industry. It finds application as a purifying and extraction medium for organic compounds and its most diversified use is as an intermediate in organic synthesis Methyl esters are employed as solvents, in perfumes, flavors, drugs and so forth. Other substances which are made from wood alcohol are dyes, formaldehyde, etc. It is extensively used as a denaturant, in antifreeze mixtures, in compositions like celluloid cements and in motor fuels. At present the tendency is to combine methanol with higher-boiling solvents to retard evaporation and retain or fortify its excellent solvency. Some other uses for methyl alcohol are in enamels, stains, chemical analysis, dyeing straw hats, paint and varnish removers, alcohol lamps, cleaning and

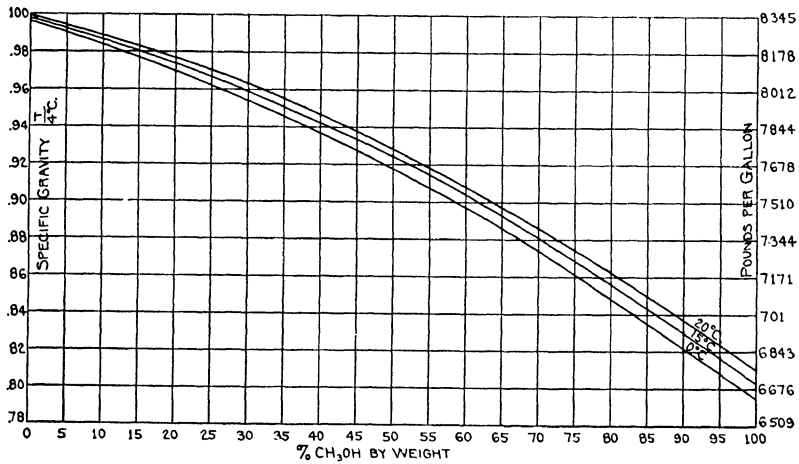


FIGURE 67. Specific Gravity and Weight per Gallon of Aqueous Solutions of Methanol.[2]

dewaxing compounds, embalming fluids, shellac solutions, spirit varnishes, wood stains and so forth.

Molecular weight	32.03
Boiling point	64.5° C.
Melting point	− 97.8° C.
Specific gravity	$0.792\ \frac{20°}{4°}$
Weight per gallon	6.59 (20° C.)
Refractive index	1.329 (20° C.)
Surface tension	22.6 dynes/cm. (20° C.)
Viscosity	0.00593 poise (20° C.)
Vapor pressure	94 mm. Hg. (20° C.)
Specific heat (vapor)	0.39 cal./g. (77° C.)
Latent heat of evaporation	262.8 cal./g. at B.P.
Heat of fusion	23.6 cal./g.
Heat of combustion	170.9 kg. cal./mol.
Flash-point	9.5° C.
Dielectric constant	31.2 (20° C.)
Purity	99.8% to 100% methyl alcohol
Acidity	Not more than 0.01%, calculated as formic acid
Color	Water-white
Distillation range	
Below 64° C.	None
Above 66° C.	None
Critical pressure	78.7 atm.
Critical temperature	240° C.
Average coefficient of cubical expansion	0.0012 from 0° C. to 61° C.
Vapor pressure	
at 0° C.	29.6 mm. Hg.
at 20° C.	96.0 mm. Hg.
at 40° C.	260.5 mm. Hg.
at 60° C.	625.0 mm. Hg.

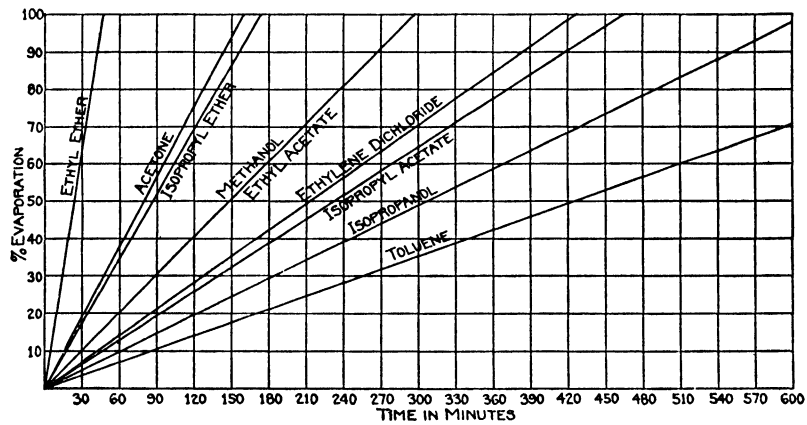


FIGURE 68. Evaporation Rate of Various Solvents at Room Temperature.[3]

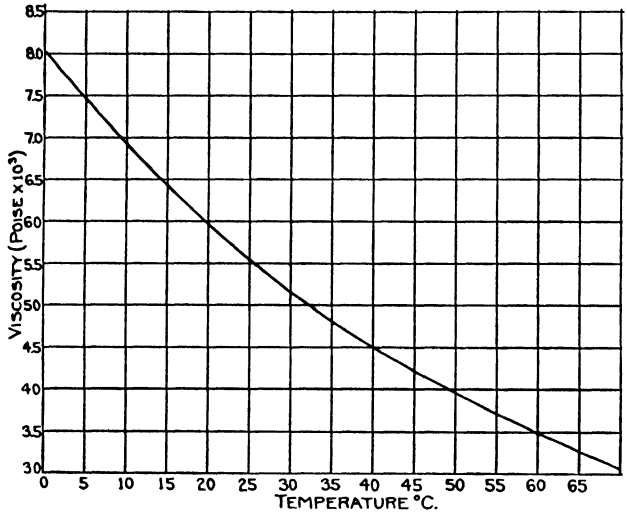


FIGURE 69. Viscosity of Methanol at Various Temperatures.[2]

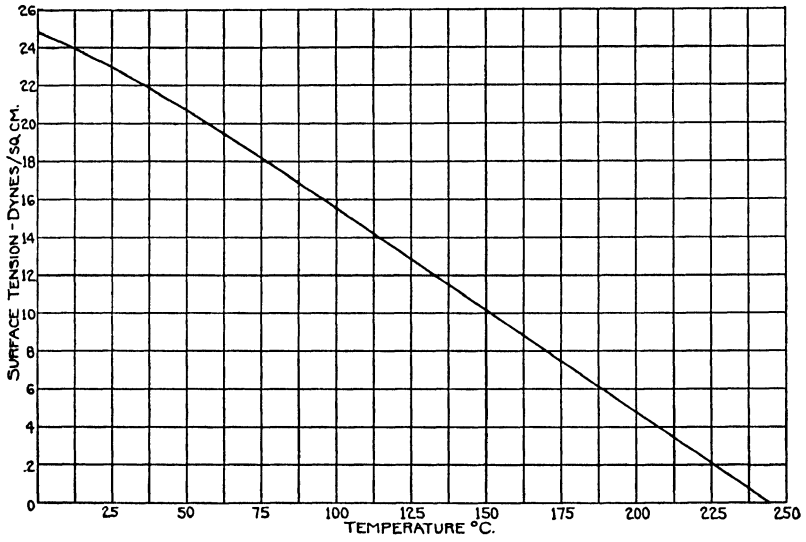


FIGURE 70. Surface Tension of Methanol at Various Temperatures.[2]

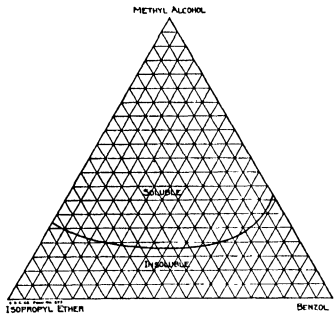


FIGURE 71. Solubility of ½-Second R.S. Nitrocellulose in Mixtures of Methanol, Isopropyl Ether and Benzene.[2]

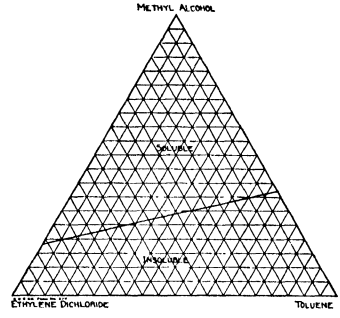


FIGURE 72. Solubility of ½-Second R.S. Nitrocellulose in Mixtures of Methanol, Ethylene Dichloride and Toluene.[2]

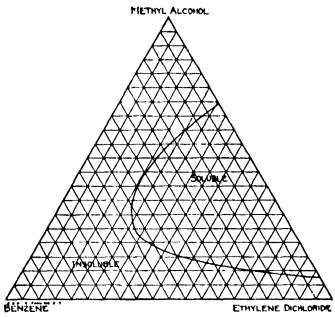


FIGURE 73. Solubility of Low-Viscosity Cellulose Acetate in Mixtures of Methanol, Benzene and Ethylene Dichloride.[2]

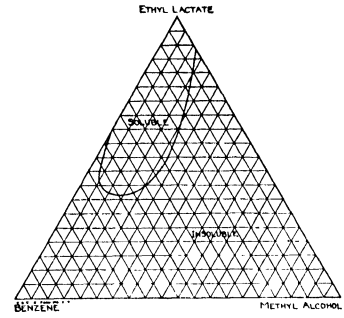


FIGURE 74 Solubility of Low-Viscosity Cellulose Acetate in Mixtures of Benzene, Ethyl Lactate and Methanol.[2]

Ethyl Alcohol

Ethyl alcohol (C_2H_5OH, Cologne spirits, grain alcohol, ethanol, alcohol) is a colorless, inflammable, volatile liquid. It is the oldest solvent, second only to water. It has been used by man since the dawn of civilization to synthesize new behavior. Its use in this connection is to dissolve away gloom and despair, two constituents incompatible with happiness. It is made by the fermentation of sugar, or converted starch, or cellulose. Today it is made synthetically. Ethyl alcohol is miscible in all proportions with water and most organic solvents and substances such as castor and croton oils, and is a solvent for a wide range of substances. Since the introduction of anhydrous ethanol it has become even more versatile in its uses owing to its increased solvency. The anhydrous form will completely dissolve gums and resins such as dammar, elemi, kauri, manila, mastic, pontianac, rosin, sandarac, shellac, and such synthetic resins as ketone-resins, ketone-aldehyde resins, phenol-aldehyde resins, and aldehyde resins, cellulose ethers, alcohol-soluble

TABLE 70.—Some of the Many Uses for Alcohol[1]

Acetaldehyde
Acetanilide
Acetic ether
Acetphenetidin
Aconite
Adeps lanae
Aletrin
Alkaloids and alkaloidal salts
Aloin
Ammunition
Analytical work
Antipyrine
Apocynin
Arabinose
Arbutin
Arsphenamine
Artificial feathers
Artificial flowers
Asclepiadin
Aspirin (acetylsalicylic acid)
Atophan
Avenin
Barometer and thermometer tubes
Benzaldehyde
Benzidine
Benzoic acid
Benzoin
Benzene
Benzol cyanide
β-naphthol
β-naphthol benzoate
β-naphthol salicylate
Billiard and pocket balls (composition)
Bluing (laundry)
Bottle caps
Brushes
Camphor (synthetic)
Caustic potash
Celluloid scrap (reworking)
Cements
Chelonin
Chloral hydrate
Chloroform
Cimicifugin
Cinchophen
Citronellol
Cocoa butter
Collodion
Collodion corn remedy
Colors and bronze powders
Compasses
Concentrations (non-liquid)
Confectioners' colors
Coumarin
Creosote carbonate
Cutlery
Dandelion
Dental alloy
Deodorants and substances of a similar nature
Dextrin
Dextros
Diethylaniline
Digestive ferments
Digitalis
Dimethylglyoxime
Dinitrotoluene
Disinfectant germicide
Door checks
Dyeing feathers
Dyes for industrial purposes
Dyestuffs
Embalming fluid
Enamel
Eosine
Essential oil orris
Ether
Ethyl acetate
Ethyl aniline
Ethyl benzoate
Ethyl bromide
Ethyl butyrate
Ethyl chloride
Ethyl levulinate
Ethyl propionate
Extracting glycerin from distillery slop
Extracting vitamins from cod-liver oil
Felt base floor covering
Fertilizers
Filaments for incandescent lamps
Fireworks
Foot powder
Formaldazone
Formaldehyde
Formic ether
Fulminate of mercury
Fungicides
Gaduol
Galactose
Gallocyanine
Gas mantles
Gelatin capsules
Gentian (solid extract)
Geraniol
Glass
Glass enamel
Glue
Glycerophosphates
Guaiacol
Guaiacol carbonate
Gum and pyroxylin solutions
Hats
Heliotropin
Hexachlorobenzene
Hydrastis (alkaloid of)
Imitation ivory goods
Imitation leather
Incense
Inks
Insecticides
Insulin
Inulin
Iriscin
Isinglass
Jalapin (non-liquid concentrations of)
Japans
Jewelry
Lacquers
Lacquer thinners and solvents
Lacquer substitutes
Levulose
Leather goods finish
Leather substitutes
Liquor cresolis compositus
Lysol
Maltose
Mandrake (powdered and solid extract of)
Mannite
Mannose
Melibiose
Metol
Mica insulators
Mirrors
Monobromated camphor
Moth repellant
Motor fuel
Moldings and picture frames
Mucilage
Nitrocellulose (solution and solvent of)
Nitrosobetanaphthol
Nonscatterable glass
Oils, greases, lubricants and soluble thread-cutting oils
Oleoresins
Optical goods
Orthotoluolsulfamid
Paints
Paper
Paper-testing compound
Paraffin
Paramidophenol
Paste
Pastes and varnishes from soluble cotton
Patent leather
Pencils
Pepsin and similar products
Perfume bases (synthetic)
Phenolphthalein
Phenyl-cinchoninic acid
Photographic dry plates
Photographic engravings
Photographic films
Phytolacin (concentration of)
Pipe-cleaning preparations
Plumbing material
Podophyllin resin and similar products
Polish preparations for metals and furniture
Postal-card colors
Potassium cyanate
Potassium hydroxide
Powder compact
Powdered drugs and extracts
Print paper and enlargements
Pyroxylin cements
Pyroxylin and gum solutions
Raffinose
Recrystallization and purification purposes
Refining mineral oils
Refining precious metals
Resin of scammony
Resins
Resorcin
Rhamnose
Rhodinol
Rouge compact
Saccharine
Saccharose
Salicylic acid
Salicylic aldehyde
Salol
Salophen
Santonin
Saponin
Shampoo (jelly)
Shampoo (liquid)
Shellac
Shellac thinner
Shellac varnish
Shoe polish
Silk fabrics
Silverware and bronze
Smokeless powder
Soap (liquid)
Soap (transparent)
Sodium benzoate
Soldering flux
Solid extracts
Solidified alcohol
Solution and solvent nitrocellulose
Solution for aniline spirits and varnishes
Solvent purposes
Sorbit
Stains
Stanolind
Stencil inks
Stencil paper
Sterilizing solution for corks
Strychnine
Sulfonic acid
Surgical ligatures
Synthetic mustard oil
Synthetic perfume bases
Tannic acid

TABLE 70.—Some of the Many Uses for Alcohol[3]—(*Continued*)

Terpin hydrate
Textile cleansing soap
Theobromine
Thermometer and hydrometer
Thermostatic devices
Tinfoil
Tobacco
Toluidine
Transparent paper
Transparent soap for waterproofing cement
Trehalose
Trinitrotoluene
Trioxyaline
Tuberculin (purified)
Uric acid
Varnish remover
Vegetable colors
Viburnum (concentration)
Washing lenses
Watches
Water colors
Waterproof fiber signs
Wax (prepared)
Wood filter
Wood finish
Wool fat
Xylose
For all purposes for which another formula is not specifically authorized

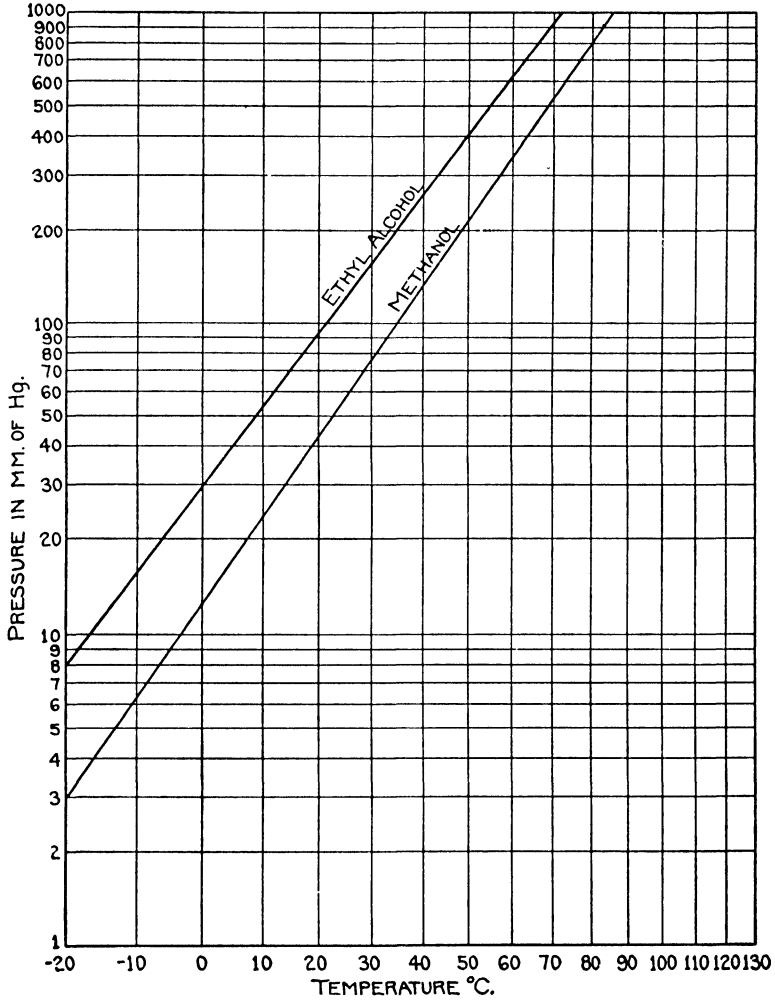


FIGURE 75. Vapor Pressure of Ethyl Alcohol and Methanol at Various Temperatures.[2]

nitrocellulose, camphor and so forth. By adding an aromatic hydrocarbon or an ester-solvent to the mixture, solvent power is imparted for an even larger number of resins and cellulose ethers.

Completely denatured alcohol is ethyl alcohol made unfit for beverage purposes. This is brought about by adding certain denaturants prescribed by the Bureau of Internal Revenue. Specially denatured alcohol is also unfit for a beverage but has a specific industrial use. Completely denatured alcohol contains such compounds as methyl alcohol, isopropyl alcohol, alpha terpineol, gasoline, or such specially prepared denaturants as Aldehol, Denatol, Calorite, Pontol, Tecsal.

Ethyl alcohol is so universal a solvent that there hardly remains one industry in which it is not used. Some of its uses are as a vehicle for perfumes, in flavoring extracts, cosmetics, drugs, tinctures, elixirs and so forth. It is extensively used in a large number of processes such as extraction, purification, crystallization and so forth. It is an ingredient in soaps, cleaning solutions, emulsions, antifreeze mixtures, lacquers, varnishes, enamels, stains, celluloid, cements, plastics, photographic films, collodion, rayon, smokeless powder, in ester formation, etc. In research and analytic work only pure absolute ethyl alcohol is used.

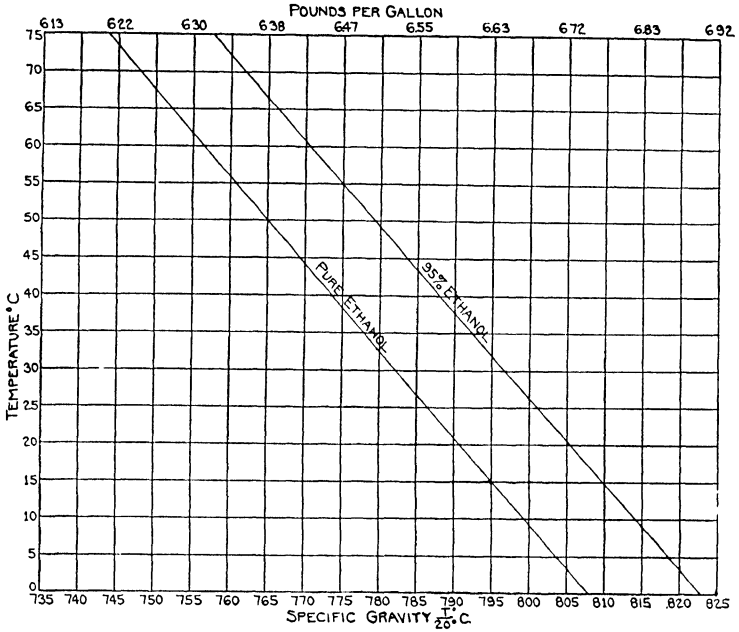


FIGURE 76. Specific Gravity and Weight per Gallon of Ethanol at Various Temperatures.[2]

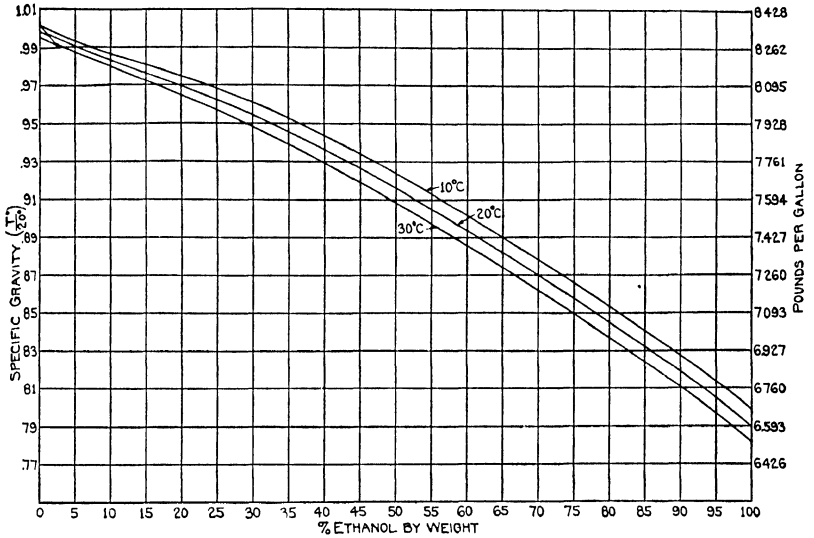


FIGURE 77. Specific Gravity and Weight per Gallon of Aqueous Solutions of Ethanol.[2]

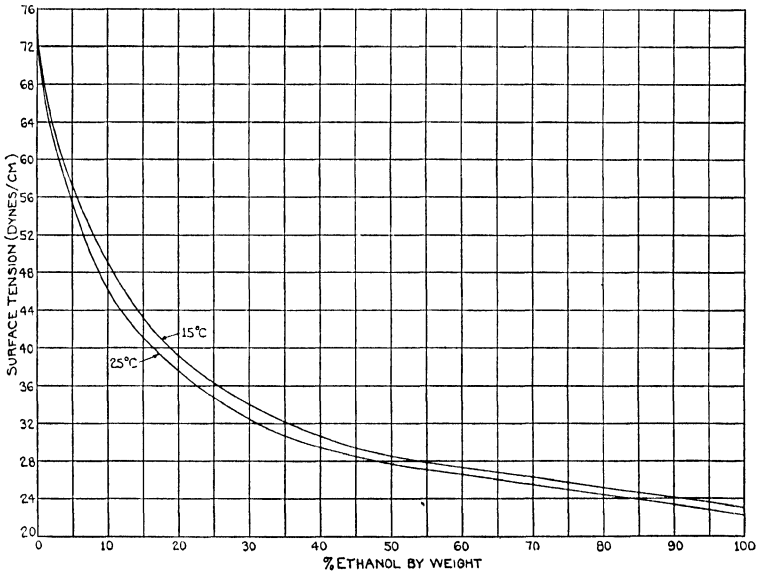


FIGURE 78. Surface Tension of Aqueous Solutions of Ethanol.[2]

TABLE 71.—Scale for Determining the Fractional Wine or Proof Gallons of Alcohol (U.S.P. 190° Proof)[2]

Ounces	Wine Gallon	Proof Gallon	Ounces	Wine Gallon	Proof Gallon	Ounces	Wine Gallon	Proof Gallon
1	.008	.015	44	.344	.65	87	.680	1 29
2	.016	.03	45	.352	.67	88	.688	1 31
3	.023	.045	46	.359	.68	89	.695	1.32
4	.031	.06	47	.367	.69	90	.703	1.34
5	.039	.075	48	.375	.71(3 Pts)	91	.711	1.35
6	.047	.09	49	.383	.73	92	.719	1.37
7	.055	.103	50	.391	.74	93	.727	1.38
8	.063	.12	51	.398	.76	94	.735	1.40
9	.070	.133	52	.406	.77	95	.742	1.41
10	.078	.15	53	.414	.79	96	.750	1.425(3 Qts.)
11	.086	.163	54	.422	.80	97	.758	1.44
12	.094	.18	55	.430	.82	98	.766	1.46
13	.102	.192	56	.438	.83	99	.773	1 47
14	.109	.21	57	.445	.85	100	.781	1.48
15	.117	.222	58	.453	.86	101	.789	1 50
16	.125	.24(1 Pt.)	59	.461	.88	102	.797	1.51
17	.133	.25	60	.469	.89	103	.805	1.53
18	.141	.27	61	.477	.91	104	.812	1.54
19	.148	.28	52	.484	.92	105	.820	1.56
20	.156	.30	63	.492	.94	106	.829	1.57
21	.164	.31	64	.5	.95(2 Qts.)	107	.836	1.59
22	.171	.33	65	.508	.96	108	.844	1.60
23	.180	.34	66	.516	.98	109	.852	1.62
24	.188	.36	67	.523	.99	110	.859	1.63
25	.195	.37	68	.531	1.01	111	.867	1.65
26	.203	.39	69	.539	1.02	112	.875	1.66(7 Pts.)
27	.211	.40	70	.547	1 04	113	.883	1.68
28	.219	.42	71	.555	1.05	114	.891	1.69
29	227	.43	72	.562	1.07	115	.898	1.71
30	.234	.44	73	.570	1.08	116	.906	1.72
31	.242	.46	74	.578	1.10	117	.914	1.74
32	.250	.475(1 Qt.)	75	.586	1.11	118	922	1.75
33	.258	.49	76	.594	1.13	119	.930	1.77
34	.265	.50	77	.602	1.14	120	.937	1.78
35	.273	.52	78	.609	1.16	121	.945	1.80
36	.281	.53	79	.617	1.17	122	.953	1 81
37	.289	.55	80	.625	1.19(5 Pts.)	123	.961	1.825
38	.297	.56	81	.633	1.20	124	.969	1.84
39	.305	.58	82	.641	1 22	125	.977	1.855
40	.312	.59	83	.648	1.23	126	.984	1.87
41	.320	.61	84	.656	1.25	127	.992	1.885
42	.328	.62	85	.664	1.26	128	1.0	1.9(1 Gal.)
43	.336	.64	86	.672	1.28			

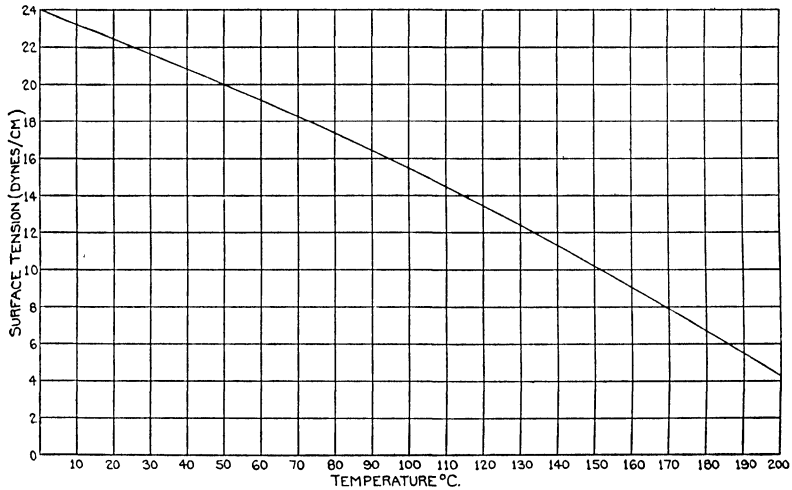


FIGURE 79. Surface Tension of Pure Ethanol at Various Temperatures.[2]

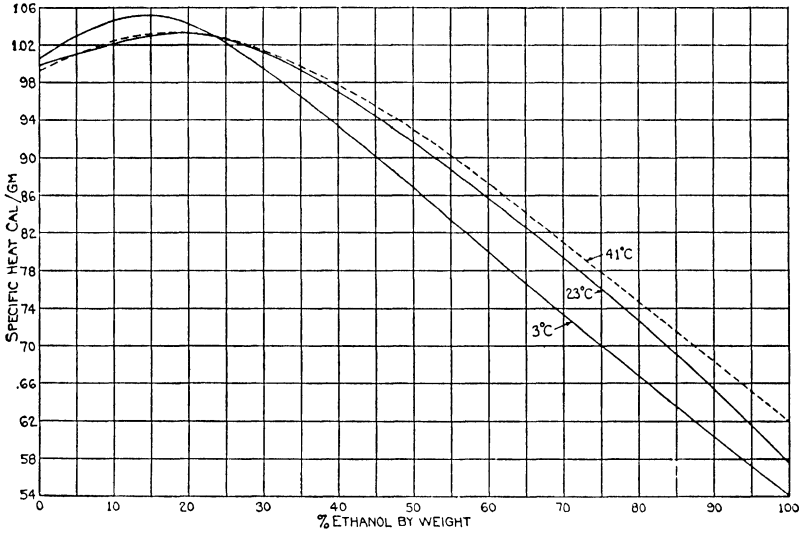


FIGURE 80. Specific Heat of Aqueous Solutions of Ethanol.[2]

Properties of Ethyl Alcohol

	Absolute	95%
Molecular weight	46.05	
Boiling point	78.4° C.	78.2° C.
Freezing point	− 114.4° C.	
Specific gravity	$0.7904\ \frac{20°\text{ C.}}{20°\text{ C.}}$	$0.8075\ \frac{20°\text{ C.}}{20°\text{ C.}}$
Weight per gallon	6.60 lb. (20° C.)	6.73 lb.(20° C.)
Refractive index	1.3633 (15° C.)	1.3651 (15° C.)
Surface tension	22.3 dynes/cm. (20° C.)	22.8 dynes/cm. (20° C.)
Viscosity	0.0122 poise (20° C.)	0 0141 poise (20° C.)
Vapor pressure	43.6 mm. Hg. (20° C.)	43.0 mm. Hg. (20° C.)
Specific heat	0.581 cal./g. (25° C.)	0.618 cal./g. (23° C.)
Flash-point (A. S. T. M. open cup)	18.3° C. (65° F.)	14° C. (57° F.)
Heat of combustion	328 kg. cal./mole	
Heat of fusion	24.9 cal./g.	
Latent heat of evaporation	204 cal./g. at B.P. 368 B.t.u./lb.	
Electrical conductivity	1.35×10^{-9} recip. ohms (25° C.)	
Explosive limits in air	3.7%–13.7%	
Apparent ignition temperature in air	371°–427° C. (700°–800° F.)	399°–432° C. (750°–810° F.)

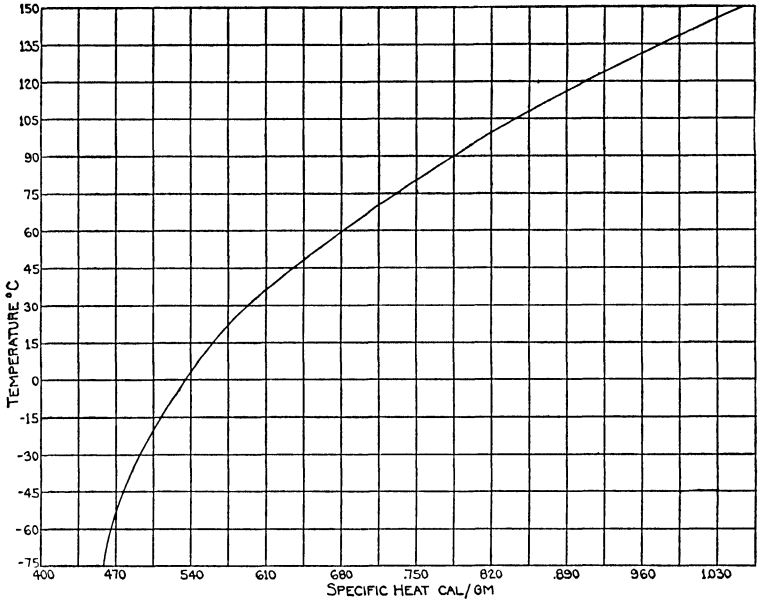


FIGURE 81. Specific Heat of Ethanol at Constant Pressure and Various Temperatures.[2]

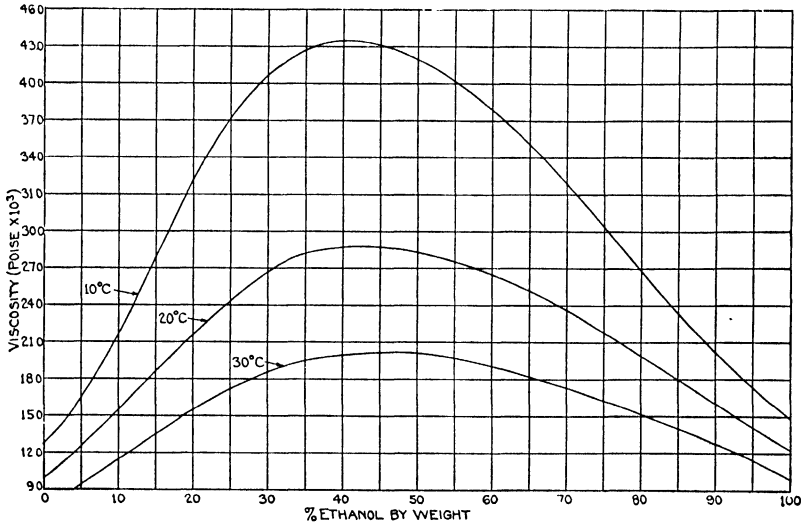


FIGURE 82. Viscosity of Aqueous Solutions of Ethanol.[2]

Properties of Ethyl Alcohol—(*Continued*)

Absolute, U.S.P.	Chemically Pure, 96%
Complies with all specifications of U.S.P. X. and also the following supplemental specifications	
Acidity:	
Free acid as acetic, not more than 0.0015 gm. per 100 cc.	Free acid as acetic, not more than 0 0014 gm. per 100 cc.
Color:	
Water-white	Water-white
Corrosion:	
Does not show rust on bright drum steel within 48 hours.	Does not show rust on bright drum steel within 72 hours.
Non-volatile matter:	
Not more than 0 0025 gm. per 100 cc.	Not more than 0.0025 gm. per 100 cc.
Odor:	
Free from foreign odors when tested at high or low proof.	Free from foreign odors when tested at high or low proof.
Purity:	
Not less than 99.87% ethyl alcohol by volume.	Not less than 96% ethyl alcohol by volume
Reducing substances:	
Not less than 25 minutes permanganate time.	Not less than 45 minutes permanganate time.
Specific gravity:	
Not more than 0.7944 $\frac{15\ 6^\circ\ C.}{15.6^\circ\ C.}$	Not more than 0.8121 $\frac{15\ 6^\circ\ C.}{15.6^\circ\ C.}$
Boiling point:	
78.4° C.	78.2° C.
Coeficient of expansion:	
Per 1° F. 0.00063 Per 1° C. 0.00113	0.00061 0.00110
Flash-point:	
57° F. (approx.)	62° F. (approx.)
Water Solubility:	
In all proportions and without turbidity.	In all proportions and without turbidity

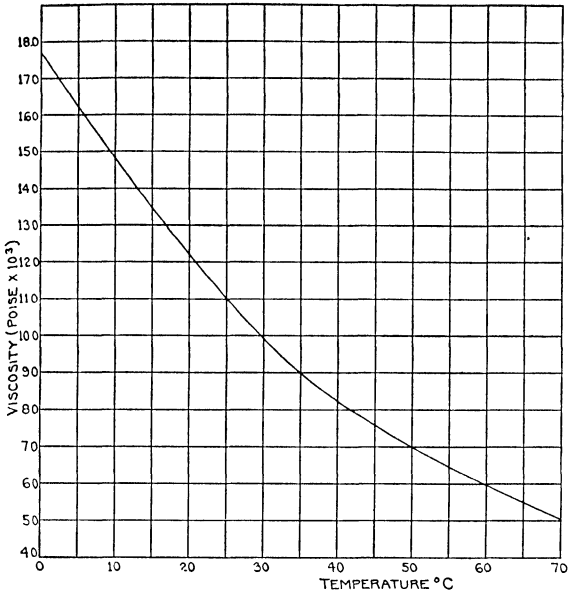


FIGURE 83. Viscosity of Ethanol at Various Temperatures.[2]

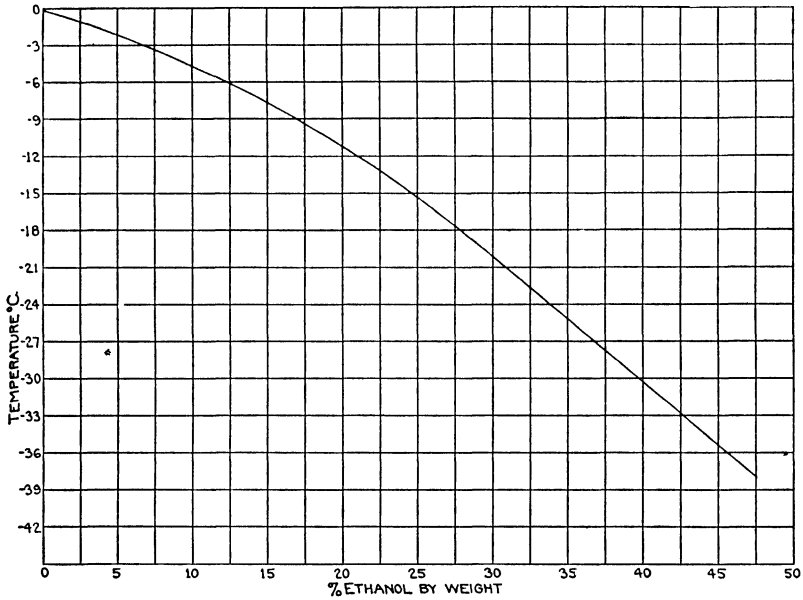


FIGURE 84. Freezing Point of Aqueous Solutions of Ethanol.[3]

n-Propyl Alcohol

n-Propyl alcohol ($CH_3CH_2CH_2OH$, propanol) is a colorless, inflammable, volatile liquid. It occurs in fusel oil from which it is isolated and purified. Generally, it has about the same solvent properties as ethyl alcohol with the added feature of having a higher boiling point, and is therefore less likely to cause chilling. The commercial grade which consists of the lighter boiling fractions of fusel oil, varies in composition and physical properties and consequently in solvent power. It is a solvent for oils like castor, croton, linseed and so forth, for natural resins like soft copals, rosin, shellac and a number of synthetic resins. It is similar to ethyl alcohol in its solvency for cellulose ethers and esters. A number of binary solvent mixtures have been proposed and these are composed of propyl alcohol and isopropyl acetate, or ethylene chlorbromide, or benzyl acetate, or methyl alcohol, or some of the higher alcohols.

TABLE 72.—Alcohols as Washing Media for Precipitates[5]

Constituent Determined	Amount Present	Ethanol Found		2-Propanol Found	
	Gram	%	*Gram*	%	*Gram*
Pb as $PbSO_4$	0 2051	95	0 2046	91	0.2044
			0.2044		0 2046
			0 2044		0 2046
			Av. 0 2044		Av. 0.2045
Mg as $MgNH_4PO_4 \cdot 6H_2O$	0.02433	95	0.02426	91	0 02423
			0 02425		0.02425
			0.02424		0.02424
			Av. 0 02425		Av. 0 02424
CNS as AgCNS	0.07686	95	0.07632	91	0.07667
			0.07654		0.07663
			0.07667		0.07667
			Av. 0.0765		Av. 0.07666
Cr as $BaCrO_4$	0 02689	50	0.02662	50	0.02666
			0.02660		0 02670
			0.02656		Av. 0.02668
			Av. 0.02659		
Cd as $Cd_2P_2O_7$	0.1028	60	0.1077	60	0.1066
			0.1074		0.1065
			0.1069		0.1071
			Av. 0.1073		Av. 0.1067
Cu as CuCNS	0.1730	20	0.1724	20	0.1719
			0.1717		0.1722
			0.1721		0.1721
			Av. 0.1721		Av. 0.1721
Cd as $CdNH_4PO_4 \cdot H_2O$	0.1079	95	0.1076	91	0.1077
			0.1078		0.1082
			0.1076		0.1079
			Av. 0.1077		Av. 0.1079
Na as sodium zinc uranyl acetate	0.00200	95[a]	0.00197	91[a]	0.00195
			0.00200		0.00196
			0.00196		0.00192
			Av. 0.00198		Av. 0.00194

[a] Alcohol used for washing was saturated with the precipitate.

TABLE 72.—Alcohols as Washing Media for Precipitates[5]—(*Continued*)

Constituent Determined	Amount Present	Ethanol		2-Propanol	
		Found		Found	
	Gram	%	*Gram*	%	*Gram*
Na as sodium magnesium uranyl acetate	0.0100	95	0.0100	91	0.00987
			0.0101		0.00988
			0.0100		0.00988
			Av. 0.0100		Av. 0.00988
				91[a]	0.00987
					0.00991
					0.00995
					Av. 0.00991
Zn as $ZnNH_4PO_4$	0.1168	50	0.1169	50	0.1168
			0.1166		0.1165
			0 1171		0.1169
			Av. 0 1169		Av. 0.1167
Zn as $ZnNH_4PO_4$	0.1123	65	0 1121	65	0.1122
		&	0.1120	&	0.1119
		95	0.1121	91	0 1119
			Av. 0.1121		Av. 0.1120
Cu as copper pyridinothiocyanate	0.0602	70	0.06037	70	0.06017
		&	0 05994	&	0.06060
		95	0.05981	91	0.06062
			Av. 0 0600		Av. 0 0605
Ca as $CaC_2O_4 H_2O$	0.1343	95	0 1354	91	0 1358
			0 1354		0.1359
			0.1356		0.1362
			Av. 0 1355		Av. 0.1360
Ba as $BaSO_4$	0.1408	95	0 1414	91	0.1415
			0.1405		0.1408
			0.1411		0 1414
			Av. 0.1410		Av. 0.1412
Ni as nickel dimethyl glyoxime	0.0552	95	0.05535	91	0 05515
			0.05523		0.05535
			0.05537		0.05525
			Av. 0 0553		Av. 0.0553
Cl as AgCl	0.0998	95	0.1000	91	0.0995
			0 0997		0.1000
			0.1000		0.1001
			Av. 0.0999		Av. 0.0999

[a] Alcohol used for washing was saturated with the precipitate

Isopropyl Alcohol

Isopropyl alcohol $\begin{matrix} CH_3 \\ \diagdown \\ \quad CHOH \\ \diagup \\ CH_3 \end{matrix}$ (isopropanol, secondary propyl alcohol, Per-spirit, Petrohol, Avantine) is a water-white, stable liquid with an odor similar to that of ethyl alcohol. It is obtained from fusel oil and is also made synthetically by the reduction of acetone and by the sulfonation and subsequent hydrolysis of propylene. In chemical properties is resembles *n*-propyl alcohol but it is not as stable. It will dissolve essential and other oils, alkaloids, gums, shellac, sandarac, rosin, mastic, copals, some synthetic resins and many organic and inorganic compounds. Like other

alcohols, it possesses latent solvent power for cellulose derivatives. When it is admixed with true solvents it enhances their solvency. It has the virtue of being anhydrous which aids in preventing water-blush. Isopropanol is used as a substitute for ethyl alcohol, and like it, has germicidal and distinfectant properties. It is used in liniments, skin lotions, cosmetics, creams, pharmaceuticals, mouth washes, hair tonics and so forth. It should not be taken internally owing to its toxic nature. Other uses are as a solvent in perfumes, in lacquers, in extraction processes and as a preservative and dehydrating agent.

TABLE 73.—Specific Gravity of Isopropyl Alcohol-Water Mixtures at 20/4°

Wt. %	Vol. %	Sp. Gr.	Wt. %	Vol. %	Sp. Gr.	Wt. %	Vol. %	Sp Gr.
0	0	.9983	34	41.1	.9441	68	74 5	.8633
1	1.3	.9963	35	42 2	.9420	69	75 4	.8610
2	2 5	.9945	36	43 3	.9400	70	76 3	.8585
3	3.8	.9927	37	44.4	.9378	71	77.2	.8561
4	5 0	.9910	38	45.5	.9356	72	77.9	.8538
5	6 2	.9894	39	46.6	.9334	73	78.8	.8514
6	7.5	.9878	40	47.7	.9311	74	79 7	.8490
7	8.7	.9863	41	48.7	.9288	75	80.5	.8465
8	9.9	.9848	42	49.7	.9265	76	81.4	.8440
9	11 0	.9834	43	50.7	.9240	77	82.3	.8416
10	12 4	.9821	44	51 6	.9216	78	83.1	8392
11	13 5	.9809	45	52.6	.9192	79	83 9	.8367
12	14.8	.9798	46	53.6	.9166	80	84.9	.8343
13	16.0	.9787	47	54.7	.9142	81	85.7	.8318
14	17.2	.9777	48	55.6	.9118	82	86.4	.8293
15	18 4	.9766	49	56 6	.9094	83	87.2	.8269
16	19.7	.9755	50	57.6	.9070	84	87.9	.8244
17	20 8	.9744	51	58.6	.9045	85	88.2	.8220
18	22 0	.9732	52	59 5	.9021	86	89 5	.8195
19	23.2	.9718	53	60 4	.8997	87	90.3	.8170
20	24 0	.9704	54	61 4	.8972	88	91.1	.8146
21	25.7	.9669	55	62 4	.8947	89	91 8	8121
22	27.0	.9670	56	63.3	.8922	90	92.6	.8097
23	28 2	.9652	57	64.4	.8897	91	93 3	.8073
24	29.4	.9635	58	65.2	.8875	82	94.1	.8048
25	30.5	.9616	59	66 2	.8851	93	94.7	.8024
26	31.8	.9598	60	67 2	.8826	94	95.5	.7999
27	33.0	.9578	61	68 1	.8801	95	96.3	.7974
28	34.3	.9559	62	69 0	.8777	96	97.0	.7950
29	35 4	.9541	63	69 9	.8752	97	97.7	.7926
30	36 7	.9521	64	70 8	.8728	98	98 4	.7902
31	37.8	.9501	65	71.7	.8703	99	99 2	7878
32	38.9	.9482	66	72 6	.8680	100	100 0	.7855
33	40.0	.9461	67	73.5	.8657			

Temperature Correction:* Change in Sp. Gr. per degree Centigrade

Strength Alcohol (%)	Correction	Strength Alcohol (%)	Correction
10	.00019	60	.00078
20	.00042	70	00079
30	.00059	80	.00080
40	.00068	90	.00080
50	.00074	100	.00080

*These data from Lebo, R. B., *J. Am Chem. Soc.*, **43**, 1005 (1921).

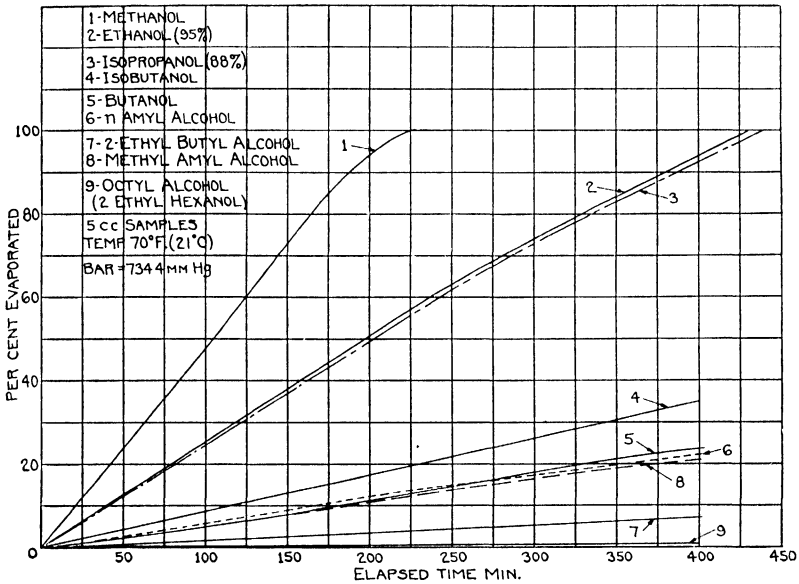


FIGURE 85. Evaporation Rate of Alcohols at Room Temperature.[2]

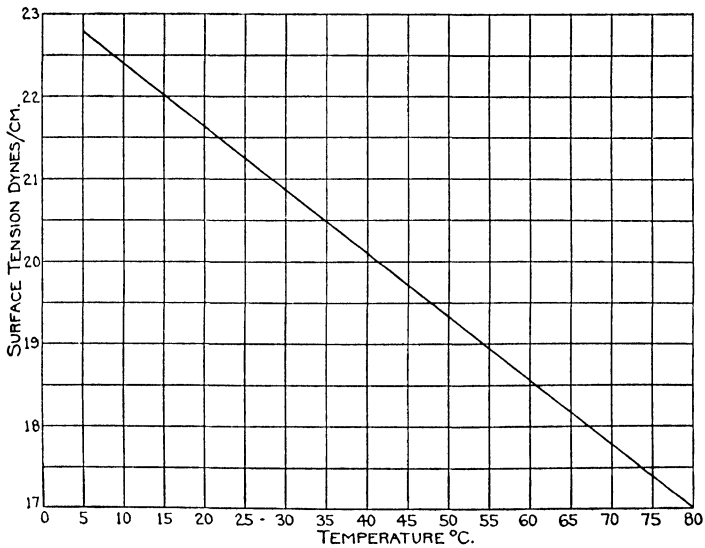


FIGURE 86. Surface Tension of Isopropanol at Various Temperatures.[2]

Properties of Isopropyl Alcohol	Anhydrous	91% (88% by wt.)
Molecular weight	60.06	
Boiling point	82.4° C.	80.4° C.
Freezing point	− 85.8° C.	
Specific gravity	$0.7874\ \frac{20°\text{ C.}}{20°\text{ C.}}$	$0.8158\ \frac{20°\text{ C.}}{20°\text{ C.}}$
Weight per gallon	6 56 lb (20° C.)	6.82 lb. (20° C.)
Refractive index	1.3776 (20° C.)	1.3769 (20° C.)
Surface tension	21.7 dynes/cm. (20° C.)	
Viscosity	0.0215 poise (24.4° C.)	0.0227 poise (24.4° C.)
Vapor pressure	31.6 mm. Hg. (20° C.)	35 mm. Hg. (20° C.)
Specific heat	0.677 cal./g. (30° C.)	0 740 cal./g. (30° C.)
Flash-point	14.5° C. (58.1° F.)	16.7° C. (62° F.)
Heat of combustion	475 kg. cal./mole	
Heat of fusion	21.4 cal./g.	
Latent heat of evaporation	159.4 cal./g. at B P.	
Electrical conductivity	35×10^{-7} recip. ohms (25° C.)	

TABLE 74.—Mixtures of Isopropyl Alcohol and Acetone[6]*

Isopropyl Al. % by Wt.	Heat of Mixing cal. per mol. of mixture 20° C.	Density 25° C.	Refract. Index† n_d^{25}	Total Vapor Pressure 25° C.	Visc. 25° C.
0	—	.7855	1.3555	226.5	.00308
15.65	− 190	.7832	1.3578	—	.00347
16.56	− 196	.7831	1.3579	221.6	.00349
30.00	− 316	.7818	1.3604	—	.00389
30.89	− 320	.7816	1.3605	—	.00395
46.34	− 362	.7805	1.3634	—	.00486
49.72	− 388 (max.)	.7806	1.3641	167.2	.00507
49.85	− 385	.7807	1.3641	—	.00513
66.90	− 343	.7801	1.3672	139.6	.00703
67.41	− 357	—	—	—	—
67.61	− 338	—	—	—	—
81.70	− 236	.7804	1.3708	—	.01071
85.37	− 197	.7805	1.3711	—	.01187
100.00	—	.7813	1.3743	44.3	.02020

Mixtures of Isopropyl Alcohol and Ethyl Alcohol‡

% Ethyl Alcohol	n_d^{25}	Viscosity 25° C.	% EtOH in Vapor at 25° C.
0	1.3750	.02048	0
17.23	1.3721	.01796	21.4
33.60	1.3697	.01607	41.2
49.87	1.3675	.01445	59.3
66.89	1.3646	.01299	73 5
83.61	1.3622	.01182	87.5
100.00	1.3595	.01080	100.

*Parks and Chaffee, *J. Phys. Chem*., **31**, 439 (1927).
†For values of n_c^{22} see Palmer, *Analyst*, **45**, 302 (1930).
‡Viscosities 25° C. } Parks and Kelley, *J. Phys. Chem*., **29**, 727 (1925).
Refractive Indexes }
Vapor Composition }

TABLE 75.—Mixtures of Isopropyl Alcohol with Aldehydes[6]*

Isopropyl Alcohol and Acetaldehyde				Isopropyl Alcohol and Heptaldehyde			
% Aldehyde	n_d^{8}	% Aldehyde	n_d^{8}	% Aldehyde	n_d^{25}	% Aldehyde	n_d^{25}
0	1 38516	70.6	1.36864	0	1.36994	62.6	1.39945
13 3	1 38391	74 2	1.36552	11.7	1.38113	69.8	1.40350
33.6	1 38247	81.0	1.36044	17.2	1.38381	80.6	1.40577
42.6	1 38008	92.1	1.35193	20.0	1.38640	89.4	1.40765
52.6	1 37640	95 8	1.34941	40.0	1.39318	91.9	1.40835
64.4	1.37218	100.	1.34445	50.4	1.39699	100.	1.40884

Isopropyl alcohol does not appear to form compounds (hemiacetals) with the above aldehydes, as does ethyl alcohol.
*Adkins, H., and Broderick, A. E., *J. Am. Chem. Soc*., **50**, 499 (1928).

TABLE 76.—Comparative Solubilities in Isopropyl and Ethyl Alcohols[68]*

Oils	Iso-Propyl alcohol	Ethyl alcohol 90%	Iso-Propyl alcohol 50%	Ethyl alcohol 45%
Almond	All	All	20.0	22.0
Ambrette seed	1.0	1.0	—	—
Anise	5.0	3.0	250.0	250.0
Bay	All	1.0	100.0	200.0
Bergamot	1.0	1.0	200 0	400.0
Bergamot, terpeneless	1.0	All	200.0	180.0
Cajuput	3.0	5.0	170.0	190.0
Cananga	1.0	1.5	250.0	500 0
Caraway	All	1.0	50.0	195.0
Cardamoms	All	1 0	50.0	80.0
Cassin	All	1 0	50.0	150.0
Cedarwood	6.0	12 0	200 0	500.0
Celery	All	10 0	250 0	—
Cinnamon bark	2.0	0.3	110.0	92.0
Cinnamon leaf	All	All	50.0	100 0
Citronella, Ceylon	2.4	1.0	220.0	200.0
Citronella, Java	All	1.0	100.0	165.0
Clove	All	All	50.0	80.0
Cognac	All	All	210.0	225.0
Coriander	0.5	0.5	180.0	200.0
Dill	All	3.0	90 0	100.0
Eucalyptus	2 6	5.0	170.0	210.0
Fennel	2.0	1.0	240.0	200.0
Geranium, African	All	All	50 0	200.0
Gingergrass	1.6	1.0	130.0	125.0
Juniper	2.4	4 0	200 0	210.0
Lavender, French	All	2 5	30.0	100.0
Lavender, terpeneless	2 0	All	110 0	90.0
Lavender, spike, Fr.	All	2 0	50 0	150 0
Lemon	2 0	4.0	100.0	200.0
Lemon, terpeneless	2.0	All	180 0	170 0
Lemongrass	2 0	14.0	45.0	85.0
Limes, Dist.	2.4	4.5	55 0	75 0
Lignaloe	All	2.0	50 0	100.0
Neroli, Bigarad.	2 4	2.0	110.0	100.0
Nutmeg	2.0	3.0	145.0	130.0
Orange, bitter	10 0	10 0	140 0	150.0
Orange, bitter, terpeneless	2.0	6 0	220 0	210.0
Orange, sweet	10 0	10 0	200 0	210.0
Orange, sweet, terpeneless	1 5	6.0	245.0	250.0
Orris, concrete	1.0	1.0	—	—
Otto Rose, (filtered)	All	All	200.0	250.0
Palmarosa	1.7	3.0	80.0	100 0
Patchouli	4 0	10 0	250 0	500 0
Pepper	All	7.0	300.0	—
Peppermint, Amer.	All	All	200.0	150.0
Peppermint, Jap.	All	2.0	50.0	180.0
Petitgrain	2 3	2 0	95.0	100 0
Petitgrain, terpeneless	2.4	All	160.0	150.0
Pimento	1.6	All	60 0	50 0
Pine, sylvest	0.5	3.0	250.0	—
Rose, Femelle	1.0	1.0	90.0	100 0
Rosemary, Fr.	All	2.0	45.0	100.0
Rosemary, Fr., terpeneless	2.0	All	110.0	100.0
Rue	2.0	All	125.0	120.0
Sage	2.6	2.0	110.0	100.0
Sage, Sclaree	2.0	2.0	—	—
Sandal, E. I.	2.7	5.0	80.0	160.0
Sassafras	3.4	3.0	220.0	200.0

TABLE 76.– Comparative Solubilities in Isopropyl and Ethyl Alcohols[6]*—(*Continued*)

Oils	Iso-Propyl alcohol	Ethyl alcohol 90%	Iso-Propyl alcohol 50 %	Ethyl alcohol 45%
Spearmint	1.8	1.0	—	—
Thyme, rouge	All	1 0	100.0	200.0
Vetivert	2.0	2.0	—	—
Ylang	turbid	0 75	40.0	100 0

*The indication is for one part by weight or volume of substance in the stated figures which are the solvent, *e. g.*, anise 1 in 5. Blank = less than 1 in 1000. "All" = in at least 0.1 of its own weight or volume.

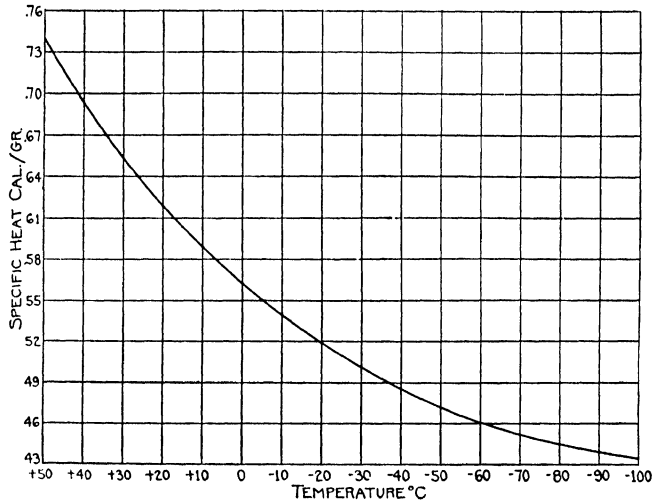


FIGURE 87. Specific Heat of Isopropanol at Various Temperatures.[2]

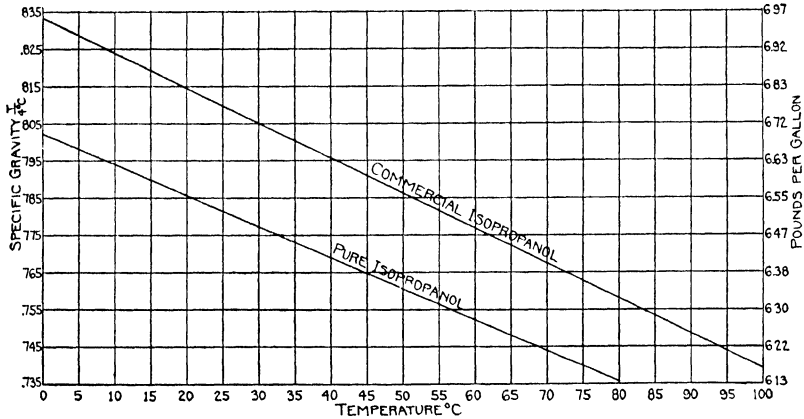


FIGURE 88. Specific Gravity and Weight per Gallon of Isopropanol at Various Temperatures.[3]

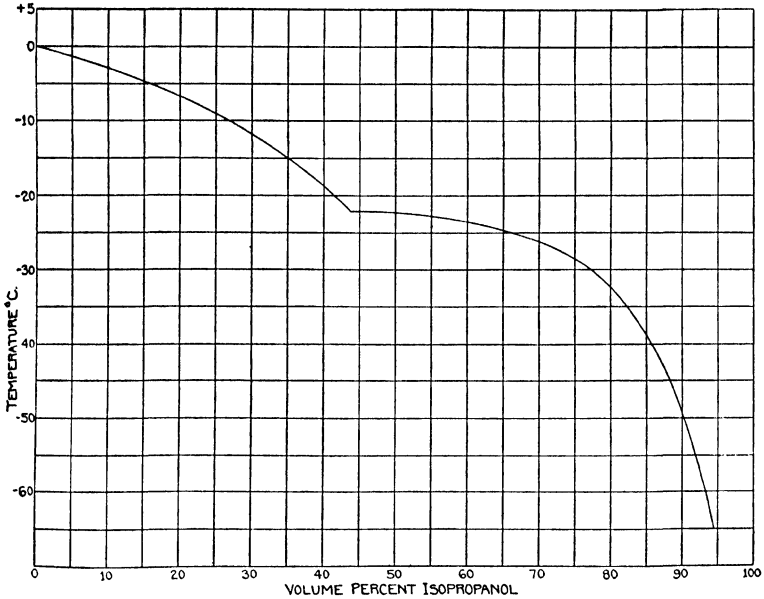


FIGURE 89. Freezing Point of Isopropanol-Water Mixtures (Temperature of Initial Crystallization).[3]

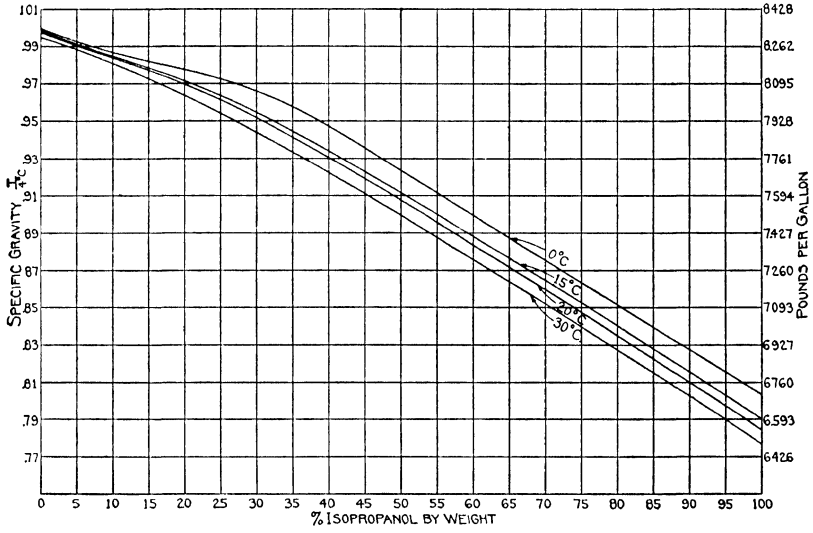


FIGURE 90. Specific Gravity and Weight per Gallon of Water-Isopropanol Mixtures.[3]

TABLE 77.—Solubilities of Synthetic Perfume Materials in Ethyl and Isopropyl Alcohols[6]*

	Iso-Propyl alcohol	Ethyl alcohol 90%	Iso-Propyl alcohol 50%	Ethyl alcohol 45%
Acetic ether	All	All	All	All
Acetophenone	All	All	7.0	8.0
Amyl acetate	All	All	20 0	21.0
Amyl alcohol	All	All	2.5	3.0
Amyl valer.	All	All	170.0	180.0
Anethol	1.0	2.0	85 0	100.0
Anisic ald.	All	All	10.0	30.0
Benzaldehyde	1.4	1.0	7.0	15.0
Benzyl acet.	All	1 0	10.0	35.0
Benzyl alc.	1.0	1 0	1.5	2.0
Benzyl benz.	2.0	2.0	—	—
Benzyl butyrate	All	All	65.0	70.0
Benzyl formate	All	All	28.0	29.0
Benzyl valer.	All	All	125.0	130.0
Benzylidene acetone	0.2	0.25	9.0	8 0
Bornyl acet.	All	All	200.0	200 0
Bromstyrol	2 0	5.0	250.0	500.0
Butyl acet.	All	All	8.0	9.0
Cinnamic alc.	All	All	7.0	7.5
Citral	1.8	1.0	—	—
Citronellal	2 8	1.0	—	—
Citronellol	All	1 0	20 0	40.0
Citronellyl acet.	All	All	300 0	330.0
Coumarin	5 0	6.0	25.0	35 0
Ethyl cinnamate	All	All	130 0	140.0
Eugenol	1.2	All	10.0	8.0
Formic ether	All	All	1.0	1.0
Geraniol	All	1.0	20.0	50.0
Geranyl acet.	All	All	750.0	800.0
Geranyl butyrate	All	All	550.0	560.0
Heliotropin	0.3	2 5	30 0	33.0
Ionone	All	All	50 0	110.0
Ionone alpha	All	All	30.0	60 0
Iso-eugenol	All	All	10 0	30.0
Iso-butyl acetate	All	All	11 0	10.0
Jasmin art.	1 0	All	70.0	70.0
Linalol	2 0	1.0	20 0	18.0
Linalyl acet.	All	1.0	50 0	200 0
Linalyl butyrate	All	All	170 0	180.0
Methyl acetophenone	All	1.0	12 0	14.0
Methyl anisate	1.5	2.0	30.0	32.0
Methyl anthranilate	7.5	5.0	25.0	20 0
Methyl benzoate	1.0	All	—	—
Methyl salicyl.	All	1 0	70.0	166.0
Mirbane	All	All	30.0	75 0
Musk ambrette	55.0	100.0	—	—
Musk xylol	200.0	250.0	—	—
Neroli art.	3.0	2.0	320.0	300.0
Nerolin	50.0	50.0	600.0	666.0
Oenanthic ether	All	All	—	—
Phenyl acetic acid	0.8	0.75	1.75	1.4
Phenyl acetic ald.	All	All	—	—
Phenyl ethyl alc.	All	All	3.0	4.5
Phenyl oxide	2.0	5.0	100.0	300.0
Phenyl propyl alc.	All	All	250.0	260.0
Rhodinol	2.0	1.0	170.0	160.0
Safrol	5.0	10.0	150.0	300.0
Salicyl amyl.	1.0	3.0	200.0	500.0
Styrolyl valer.	All	All	140.0	150.0

TABLE 77.—Solubilities of Synthetic Perfume Materials in Ethyl and Isopropyl Alcohols[6*]—(*Continued*)

	Iso-Propyl alcohol	Ethyl alcohol 90%	Iso-Propyl alcohol 50%	Ethyl alcohol 45%
Terpineol	All	1.0	10 0	30.0
Terpinyl acet.	All	1 0	—	—
Terpinyl prop.	All	All	100 0	110.0
Vanillin	1.25	2.5	5.0	10.0

*The foregoing table of solubilities has been taken from *Perfumery and Essential Oil Record* (December, 1925).

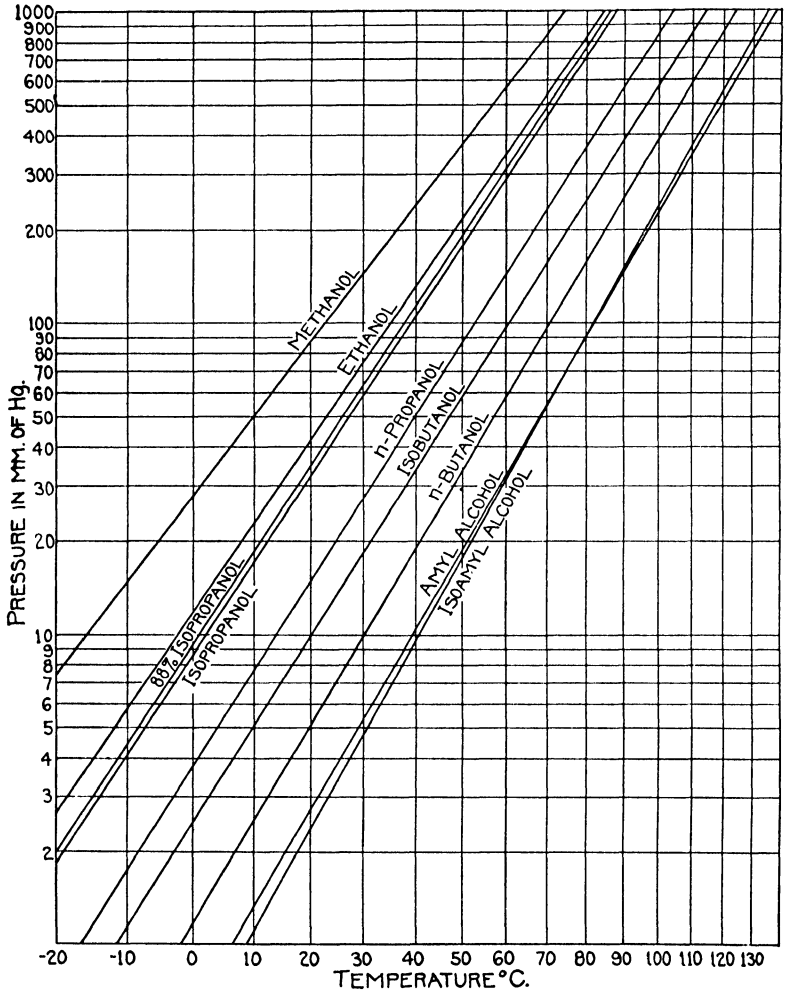


FIGURE 91. Vapor Pressure of Alcohols at Various Temperatures.[3]

TABLE 78.—Data for Free Energies of Higher Alcohols[7]

	Ethanol C_2H_5OH	*n*-Propanol C_3H_7OH	Isopropanol $(CH_3)_2CHOH$	*n*-Butanol C_4H_9OH
(*a*) Boiling point	351.5° K.	370.9° K.	355.4° K.	390.8° K.
(*b*) Vapor pres. at 25° C.	59 mm.	20.8 mm	44.0 mm.	6.5 mm.
(*c*) ΔH_v at boiling point	9500	9890	9580	10,410
(*d*) ΔH_{298}	−65,660	−72,260	−77,500	−78,770
(*d*) ΔF_{298}	−44,000	−44,100	−47,700	−44,100
(*e*) C_p of elements	$25.64 + 0.0118T - 0.0_524T^2$	$33.38 + 0.0149T$	$33.28 + 0.0173T - 0.0_536T^2$	$41.13 + 0.0228T - 0.0_548T^2$
(*f*) C_p liquid	$5.92 - 0.004T + 0.000248T^2$	$-12.1 + 0.16T$	$-17.6 + 0.163T + 0.0_496T^2$	$-6.28 + 0.122T + 0.0_31333T^2$
(*g*) C_p vapor	$5.31 + 0.0364T$	$10 + 0.0393$	$7.66 + 0.0379T$	$14.72 + 0.0422T$
ΔC_p liquid	$-19.72 - 0.0158T + 0.0002504T^2$	$-45.48 - 0.1451T$	$-50.98 + 0.1457T + 0.0_4132T^2$	$-47.41 + 0.0992T + 0.0_31381T^2$
ΔC_p vapor	$-20.33 + 0.0262T$	$-23.38 + 0.0244T$	$-25.72 + 0.023T$	$-26.41 + 0.0226T$
ΔH liquid	$-61,310 - 19.72T - 0.0079T^2 + 0.0_4835T^3$	$-65,110 - 45.48T - 0.07255T^2$	$-68,890 - 50.98T + 0.07285T^2 + 0.0_644T^3$	$-70,270 - 47.41T + 0.0496T^2 + 0.0_446T^3$
ΔH_b liquid	−65,550	−72,000	−77,140	−78,470
ΔH_b vapor	−56,050	−62,110	−67,560	−68,060
ΔH vapor	$-50,520 - 20.33T + 0.0131T^2$	$-55,110 - 23.38T + 0.0122T^2$	$-59,820 - 25.72T + 0.0115T^2$	$-59,470 - 26.41T + 0.0113T^2$
ΔF liquid	$-61,310 + 19.72T\ln T + 0.0079T^2 - 0.0_442T^3 - 53T$	$-65,110 + 45.48T\ln T - 0.07255T^2 - 166.8T$	$-68,890 + 50.98T\ln T - 0.07285T^2 - 0.0_522T^3 - 197.3T$	$-70,270 + 47.41T\ln T - 0.0496T^2 - 0.0_423T^3 - 165.6T$
ΔF_b	−40,100	−37,140	−41,900	−33,326
ΔF vapor	$-50,520 + 20.33T\ln T - 0.0131T^2 - 85T$	$-55,110 + 23.38T\ln T - 0.0122T^2 - 85.4T$	$-59,820 + 25.72T\ln T - 0.0115T^2 - 96.5T$	$-59,470 + 26.41T\ln T - 0.0113T^2 - 86.8T$
ΔF_{298} vapor	−42,470	−41,970	−45,920	−41,320
ΔF_{298} evaporation	1511	2135	1691	2820
ΔF_{500} vapor	−33,130	−28,285	−31,045	−23,635
ΔF_{700} vapor	−23,220	−13,770	−15,120	−4660
ΔF vapor	$-57,880 + 49.5T$	$-64,590 + 72.6T$	$-70,840 + 79.6T$	$-71,090 + 94.9T$

TABLE 78.—Data for Free Energies of Higher Alcohols[7]—(*Continued*)

	Isobutanol $(CH_3)_2CHCH_2OH$	*Tert*-Butanol $(CH_3)_3COH$	Active Amyl Alcohol $C_2H_5(CH_3)CHCH_2OH$	*n*-Heptanol $C_7H_{15}OH$
(*a*) Boiling point	380.4° K.	355.9° K.	401.1° K.	448.9° K.
(*b*) Vapor pres. at 25° C.	12.2 mm.	42.0 mm.	3.4 mm.	..
(*c*) ΔH_v at boiling point	10,100	9700	10,600	12,200
(*d*) ΔH_{298}	−80,000	−88,400	−87,880	−100,580
(*d*) ΔF_{298}	−45,900	−45,900	−45,900	−44,100
(*e*) C_p of elements	$41.13 + 0.0228T - 0.0_548T^2$	$41.13 + 0.0196T$	$48.88 + 0.0243T$	$64.38 + 0.0337T$
(*f*) C_p liquid	$-14.34 + 0.1332T + 0.0002T^2$	$-18 + 0.1796T$	$-18.2 + 0.2303T$	$-30.7 + 0.3237T$
(*g*) C_p vapor	$12.36 + 0.0408T$	$10 + 0.0396T$	$18.63 + 0.0443T$	$28.85 + 0.0509T$
ΔC_p liquid	$-55.47 + 0.1104T + 0.0002048T^2$	$-59.13 + 0.16T$	$-67.08 + 0.206T$	$-95.08 + 0.29T$
ΔC_p vapor	$-28.77 + 0.0212T$	$-31.13 + 0.02T$	$-32.05 + 0.02T$	$-35.53 + 0.0172T$
ΔH liquid	$-70,170 - 55.47T + 0.0552T_2 + 0.0_4683T^2$	$-77,890 - 59.13T + 0.08T^2$	$-77,040 - 67.08T + 0.103T^2$	$-85,140 - 95.08T + 0.145T^2$
ΔH_b liquid	−79,530	−88,790	−87,374	−98,640
ΔH_b vapor	−69,430	−79,090	−76,774	−86,440
ΔH vapor	$-60,020 - 28.77T + 0.0106T^2$	$-69,290 - 31.13T + 0.01T^2$	$-65,527 - 32.05T + 0.01T^2$	$-72,230 - 35.53T + 0.0086T^2$
ΔF liquid	$-70,170 + 55.47T\ln T - 0.0552T^2 - 0.0_4341T^2 - 215.22T - 36,540$	$-77,890 + 59.13T\ln T - 0.08T^2 - 219.22T - 42,390$	$-77,040 + 67.08T\ln T - 0.103T^2 - 247.16T - 31,435$	$-85,140 + 95.08T\ln T - 0.145T^2 - 360.96T - 15,750$
ΔF_b	$-60,020 + 28.77T\ln T$	$-69,290 + 31.13T\ln T$	$-65,527 + 32.05T\ln T$	$-72,230 + 35.53T\ln T$
ΔF vapor	$-0.0106T^2 - 106.16T$	$-0.01T^2 - 103.87T$	$-0.01T^2 - 103.06T$	$-0.0086T^2 - 87.29T$
ΔF_{298} vapor	−43,440	−48,260	−42,695	−38,637
ΔF_{298} evaporation	2450	1718	3206	.
ΔF_{500} vapor	−26,360	−27,000	−19,977	−7628
ΔF_{700} vapor	−7620	−4170	+4382	+26,366
ΔF vapor	$73,210 + 93.7T$	$-84,075 + 114.15T$	$+80,880 + 121.8T$	$-92,630 + 170T$

(*a*) International Critical Tables, **1**, 180, McGraw-Hill Book Co., 1926.

(*b*) L-B, 1362, Parks, G. S., and Barton, B., *J. Am. Chem. Soc.*, **50**, 24 (1928)

(*c*) L-B, 1480. The value used for *tert*-butanol was estimated from Trouton's rule.

(*d*) Reference 5. *Ind. and Eng. Chem.*, **20**, 283 (1928). The heats of formation of iso-butanol, active amyl alcohol, and *n*-heptanol were estimated from their heats of combustion, L-B, 1592. The free energy of *n*-heptanol at 25° C. was assumed to be the same as those of the other normal alcohols. Those of iso-butanol and active amyl alcohol were assumed to be the mean between those of normal and those of secondary alcohols (iso-propanol).

(*e*) References 5 and 9. *Ind. and Eng. Chem.*, **20**, 283 (1928)

(*f*) Williams, J. W., and Daniels, F., *J. Am. Chem. Soc.*, **46**, 912 (1924); L-B, 1266. The heat capacities of active amyl alcohol and *n*-heptanol are extrapolations from those of the lower primary alcohols. That of *tert*-butanol was found by adding to that of *n*-butanol twice the difference between those of iso-propyanol and *n*-propanol.

(*g*) The heat capacities of methanol and ethanol vapors were obtained from reference 7. *Ind. and Eng. Chem.*, **20**, 283 (1928). Those of the other alcohols are suitable extrapolations of these two. Moderate errors in the heat capacities make very little differences in the free energies calculated, because of the compensating effect of the chemical constant, *I*.

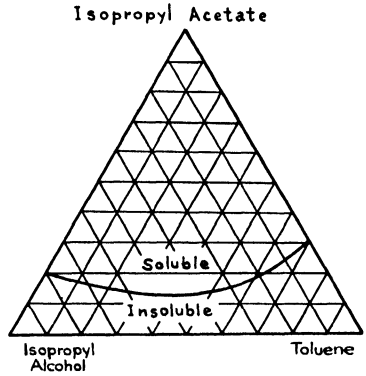


FIGURE 92.

Solubility of ½-sec. Nitrocellulose.[4]

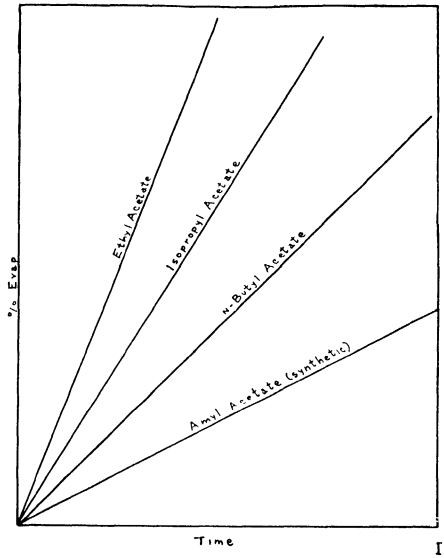


FIGURE 93.

Evaporation Rate of Various Acetates at Room Temperature.[4]

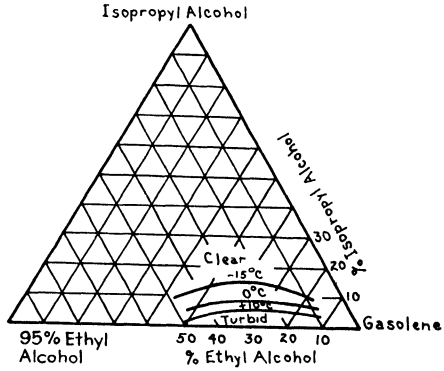
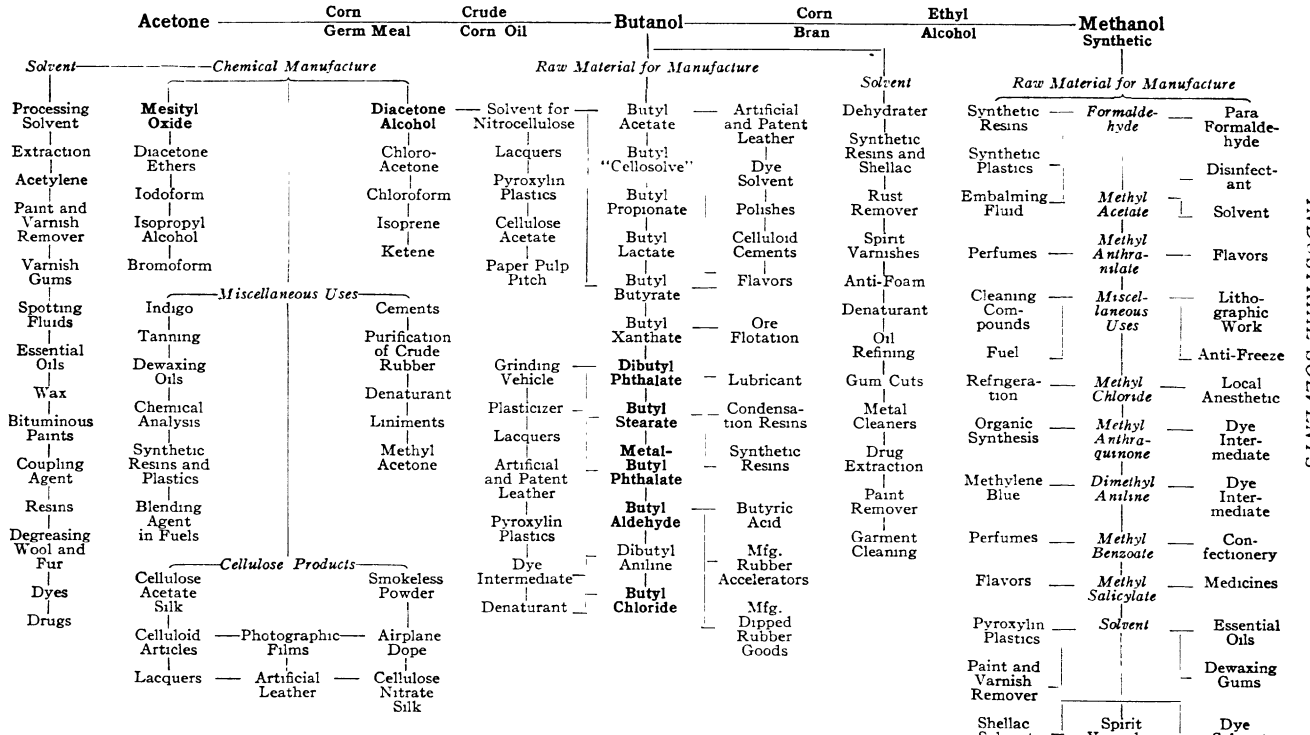


FIGURE 94.

Miscibility of Isopropyl Alcohol, 95% Ethyl Alcohol and Gasoline $\left(\text{d}\ \frac{15}{15}\ 0.7231\right)$. (Plotted from Rothen and Bentier, *Chemie et Industrie*, Spec. No. 733 (1923).[4]

TABLE 79.—Industrial Uses of Acetone, Butanol, Methanol and Their Derivatives

(Courtesy of Commercial Solvents Corporation)



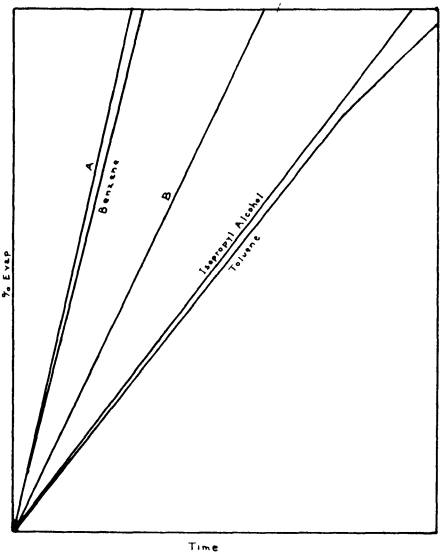


FIGURE 95.

Evaporation Rates:
A=75 Benzene, 25 Isopropyl Alcohol
B=48 Toluene, 52 Isopropyl Alcohol
Constant Evaporating Mixtures.[6]
Room Temperature.

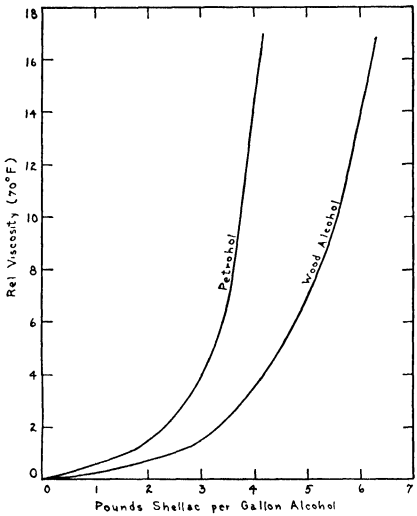


FIGURE 96.

Viscosity of Shellac Solutions at Room Temperature.[6]

n-Butyl Alcohol

n-Butyl alcohol ($CH_3CH_2CH_2CH_2OH$, Butanol) is a water-white, combustible but not inflammable liquid. The butanols are medium-boiling alcohols and the normal derivative is of special interest since it serves as the basis for making butyl esters. The bulk of commercial butyl alcohol is made by selective fermentation processes. The crude distillate contains

acetone, small amounts of ethyl, *n*-amyl, and *n*-hexyl alcohols and esters of acetic, butyric, caprylic and caproic acids. Butanol is also made synthetically from acetaldehyde or ethyl alcohol. Normal butyl alcohol is miscible with most organic solvents and is used as a blending medium for many immiscible liquids. It is a solvent for alkaloids, camphor, capsicum, resorcinol, dyes, oils, gums and waxes; natural resins like congo, dammar, elemi, kauri, manila, sandarac and shellac; synthetic resins like ester gum, ketone-aldehydes, resins, urea-aldehyde resins, benzyl abietate and metallic soaps; and it possesses latent solvent properties for nitrocellulose. When it is mixed with aromatic hydrocarbons, or chlorinated hydrocarbons, or alkyl acetates, butyl alcohol will dissolve many of the cellulose esters and ethers.

It is also used as an adjunct with active solvents in order to enhance their solvent properties. A large quantity of butanol is used as a "medium boiler" in the manufacture of pyroxylin lacquers owing to its solvency, its power to impart flow, gloss, blush prevention and lower viscosity. It is also used in the varnish industry, as a general solvent, as a dehydrating agent, in butyl ester manufacture, and as a blending agent for incompatible material such as liquids, gums and resins. In the solution of synthetic resins or oleoresins butanol is especially valuable because it imparts good leveling qualities, reduces viscosity, prevents blushing and improves flow and working qualities. It is also used as a detergent, defrother, penetrant and denaturant; in film production, motor fuel, printing inks, cleaners, polishes, varnish removers, perfumes, dewaxing and so forth.

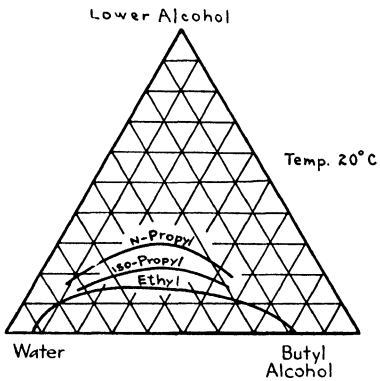


FIGURE 97.

Miscibility of Certain Lower Alcohols with Water and Butyl Alcohol[4] (Int. Critical Tables III, 412).

Molecular weight	74.08
Boiling point	117.7° C.
Freezing point	− 89.8° C.
Specific gravity	$0.8108 \frac{20° \text{ C.}}{20° \text{ C.}}$
Weight per gallon	6.75 lb. (20° C.)
Refractive index	1.3974 (25° C.)
Surface tension	24.6 dynes/cm. (20° C.)

Viscosity	0.0291 poise (20° C.)
Specific heat	0.562 cal./g.
Flash-point (A. S. T. M. open cup)	43.9° C. (111° F.)
Heat of combustion	639 kg. cal./mole.
Heat of fusion	29.9 cal./g.
Latent heat of evaporation	141.3 cal./g. at B.P.
Electrical conductivity	3.6×10^{-7} recip. ohm (26° C.)
Color	Water-white

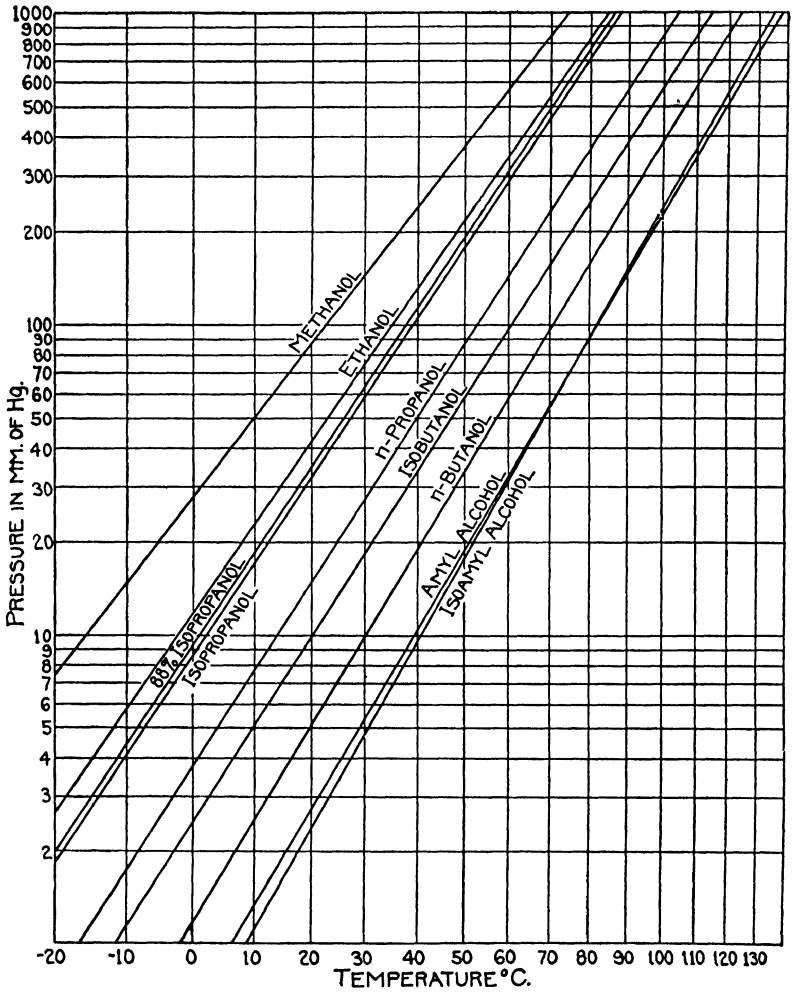


FIGURE 98. Vapor Pressure of Alcohols at Various Temperatures.[2]

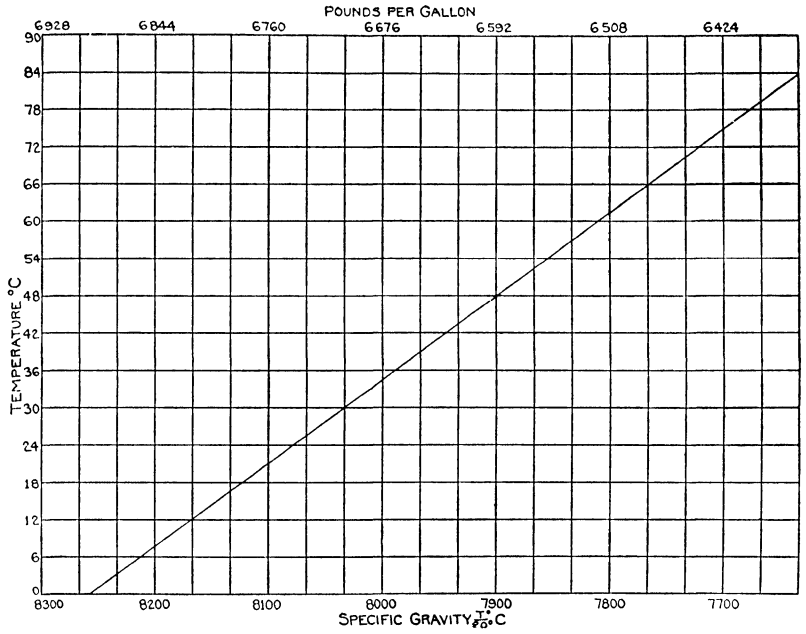


FIGURE 99. Specific Gravity and Weight per Gallon of *n*-Butyl Alcohol at Various Temperatures.[2]

Distillation range	
Below 115° C.	None
Above 118° C.	None
Iron	None
Chlorides	None
Approximate change in weight per gallon per ° F.	0 0035 pound
Solubility in water	8.90% by vol. (25° C.)
Solubility of water in Butanol	17.12% by vol. (25° C.)
Critical pressure	48.4 atm.
Critical temperature	287° C.
Average coefficient of cubical expansion (ordinary temperatures)	0.00095
Dielectric constant	16.1 (25° C.)
Vapor pressure	
at 20.0° C.	5.3 mm. Hg.
at 100.8° C.	400 mm. Hg.
at 117.6° C.	760 mm. Hg.

Evaporation rate at 95° F. (in minutes)	5%	25%	50%	75%	90%	95%
	2½	13¾	26¼	44½	59½	67

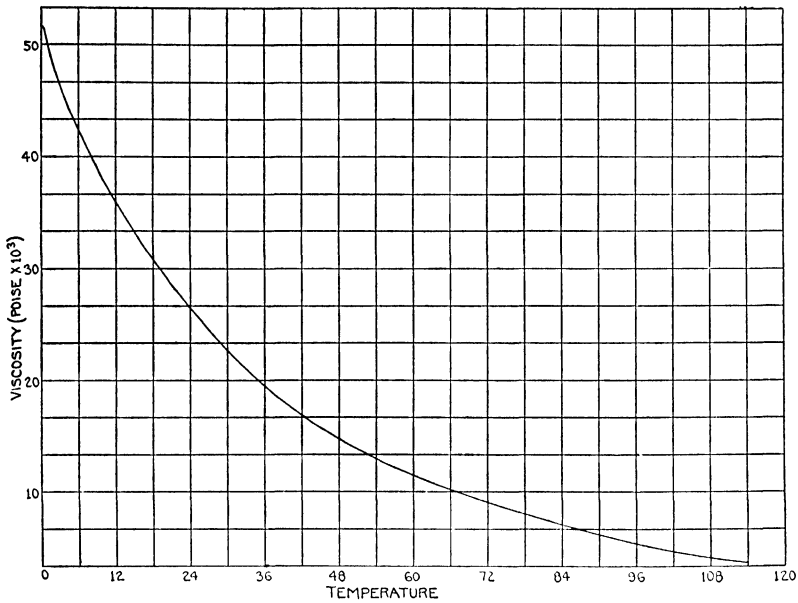


FIGURE 100. Viscosity of *n*-Butyl Alcohol at Various Temperatures.[2]

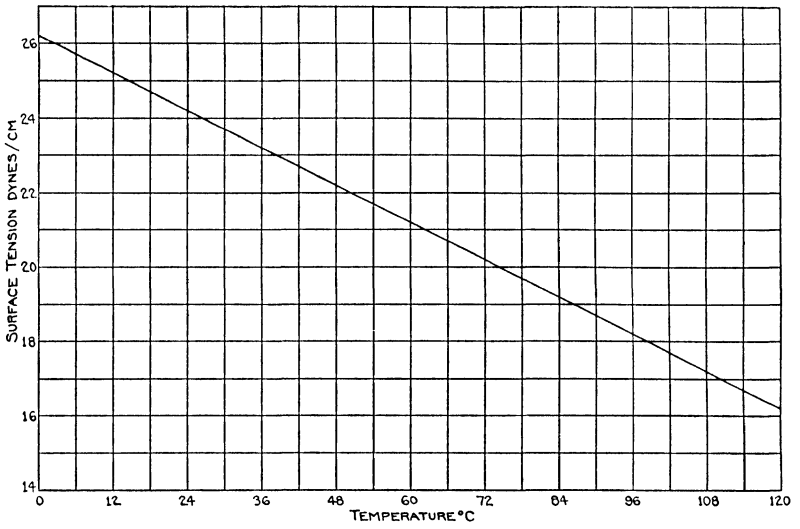


FIGURE 101. Surface Tension of *n*-Butyl Alcohol at Various Temperatures.[2]

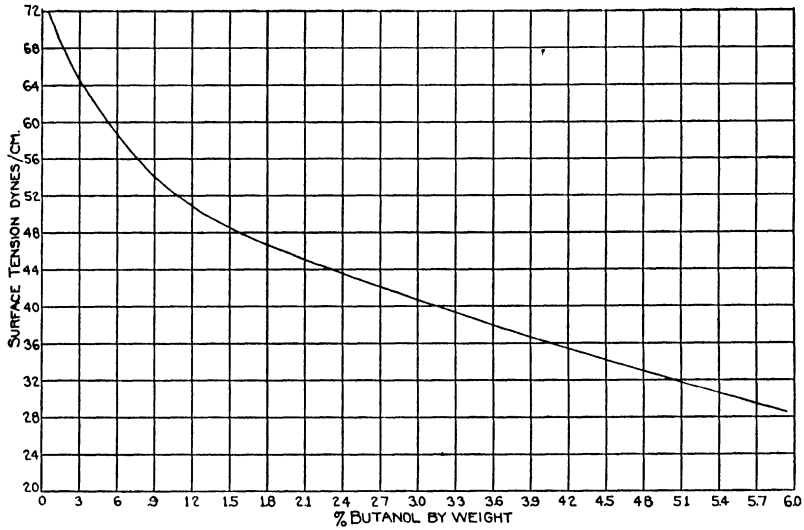


FIGURE 102. Surface Tension of Aqueous Solutions (at 25° C.) of *n*-Butyl Alcohol.[2]

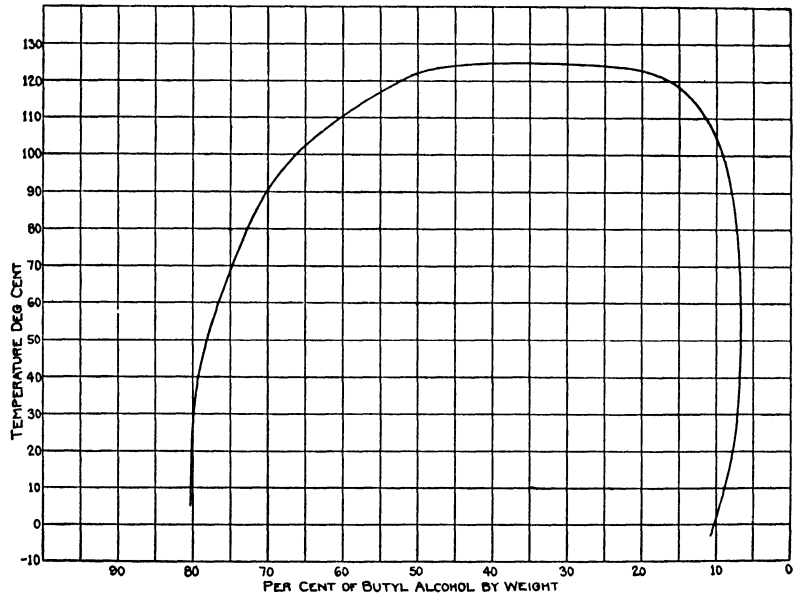


FIGURE 103. Solubility of *n*-Butyl Alcohol in Water.[3]

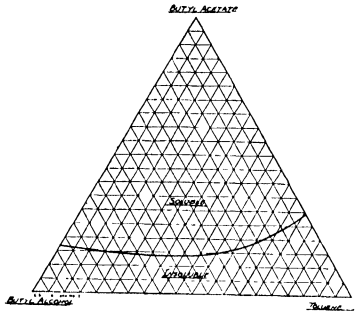


FIGURE 104. Solubility of ½-Second R S Nitrocellulose in Mixtures of Butyl Acetate, Butyl Alcohol, and Toluene.[2]

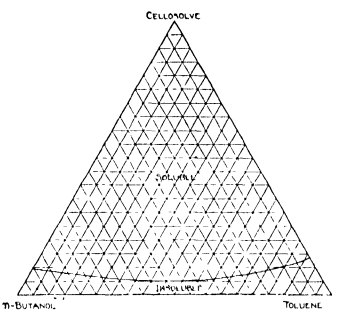


FIGURE 105. Solubility of ½-Second R.S. Nitrocellulose in Mixtures of "Cellosolve," Butyl Alcohol and Toluene.[2]

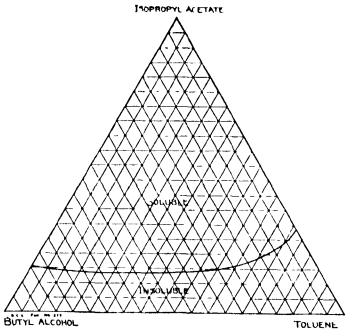


FIGURE 106. Solubility of ½-Second R S Nitrocellulose in Mixtures of Isopropyl Acetate, Butyl Alcohol, and Toluene.[2]

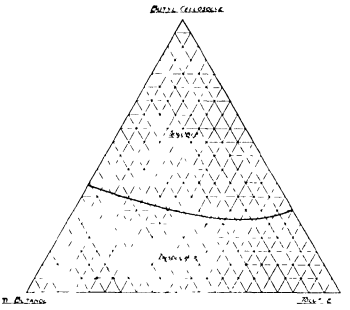


FIGURE 107. Solubility of ½-Second Nitrocellulose (Dry) in Mixtures of Butyl "Cellosolve," Butyl Alcohol, and Toluene.[2]

TABLE 80.—Freezing Points and Specific Gravities of Certain Anti-freeze Solutions[1]

Solution	Percentage (by volume) in water, and freezing points				
	10%	20%	30%	40%	50%
	°C. °F	°C. °F.	°C. °F.	°C. °F.	°C. °F.
Denatured alcohol (90% by vol.)	− 3 + 27 (0 988)	− 7 + 19 (0 978)	− 12 + 10 (0.968)	− 19 − 2 (0.957)	−28 − 18 (0 943)
Wood alcohol	− 5 + 23 (0.987)	− 12 + 10 (0.975)	− 19 − 2 (0.963)	− 29 − 20 (0.952)	− 40 − 40 (0.937)
Distilled glycerin (95% by wt.)	− 2 + 29 (1.029)	− 6 + 21 (1.057)	− 11 + 12 (1.085)	− 18 0 (1.112)	− 26 − 15 (1.140)
Ethylene glycol	− 3 + 26 (1.016)	− 9 + 16 (1.031)	− 16 + 3 (1.045)	− 24 − 11 (1.058)	− 35 − 31 (1.070)

Isobutyl Alcohol

Isobutyl alcohol $\begin{matrix}CH_3\\ \\ CH_3\end{matrix}\!\!>\!CHCH_2OH$ (isopropyl carbinol, 2-methyl propanol 1) is a water-white, inflammable liquid and is found as a constituent part of fusel oil from which it is obtained by distillation. It is also made synthetically from butylene

Boiling point	107–108° C
Flash-point	22° C.
Melting point	– 108° C.
Refractive index	1.397
Specific gravity	0.8057

Isobutyl alcohol resembles the normal isomer to some extent in physical and chemical properties.

Secondary Butyl Alcohol

Secondary butyl alcohol $\begin{matrix}CH_3\\ \\ C_2H_5\end{matrix}\!\!>\!CHOH$ (methyl ethyl carbinol, butanol 2) is a water-white, inflammable liquid with a choking odor and is made both from butylene and by the hydrogenation of methyl ethyl ketone. It is used in the manufacture of secondary butyl esters and ketones and as a solvent and thinner in lacquers.

Acidity	Less than 0.003% as free acetic
Boiling range	95–101° C.
Color	Clear white
Dilution ratio with toluene	Extender with toluene
Dryness	Complete, standing all volumes of gasoline without turbidity
Ester content	Not saponifiable
Evaporation rate	Slower than isopropyl, slightly faster than normal butyl alcohol
Initial odor	Characteristic
Residual odor	None
Residue on evaporation	None
Specific gravity	0.805–0.815 (15½° C.)
Distillation range	
Below 95° C.	None
Above 101° C.	None
More than 90% distills over between 97° and 100° C.	

Tertiary Butyl Alcohol

Purity	Contains more than 99% tertiary butyl alcohol
Specific gravity	$0.783 \pm 0.003\ \frac{25°\text{ C.}}{25°\text{ C.}}$
Color	Water-white
Water	Miscible without turbidity with 19 volumes of 60° Bé. gasoline at 20° C.

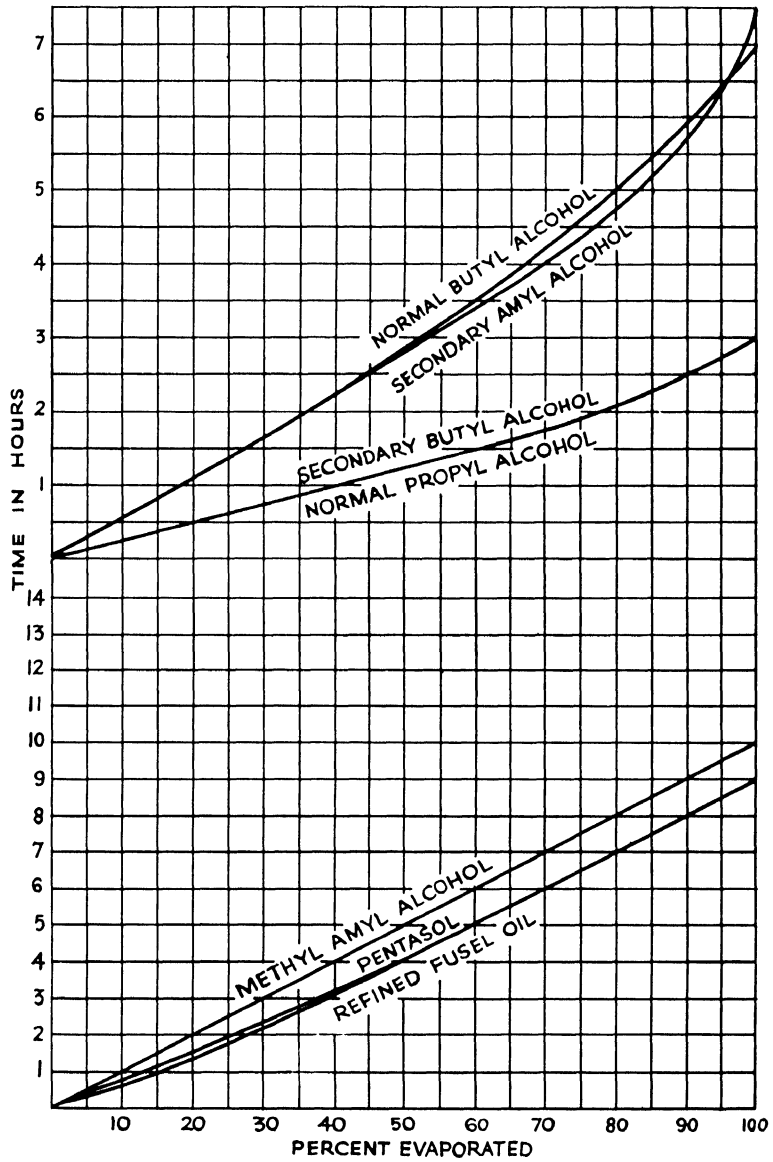


FIGURE 108. Rate of Evaporation of Various Solvents at Room Temperature.[8]

Acidity	
(free acid as acetic acid)	Less than 0 003%
Distillation range	
Below 78° C.	None
Above 85° C.	None
More than 95% distills over between 81° and 83° C.	
Freezing point	
(first needle)	Above 20° C.

Amyl Alcohols

Fusel Oil

Amyl alcohols ($C_5H_{11}OH$) include eight isomeric forms. Fusel oil, obtained as a by-product in the manufacture of ethyl alcohol, is a blend of a number of amyl alcohols with small amounts of lower alcohols, esters, furfural, pyridine and so forth. It is an excellent solvent for resins, possesses unusual blending properties and imparts flow and gloss to lacquers. Its output is largely consumed in the manufacture of amyl compounds and in lacquers. The highly refined amyl alcohol is used as an intermediate and as a laboratory reagent.

Refined amyl alcohol has the approximate composition of 85 per cent iso-amyl alcohol and 15 per cent of active amyl alcohol.

Amyl Alcohols

	Approximate Boiling Point
$CH_3CH_2CHOHCH_2CH_3$ Secondary amyl alcohol	116° C.
$CH_3CHOHCH_2CH_2CH_3$ Secondary amyl alcohol	119° C.
$CH_2OHCH(CH_3)CH_2CH_3$ Active amyl alcohol	128° C.
$(CH_3)_2CHCH_2CH_2OH$ Isoamyl alcohol	131° C.
$CH_2OHCH_2CH_2CH_2CH_3$ Normal amyl alcohol	136° C.

Fusel oil, or fermentation amyl alcohol, and the less pure products are miscible with aromatic hydrocarbons and oils. These are solvents for camphor, alkaloids, resins (such as copals, cumar resins, mastic, sandarac, shellac) iodine, phosphorus, sulfur, synthetic resins like benzyl abietate, copal ester, ester gum, glyptol resins, ketone-aldehyde resins, urea-aldehyde resins and so forth. When fusel oil is used together with active solvents the mixture will dissolve acetyl and nitrocellulose and when mixed with benzene or methyl or ethyl acetate the combination will dissolve many of the cellulose ethers. Amyl alcohols are used in spirit varnishes, artificial fruit essences, dyestuffs, perfume preparations, dyeing, textiles, and purification of minerals.

The synthetic amyl alcohols are known as Pentosols. They are composed of a mixture of isomeric amyl alcohols and are made by the chlorination of the pentane fraction of gasoline. The chlorpentanes are converted to alcohols by hydrolysis. These alcohols are chemically pure, mild in

odor, free of moisture and do not possess residual odor. They are used in lacquer fabrication because they help to blend together gums, oils and resins, and they impart flow, gloss, polishing qualities and blush resistance.

Peramyl Alcohol

Peramyl alcohol is said to be related to amyl alcohol. It is a colorless liquid with a boiling range of 90 to 160 °C. and a specific gravity of

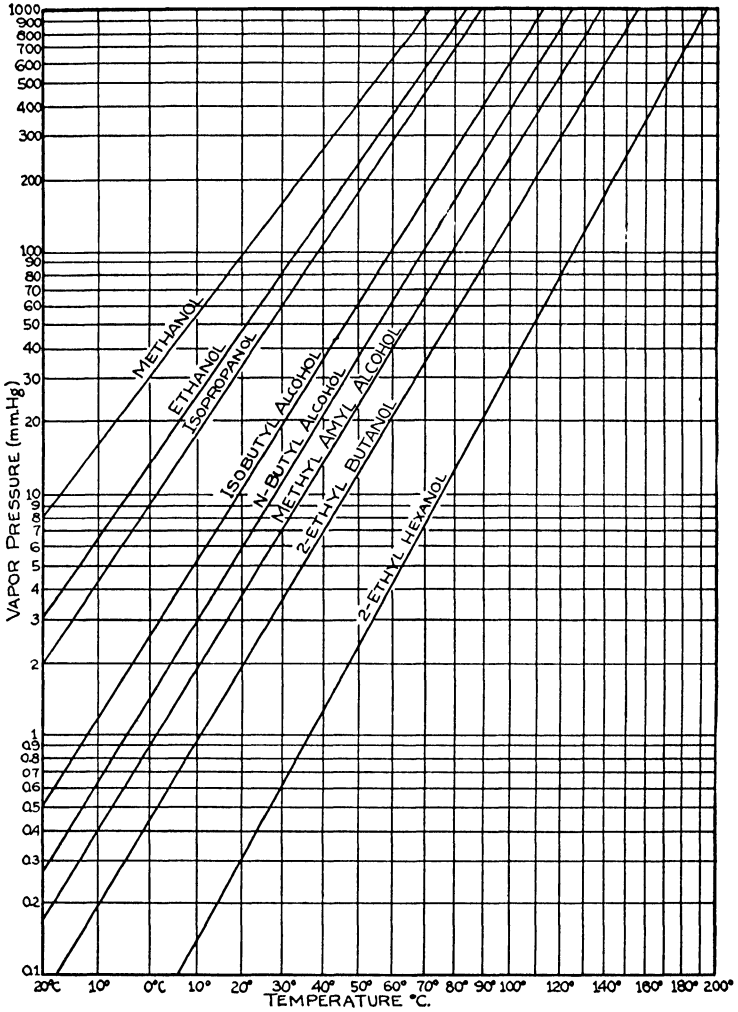


FIGURE 109. Vapor Pressure of Alcohols at Various Temperatures.[1]

0.883. It is a solvent for a large number of organic compounds such as oils, waxes, resins, nitrocellulose and so forth. Durrans is of the opinion that it is a mixture of cyclohexanol, isopropyl alcohol and *n*-butyl alcohol.

These alcohols are chemically pure, mild in odor, free of moisture and do not possess residual odor. They are used in lacquer fabrication because they help to blend together gums, oils and resins, and they impart flow, gloss, polishing qualities and blush resistance.

Methyl Amyl Alcohol

Methyl amyl alcohol $\begin{matrix}CH_3\\ \\ CH_3\end{matrix}\!\!\rangle CHCH_2CHOH$ (methyl isobutyl carbinol) is
$\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\quad CH_3$

a colorless, stable liquid. It is miscible with most of the commonly used organic solvents and is a solvent for oils, fats, waxes, resins, camphor, blown oils, dyes and so forth. It is used as a solvent in lacquers and in organic synthesis.

Molecular weight	102.11
Boiling point	131.4° C.
Specific gravity	$0.8072\ \frac{20°\text{ C.}}{20°\text{ C.}}$

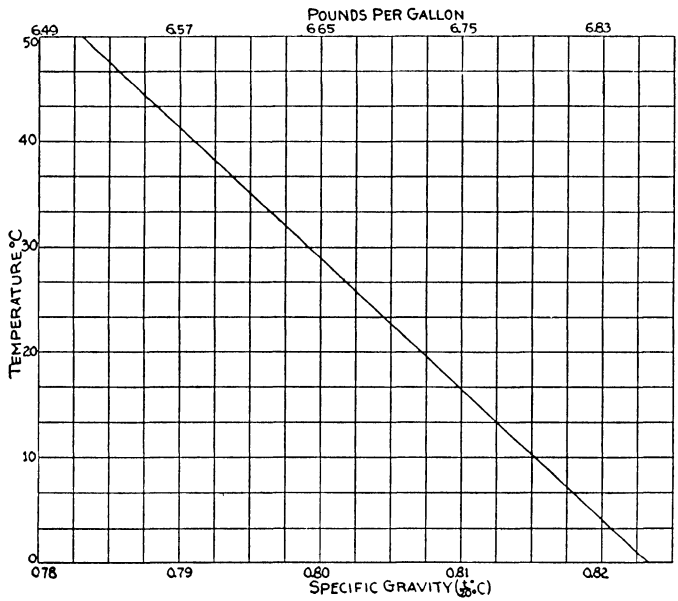


FIGURE 110. Specific Gravity and Weight per Gallon of Methyl Amyl Alcohol at Various Temperatures.[1]

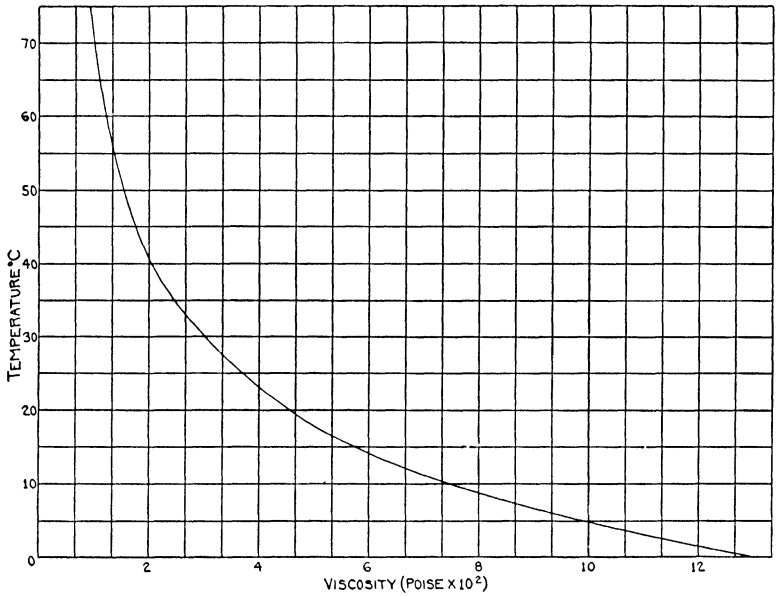


FIGURE 111. Viscosity of Methyl Amyl Alcohol at Various Temperatures.[1]

Weight per gallon	6.72 lb. (20° C.)
Refractive index	1.4089 (25° C.)
Surface tension	25.1 dynes/cm. (25° C.)
Viscosity	0.0459 poise (20° C.)
Vapor pressure	3.52 mm. Hg. (20° C.)
Specific heat	0.654 cal./g. (25° C.)
Latent heat of evaporation	102.0 cal./g. at B P.
Flash-point (A. S. T. M. open cup)	45.6° C. (114° F.)
Solubility in water	1.73% by wt. (20° C.)
Solubility of water in methyl amyl alcohol	6.39% by wt. (20° C.)
Electrical conductivity	7×10^{-8} recip. ohms (25° C.)
Coefficient of expansion (per ° C.)	0.001000 to 20° C. 0.001038 to 55° C.

Octyl Alcohol

Octyl alcohol $CH_3CH_2CH_2CH_2\underset{\underset{C_2H_5}{|}}{C}HCH_2OH$ (2-ethyl hexanol, 2-ethyl hexyl alcohol) is a colorless, viscous liquid. It is miscible with most organic solvents and will dissolve a wide variety of raw and blown oils, natural and synthetic gums and resins, waxes, dyes, camphor and so forth. Octyl alcohol and sulfonated octyl alcohol are each used as a slow-evaporating solvent in lacquers. Other uses are in textile processing such as merceriz-

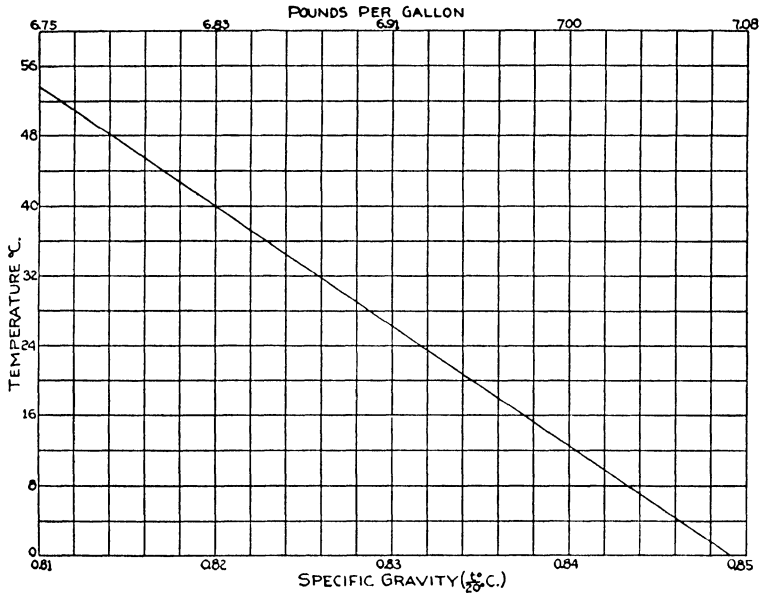


FIGURE 112. Specific Gravity and Weight per Gallon of Octyl Alcohol at Various Temperatures.[2]

ing, dyeing, and as penetrants, wetting-agents and surface tension depressants.

Molecular weight	130.14
Boiling point	184.6° C.
Specific gravity	$0.8344 \frac{20° \text{ C.}}{20° \text{ C.}}$
Weight per gallon	6.94 lb. (20° C.)
Refractive index	1.4300 (20° C.)
Surface tension	30.0 dynes/cm. (22° C.)
Viscosity	0 0705 poise (25° C.)
Vapor pressure	0.29 mm. Hg. (20° C.)
Specific heat	0.564 cal./g. (25° C.)
Latent heat of evaporation	92.8 cal./g. at B.P.
Flash-point (A. S. T. M. open cup)	81.0° C. (178° F.)
Solubility in water	0.14% by wt. (25° C.)
Solubility of water in octyl alcohol	2.55% by wt. (25° C.)
Coefficient of expansion (per ° C.)	0.000875 to 20° C. 0.000902 to 55° C.

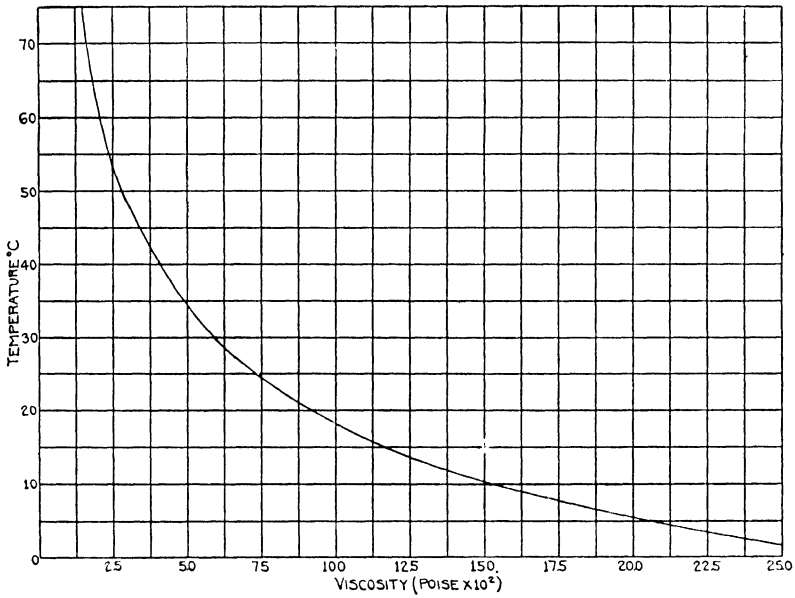


FIGURE 113. Viscosity of Octyl Alcohol at Various Temperatures.[2]

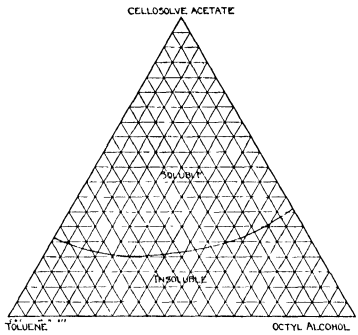


FIGURE 114.

Solubility of ½ Sec. R. S. Nitrocellulose in Mixtures of "Cellosolve" Acetate, Octyl Alcohol and Toluene.[2]

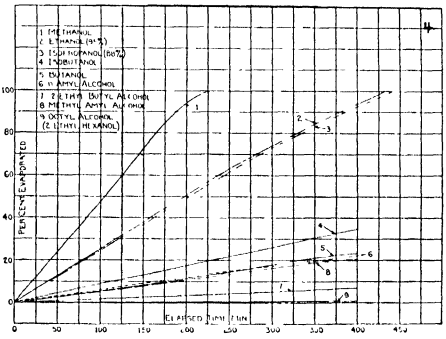


FIGURE 115.

Evaporation Rate of Various Alcohols at Room Temperature.[2]

2-Ethyl Butanol

2-Ethyl butanol $CH_3CH_2CHCH_2OH$ (2-ethyl butyl alcohol, pseudo hexyl alcohol) is a colorless, stable liquid. It is miscible with most solvents and will dissolve a large variety of oils, gums, natural and synthetic resins, waxes, dyes and so forth. It is used as a solvent and diluent and also employed in organic synthesis of perfumes, hypnotic drugs (barbituric acid type) and flavoring materials.

Molecular weight	102.11
Boiling point	148.9° C.
Specific gravity	$0.8328\ \frac{20°\ C.}{20°\ C.}$
Weight per gallon	6.93 lb. (20° C.)
Refractive index	1.4229 (20° C.)
Surface tension	28.05 dynes/cm. (28° C.)
Viscosity	0.0563 poise (20° C.)
Vapor pressure	1.80 mm. Hg. (20° C.)
Specific heat	0.586 cal /g. (25° C.)
Latent heat of vaporation	108.9 cal./g. at B.P.
Flash-point (A.S.T.M. open cup)	58° C. (137° F.)

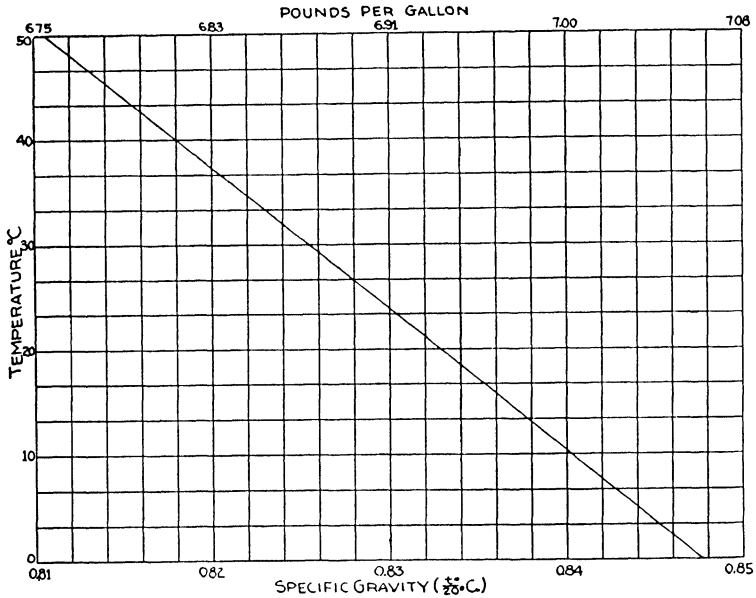


FIGURE 116. Specific Gravity and Weight per Gallon of 2-Ethyl Butyl Alcohol at Various Temperatures.[2]

Solubility in water	0 43% by wt. (20° C.)
Solubility of water in 2-ethyl butanol	4.56% by wt. (20° C.)
Coefficient of expansion (per ° C.)	{0.000892 to 20° C. {0.000921 to 55° C.

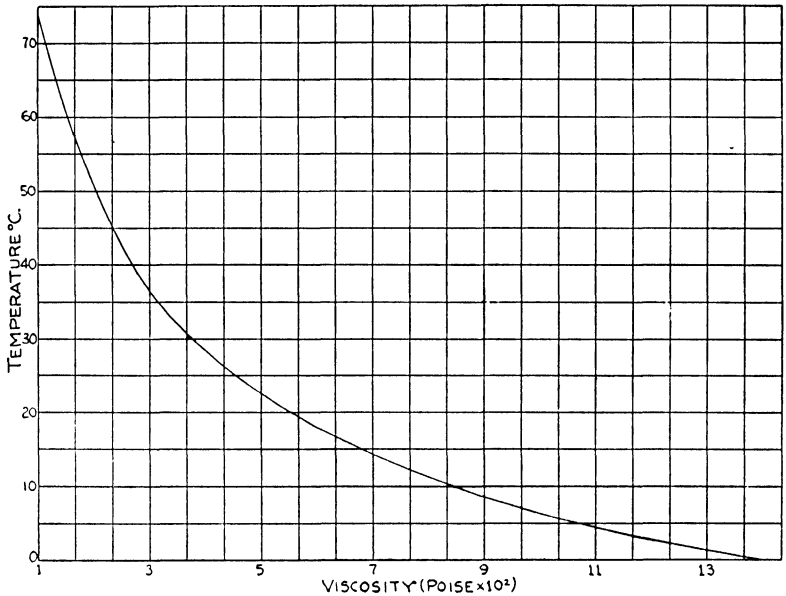


FIGURE 117. Viscosity of 2-Ethyl Butyl Alcohol at Various Temperatures.[2]

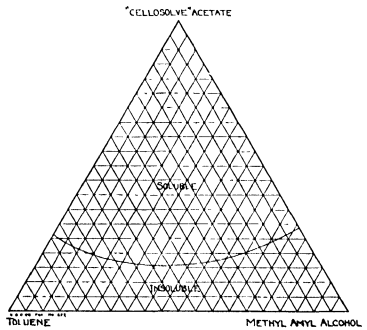


FIGURE 118. Solubility of ½ Second R. S. Nitrocellulose in Mixtures of "Cellosolve" Acetate, Toluene, and Methyl Amyl Alcohol.[2]

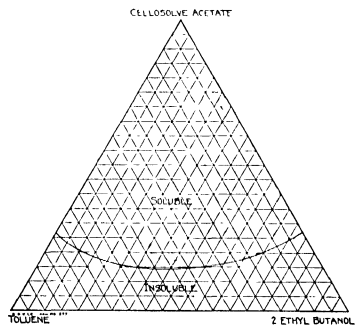


FIGURE 119. Solubility of ½ Sec. R. S. Nitrocellulose in Mixtures of "Cellosolve" Acetate, 2-Ethyl Butanol and Toluene.[2]

Benzyl Alcohol

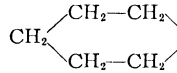
Benzyl alcohol ($C_6H_5CH_2OH$, phenmethylol) is a colorless, high-boiling liquid of faint odor. Owing to the fact that it is made from benzyl chloride the impurities will consequently comprise benzaldehyde, chlortoluene, dibenzyl ether, dibenzyl, benzyl chloride and so forth. Benzyl alcohol is miscible with most cellulose ether solvents, aromatic hydrocarbons and oils. It will dissolve such substances as methyl, ethyl, and benzylcellulose, nitro and acetylcellulose, benzyl abietate, copal esters, cumar resins, ester gum, linoxyl, glyptol resins, mastic, sulfur and so forth. The addition of an active solvent activates the solvency of benzyl alcohol. It is widely used as a high-boiling solvent and plasticizer. It is volatile and therefore does not remain permanently in the film. It is used to make lacquers which contain mixed cellulose derivatives. It is also employed in film manufacture, paint and varnish removers and as a medium for grinding and suspending lacquer pigments.

Anhydrous	97%
Acidity	0.1% max.
Boiling point	200° C. min.
Boiling range	95% between 200°-210° C.
Flash-point	96° C.
Residue	1% max.
Refractive index	1.538–1.541
Specific gravity	1.050–1.55

Phenol

Phenol (C_6H_5OH, carbolic acid) is a white, crystalline solid and is a solvent for many substances including such materials as cellulose esters and ethers, casein, rubber and so forth. Its use is limited to a large extent by its toxic properties and escharotic nature. This is also true of the cresols and creosote oils despite their excellent solvent powers. Some of the dehydric phenols which have been proposed as solvents for cellulose esters and ethers are resorcinol, ethylidene-phenol and phlorglucinol. The polyhydric compounds comprise anisol, phenetol, thymol, benzosol (benzoylguaiacol), carvacol and eugenol.

Hexahydrophenol

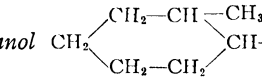
Hexahydrophenol  (Anol, Hydralin, Adronol, cyclohexanol, Hexalin) is a water-white, oily, hygroscopic, slightly toxic liquid of menthol-like odor. It is a cyclic alcohol made by the catalytic hydrogenation of phenol. It contains such impurities as hydrogenated phenol and cyclohexanone. Hexahydrophenol is a solvent for glyptol resins, alkyd resins, benzyl abietate, cumar resins, ester gum, kauri, manila, mastic, shellac, metallic soaps, rubber, basic chrome and acid dyes and oils (vegetable, essential and mineral). Commercial cyclohexanol will dissolve some types of cellulose esters and ethers and is miscible with

most solvents and oils. Since cyclohexanol is a powerful solvent with stabilizing and homogenizing properties, it has the faculty of converting cloudy dispersions into clear solutions or good emulsions. Other uses are as a blending agent for solutions of nitrocellulose and rubber, and for lacquers containing cellulose derivatives and resins.

The presence of cyclohexanol in a solvent mixture will increase the dilution tolerance for coal-tar and petroleum hydrocarbons. Both its solvency and low volatility promote good and also secondary flow and homogeneity throughout all stages of drying which consequently results in flat glossy films. By adding hexahydrophenol to a xylene solution of alkyd resins the viscosity is reduced, skinning is prevented, and the lead driers are held in solution. It is also added to soaps and detergents to increase their effectiveness in textile processes. It can be made water-soluble by mixing with sulfonated higher fatty alcohols, soaps or sulfonated oils and its presence in these solutions will permit mixing with hydrocarbons. Hexalin, owing to its stabilizing and homogenizing properties for emulsions and other solutions, is used in dry-cleaning, textile-cleaning, laundry and household preparations. It is also used in making asphalt emulsions, cutting oils, disinfectant emulsions, degreasing leather, wax creams and polishes. Cyclohexanol finds application in the preparation of water-soluble solvents, emulsifying and dispersing agents for oils, fats, waxes, asphalt, hydrocarbons, dyes, and in printing and dyeing processing for its solvency and penetrating power.

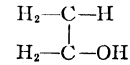
Its excellent blending qualities and low rate of evaporation make it particularly suitable for mixing nitrocellulose with resins and drying oils. The presence of Hexalin in leather lacquers and dopes imparts penetrating plasticizing and softening qualities. It is also used with success in plastic and synthetic resins, spirit varnishes, polishes and paint and varnish manufacture; as a paint and varnish remover; as a solvent for fats, oils and waxes in the textile, rubber and polish industries; and as a spotting agent in natural and synthetic silks.

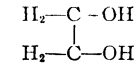
Methyl Cyclohexanol

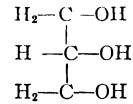
Methyl cyclohexanol  (methyl Hexalin, hexahydromethyl phenol, hexahydrocresol, Sextol, methyl adronol, methyl anol) is a colorless, viscous liquid of an aromatic menthol-like odor and is a mixture of three isomeric cyclic secondary alcohols made by the hydrogenation of cresol. This mixture of methylcyclohexanols is non-explosive and slightly toxic. Its physical properties are very similar to those of cyclohexanol with the exception of a wider boiling range owing to the relative amounts of ortho, meta and para compounds. Its dissolvent power is somewhat inferior to that of Hexalin. For all practical purposes, however, these two solvents can be used interchangeably especially where boiling points are of importance.

Dihydric Aliphatic Alcohols

Ethylene glycol ($HOCH_2CH_2OH$, glycol, alcohol ethylene) is a dihydric alcohol which is intermediate between ethyl alcohol and glycerin.


ethyl alcohol


ethylene glycol


glycerin

It has one less hydroxyl group than glycerin, the trihydric alcohol, and one more hydroxyl group than the monohydric ethyl alcohol. It is a colorless, odorless, hygroscopic, limpid liquid of sweetish taste. It is miscible in all proportions with water, alcohols, ketones, and so forth. It will dissolve dyes and when it is mixed with an active low-boiling solvent it will dissolve cellulose ethers and esters. It is a solvent for fruit flavors, waxes, resins, organic chemicals, drugs and so forth. One of the most important uses for ethylene glycol is in the manufacture of glycol dinitrate which is used in explosives. Ethylene glycol is used as an antifreeze for automobiles and motor cooling. Its hygroscopic and solvent properties make it applicable as a softener in lacquers, in dye pastes, in printing inks, in wood stains, in glue mixtures, in dyeing of leather, in textile processing and for the moistening of tobacco. In combination with silica flour it is used in making molds for casting. Further uses are in concentrated fruit essences, flavorings, extracts, food preparations, canned goods, toilet preparations, food products, electrical insulation compositions, dopes and as a plastic and colloidant in lacquers. Rae [12] found that by extracting cudbear with ethylene glycol, he obtained superior tinctorial power. Red saunders, red rose petals, and saffron did not respond with as strong a color especially when in the presence of water. Henna and madder on the other hand gave deeper tints in the presence of water. Ethylene glycol can be used efficiently as an extractant for carmine, buttercup and centaurea montana but cannot be used for the extraction of litmus, alkanet root or gamboge.

Molecular weight	62 05
Boiling point	197.2° C.
Freezing point	− 12.3° C.
Specific gravity	$1.1176\ \frac{15°\text{ C.}}{15°\text{ C.}}$
Weight per gallon	9.31 lbs. $\frac{15°\text{ C.}}{15°\text{ C.}}$
Refractive index	1.430 (25° C.) 1.4311 (20° C.)
Surface tension	52.5 dynes/cm. (25° C.)
Viscosity	0.26 poise (15° C.) 0.21 poise (20° C.) 0.17 poise (25° C.)
Vapor pressure	0.09 mm. Hg. (20° C.)

Specific heat	0.537 (− 9.8° C.) 0 556 (5.2° C.) 0.571 (15° C.) 0.575 (20° C.)
Flash-point	116° C. (240.8° F.)
Fire point	120° C. (248° F.)
Heat of combustion Constant pressure Constant volume	 282,200 cal./g. mol. 281.400 cal./g. mol.
Apparent ignition temperature in air	417° C. (782.6° F.)
Heat of fusion	44.76 cal./g.
Heat of dilution $[C_2H_4(OH)_2 \cdot 2H_2O]$	0.60 cal./g.
Latent heat of evaporation	235 5 cal./g. (130.6° C.) 282 2 cal./g. (160.3° C.) 210.3 cal./g. (188.4° C.)
Electrical conductivity	1.07×10^{-6} recip. ohms (25° C.)
Coefficient of expansion	$Vt = 1 + 0.0005657t$
Solubility	Completely miscible with water

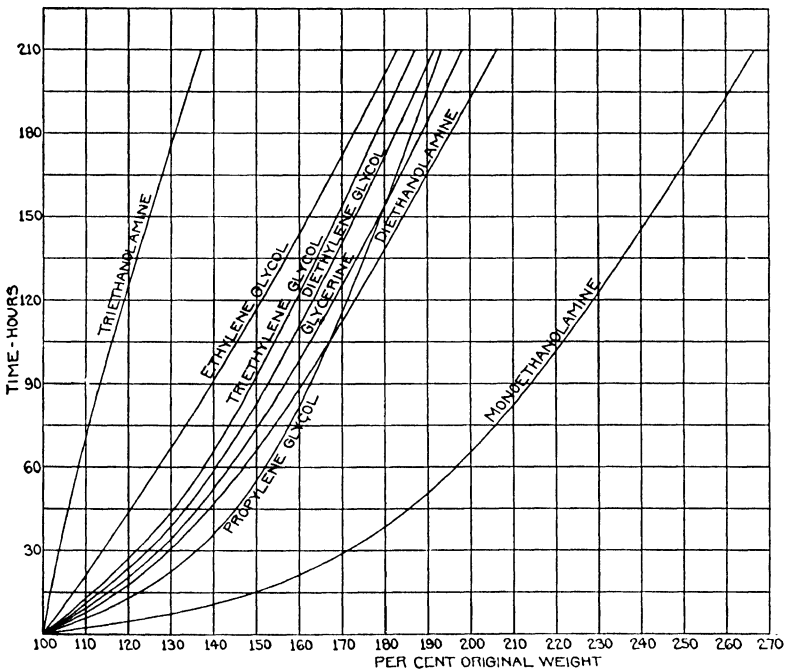


FIGURE 120. Comparative Hydroscopicities at 100 Per Cent Relative Humidity and 100° F.[2]

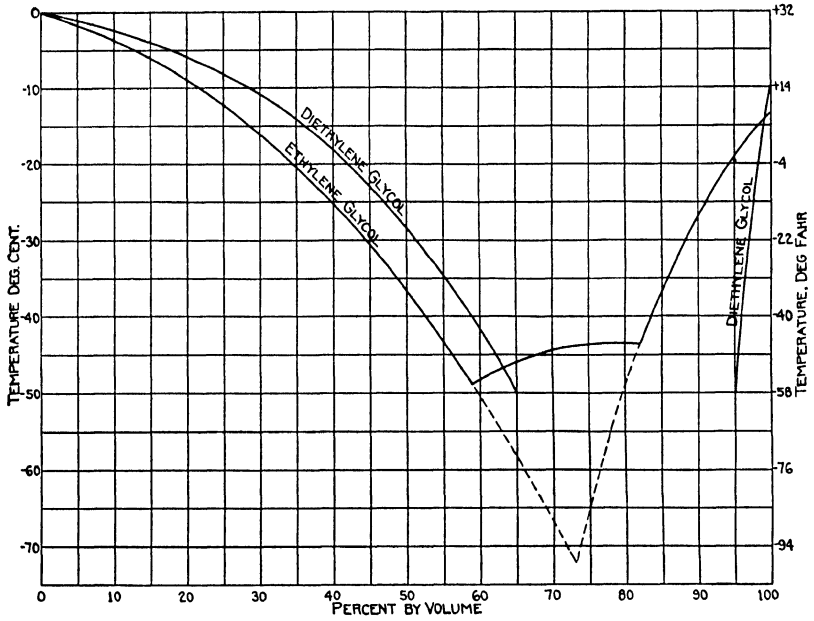


FIGURE 121. Approximate Freezing Points of Aqueous Solutions of Ethylene Glycol and Diethylene Glycol at Various Temperatures.[2]

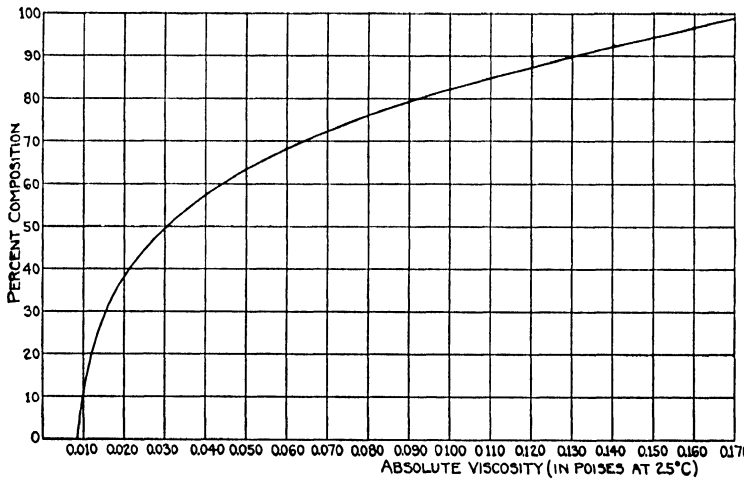


FIGURE 123. Viscosity of Ethylene Glycol-Water Solutions.[2]

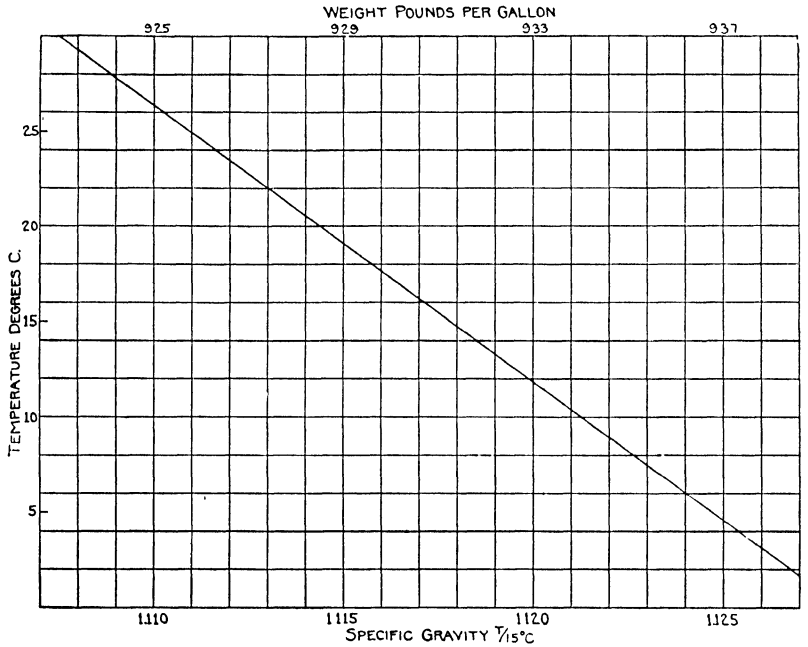


FIGURE 122. Specific Gravity and Weight per Gallon of Ethylene Glycol at Various Temperatures.[2]

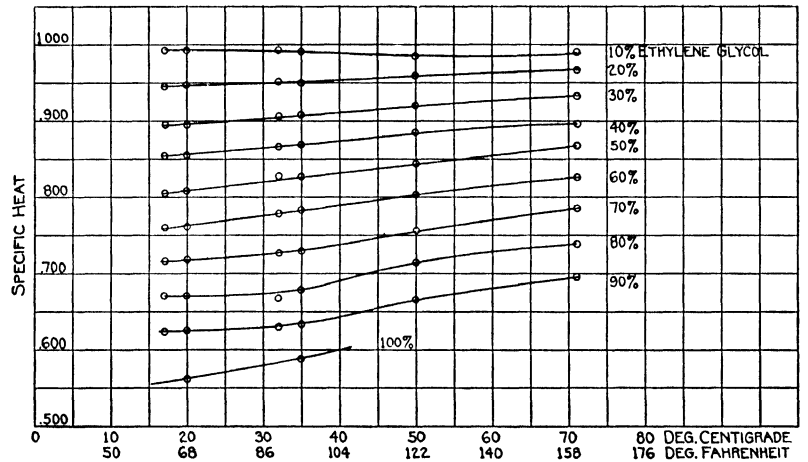


FIGURE 124. Specific Heat of Ethylene Glycol-Water Solutions.[2]

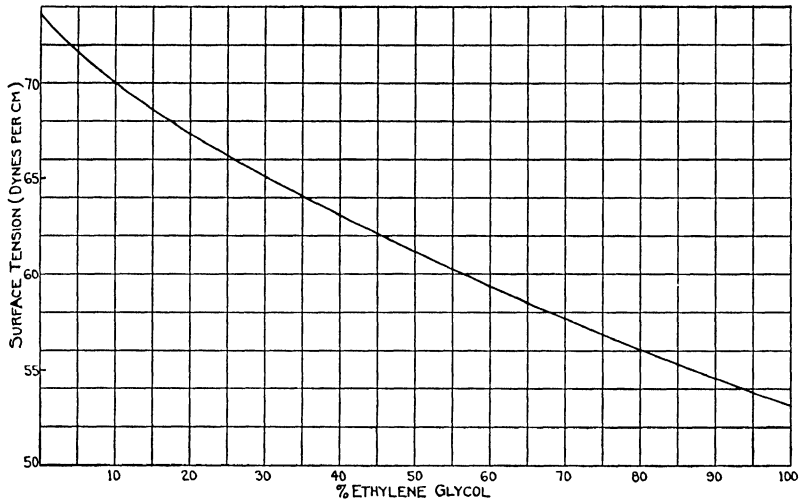


FIGURE 125. Surface Tension of Ethylene Glycol-Water Mixtures (du Noüy Apparatus. Water=74 dynes/sq. cm.) Room Temperature.[2]

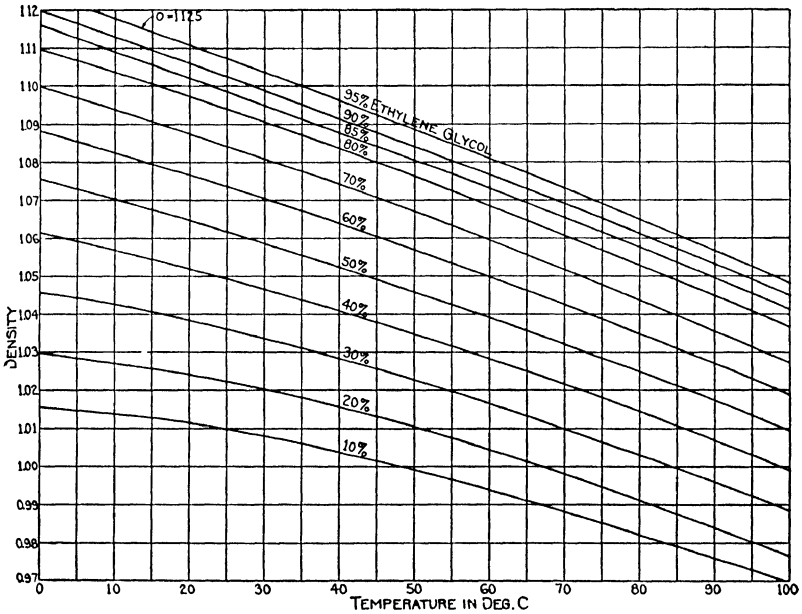


FIGURE 126. Density of Ethylene Glycol-Water Solution at Various Temperatures.[2]

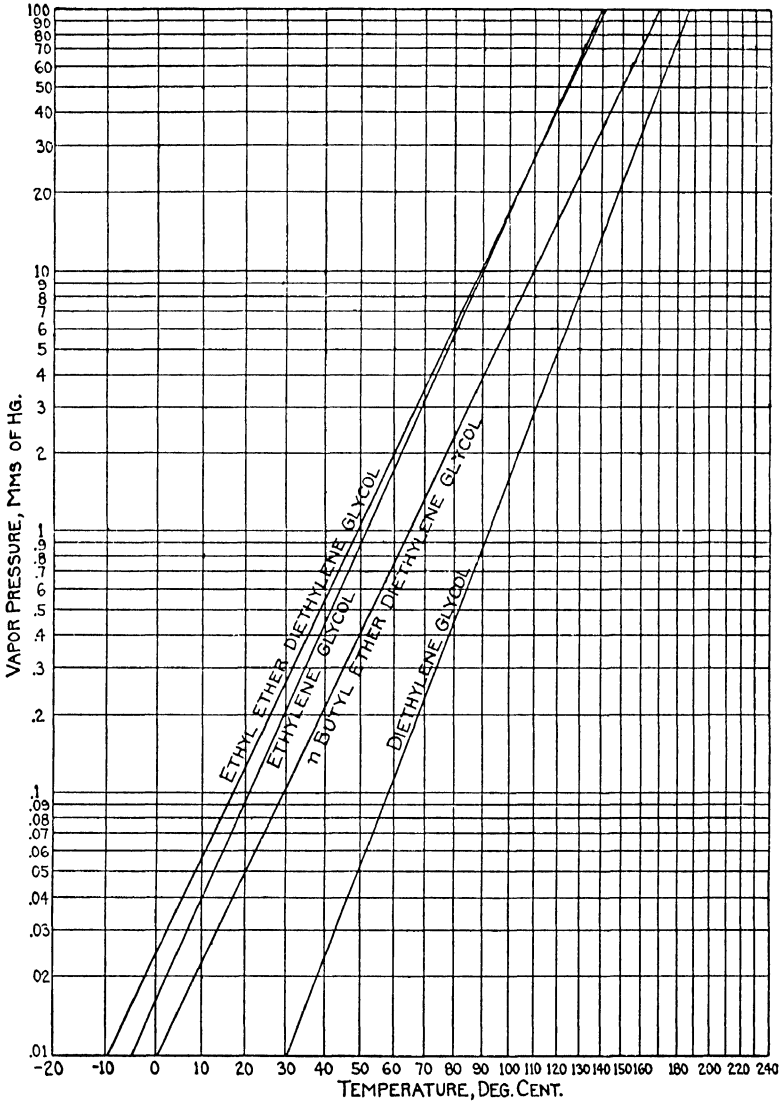


FIGURE 127. Vapor Pressure of Glycols at Various Temperatures.[2]

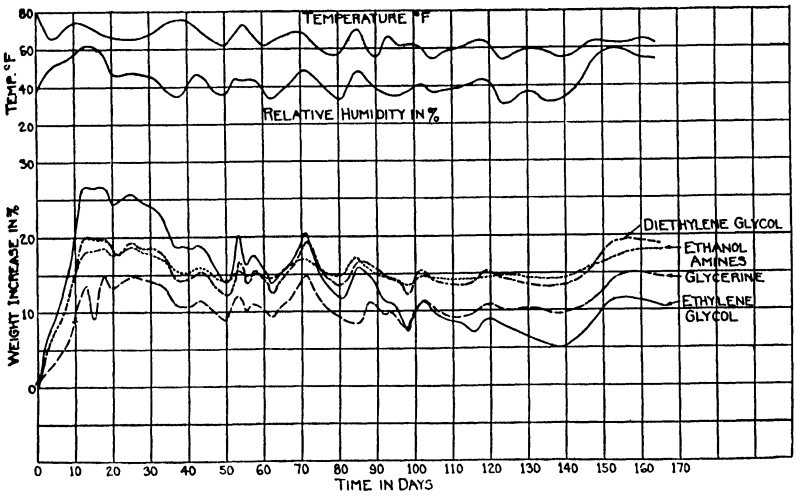
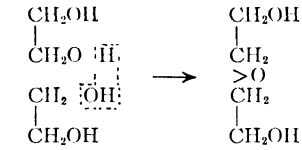


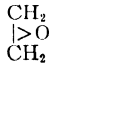
FIGURE 128. Comparative Hydroscopicities, Atmospheric Temperatures, and Humidities.[2]

Propylene glycol CH_3CHOH (trimethyl glycol, methyl glycol, propane-
CH_2OH
diol, methylethylene glycol, 1,2-dihydroxypropane, 1,2-propanediol) is a water-white, viscous, stable, hygroscopic liquid. It is miscible with water, alcohols and many organic solvents. It is a solvent for oils, fats, waxes, resins, dyes, flavoring extracts and perfumes, and is used as a solvent for essential oils in aqueous toilet preparations. It is also used as an antifreeze, as a hygroscopic agent and as a lubricant in refrigeration machines.

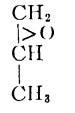
Molecular weight	76.06
Boiling point	187.4° C.
Specific gravity	1.0381 $\frac{20° C.}{20° C.}$
Weight per gallon	8.64 lb. (20° C.)
Refractive index	1.4293 (27° C.)
Surface tension	40.1 dynes/cm. (25° C.)
Viscosity	0 406 poise (25° C.)
Vapor pressure	0.16 mm. Hg. (20° C.)
Specific heat	0.590 cal./g. (20° C.)
Latent heat of evaporation	168.6 cal./g. at B.P.
Flash-point (A. S. T. M. open cup)	99° C. (210° F.)
Heat of combustion	431.0 kg.cal./mole.
Solubility in water	Complete
Coefficient of expansion (per ° C.)	{0.000695 to 20° C. {0.000743 to 55° C.



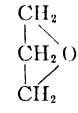
Diethylene glycol
(B. p. 245° C.)



Ethylene oxide
(B. p. 10.5° C.)



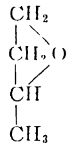
α-Propylene oxide
(B. p. 35° C.)



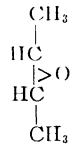
β-Propylene oxide
(B. p. 50° C.)



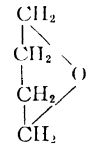
α-Butylene oxide



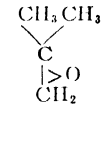
β-Butylene oxide



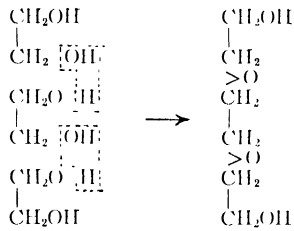
Dimethyl ethylene oxide
(B. p. 50° to 60° C.)



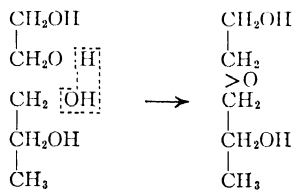
γ-Butylene oxide



Isobutylene oxide
(B. p. 51° to 52° C.)



Triethylene glycol
(B. p. 278° C.)



Ethylene propylene, diglycol

FIG. 129.—Graphical Structure of Glycols[1]

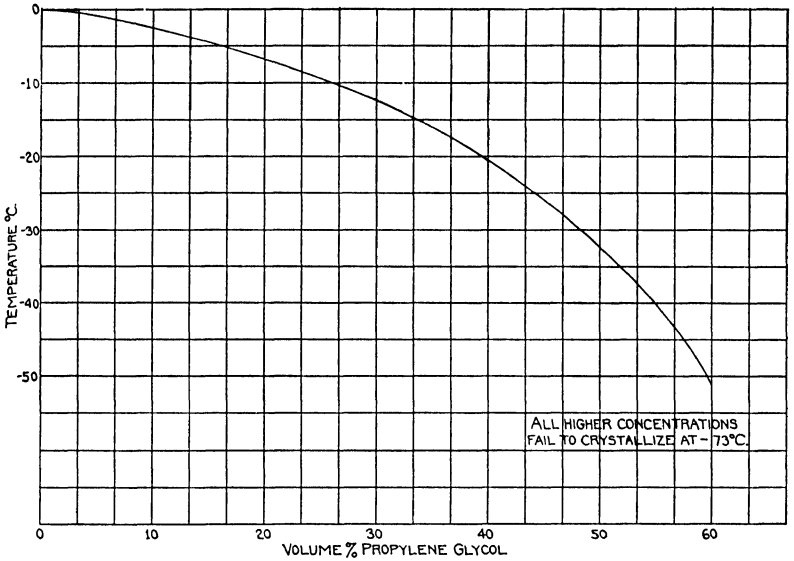


FIGURE 130. Freezing Point of Propylene Glycol-Water Mixtures at Various Temperatures.[2]

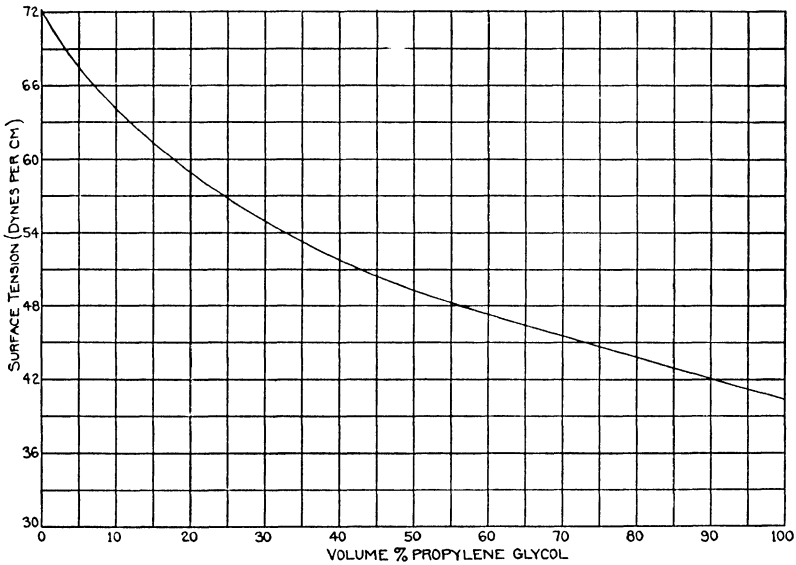


FIGURE 131. Surface Tension of Propylene Glycol-Water Mixtures at 25° C. (Approx.).[2]

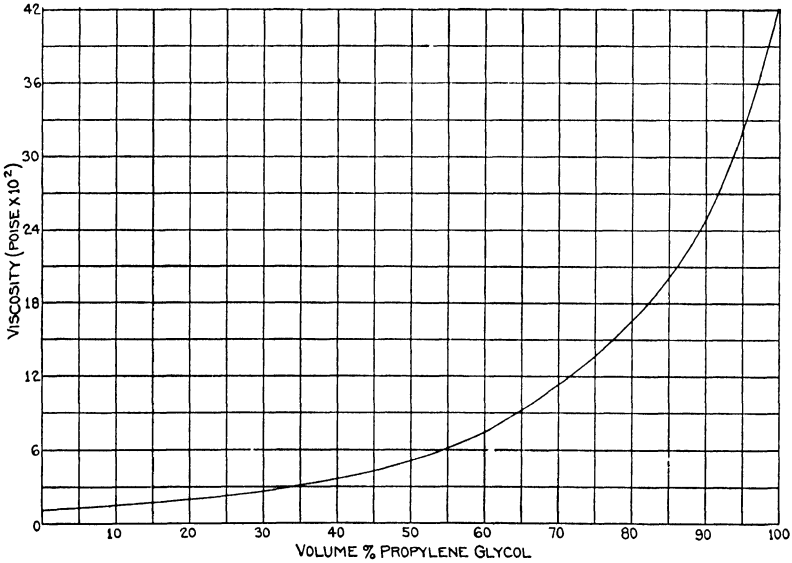


FIGURE 132. Viscosity of Propylene Glycol-Water Mixtures at 25° C.[2]

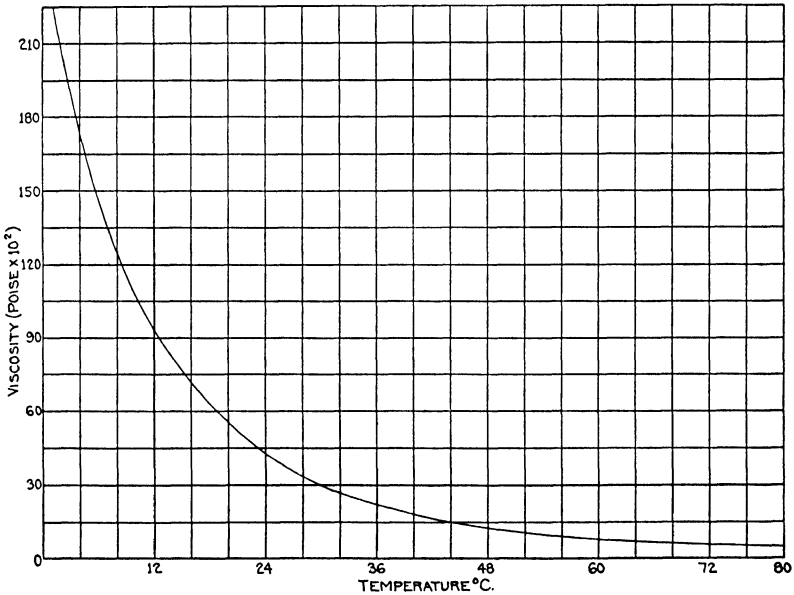


FIGURE 133. Viscosity of Propylene Glycol at Various Temperatures.[2]

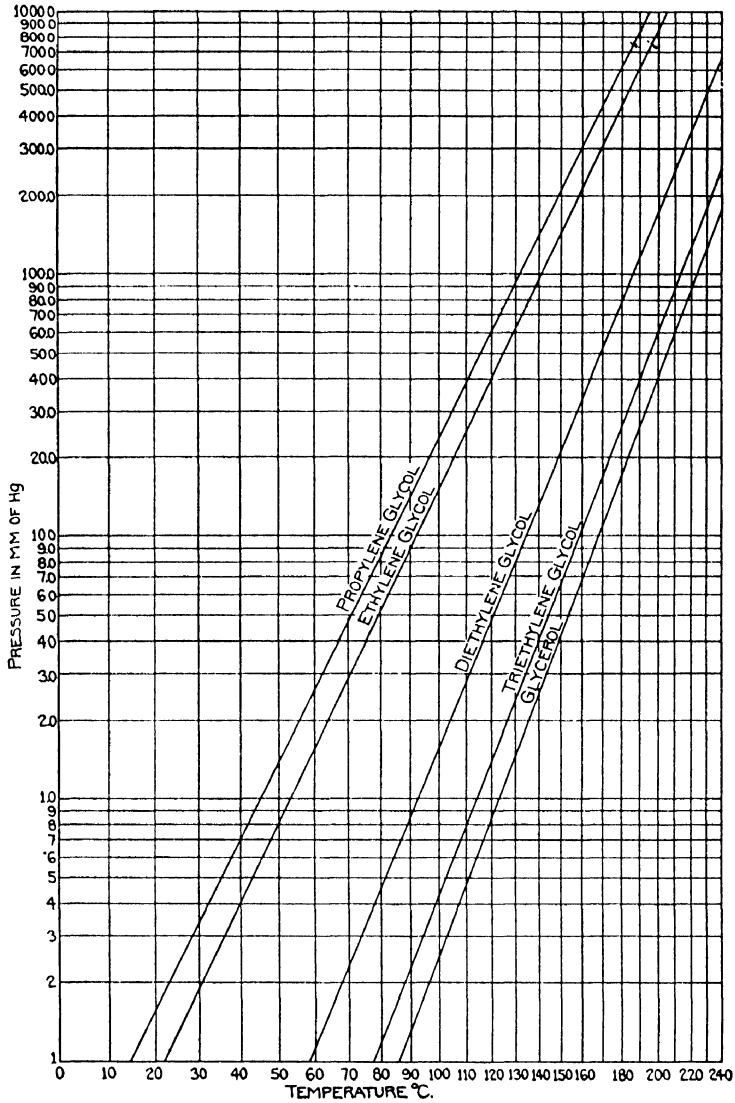


FIGURE 134. Vapor Pressure of Glycols and Glycerol at Various Temperatures.[2]



FIGURE 135. Specific Gravity and Weight per Gallon of Propylene Glycol-Water Mixtures.[2]

Glycerol

Glycerol ($CH_2OHCHOHCH_2OH$, glycerin) is a clear, colorless, syrupy, hygroscopic liquid of faint odor and sweetish taste. It is a trihydric alcohol first made by Sheele in 1779 by heating together olive oil and litharge. The bulk of glycerol is obtained as a by-product in the saponification of fats and oils. Small quantities are also made by the selective fermentation of sucrose in the presence of salts. It is miscible in all proportions with water, alcohols, ketones and glycols, and will dissolve many organic and inorganic salts, oils, fats, tars, aniline dyes and so forth. When it is mixed with alcohol it will dissolve starch acetate. This trihydric alcohol has weak acidic properties, thus being able to form salts. Owing to the fact that it is both a primary and secondary alcohol it will react to form ethers and esters.

Halohydrins

CH_2Cl	CH_2OH	CH_2Cl	CH_2OH
$CHOH$	$CHCl$	$CHOH$	$CHCl$
CH_2OH	CH_2OH	CH_2Cl	CH_2Cl
alpha-chlorohydrin	*beta-chlorohydrin*	*alpha-dichlorohydrin*	*beta-dichlorohydrin*

The important uses for glycerol are in the manufacture of explosives, as an antiseptic, as a moistening and sweetening agent for tobacco and as an antifreeze. Its emollient, hygroscopic, penetrating and softening properties give glycerol wide application in many different processes such as those in the textile, paper and leather industries, and in such preparations as cosmetic, toilet and medicinal compounds, in dyes, colors, ink pastes, glues, soaps, carbon paper, polishes, Cellophane molding compounds, etc. It is used in soft drinks and hard liquors because it adds "smoothness" to the drink, and finally as a constituent part in synthetic resins.

TABLE 81.—Anti-Freeze Substances[10]

Solution	Percentage (by volume) for protection at $t°$ F				
	$t = +10$	$t = 0$	$t = -10$	$t = -20$	$t = -30$
	%	%	%	%	%
Denatured alcohol 180° proof	30	38	45	51	61
" " 188° proof	29	37	43	49	59
Wood alcohol, 97%	20	28	35	40	45
Glycerin (U.S.P.), 95%	32	40	47	53	57
Radiator glycerin, 60%	56	70	83	93	100
Ethylene glycol, 95%	25	33	39	45	50
	Quantity (pints/gallon of water) for protection at $t°$ F.				
Denatured alcohol 180° proof	3.4	4.9	6.5	8.3	
" " 188° proof	3.3	4.7	6.0	7.7	
Wood alcohol, 97%	2.0	3.1	4.3	5.3	
Glycerin (U.S.P.), 95%	3.8	5.3	7.1	9.0	
Radiator glycerin, 60%	10 0	18.7	39.0	106.5	
Ethylene glycol, 95%	2.7	4.0	5.1	6.5	
	Specific gravity (60°/60°) for protection at $t°$ F.				
Denatured alcohol	0.968	0.959	0.950	0.942	0.921
Wood alcohol	0.975	0.966	0.958	0.952	0 945
Glycerin	1.090	1.112	1.131	1.147	1.158
Ethylene glycol	1 038	1 048	1 056	1.064	1.069

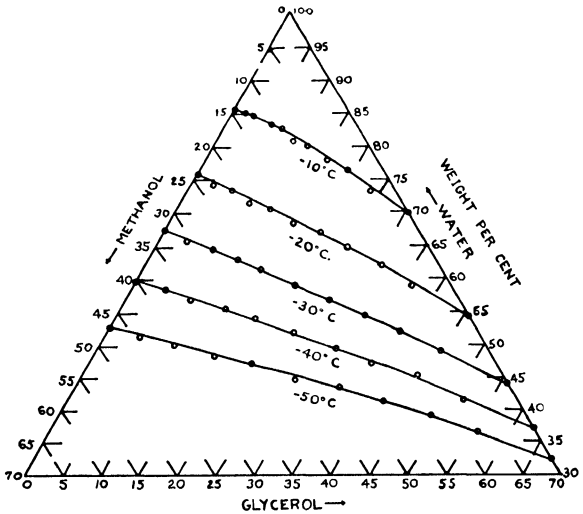


FIGURE 136.
Freezing Point of Aqueous Glycerol-Methanol Solutions.[13]

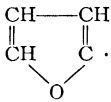
TABLE 82.—Tables for Specific Gravity and Per Cent Glycerol[9]

Glycerol	Apparent Specific Gravity			True Specific Gravity		
	15.5/15.5° C.	20/20° C.	25/25° C.	15.5/15.5° C.	20/20° C.	25/25° C.
Per Cent						
100	1.2653	1.2636	1.2620	1.2650	1.2633	1.2617
99	1.2627	1.2610	1.2594	1.2624	1.2607	1.2591
98	1.2602	1.2584	1.2568	1.2598	1.2581	1.2565
97	1.2576	1.2558	1.2542	1.2573	1.2555	1.2539
96	1.2550	1.2533	1.2516	1.2547	1.2530	1.2514
95	1.2524	1.2507	1.2491	1.2521	1.2504	1.2488
94	1.2498	1.2481	1.2464	1.2495	1.2478	1.2461
93	1.2471	1.2454	1.2438	1.2468	1.2451	1.2435
92	1.2445	1.2428	1.2411	1.2442	1.2425	1.2408
91	1.2418	1.2402	1.2385	1.2415	1.2398	1.2382
90	1.2392	1.2375	1.2358	1.2389	1.2372	1.2356
89	1.2365	1.2349	1.2332	1.2362	1.2346	1.2329
88	1.2339	1.2322	1.2305	1.2336	1.2319	1.2302
87	1.2312	1.2295	1.2279	1.2309	1.2293	1.2276
86	1.2285	1.2269	1.2252	1.2283	1.2266	1.2249
85	1.2259	1.2242	1.2225	1.2256	1 2239	1.2223
84	1.2232	1.2215	1.2199	1.2230	1.2213	1.2196
83	1.2205	1.2189	1.2172	1.2203	1.2186	1.2169
82	1 2179	1.2162	1.2145	1.2176	1.2159	1.2143
81	1.2152	1.2135	1.2119	1.2150	1.2133	1.2116
80	1.2126	1.2109	1.2092	1.2123	1.2106	1.2090
79	1.2098	1.2081	1.2065			
78	1.2071	1.2054	1.2038			
77	1.2044	1.2027	1.2011			
76	1.2016	1.1999	1.1984			
75	1.1989	1.1972	1.1956	1.1986	1.1970	1.1954
74	1.1961	1 1945	1.1929			
73	1.1934	1.1917	1.1902			
72	1.1907	1 1890	1.1875			
71	1.1879	1.1863	1 1848			
70	1 1852	1.1835	1.1821	1.1849	1.1833	1.1818
69	1.1824	1.1808	1.1793			
68	1.1796	1.1780	1.1766			
67	1.1768	1.1753	1.1738			
66	1.1741	1.1725	1.1711			
65	1.1713	1.1698	1.1683	1 1711	1.1696	1.1681
64	1 1685	1.1670	1.1656			
63	1.1657	1.1643	1.1628			
62	1.1630	1.1615	1.1601			
61	1.1602	1.1587	1.1573			
60	1 1574	1.1560	1.1546	1.1572	1.1558	1.1544
59	1.1546	1.1532	1.1518			
58	1.1519	1.1505	1.1491			
57	1.1491	1.1477	1.1464			
56	1.1463	1 1450	1.1436			
55	1.1435	1 1422	1 1409	1.1434	1.1420	1.1407
54	1.1408	1.1394	1.1381			
53	1.1380	1.1367	1.1354			
52	1.1352	1.1339	1.1326			
51	1.1324	1.1312	1.1299			
50	1.1297	1.1284	1.1272	1.1295	1.1283	1.1270
49	1.1269	1.1257	1.1245			
48	1.1242	1.1230	1.1218			
47	1.1215	1.1203	1.1191			
46	1.1188	1.1176	1.1165			
45	1.1160	1.1149	1.1138	1.1159	1.1147	1.1136
44	1.1133	1.1122	1.1111			
43	1.1106	1.1095	1.1084			
42	1.1079	1.1068	1 1057			
41	1.1051	1.1041	1.1031			
40	1.1024	1.1013	1 1004	1.1023	1.1012	1.1003
39	1.0997	1 0987	1.0977			
38	1.0970	1.0960	1.0951			
37	1.0943	1.0933	1.0924			
36	1.0916	1.0907	1.0898			
35	1.0889	1.0880	1.0871	1.0888	1.0879	1.0870
34	1.0862	1.0853	1.0845			
33	1.0835	1.0827	1.0819			

TABLE 82.—Tables for Specific Gravity and Per Cent Glycerol[9]—(*Continued*)

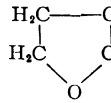
Glycerol *Per Cent*	Apparent Specific Gravity 15.5/15.5° C.	Apparent Specific Gravity 20/20° C.	Apparent Specific Gravity 25/25° C.	True Specific Gravity 15.5/15.5° C.	True Specific Gravity 20/20° C.	True Specific Gravity 25/25° C
32	1.0808	1.0800	1.0792			
31	1.0781	1.0773	1.0766			
30	1.0754	1.0747	1.0739	1.0753	1.0746	1.0738
29	1.0728	1.0721	1.0713			
28	1.0702	1.0695	1.0688			
27	1.0676	1.0669	1.0662			
26	1.0650	1.0643	1.0637			
25	1.0624	1.0617	1.0611	1.0623	1.0616	1.0611
24	1.0598	1.0591	1.0586			
23	1.0571	1.0565	1.0560			
22	1.0545	1.0540	1.0535			
21	1.0519	1.0514	1.0509			
20	1.0493	1.0488	1.0484	1.0492	1.0487	1.0483
19	1.0468	1.0463	1.0459			
18	1 0443	1.0438	1.0434			
17	1.0418	1.0413	1.0410			
16	1.0392	1.0388	1.0385			
15	1.0367	1.0363	1.0360	1.0367	1.0363	1.0360
14	1.0342	1.0339	1.0336			
13	1.0317	1.0314	1.0311			
12	1.0292	1.0289	1.0286			
11	1.0266	1.0264	1.0262			
10	1.0241	1.0239	1.0237	1.0241	1.0239	1.0237
9	1.0217	1.0215	1.0213			
8	1.0193	1.0191	1.0190			
7	1.0169	1.0167	1 0166			
6	1.0145	1.0143	1.0142			
5	1.0120	1.0119	1.0118	1.0120	1.0119	1.0118
4	1.0096	1.0095	1.0095			
3	1.0072	1.0072	1.0071			
2	1.0048	1.0048	1.0047			
1	1.0024	1.0024	1.0023			

Furfuryl Alcohol

Furfuryl alcohol  (furyl carbinol) is a water-white liquid of mild odor which darkens upon exposure. It is miscible with water and most organic solvents with the exception of petroleum hydrocarbons. It is a solvent for a wide range of organic products such as cellulose ethers and esters, ester gum, cumar resins, kauri, mastic, pontianac, shellac, sandarac and so forth, and is used as a solvent for dyes in textile printing, and in the manufacture of synthetic resins.

Alcohol content	93–96%
Boiling point	165–168° C.
Refractive index	1.4864
Specific gravity	1.1351

Tetrahydrofurfuryl Alcohol

Tetrahydrofurfuryl alcohol  is a stable, water-white liquid of a mild and pleasant odor, is miscible with water and most organic solvents, and in its solvent power is similar to furfuryl alcohol. It is used

as a solvent for textile dyes, and as a wetting and dispersing agent.

Boiling point	178–180° C.
Refractive index	1.4508
Specific gravity	1.055 (20° C.)

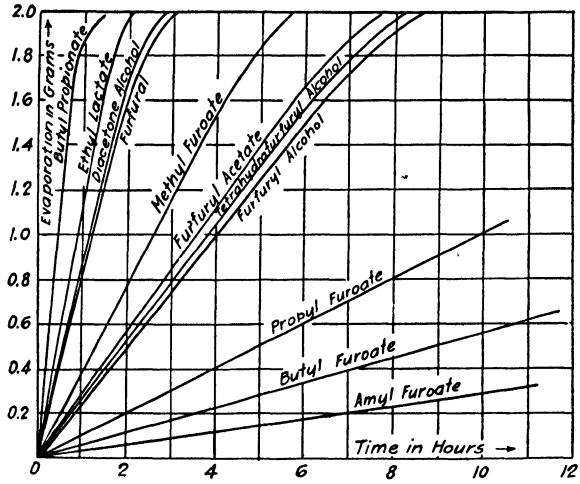
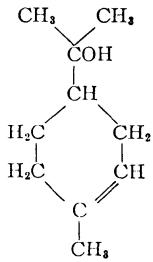


FIGURE 137. Evaporation Rate of Furfural and its Derivatives at Room Temperature.[2]

Alpha Terpineol



Alpha terpineol (terpene) is a tertiary alcohol boiling at 210° C. The commercial grade is made from turpentine and terpene hydrate. It is a powerful solvent for fossil resins, kauri, pontianac, manila, synthetic resins, waxes, oils and so forth. It will dissolve many of these resins without "pre-melting" of the resin. In fact, it is used in the terpineol process for the solution of resins and gums without loss of weight. It is used as a mutual solvent for resins and cellulose esters and ethers.

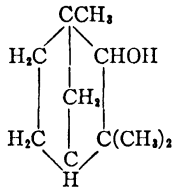
Specific rotation	+ 7 to + 11°
Freezing point	27° C. to 32° C.
Specific gravity	0.939–0.942
Boiling range	210° C. to 221° C.

TABLE 84.—Vapor Pressure*-Temperature Data on Terpenes and Terpene Alcohols[11]

α-Pinene		β-Pinene		Dipentene		Terpinolene		Fenchyl Alcohol		α-Terpineol	
° C.	Mm.	° C.	Mm.	° C.	Mm.	° C.	Mm.	° C.	Mm.	° C.	Mm.
21.2	4.0	24 3	3.4	21.1	1.5	40 5	1.2	59.1	2.5	83.8	5.9
22.0	4.3	24.5	3.6	21.2	1.6	45.5	4.2	63.6	3.5	89.9	8.1
22.2	4 8	24 7	3 9	55.7	11.5	58.2	6.5	64.4	3.9	90.6	8.6
22.5	6.0	24.8	3.0	56.2	12.3	59 7	7.5	71.1	5.3	94.7	9.6
54.7	22.8	25 0	4.6	78.5	29.8	63.3	8.4	72.1	5.6	100.0	12.6
55.3	24.0	25.4	4.9	78.9	30.1	83.0	22.5	73.0	5.9	100.7	12.7
55.5	24.8	53.5	17.9	79.0	30 3	83.5	23.6	74.0	6.5	105.8	18.6
77.4	58.8	54.0	18.3	79.7	31.7	84.0	24.8	77.1	7.9	106.6	19.2
77.5	59.3	54.4	18.5	80 2	32.2	84.1	25.3	78.1	8.8	107.3	20.1
77.7	59.7	54.6	18.9	80 5	32 5	107.6	63.4	108.5	36.6	107.9	20.6
77.9	60.2	55.0	19.4	81.8	34.8	107.7	63.7	108.9	38.1	108.2	20.7
78.6	61.9	68.7	35.1	81.9	35.0	108.5	68.6	109.0	37.7	108.6	21.0
78.7	62.2	68.9	36.4	82.0	36 5	108.6	69 0	137.6	119.6	108.7	21.2
79.3	63.9	69.1	36.5	82 6	36.7	108.7	74.1	138.0	122.5	119.1	29.1
79.6	64.8	70 9	39.3	82.9	38.5	108.8	74.5	138.2	128.0	119.9	29.7
101.1	147.2	94.7	103.8	90 0	51.4	131.2	148.2	167.1	339.3	140.9	72.6
102.8	155.7	95.1	106.7	91 2	52 1	131.4	149.2	168.1	344.9	141.5	74.6
103.2	157.5	95.7	109.4	92 1	54 2	131.8	151.0	168.5	355.2	142.3	73.7
103.5	159.3	96 0	110.3	93.5	57 9	132.1	152.0	169.1	358.9	172.0	207.2
103.7	160.3	96 2	110.8	98 9	70 5	133.5	161.4	195.5	704.0	173.3	216.5
103.8	160.9	96.5	111.8	101 6	78 5	133.6	161.6	196.9	724.3	174.0	220.4
131.2	391.5	105 8	156.2	102 1	79.5	133.9	162.8	198.6	747.0	174.5	223.0
132.3	401.0	106.0	157.5	102.5	81.1	157 8	343.8	198.8	751.3	177.6	246.0
132.4	404.0	106.4	159.8	102 7	82.4	158.2	357.0	199.2	759.3	178.0	249.5
132.5	404.3	106.9	162 5	103 2	83 1	164.1	414.3			178.3	251.9
132.7	405.7	107.1	163.6	103.6	84.7	175.9	559.6			178.8	255.8
132.9	407.1	107.6	164.5	105 7	91.8	176.0	571.3			208.4	597.1
133.0	410.7	108.2	168.9	108 0	99 5	176.4	579.2			209.5	612.0
133.1	411.5	131.2	356 5	109 0	103.5	178.0	602.2			209.6	614.5
133.2	412.5	131.6	359.5	109 5	105 4	178 2	609.0			209.7	617.8
134.9	428.5	131.7	358 6	130 1	218 5	178.5	619.0			216.9	747.5
135.4	432.1	131.9	362.5	131 5	228.0	178 8	622.3			216.5	749.5
138.5	478.0	132.1	366.7	132 5	235 0	178 9	623.9				
138.8	482.0	132 6	371.9	133 3	240 0						
139.8	494.0	132.9	375.0	134 0	247 0						
140.1	501.0	133.6	379.7	134 1	250.3						
140.5	506.0	133.9	381.0	161 9	560 0						
141.2	516.0	154.7	688.5	166.4	631 5						
141.3	520.0	154.9	691.0	166.9	643.5						
141.9	528 0	155.2	693.5	167.2	648.5						
147.0	604.0	156.2	711.5	167.5	650 5						
148.0	623.9	158.0	752.0	167 9	655 5						
		158.1	757.0	168 8	667.5						
				169.1	670 5						
				169 2	683 5						
				170 3	695 5						

*Pressures for Hg. at 25° C.

Fenchyl Alcohol

Fenchyl alcohol  is a solvent for a wide variety of organic materials. It is used in organic synthesis.

Specific rotation	−0.1°
Freezing point	30–34° C.
Specific gravity	0.962 (approx.)
Boiling range	198–204° C.

TABLE 83.—Physical Properties of Terpenes and Terpene Alcohols[11]

Sample	Boiling Range 5% °C.	Boiling Range 95% °C.	Specific Gravity	Refractive Index	Optical Rotation
α-Pinene	155	158	0.8625	1.4560	+ 26.50
β-Pinene[a]	160.2	163.8	0.8677	1.4709	− 11.71
Dipentene	174	178	0.8481	1.4743	+ 4.2
Terpinolene	187	189.7	0.8744	1.4809	+ 0.2 (27.9° C.)
Fenchyl alcohol	200	201.3	0.94 (35° C.) 0.961 (15.6° C.)[b]	1.4626	−0.1 (20° C.)
α-Terpineol	218	219	(m. p. 35° C.)	1.4789 (25° C.)[b]	+ 0.19 (10% in alc.)

[a]Distilled from gum turpentine.
[b]Supercooled.

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Chapter 11

Aldehydes

Formaldehyde

Formaldehyde (HCHO) is a colorless gas which appears on the market as an aqueous solution containing 40 per cent by volume. This solution is clear and colorless, with a pungent suffocating odor; its specific gravity ranges from 1.075 to 1.085. It is made by the pressure-catalytic oxidation of methanol. The bulk of the manufactured formaldehyde is used in making synthetic resins. Other uses for it are as a deodorizer, bactericide and preservative, and in dye manufacture. In the leather industry formaldehyde is used to harden, preserve, tan and stiffen skins, hides and leather, and in the rubber industry as an accelerator. It is also used as a waterproofing agent and a reducing agent. Other industries like the textile, cellulose and photographic find need of formaldehyde for various purposes.

Acetaldehyde

Acetaldehyde (CH_3CHO, acetic aldehyde, ethanal, aldehyde, ethyl aldehyde) is a water-white, mobile, inflammable liquid of aromatic, penetrating odor. It is completely miscible with water, alcohol, benzene, ether, gasoline, solvent naphtha, toluene, xylene, turpentine and water. It will dissolve oils, iodine and many of the natural and synthetic resins. Its uses are as a hardening agent for glue and casein, and in the manufacture of perfumes, drugs, dyes and so forth.

Acetaldehyde	99% min.
Acidity	0.1% acetic acid max.
Color	Water-white
Specific gravity	0.785 to 0.795 at $\frac{15.6^\circ \text{ C.}}{4^\circ \text{ C.}}$
Weight	6.55 lbs./gal. at $\frac{15.6^\circ \text{ C.}}{4^\circ \text{ C.}}$

Paraldehyde

Paraldehyde $(CH_3CHO)_3$ is a colorless, inflammable liquid of pleasant odor. It is completely miscible with most common organic solvents and will dissolve oils, fats, waxes, gums, and natural and synthetic resins. The more important uses for it are in the production of rubber accelerators and synthetic resins. It is also used in medicine, in the making of dyes, and in place of acetaldehyde in the treatment of leather owing to its higher boiling point and ease of handling. A mixture of paraldehyde and ethyl alcohol will dissolve nitrocellulose. When acetone is used in place of ethyl alcohol, the mixture will dissolve cellulose esters.

Technical Grade	
Paraldehyde	90% min.
Acetaldehyde	10% max.
Acidity	0.5% max. as acetic acid
Color	Water-white
Specific gravity	0.975 to 0.982 at $\frac{15.6^\circ\text{ C.}}{4^\circ\text{ C.}}$
Weight	8.15 lbs./gal. (15.6° C.)

Refined Grade	
Paraldehyde	99% min.
Acetaldehyde	1% max.
Acidity	0.1% max. as acetic acid
Color	Water-white
Specific gravity	0.996 to 0.998 at $\frac{15.6^\circ\text{ C.}}{4^\circ\text{ C.}}$
Weight	8.32 lbs./gal. (15.6° C.)

Butyraldehyde

Butyraldehyde ($CH_3(CH_2)_2CHO$, butyric aldehyde, butaldehyde, normal butylaldehyde) is a colorless, inflammable liquid of a characteristic pungent, aldehyde odor. It is used in preparing rubber accelerators, synthetic resins, tanning extracts, perfumes and flavoring extracts, and as an intermediate in organic synthesis.

Purity	Not less than 9% normal butyraldehyde
Specific gravity	0.803 to 0.809 at $\frac{20^\circ\text{ C.}}{20^\circ\text{ C.}}$
Acidity	Less than 0.75%, calculated as butyric acid. Not more than 4.77 mg. KOH required for neutralization of 1 g.
Water	Less than 0.5% of water. (One volume mixes without turbidity with 1.5 volumes of water-saturated benzene.)
Color	Water-white
Acetaldehyde	None
Crotonaldehyde	None
Molecular weight	72.08
Flash-point	18° C. (64.4° F.)
Distillation range	71° C. to 78° C.
Weight per U.S. gallon	6.71 pounds (68° F.)
Approximate change in wt. per gal. per ° F.	0.0045 lb.
Solubility in water	7.7% by vol. (25° C.)
Solubility of water in butyraldehyde	3.5% by vol. (25° C.)

Acetaldol

Acetaldol ($CH_3CHOHCH_2CHO$, aldol, 3-butanolal, hydroxybutyraldehyde, β-hydroxybutyraldehyde, oxybutyricaldehyde) is a thick viscous liquid, completely miscible with water, ether, alcohols and so forth. It is a solvent for pyroxylin and many organic substances owing to the presence of both the alcohol and the aldehyde group in the molecule. When it is admixed with an active solvent it will dissolve cellulose acetate. Other uses are as a frothing and collecting agent in ore and coal flotation; as an intermediate in the making of perfumes, dyes and drugs; as a dyeing

assistant; in engraving; in resin formation; and as a mutual solvent for pyroxylin and castor oil.

Acetaldol	85% to 95%
Color	Pale yellow
Specific gravity	1.1024 to 1.1064 (15.6° C.)
Weight	9.24 lbs./gal. (15.6° C.)

Crotonaldehyde

Crotonaldehyde ($CH_3CHCHCHO$) is a colorless, inflammable, mobile liquid of pungent odor. It is partly miscible with water and completely miscible in all proportions with alcohol, ether, benzene, toluene, kerosene, gasoline, solvent naphtha and so forth. It is a solvent for vegetable and mineral oils, fats, waxes, gums, rubber, sulfur, natural and synthetic resins, etc. It is used in the manufacture of intermediates, dyes, resins, rubber accelerators and tear gas, and as a warning agent for gases. It is also used as a selective solvent for the removal of impurities from lubricating oils.

Crotonaldehyde	97% to 99%
Acetaldehyde	1% max.
Paraldehyde	1% max.
Water	1% max.
Acidity	0.3% max. as acetic acid
Color	Water-white to yellow
Specific gravity	Below 0.862 at $\frac{15.6° \text{ C.}}{4° \text{ C.}}$
Weight	7.14 lbs./gal. (15.6° C.)
Flash-point	127.4° F.
Boiling range	
Below 82° C.	None
Below 108° C.	Not less than 90%
Vapor pressure	30 mm. Hg. (20° C.)

Paraldol

Paraldol [$(CH_3CHOHCH_2CHO)_2$] is a white crystalline solid comprising 70 per cent paraldol and 30 per cent aldol and it is soluble in water. Boiling point 96 to 98° C.

Octyl Aldehyde

Octyl aldehyde ($C_4H_9CHC_2H_5CHO$, 2-ethyl hexanal) is a colorless, high-boiling liquid of mild aldehyde-like odor. It is miscible with most organic solvents and is used both in chemical synthesis and in perfumes.

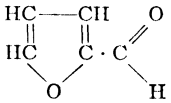
Acidity	Not more than 0.1% as acetic acid.
Color	Water-white
Specific gravity	0.822 to 0.828 at $\frac{20° \text{ C.}}{20° \text{ C.}}$
Boiling range (760 mm.)	Not more than 5% distills below 160° C. Not more than 3% distills above 175° C.
Average weight	6.9 lbs./gal. (20° C.)

Benzaldehyde

Benzaldehyde (C_6H_5CHO, artificial essential oil of almond, benzoic aldehyde, benzoyl hydride) is a colorless liquid of fragrant odor. It is miscible with alcohols, ether, aldehydes, ketones and so forth. It will dissolve oils, resins, some cellulose ethers, cellulose acetate and nitrate. When it is admixed with ethyl alcohol or an active solvent like methyl acetate, acetone and so forth, the mixture will dissolve a wide range of cellulose esters or ethers. Uses for it are in the manufacture of intermediates, medicinals, dyes, flavoring compounds, toilet preparations and soaps, and as an intermediate in organic synthesis.

Specific gravity	1.045 (25° C.)
Melting point	−13.5° C.
Boiling point	179.5° C.

Furfural



Furfural (furfurol, furfuraldehyde, furol, artificial oil of ants, furfuranecarboxylic aldehyde, pyromucic aldehyde) is a colorless mobile liquid of aromatic odor suggestive of bitter almonds, and upon exposure will turn red. It was discovered over a hundred years ago and, owing to its original source from bran, was given the name of furfurol (furfur—bran; oleum—oil). It is commercially obtained from oat hulls.

Furfural is miscible with alcohols, ethers, ketones, and most organic solvents with the exception of the paraffin hydrocarbons. It possesses a wide range of solvent action, dissolving most types of cellulose esters and ethers, gums, natural and synthetic resins, waxes, oils and dyes, and many organic substances, some of which are oleic acid, carbazole, anthracene and so forth. By adding an aliphatic alcohol or ester to it, its solvency for cellulose derivatives will be augmented.

The largest commercial use for furfural is in the manufacture of resinous material by condensing it with amines, ketones, phenols and so forth. The furans are also used in making vulcanization accelerators, antioxidants, dyes and intermediates. Other uses for furfural are as a solvent in lacquers with a cellulose ester, or cellulose ether, or varnish gum base; as a solvent for such substances as formaldehyde, oleic acid and diphenylaminechlorarsine; in the purification and bleaching of organic compounds; and as a fly-repellant, preservative, fungicide, herbicide and tanning agent. The condensation products of furfural and ketones are sensitive to light and are therefore utilized in photolithographic and photoengraving processes. As a selective solvent furfural is employed in the refining of mineral oils, in the isolation and purification of anthracene from an admixture with phenanthrene and carbozole, and in the purification and oxidation of rosin. Its solvent and penetrating properties make it a valuable component in dyeing mixtures for wood, vegetable matter, leather,

shoes, textiles and other such substances. Owing to its penetrating power it finds application for resin impregnation.

	Technical	Refined
Boiling point	158–162° C.	158–160° C.
Specific Gravity	1.158–1.16	1.159–1.161
Flash-point	55–58° C.	55–58° C.
Acid (as acetic)	0.3% max.	0.1% max.
Aldehyde content	98.5%	99.0–99.5%

(See Fig. 137 for rate of evaporation of furfural and its derivatives.)

TABLE 85.—Some Physical Constants of Furfural and Its Derivatives

Name	Melting Point (° C.)	Boiling Point (° C.)	Density d_4^{20}	Refractive Index
n-Amyl furoate		233	1.033	
n-Butyl furoate		227	1.0555	1.4740
n-Butyl furfuryl ether		189–190	0.955	
Ethyl furoate	34	195–7	1.1774	1.4782
Furylacrolein		200		
Furylacrylic acid		226		
Furan		31	0.937	1.4216
Furfural	– 36.5	158–162	1.1598	1.4161
Furfural acetone	125	229 (decomposes)		
Furfural acetophenone		180–1 (8 mm.)		
Furfural diacetate		143–4 (20 mm.)		
Furfuraldoxime (sym.)	89			
Furfuraldoxime (anti)	73			
Furfurin	117			
Furfuryl acetate		175–7	1.1175	1.4627
Furfuryl alcohol		165–8	1.1351	1.4864
Furfuryl amine		145–6	0.955	
Furfuryl butyl ether		189–190		
Furil	162–5			
Furoin	135–9			
Furoic acid	132–3	230–2		
Furoyl chloride		170		
Hydrofuramide	115–120			
Isoamyl furoate		232	1.0335	1.4720
Methyl furoate		181	1.178	1.4869
2-Propyl furoate		211	1.075	1.4750
Tetrahydrofurfuryl acetate		84–6 (14 mm.)		
Tetrahydrofurfuryl alcohol		177–8	1.055	1.4508
Tetrahydrofurfuryl benzoate		143–5 (3 mm.)		

TABLE 86.—Solubility of Gums and Resins[1]

Product	Congo	Guaiac	Dammar	Coumarone	Ester Gum	Sandarac	Mastic	Kauri	Pontianac	Shellac
Furfural	SW	SS	SS	S	S	SS	SS	SS	SW	SS
Methyl furoate	SW	SS	SS	S	S	SW	SW	SW	SW	SS
Ethyl furoate	SW	S	SW	S	S	SW	SW	SW	SW	SS
Propyl furoate	SW	SS	SW	S	S	SW	SW	SW	SW	SS
n-Butyl furoate	SW	SS	SW	S	S	SW	SW	SS	S	SS
Isoamyl furoate	SW	SS	SW	S	S	SW	SW	SS	SS	SS
Furfuryl alcohol	SW	SS	SW	S	S	S	S	S	S	S
Furfuryl acetate	SW	SS	SW	S	S	SW	SW	SS	SW	SS
Tetrahydrofurfuryl alcohol	SS	S	SW	S	S	S	S	S	S	S

sw = swells; ss = slightly soluble; s = soluble.

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[1] Quaker Oats Company, Chicago, Ill.

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Niacet Chemical Company, New York, N. Y.
Trickey, J. P., *Ind. Eng. Chem.*, **19**, 643 (1927).
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Chapter 12

Acids

Aliphatic

Formic Acid

Formic acid (HCOOH, acid hydrogen carboxylic) is a colorless liquid of a pungent odor. It is soluble in water, alcohols, glycerin, ether and many other solvents. It will dissolve cellulose acetate and many types of cellulose ethers. It is used to toughen films of cellulose acetate. The presence of formic acid in pyroxylin lacquers increases not only the pliability of the film but also its adhesive property. A mixture of formic acid and furfural has been proposed as a solvent for nitrocellulose and as a stabilizer for ethyl acetanilid, when it is used as a camphor substitute. Other uses for formic acid are in the manufacture of esters, as a preservative for foods and hides, as a deliming agent, as a solvent and mordant in dyeing and printing textiles, and in electroplating.

Specific gravity	1.2178
Melting point	8.3° C.
Boiling point	100.8° C.

Acetic Acid

Acetic acid (CH_3COOH, vinegar acid, methane carboxylic acid) is a colorless liquid with a pungent odor. It is soluble in water, alcohols, ether and so forth, and is a solvent for cellulose esters. Processes have been patented for its use in celluloid substitute manufacture, as a mutual solvent for cellulose acetate and dyes and in mending compositions for cellulose ester films. Other uses for acetic acid are in the manufacture of acetates, acetyl derivatives, esters, intermediates, curing agents, dyes, matches, printing inks and polishes, and as an assistant in dyeing processes.

	Glacial
Acetic acid	99.5% min.
Color	Water-white
Chlorides	Nil
Sulfates	Nil
Metals	Nil
Aldehyde	0.05% max.
Formic acid	0.2% max.
Water	0.5% max.
Freezing point	15.6° C. min.
Weight	8.77 lbs./gal. (15.6° C.)

The freezing points of pure acetic acid in water solutions are as follows:

Acetic Acid (Per cent)	°C.	°F.	Acetic Acid (Per cent)	°C.	°F.
80.0	− 8.4	16.9	99.3	15.28	59.5
85.0	− 2.4	27.7	99.4	15.47	59.8
90.0	3.3	38.0	99.5	15.65	60.1
95.0	9.0	48.2	99.6	15.84	60.4
98.0	13.2	55.8	99.7	16.04	60.8
99.0	14.74	58.6	99.8	16.24	61.2
99.1	14.92	58.9	99.9	16.43	61.6
99.2	15.10	59.2	100.0	16.60	61.9

Acetic Anhydride

Acetic anhydride [$(CH_3CO)_2O$, acetic oxide, acetyl oxide] is a colorless liquid with a pungent acetic odor. It is soluble in alcohols, chloroform and ether. It will hydrolyze to acetic acid upon the addition of water. It is used for the introduction of the acetyl group in organic compounds, in the manufacture of cellulose derivatives, drugs, dyes and intermediates. It is added to film-producing lacquers in order to impart noninflammability, and is also added to airplane dopes and varnishes.

Specific gravity	1.082 (15° C.)
Boiling point	139.5° C.

Propionic Acid

Propionic acid [CH_3CH_2COOH] is a colorless liquid of fragrant odor. It is soluble in alcohols, ether, chloroform and so forth, and is a solvent for acetone-soluble cellulose acetate. When it is admixed with a small amount of alcohol it will dissolve many cellulose ethers. Uses for it are in the manufacture of esters, artificial fruit flavors and perfumes.

Butyric Acid

Butyric acid [$CH_3(CH_2)_2CO_2H$, ethyl acetic acid, propylformic acid] is a colorless liquid of rancid odor. It is soluble in alcohols, ethers and so forth. It is used in the manufacture of esters which are used as solvents, as perfumes and flavoring agents; as a tanning agent and a disinfectant; and in deliming hides.

Purity	Not less than 99.0%
Specific gravity	0.957 to 0.961 at $\frac{20° \text{ C.}}{20° \text{ C.}}$
Color	Water-white
Boiling range (760 mm.)	
Below 160° C.	None
Above 165° C.	None
Miscibility with water	Miscible in all proportions
Miscibility with H_2SO_4	50 cc. should dissolve 5 cc. 95% H_2SO_4. After standing 30 minutes at 20° C., the mixture should not be darker than No. 6 pink color standard.
Chlorides	None
Average weight	7.98 lbs./gal. (20° C.)

Butyric Anhydride

Butyric anhydride is a water-white liquid which hydrolyzes to butyric acid in the presence of water. Like butyric acid, it is used in making butyrates, flavors, drugs, tanning agents and so forth.

Purity	Not less than 85%
Specific gravity	0.965 to 0.970 at $\frac{20° C.}{20° C.}$
Color	Water-white
Boiling range (760 mm.)	
Below 190° C.	None
Above 200° C.	None
Below 195° C.	Not more than 10%
Average weight	8.05 lbs./gal. (20° C.)

Furoic Acid

Furoic acid (C_4H_3OCOOH, pyromucic acid) is a stable, crystalline product, which is white when pure. The impure product is brown and can be purified by sublimation. It is soluble in most organic solvents and is used both as a fumigant and for making furoic acid derivatives.

Melting point	128 to 129° C.
Moisture	3% max.
Ash	0.1% max.
Sulfate	tr.
Acidity (as furoic with phenolphthalein)	99.0 to 99.5%

Crotonic Acid

Crotonic acid is a water-white crystalline substance that is chemically unsaturated. It is used in making esters and resinous material.

Aromatic

Benzoic acid and other acids of this group have been proposed as solid-solvent-mixtures for cellulose esters and ethers in making films and plastics. Salicylic acid is added to it owing to the beautiful crystalline effect produced. Anthranilic acid and an aminobenzoic acid have been proposed as plasticizers for cellulose esters.

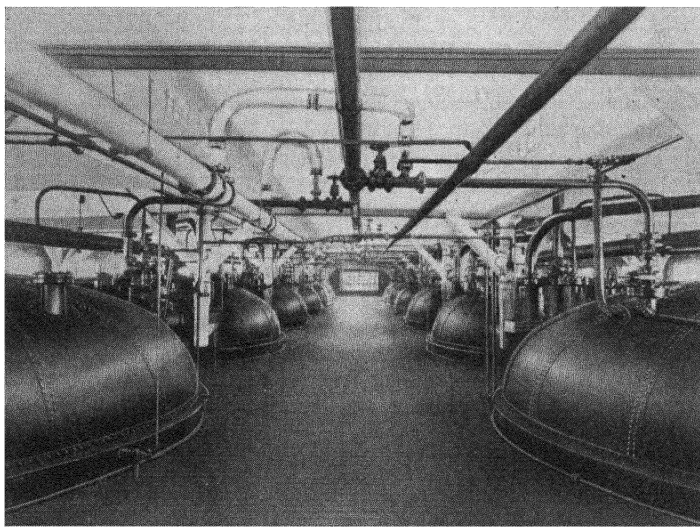
General References

Carbide & Carbon Chemicals Corporation, New York, N. Y.
Niacet Chemical Corporation, New York, N. Y.

Chapter 13

Ketones

Ketones $\begin{matrix} R \\ \diagdown \\ \quad CO \\ \diagup \\ R \end{matrix}$ are stable solvents possessing high dilution ratios and good blush resistance; and they are compatible with lacquer ingredients. Their evaporation rates are in relation to their boiling points. They are miscible with most lacquer solvents and diluents. As a rule ketones are good solvents for cellulose esters and ethers and many natural and synthetic resins. The higher ketones are solvents for nitrocellulose and act as latent solvents for cellulose acetate in the presence of some plasticizers. Park and Hofmann[1] have found that each ketone evaporates approximately twice as slowly as the one before it in the series. They have also observed that methyl ethyl ketone and ethyl acetate have about the same evaporation rate and they therefore recommend the substitution of this ketone for the ester in nitrocellulose lacquer. Further, methyl butyl ketone equals



Courtesy of Commercial Solvents Corp.

PLATE 11. Top View of Fermentation Tanks in Butyl-Acetonic Fermentation of Xylose.

n-butyl acetate in evaporation rate and can replace it in lacquer fabrication. The rate of evaporation of methyl amyl ketone is slower than that of butyl propionate or amyl acetate, and approximately equal to that of secondary hexyl acetate; and methyl propyl ketone has a rate of evaporation which lies between those of ethyl and butyl acetate.

TABLE 87.—Solvent Properties Affecting Blush Resistance[1]

Solvent	Solubility of: Solvent in H_2O	Solubility of: H_2O in solvent	Wet-Bulb Depression (° C.)
Acetone	Infinite	Infinite	30.5
Methyl ethyl ketone	22.6	9.9	21.5
Methyl propyl ketone	6.0	3.6	12.0
Methyl butyl ketone	3.44	3.70	6.5
Methyl amyl ketone	1.95	2.15	3.0
Ethyl acetate	7.9	3.0[a]	21.5
n-Butyl acetate	2.3	2.4	6.5

[a]For C. P. product containing no alcohol; commercial material dissolves more water than this.

Acetone

Acetone (CH_3COCH_3, dimethylketone, methyl acetyl, propanone) is a colorless, limpid, mobile, hygroscopic, inflammable liquid of mint-like odor. It was formerly obtained by the destructive distillation of wood. The yield of acetone was increased by converting the acetic acid, in the aqueous distillate, to calcium acetate and then subjecting this salt to dry distillation. Acetone is also made by the catalytic conversion of acetic acid by passing it through heated tubes. More recently, acetone and higher ketones have been made from olefinic hydrocarbons. The olefins are converted to sulfonic acids which on hydrolysis yield alcohol, and on oxidation form the corresponding ketones. The bulk of acetone which is produced is made by the Fernbach-Strange-Weizmann fermentation process and *n*-butyl alcohol is also produced at the same time. This ketone can also be made by a bacterial fermentation of a giant seaweed which grows along the Pacific Coast. This widely-used, "low-boiling" ketone is completely miscible with water, alcohols, ethers, oils, hydrocarbons, halogenated hydrocarbons, fatty acid esters and most organic solvents. It is one of the most powerful solvents known. It will dissolve 25 times its volume of acetylene at a pressure of one atmosphere, and it will continue to dissolve 25 times its volume of this gas for each additional atmosphere of pressure.

Its solvent power varies widely for different substances. Resins such as pontianac, elemi, soft manila, dammar, sandarac, rosin, Burgundy pitch and shellac are wholly, or almost wholly, soluble. This is true also of celluloid, cellulose esters, fats, greases, essential oils, dyes, Japan and Bayberry wax, and synthetic resins such as benzyl abietate, copal and ester gums, crotonaldehyde and cyclohexanone-formaldehyde. Other types of natural resins and waxes, however, are only partially soluble in acetone (see Tables 88, 94, 98, 100). Petroleum products are slightly soluble (Table 89). A mixture of acetone and benzene (3:11) will dissolve many types of cellulose ether.

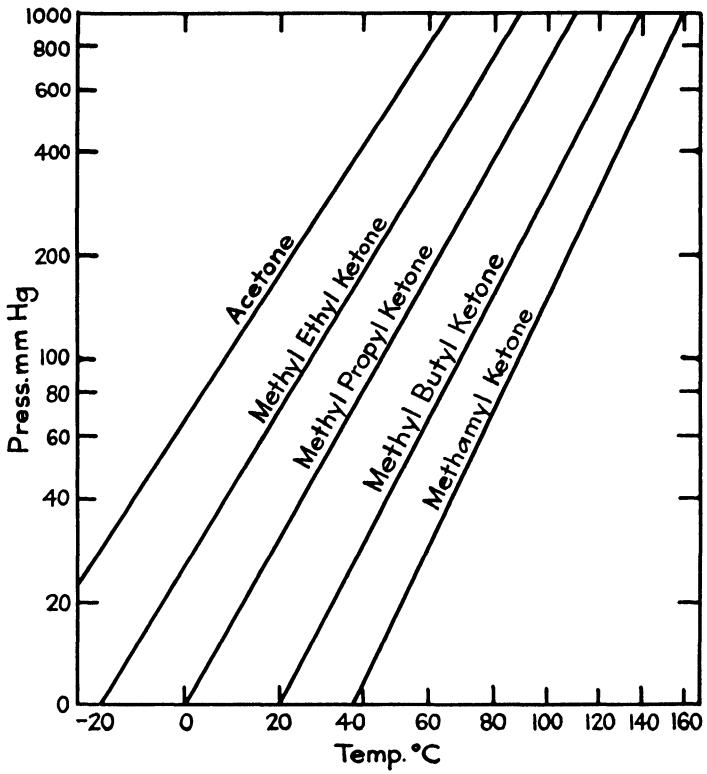


FIGURE 138. Vapor Pressure of Various Aliphatic Ketones at Different Temperatures.

Acetone is widely used as an extracting medium for substances which are themselves insoluble, but contain acetone-soluble impurities in the form of fats, greases and resins. In this category fall rubber, pitches, asphalts, etc. (Table 97). Crude plantation rubber, for example, contains from 2 to 3 per cent of acetone-soluble substances; and related materials such as gutta percha and balata have considerably more (Table 91). In addition to this, acetone is used as a solvent in paint and varnish removers, motor fuels, airplane dopes, nitrocellulose lacquers, and carbon removers; as an alcohol denaturant; in degreasing wool and manufacturing rayon; in artificial seasoning of wood, in lubricating compositions, in smokeless powder, in cordite; in bituminous paint; as a refrigerant; in coating of fabrics, film manufacture and water-proofing compounds. Acetone finds considerable use also in the organic synthesis of drugs, dyes, acetone derivatives, etc.

Purity	98% to 100% dimethyl ketone
Acidity	Less than 0.002%, calculated as CO_2. Not more than 0.051 mg. KOH required for neutralization of 1 g.
Color	Water-white
Non-volatile matter	Not more than 0.001 gram when 100 cc. are evaporated and heated to constant weight at 100° C. to 110° C.
Approx. change in wt.	0.0054 lb./gal./° F.
Molecular weight	58.06
Boiling point	56.5° C.
Melting point	−94.9° C.
Critical pressure	47 atm.
Critical temperature	235° C.
Heat of combustion	7.373 cal./g.
Refractive index	1.3591 (20° C.)
Surface tension	23.7 dynes/cm. (20° C.)
Electrical conductivity	5.5×10^{-8} recip. ohms (15° C.)
Latent heat of vaporization	124.6 cal./g. (56.1° C.)
Viscosity	0.316 centipoise (25° C.)
Vapor pressure:	

Temperature (° C.)	Millimeters of Hg.
0	69.5
10	117.4
20	186.3
30	284.6
40	425.3
50	620.9
60	860.4

Specific gravity	0.7972 (15° C.)
Weight per gallon	6.64 lbs. (15° C.)
Specific heat	0.3468 (26–100° C.) 0.3740 (27–179° C.)
Flash-point	− 16° C. (3° F.)
Solubility	Miscible with water and most organic liquids
Dilution ratio	Water 0.21 Toluene 4.95 V. & P. naphtha 0.55 Final conc. ½-sec. R. S. nitrocellulose 8%
Explosive limits in air	2.89–13.0
Alkalinity	Not alkaline to para-nitrophenol
Distillation range	
Below 55° C.	None
Above 57.5° C.	None
Dryness	Miscible without turbidity with 20 vols. 60° Bé. gasoline at 20° C.
Reducing Substances	Color of added permanganate to be retained for not less than 30 minutes

Blush resistance at 90° F.
(10% ½-sec. R.S. nitrocellulose solution)

	Clear	Blush
Relative humidity	35%	40%

Coefficient of expansion	
Per 1° F.	0.00080
Per 1° C.	0.00144

Evaporation rate at 95° F

	5%	25%	50%	75%	90%	95%
Minutes	¼	1¼	2¾	4¼	5¼	5½

Water solubility — In all proportions and without turbidity

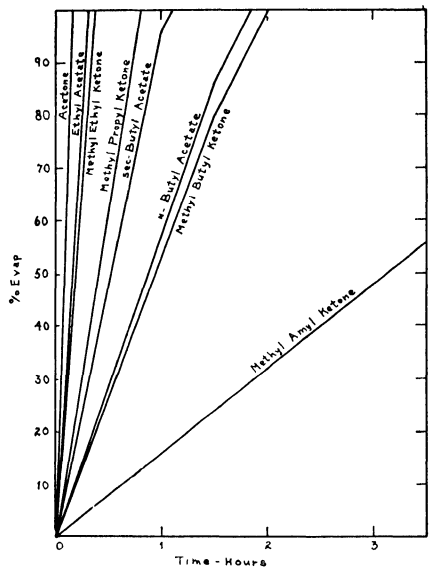


FIGURE 139.

Evaporation Rate of Various Ketones and Esters (Temperature 18.5-19.5° C.).[1]

TABLE 88.—Percentage of Acetone-insoluble Matter in Various Resins[4]

Resin	Per cent Insoluble in Acetone
Brazilian	37.60
Zanzibar	77.30
Madagascar	64.30
Demerara	69 20
Columbian	43.60
Benguela	24.80
Angola, red	77.70
Angola, white	61.00
Congo	45.80
Pontianac	Soluble
Kissel	49.50
Akkra	45.80
Cameroon	60 50
Sierra Leone	40.30
Guapinol resin	57.10
Courbaril (Cayenne)	33.90
Manila, hard	52.00

TABLE 89.—Solubility of Petroleum Products in Acetone[4]

Product	Cc. of oil Soluble in 100 cc. of Acetone at 25° C.
Gulf Supreme light auto	13.0
Gulf Supreme medium auto	8.6
Gulf Supreme heavy auto	8.0
Gulf Liberty aero	6.0
Brownley Liberty aero	3.2
High-viscosity pale	6.0
Vacuoline, Extra B	4.2
Turbin	4.2
Western	9.2

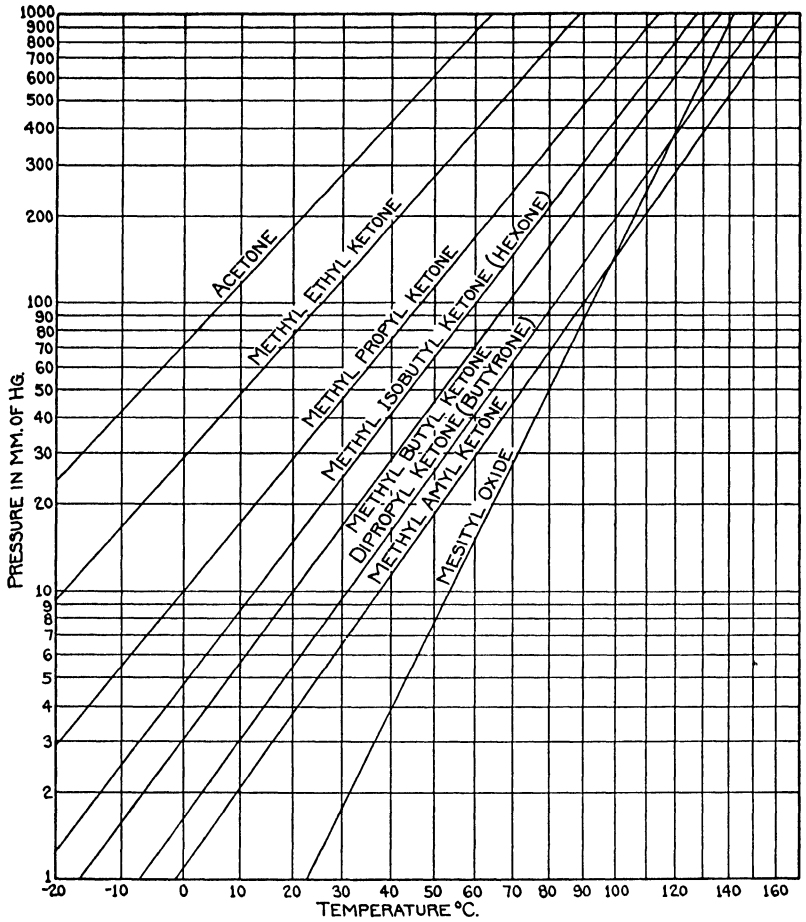


FIGURE 140. Vapor Pressure of Various Ketones at Different Temperatures.[3]

TABLE 90.—Solubility of Resins in Acetone[4]

Resin	Solubility at Room Temperature
Rosin: WW grade	M
M grade	m
E grade	m
Synthetic resins	
Coumarone: m. p. 85° C.	M
m. p. 115° C.	M[1]

M—miscible in all proportions.
M[1]—miscible in concentrated solution with part separating on dilution.
m—part soluble is miscible in all proportions at room temperature.

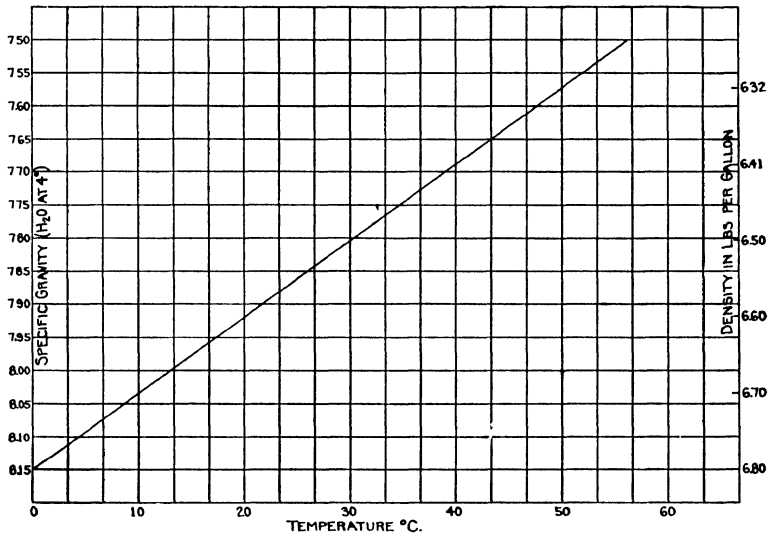
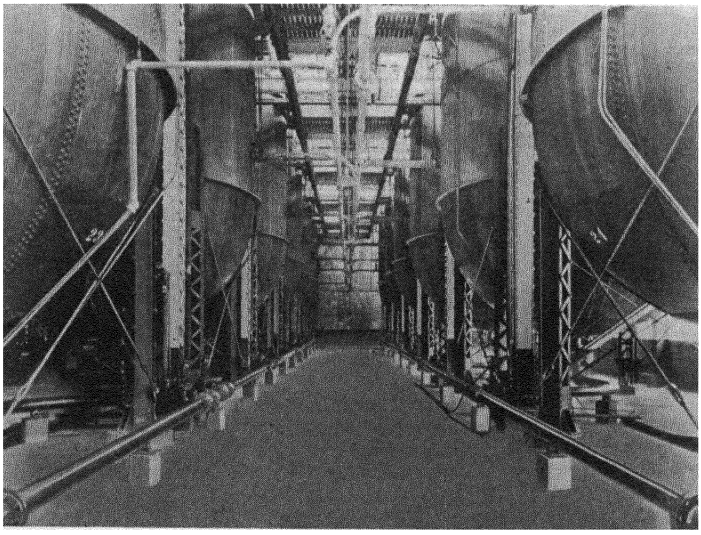


FIGURE 141. Specific Gravity and Weight per Gallon of Acetone at Various Temperatures.[3]



Courtesy of Commercial Solvents Corp.

PLATE 12. Bottom View of Fermentation Tanks. See Plate 11.

TABLE 91.—Acetone-Soluble Portion of Crude Rubbers and Related Gums[4]

Type	Per cent Soluble at Boiling Point of Acetone
Balata, Surian sheet	41.9
Balata Venezuela block	44.5
Benguellas	4.5
Caucha, Ball	2.9
Caucha, Central	2.8
Crepe, brown	2.8
Crepe, first latex	2.9
Guayule	21.0
Gutta-percha	25.0
Smoked sheet, prime ribbed	3.15
Upper Congo, red	5.8
Upriver Fine Para	1.25

TABLE 92.—Solubility of Fats, Oils and Greases in Acetone[4]

Type	Miscibility at 25° C.	Per cent Soluble at 25° C.	Per cent Soluble at Boiling Point of Acetone
Linseed oil, ozonized	M		
Neatsfoot oil	m	98.7	M
Olive oil (commercial)	M		
Olive elaine (red oil)	M		
Palm oil, Legos (commercial)	m	82.0	99.8
Palm oil, raw	..	100.0	M
Palm kernel oil (extracted, raw)	M		
Peanut oil (refined and bleached)	M		
Peanut oil (hydrogenated)	..	100.0	M
Pine oil	M		
Seal oil (Norwegian, raw)	M		
Soy-bean oil	M		
Sperm oil	M		
Tallow (prime)	..	89.1	M
Whale oil	M		

M—miscible in all proportions.
m—part soluble at 25° C is miscible in all proportions.

TABLE 93.—Solubility of Blown Asphalts in Acetone[4]

Type	Acetone Extract Per cent
Residual oil	61.0
After blowing 3 hours	40.2
After blowing 6 hours	33.6
After blowing 8 hours	25.1

TABLE 94.—Solubility of Copal Resins in Acetone[4]

Type	Per cent Soluble at Boiling Point of Acetone	Solubility of Part Soluble at 25° C.
Congo	40.8	M[1]
Manila, soft	96.6	M
Elemi	100.0	M
Yacca	96.6	M
Sandarac	97.0	M[1]
Sierra Leone	55.5	M[1]
Borneo pontianac	93.5	M[1]
Batavia dammar	88.7	M[1]
Red, accrodites	95.2	M

M—miscible in all proportions.
M[1]—miscible in concentrated solutions with separation on dilution.

TABLE 95.—Solubility of Water Gums in Acetone[4]

Type	Per cent Soluble at Boiling Point of Acetone
Arabic gum	11.9
Indian gum	16.7
Senegal gum	12.0
Tragacanth, Allepa	9.2
Tragacanth, Persian	8.0
Tragacanth, Turkey	7.2

TABLE 96.—Solubility of Shellacs in Acetone[4]

Type	Per cent Soluble at Boiling Point of Acetone
Superfine orange shellac	98.8
Superfine shellac	92.8
T. N. shellac No. 1	95.6
T. N. shellac, No. 2	98.8
A. C. garnet	81.3
Refus lac	63.0

TABLE 97.—Solubility of Asphalts and Bitumens in Acetone[4]

Type	Per cent Soluble at Boiling Point of Acetone
Alberite	5.8
Asphalt, blown, from mid-continental petroleum	56.4
Bermudez pitch, refined	62.4
Coal-tar pitch, refined	70.4
Fatty acid pitch, soft grade	62.4
Fatty acid pitch, medium grade	54.3
Gilsonite selex	25.0
Grahamite	1.6
Mexican petroleum asphalt, steam-distilled, medium grade	44.2
Mexican petroleum asphalt, steam-distilled, soft grade	64.3
Petroleum asphalt, steam-distilled, California, medium grade	81.0
Residual oil from Gulf Coast	61.0
Residual oil from steam distillation of mid-continental petroleum asphalt	97.2
Syrian asphalt	5.9
Trinidad pitch, refined	42.0

TABLE 98.—Percentage of Acetone-insoluble Matter in Various Resins[4]

Type	Per cent Insoluble in Acetone
Kauri, pale	8.90
Kauri, brown	38.70
Kauri, bush	20.70
Rosin	Soluble
Burgundy pitch	Soluble
Stockholm tar	Soluble
Mastic	9.50
Sandarac	Soluble
Madagascar copal, fused	84.80

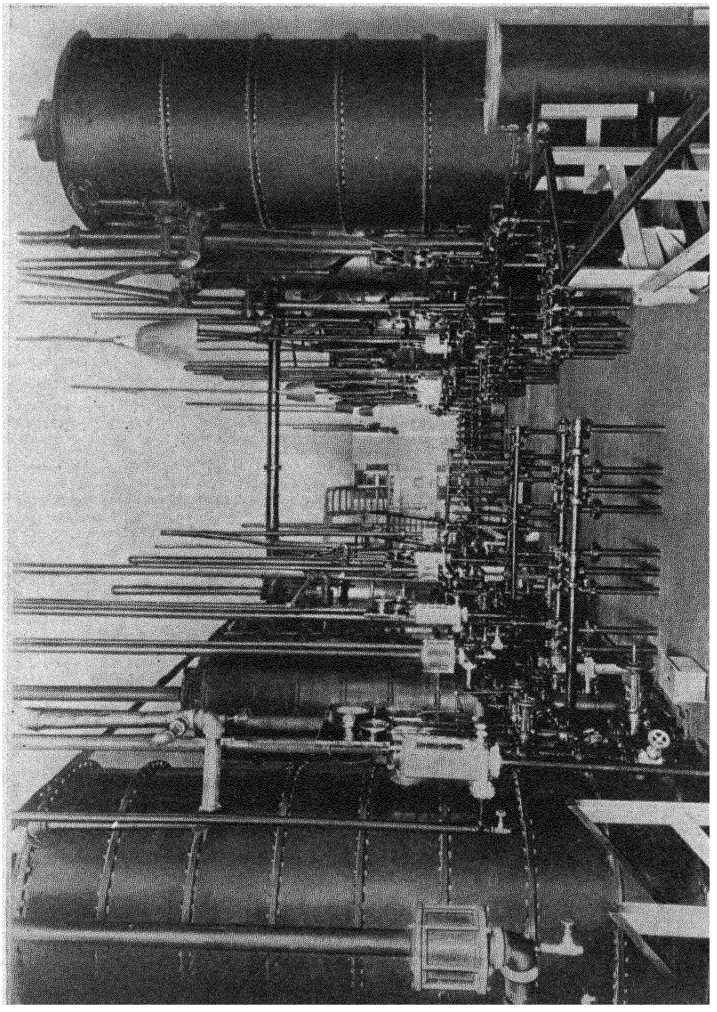


PLATE 13. Interior of a Still Tower.

Courtesy of Commercial Solvents Corp.

TABLE 99.—Solubility of Fats, Oils and Greases in Acetone[4]

Type	Miscibility at 25° C.	Per cent Soluble at 25° C.	Solubility at Boiling Point of Acetone
Chinawood oil	M		
Cocoanut oil (refined and bleached)	M		
Corn oil (raw)	M		
Cottonseed oil (refined and bleached)	M		
Cottonseed oil (hydrogenated, Crisco)	M	100 0	M
Cottonseed oil (hydrogenated)	..	32.0	M
Cottonseed oil (stearin)	M		
Cottonseed oil (summer)	M		
Cottonseed oil (winter)	M		
Fish oil (herring, raw)	M		
Fish oil (hydrogenated)	..	35.8	M
Fish oil (menhaden, raw)	m	99.8	M
Grease, brown	m	96.4	99.8
Grease, garbage	m	99.6	99.7
Grease, white	m	97.3	M
Linseed oil, raw	M		

M—miscible in all proportions
m—part soluble at 25° C. is miscible in all proportions.

TABLE 100.—Solubility of Waxes in Acetone[4]

Type	Per cent Soluble at Boiling Point of Acetone
Bayberry wax	100.0
Beeswax, African	93.9
Beeswax, Cuban	99.2
Candelilla wax	99.8
Carnauba wax, Flora	35.8
Carnauba wax, Ceara	48.8
Japan wax	100.0
Montan wax	62.5
Ozocerite, black	69.0
Shellac wax	58.8

Wood Spirit (Wood Naphtha)

Wood spirit (wood naphtha) is a mixture of methyl alcohol, acetone, methyl acetate, acetal, allyl alcohol, acetaldehyde and methylamine. It is miscible with water, alcohols, ethers, ketones and hydrocarbons. It is a solvent for cellulose nitrate and acetate, benzyl abietate, cumar, oils, glyptol resins, and many other natural and synthetic gums and resins.

Methyl Acetone

Methyl acetone (methyl ketone) is a clear, colorless, inflammable, volatile liquid. It is obtained from the distillate of the destructive distillation of wood. It varies in composition but within its limits it is composed of acetone 35 to 60 per cent, methyl alcohol 20 to 40 per cent and methyl acetate 20 to 30 per cent.

This mixture is miscible with water, oils and hydrocarbons in all proportions and is an excellent solvent for acetyl and nitrocellulose, benzyl abietate, ester gum, glyptol resins, gums, resins, etc. Methyl acetone is used in the manufacture of cements, extracts, artificial leather, gas mantles, rubberized fabrics and so forth. It is used in extracting perfumes and in varnish removers; as a solvent for alcohol-soluble gums and gum mixtures; in celluloid cement, dopes, enamels, lacquers and stains; and in the manufacture of rawhide, artificial leather, solidified alcohol, plastics and so forth.

Specific gravity	0.830
Boiling range	50° to 70° C.
Acidity	0.02% max.

"Methane" is a type of methyl acetone in which esters are added to replace the alcohol. This addition augments the solvency of the mixture.

Acetone Oils

Acetone oils (ketone oils) are oily mixtures of high-boiling ketones containing other substances. They are slightly-colored liquids of pungent and acreolin-like odor. These oils are obtained from the destructive distillation of wood and by the dry distillation of calcium salts of aliphatic monocarboxylic acids. The distillate is divided into a light fraction called "light acetone oil" and a heavy fraction called "heavy acetone oil." The latter has, by far, the more disagreeable and penetrating odor and is therefore limited in its commercial use. The acetone oils are potent solvents. Their solvent action is not as rapid as that of acetone or methyl or ethyl acetate although they have the added advantage of lower volatility and lower water-absorption. Acetone oils are solvents for cellulose nitrate and acetate, gums, natural and synthetic resins, oils and so forth. These oils are also used as solvents for making cellulose ester and ether lacquers, cements and varnishes. Other uses are as an alcohol denaturant and for

	Light	Heavy
Specific gravity	0.810–0.830 (15° C.)	0.880–0.927 (15° C.)
Boiling range	75°–160° C.	160°–226° C.
Lbs. per gallon	6.91	7.72
Color	straw color	darker than straw

Boiling Ranges

—Light Refined Grade—		—Heavy Refined Grade—	
Over at	64° C.	Over at	110° C.
10%	68	10%	136
20	70	20	145
30	71	30	150
40	73	40	161
50	79	50	170
60	87	60	183
70	95	70	193
80	111	80	207
90	134	90	224
95	143	95	230

purifying dyes. A celluloid substitute has been proposed comprising acetone oils, nitrocellulose and gelatin. Scheele [5] describes an enamel of copal, nitrocellulose and acetone oils. An advocated varnish formula was composed of pyroxylin, cumar resin and acetone oil.

Methyl Ethyl Ketone

Methyl ethyl ketone ($CH_3COC_2H_5$, ethyl methyl ketone) is a colorless, inflammable liquid of acetone-like odor. It is miscible with oils and hydrocarbon solvents. It is equivalent to acetone in solvent power with the added advantage of being less soluble in water, having both a higher boiling point and a lower vapor pressure. These factors render it less prone to cause "chilling." Were it commercially abundant it would, to a large extent, replace acetone.

Commercial grades of methyl ethyl ketone usually contain 20 to 30 per cent of methyl acetate and about 10 per cent of methyl alcohol. It is used as a solvent for lacquers, celluloid, artificial leather dressing, dopes and dyes.

Purity	Contains more than 98% methyl ethyl ketone
Specific gravity	0.808 ($\pm$ 0.002) at $\frac{20° C.}{20° C.}$
Color	Water-white
Water	Miscible without turbidity with 19 volumes of 60° Bé. gasoline at 20° C.
Acidity	Less than 0.003% (as acetic acid)
Distillation range*	
Below 76° C.	None
Above 82° C	None
	More than 90% distills over between 78° C. and 81° C
Non-volatile matter	Less than 0.005%
Molecular weight	72
Boiling point	79.6° C. (760 mm.)
Refractive index	1.3791 (20° C.)
Viscosity	0.401 centipoise (25° C.)
Vapor pressure	77.5 (20° C.)
Flash-point	– 7.2° C. (closed cup)
Latent heat	106 cal./g.
Specific heat	0.550 cal./g.
Dielectric constant	18.4
Surface tension	24.6 (20° C.)

*According to A. S. T. M. Specification D268/31T.

Methyl Propyl Ketone

Molecular weight	86
Purity	Consists of a mixture of methyl propyl and diethyl ketones in the approximate ratio of 3 to 1 and contains at least 97% of these ketones, the balance being secondary amyl alcohol.
Vapor pressure	30 (20° C.)

Specific gravity	0.809 (± 0.002) at $\frac{20° C.}{20° C.}$
Boiling point	101.7° C.
Color	Water-white
Refractive Index	1.3895 at 20° C.
Water	Miscible without turbidity with 19 volumes of 60° Bé. gasoline at 20° C.
Viscosity	0.473 centipoise (25° C.)
Acidity	Less than 0.003% (as acetic acid)
Flash-point	45° F. (7.2° C.) (closed cup)
Distillation range*	More than 90% distills over between 100° and 103° C.
Latent heat	91 cal./g.
Non-volatile matter	Less than 0.005%
Dielectric constant	15.4
Surface tension	25.2 (20° C.)

*According to A. S. T. M. Specification D268/31T.

Methyl Butyl Ketone

Molecular weight	100.1
Boiling point	127.2° C. (760 mm.)
Specific gravity	0.8209 at $\frac{20° C.}{4° C.}$
Refractive index	1.4024 (20° C.)
Viscosity	0 584 centipoise (25° C.)
Vapor pressure	10 (20° C.)
Flash-point*	73° F. (22.8)
Latent heat	83 cal./g.
Specific heat	0.553 cal./g.
Dielectric constant	12.2
Surface tension	25.2 (20° C.)

*Closed Cup.

Methyl Amyl Ketone

Molecular weight	114 11
Boiling point	150.2° C. (760 mm.)
Specific gravity	0.8269 at $\frac{20° C.}{40° C.}$
Refractive index	1.4110 (20° C.)
Viscosity	0.766 centipoise (25° C.)
Vapor pressure	3.6 (20° C.)
Flash-point*	106° F. (41.1)
Latent heat	83 cal./g.

*Closed Cup.

Butyrone

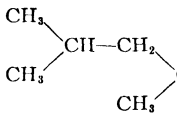
Butyrone $\begin{matrix} CH_3CH_2CH_2 \\ \\ CH_3CH_2CH_2 \end{matrix}\!\!>\!CO$ (di-*n*-propyl ketone, amyl ketone) is a colorless, stable liquid of pleasant odor. The commercial grade is a purified light acetone oil in which the di-*n*-propyl ketone is in predominance. In 1933, the Carbide and Carbon Chemicals Corporation first began to make it synthetically on a commercial scale. It is made by the butyric acid fermentation of hydrolyzed wood cellulose in the presence of lime and the

calcium butyrate produced is subjected to distillation. In the fermentation process other acids are produced with the consequence that other ketones are also present in the finished product. Butyrone is miscible with many of the organic solvents. It dissolves a wide variety of materials, some of which are caoutchouc, nitrocellulose, raw and blown oils, many natural and synthetic resins like dewaxed dammar, manila, rosin, cumar, ester gum, glyptols and waxes. The most important use of butyrone is as a solvent in lacquers and synethic resin finishes. It is also used in chemical synthesis.

Molecular weight	114.11
Boiling point	143.7° C.
Freezing point	− 32.1° C.
Specific gravity	0.8162 at $\frac{20° C.}{20° C.}$
Weight per gallon	6.79 lb. (20° C.)
Refractive index	1.4068 (20° C.)
Surface tension	25.2 dynes/cm. (25° C.)
Viscosity	0.0074 poise (20° C.)
Vapor pressure	5.2 mm. Hg. (20° C.)
Specific heat	0.553 cal./g. (25° C.)
Latent heat of vaporization	75.8 cal./g. at B.P.
Flash-point*	49° C. (120° F.)
Heat of combustion	1051 kg. cal./mole.
Solubility in water	0.53% by wt. (20° C.)
Solubility of water in butyrone	1.27% by wt. (20° C.)
Coefficient of Expansion	0.001073 (per ° C.) to 20° C. 0.001115 (per ° C.) to 55° C.
Dilution ratio	Kemsolene = 0.8 Toluene = 3.1 Final conc. ½-sec. R.S. nitrocellulose 8%

*(A S.T.M. Open Cup)

Hexone



Hexone (methyl isobutyl ketone, 2-methyl-4-pentanone) is a colorless, stable liquid of pleasant odor. It is miscible with most organic solvents and has a wide range of solubility. It will dissolve such substances as nitrocellulose, certain types of cellulose ethers, camphor, oils, such as natural, mineral, synthetic, blown and sulfonated oils, fats, waxes and many types of natural and synthetic gums and resins. It will dissolve cellulose acetate when it is admixed with ethylene dichloride. Hexone is a medium-boiling ketone and its dilution ratio for toluene is 3.5. It is a component of solvent mixtures for lacquers and finishes. Other uses are in extraction processes and in chemical synthesis.

Molecular weight	100.10
Boiling point	118.0° C.
Freezing point	− 84.7° C.

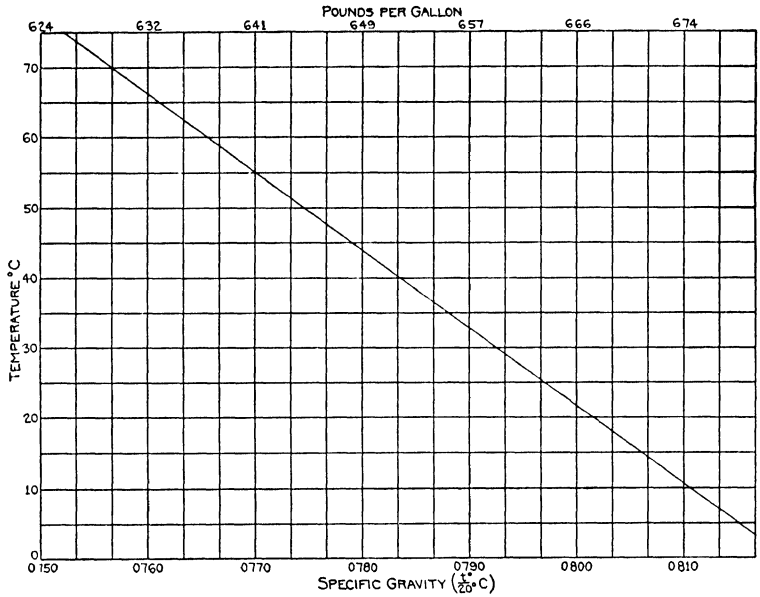


FIGURE 142. Specific Gravity and Weight per Gallon of Hexone at Various Temperatures.[2]

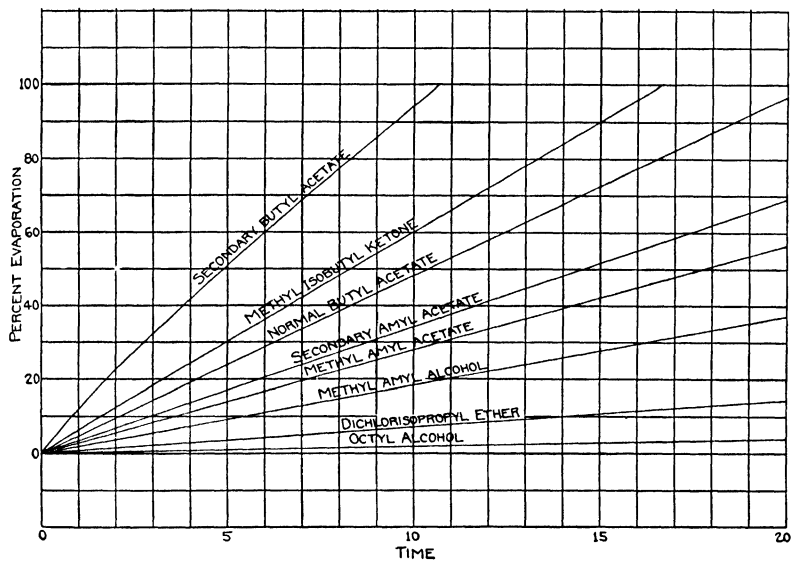


FIGURE 144. Evaporation Rate of Various Solvents at Room Temperature.[2]



FIGURE 143. Viscosity of Hexone at Various Temperatures.[2]

Specific gravity	0.8017 at $\frac{20° \text{ C.}}{20° \text{ C.}}$
Weight per gallon	6.68 lb. (20° C.)
Vapor pressure	11.2 mm. Hg. (20° C.)
Refractive index	1.3959 (20° C.)
Surface tension	25.4 dynes/cm. (25° C.)
Viscosity	0.00546 poise (25° C.)
Specific heat	0.496 cal./g. (25° C.)
Latent heat of evaporation	86.0 cal./g. at B.P.
Flash-point*	23° C. (74° F.)

*(A. S. T. M. Open Cup)

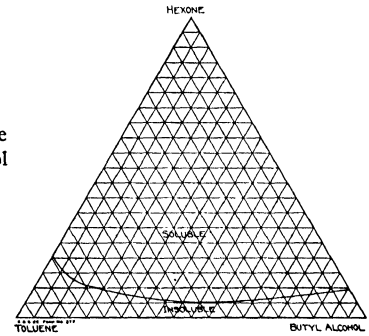


FIGURE 145.

Solubility of ½ Sec. R. S. Nitrocellulose in Mixtures of Hexone, Butyl Alcohol and Toluene.[2]

Coefficient of expansion	0.00112 (per ° C.) to 20° C. 0.001170 (per ° C.) to 55° C.
Solubility in water	1.91% by wt. (20° C.)
Solubility of water in hexone	2.81% by wt. (20° C.)
Dilution ratio	Kemsolene = 1.1 Toluene = 3.5 Final conc. ½-sec. R.S. nitrocellulose 8%

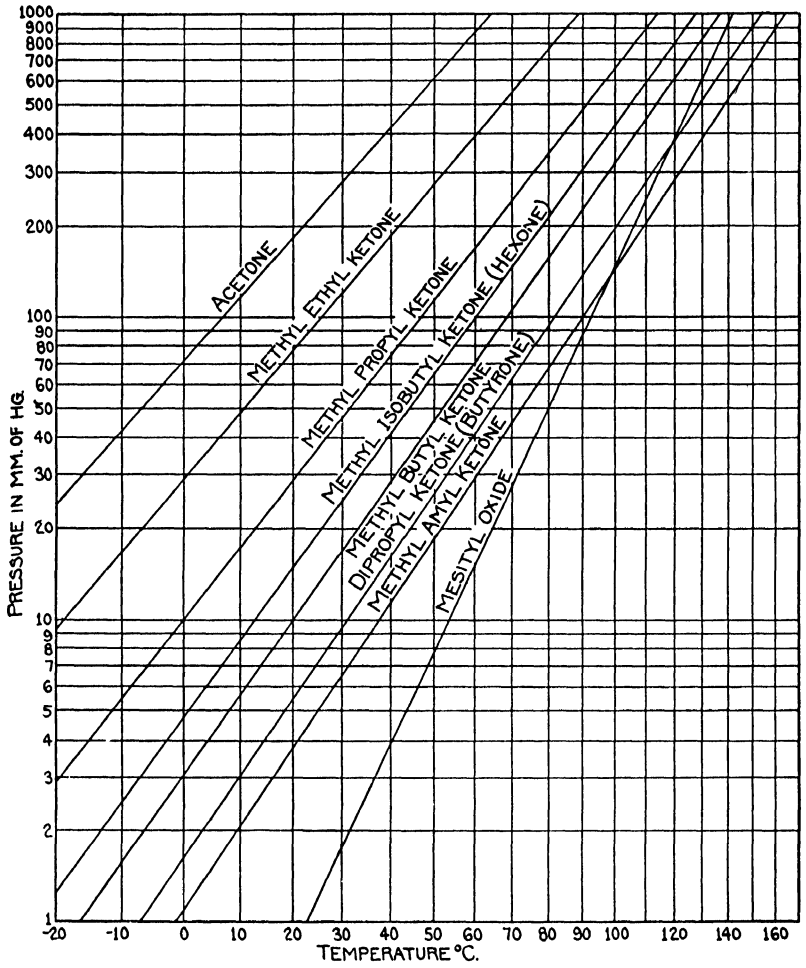


FIGURE 146. Vapor Pressure of Various Ketones at Different Temperatures.[2]

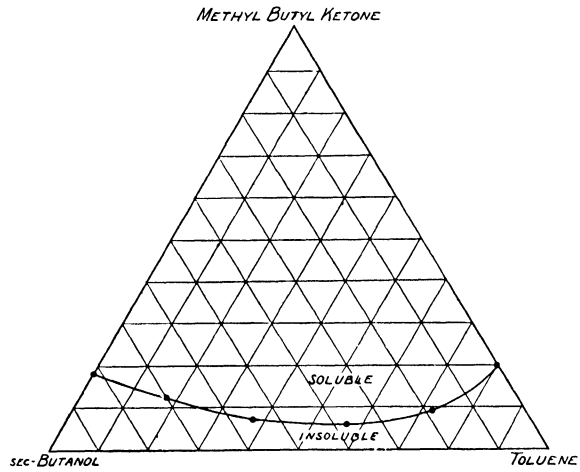


FIGURE 147. Solubility of Dry Half-Second R. S. Nitrocellulose in a System of Methyl Butyl Ketone-sec-Butanol-Toluene.[1]

Diacetone Alcohol

Diacetone alcohol, $CH_3\diagdown\atop CH_3\diagup$$C(OH)CH_2COCH_3$ (diacetone, 4-hydroxy-4-methyl pentanone-2, Pyranton A, diacetonyl alcohol, alco, Deo) a ketol or ketonic alcohol, is an inflammable liquid which, when pure, is colorless with a mint-like odor. It is made by the condensation of acetone. The commercial grades contain small quantities of acetone, mesityl oxide and so forth. Diacetone is miscible with water, alcohols, aromatic and halogenated hydrocarbons, esters, etc. It will dissolve natural resins like copals, elemi, guaiac, manila, mastic, kauri, rosin, sandarac, shellac and zanzibar, and synthetic resins like Bakelite, benzyl abietate, cumar resins, ester gum, glyptols, coumarone and so forth. It will also dissolve oils, fats, tars, cellulose esters, dyes, etc. The unusual solvent power of diacetone alcohol is owing to its structure and is consequently of particular value in the industries. In most respects it is quite similar to acetone with the difference of a slower rate of evaporation.

Diacetone alcohol is used in cellulose ester lacquers, particularly of the brushing type. Its presence in the solvent mixture produces a brilliant gloss and hard film. Numerous solvent mixtures have been proposed wherein diacetone is one of the component parts, and one in particular comprises diacetone, *n*-butyl alcohol and benzene. It is used as a solvent in lacquers, dopes and coating compositions for paper and textiles; in making artificial silk and leather, in the imitation of gold leaf, in celluloid cements and in dyeing mixtures. It finds further application in the extraction of

resins and waxes; as a preservative for animal tissue; in metal cleaning compounds, antifreeze solutions, hydraulic compression fluids, in wood preservatives and in non-aqueous stains.

	Pure	Technical
Diacetone content		85%
Boiling range		Theoretical B.P. 164° C. (Decomposes at 120° C.)
Dryness		Dry against petroleum naphtha
Acidity		Neutral
Color	Water-white	Water-white
Odor		Characteristic
Weight per gallon	7.81 lbs. (68° F.)	7.60 lbs.
Flash-point	About 55° C. (131° F.)	36° F.
Specific gravity	0.937 to 0.943 at $\frac{20° C.}{20° C.}$	0.915–0.920 at $\frac{20° C.}{20° C.}$
Water solubility	Miscible with distilled water in all proportions without turbidity	Miscible with distilled water in all proportions without turbidity
Distillation range	Distills between 130° C. and 180° C. Approximately 85% distills between 150° C. and 170° C. At atmospheric pressure slight decomposition occurs but at reduced pressures distillation can be accomplished without decomposition.	
Melting point	– 54° C. to – 57° C.	
Approximate change in wt.	0.0032 lb./gal./° F.	
Saybolt viscosity	113 sec. (– 12° C.) 674 sec. (– 30° C.) 1980 sec. (– 48° C.)	
Refractive index	1.42416 (20° C.)	
Molecular weight	116.12	
Boiling point	164° C. to 166° C. (760 mm. Hg.)	
Vapor pressure	3.3 mm. Hg. (20° C.)	
Density	0.9555 g./cc. (0° C.) 0.9306 g /cc. (25° C.)	

Mesityl Oxide

Mesityl oxide $\begin{matrix}CH_3\\ \\ CH_3\end{matrix}\!\!\diagdown\!\!\diagup C : CHCOCH_3$ [4-methyl-3-penten-2-one, isopropylidineacetone, methyl isobutenylketone] is an unsaturated ketone made by the dehydration of acetone or diacetone alcohol and it also occurs in acetone oils. It is a colorless, oily liquid of strong odor. It is miscible with alcohols and ethers and is an excellent solvent for cellulose esters and ethers, oils, gums and resins. A number of solvent mixtures have been proposed containing mesityl oxide, benzene, diacetone alcohol and others. Lacquers which contain mesityl oxide will yield films which are tough,

transparent and glossy. It is used in the flotation of ores, and in paint and varnish removers.

Boiling point	129.5° C.
Refractive index	1.444 (20° C.)
Specific gravity	0.861

Acetoxime

Acetoxime (propanoxime, acetonoxime-β-isonitroisopropane) is a ketoxime, having a chloral-like odor. It is soluble in water, alcohols, ethers and so forth, and is used as an intermediate. Some recent workers advocate its use as a solvent for cellulose ethers.

Cyclic Ketones

The cyclic ketones are remarkable solvents for resins, oils, fats and waxes. Cyclobutanone and the dimethyl and diethyl derivatives are colorless liquids, solvents for cellulose acetate, and are used in varnish making. Cyclopentanone (a dipin-ketone) is a ketone of adipic acid and it will dissolve many types of cellulose esters.

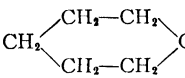
Acetophenone

Acetophenone ($C_6H_5COCH_3$, phenyl methyl ketone) is a solvent for cellulose ethers. It is also used in conjunction with alcohol, ketone, ester and other active solvents.

Boiling point	200° C
Specific gravity	1.031 (15° C.)

The brom, chlor, and nitro derivatives of acetophenone have been proposed as camphor substitutes.

Cyclohexanone

Cyclohexanone  (Sextone, Hexanon, Anon, Pimelin ketone, keto hexamethylene) is a water-white to pale-yellow, non-inflammable, non-explosive, non-toxic, non-corrosive liquid with an acetone-like odor. It is a cyclic ketone made by the high-temperature, catalytic hydrogenation of phenol and by the dehydrogenation of cyclohexanol. It is miscible in all proportions with most solvents and is a good solvent for cellulose ethers and esters, basic dyes, fats, blown oils, waxes, crude rubber, resins like ester gum, Bakelite, albertols, glyptols, rezyls, vinyls, coumarone resins, cyclohexanone resins, rosin, kauri, elemi, manila, shellac, unrun copals and so forth. It has a very high dilution ratio with benzene, toluene and xylene. Its solvency for basic dyes makes it applicable for use in wood stains. It is also used in spraying and brushing lacquers, and as a medium-boiler. Its low rate of evaporation together with its strong solvent powers impart to lacquers blush-resistance, good flow and working qualities, and give films which are clear, smooth, glossy and strongly

adhesive. It is particularly effective for blending nitrocellulose with spirit-soluble and hydrocarbon-soluble resins and oils. Cyclohexanone finds application in the air-drying and stoving type of synthetic resins, in plastics and molding powders, in paint and varnish removers and in spot and stain removers. It is also used for degreasing metals, as a solvent for fats, oils, waxes and bitumens; in polishes; as a leveling agent in dyeing; and finally in delustering silk.

Methyl Cyclohexanone

Methyl cyclohexanone ($CH_3C_5H_9CO$, methyl anon, Sextone B) is a water-white to pale-yellow liquid with an odor resembling that of acetone. It is a mixture of cyclic ketones made by high-temperature, catalytic hydrogenation of cresols or by the dehydrogenation of methyl cyclohexanol. It closely resembles cyclohexanone in its physical properties, miscibility, tolerance for non-solvents and solvent action. As solvents, methyl cyclohexanone and cyclohexanone are interchangeable. Methyl anon is used to blend pyroxylin with resins, oils and rubber in

TABLE 101.—Solvent Properties Affecting Blush Resistance[1]

Solvent	Solubility of: Solvent in H_2O	Solubility of: H_2O in solvent	Wet-Bulb Depression (° C.)
Acetone	Infinite	Infinite	30.5
Methyl ethyl ketone	22.6	9.9	21.5
Methyl propyl ketone	6.0	3.6	12.0
Methyl butyl ketone	3.44	3.70	6.5
Methyl amyl ketone	1.95	2.15	3.0
Ethyl acetate	7.9	3.0[a]	21.5
n-Butyl acetate	2.3	2.4	6.5

[a]For C.P. product containing no alcohol; commercial material dissolves more water than this.

TABLE 102.—Blushing Tests on Lacquers Containing Ketones, etc [1]

Standard Formula	Solvent % by volume
14 grams (wet) ½-sec. R. S. nitrocellulose	60 toluene
5 grams Ester gum	10 *n*-butyl alcohol
5 grams dibutyl phthalate	20 ethyl acetate
100 cc. solvent	10 other solvent

Dry Bulb (° F.)	Dry Bulb (° C.)	Wet Bulb (° F.)	Wet Bulb (° C.)	Difference (° F.)	Relative Humidity %	Behavior of Lacquer When Other Solvent Is: Me Pr ketone	Me Bu ketone	Me Am ketone	*n*-Butyl acetate	*sec*-Butyl acetate
87	30.6	85	29.4	2	92	−	−	−	−	−
87	30.6	84	28.9	3	89	−	−	−	−	−
86	30	83	28.3	3	89	−	−	−	−	−
82	27.8	79	26.1	3	88	−	−	±	−	−
87	30.6	83	28.3	4	85	−	−	±	±	−
86	30	82	27.8	4	85	−	±	+	±	−
85	29.4	81	27.2	4	85	−	±	+	±	−
83	28.3	79	26.1	4	85	−	±	+	±	−
87	30.6	82	27.8	5	81	−	±	+	±	−
85	29.4	80	26.7	5	81	±	+	+	+	±
84	28.9	79	26.1	5	80	±	+	+	+	+
87	30.6	81	27.2	6	77	+	+	+	+	+
85	29.4	79	26.1	6	77	±	+	+	+	+
87	30.6	79	26.1	8	70	+	+	+	+	+

−Bad blush; ± slight blush; + no blush.

lacquers. Other uses for it are in crystallizing lacquers for the purpose of retarding evaporation to permit crystal growth, in slow setting varnish removers, in nitro and acetylcellulose lacquers, and as a solvent for crude and chlorinated rubber.

TABLE 103.—Properties of Ketones

	Boiling Point (° C.)	Flash-Point (° C.)	Specific Gravity	Dilution Ratio			White Spirits
				Benzene	Toluene	Xylene	
Acetone	56.5	– 16	0.797 (15)		4.95	3.65	0.55
Acetonylacetone						1.8	
Acetophenone	200.0		1.031 (15)				
Cyclobutanone	99.0		0.930				
Cycloheptanone	180.0		0.969				
Cyclohexanone	154–156	117	0.945	6.5	7.25	7.5	1.25
Diacetone alcohol	160–170	55	0.941	2.75	3.25	2.86	
Diethyl ketone	101.7		0.814		3.0		0 7
Di-isobutyl ketone	165.0				1.5		0.6
Di-isopropyl ketone	124.0		0.806				
Di-*n*-propyl ketone	144.0	49.0	0.823		3.1	2.7	0 9
Hexone	118	23.0	0.802		3.5		1.1
Mesityl oxide	129.5		0.861		3.8		0.9
Methyl acetone		32° F.	0.830		4.7		0.7
Methyl amyl ketone	150.2	41.1	0.827				
Methyl butyl ketone	127.2	22.8	0.821				
Methyl cyclohexanone	160–170	130	0.925	5.5	5.5	7.0	1.25
Methyl cyclohexone						4.5	1.0
Methyl ethyl ketone	79.6	– 7.2	0.808 (20)		4.3	3.1	0.9
Methyl *n*-hexyl ketone					3.6		0.9
Methyl isopropyl ketone	118		0.815		3.6		0.85
Methyl propyl ketone	101.7		0.812		4.0	3.42	1.0
Tetraethylacetone	203.0						

Literature References

[1] Park, J. G., and Hofmann, H. E., *Ind. Eng. Chem.*, **24**, 132 (1932).
[2] Carbide & Carbon Chemicals Corp., New York, N. Y.
[3] Commercial Solvents Corporation, New York, N. Y.
[4] Remler, R. F., "Acetone: Its Production and Uses," National Wood Chemical Association.
[5] Scheele, W. T., U. S. Patent 1,408,035 (Feb. 1922).
[6] Underkofler, L. A., Christensen, L. M., and Fulmer, E. I., *Ind. Eng. Chem.*, **28**, 350 (1936).

General References

Merrimac Chemical Company, Everett, Mass.
Shell Chemical Company, San Francisco, Cal.

Chapter 14

Ethers

Ethyl Ether

Ethyl ether [$(C_2H_5)_2O$, ether, sulfuric ether, anesthetic ether, vinic ether] is a colorless, inflammable, very volatile liquid of pleasant ethereal odor and is strongly narcotic. It was in 1840 that ethyl ether was first made from ethyl alcohol and sulfuric acid and with but few improvements this method is still in existence today. Ethyl ether is completely miscible with alcohol and many organic solvents. It is a very good solvent dissolving many organic substances, among which are alkaloids, oils, dyes, fats, gums, resins, nitrocellulose, perfumes, smokeless powder and so forth. A mixture of ether and ethyl alcohol possesses excellent solvent properties for nitrocellulose. This mixture is, and has been, extensively used in celluloid manufacture. Although ether is used as a general anes-

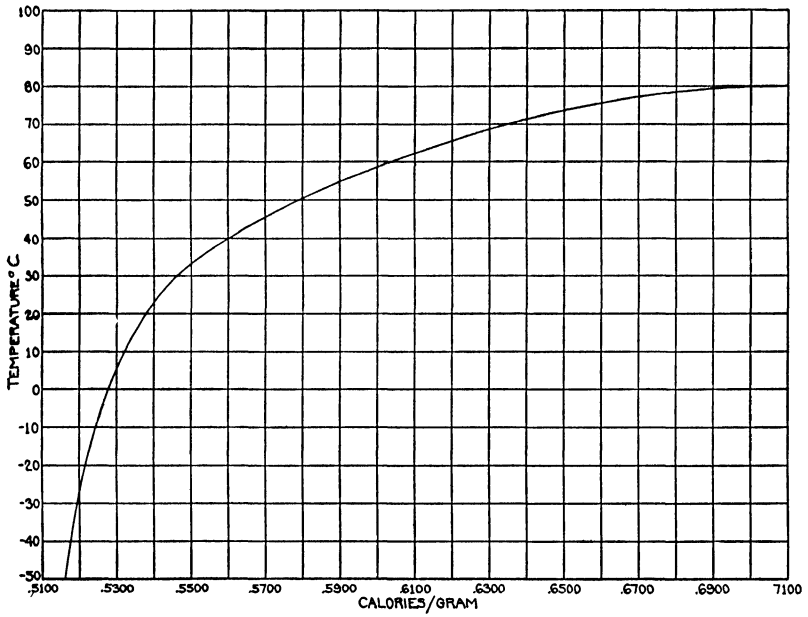


FIGURE 148. Specific Heat of Ethyl Ether at Various Temperatures.[1]

thetic in surgery, the bulk of its manufacture is utilized as a solvent for nitrocellulose in making artificial silk, gun cotton, collodion and plastics. An equally important use for ether is as an extracting medium for alkaloids, fats, oils and waxes, and for the extraction and concentration of acetic acid. Other uses are as a reagent in Grignard reaction, as a refrigerant, in motor fuels and dry-cleaning.

Molecular weight	74.08
Boiling point	34.5° C.
Freezing point	− 116.2° C.
Specific gravity	0.7147 at $\frac{20° \text{ C.}}{20° \text{ C.}}$
Weight per gallon	1.3542 (17° C.)
Surface tension	17.0 dynes/cm. (20° C.)
Viscosity	0.00233 poise (20° C.)
Vapor pressure	442 mm. Hg. (20° C.)
Specific heat	0.5476 cal./g (30° C.)
Flash-point	− 40° C.
Heat of combustion	651 kg. cal /mol.
Apparent ignition temperature in air	190° C.
Latent heat of evaporation	83.96 cal /g. at B.P.
Electrical conductivity	4×10^{-13} recip. ohms (25° C.)
Explosive limits in air	2.34–6.15% (20° C.)
Solubility in water	6.89% by wt. (20° C.)
Solubility of water in ethyl ether	1.26% by wt. (20° C.)
Coefficient of expansion	0.00164 per 1° C.

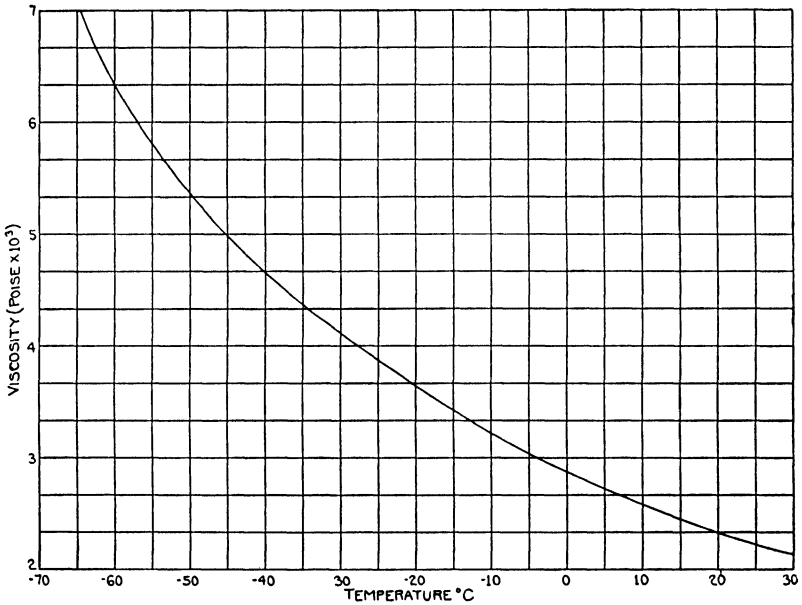


FIGURE 149. Viscosity of Ethyl Ether at Various Temperatures.[1]

TABLE 104.—Physical Properties of Ethylene Dichloride, Dichloroethyl Ether and Isopropyl Ether[2]

Property	Ethylene Dichloride $Cl—CH_2—CH_2—Cl$	Dichloroethyl Ether $Cl—CH_2—CH_2—O—CH_2—CH_2—Cl$	Isopropyl Ether $(CH_3)_2—CH—O—CH(CH_3)_2$
Molecular weight	98.95	142 98	102.11
Boiling point (760 mm.), ° C.	83.5	178.0	67 5
Freezing point, ° C.	−36.0	−51.7	<−60
Specific gravity	1.2569 (20°/4° C.)	1.22 (20°/20° C.)	0.7247 (20°/20° C.)
Weight per gallon, pounds	10.53 (15° C.)	10.1 (20° C.)	6.04 (25° C.)
Refractive index	1 444 (20° C.)	1.457 (20° C.)	1.3678 (23° C.)
Surface tension, dynes/sq. cm.	37.5 (25° C.)	41.8 (25° C.)	32 (23° C.)
Viscosity, centipoises	0.78 (25° C.)	2.0653 (25.5° C.)	0.379 (25° C.)
Vapor pressure, mm. (20° C.)	61.6	(Approx.) 0.73 mm.	158
Specific heat, cal./g.	0.3054 (30° C.)	0.369 (30° C.)	0.526 (22–27° C.)
Flash-point (closed cup), ° F.	58	131	−6.7
Apparent ignition temperature in air, ° C.	449	369	
Latent heat of evaporation, cal./g.	77.34 (82.2° C)	64.1 (178° C.)	68.2 (67.5° C.)
Solubility	Practicallv insoluble in water, soluble in most organic liquids.		

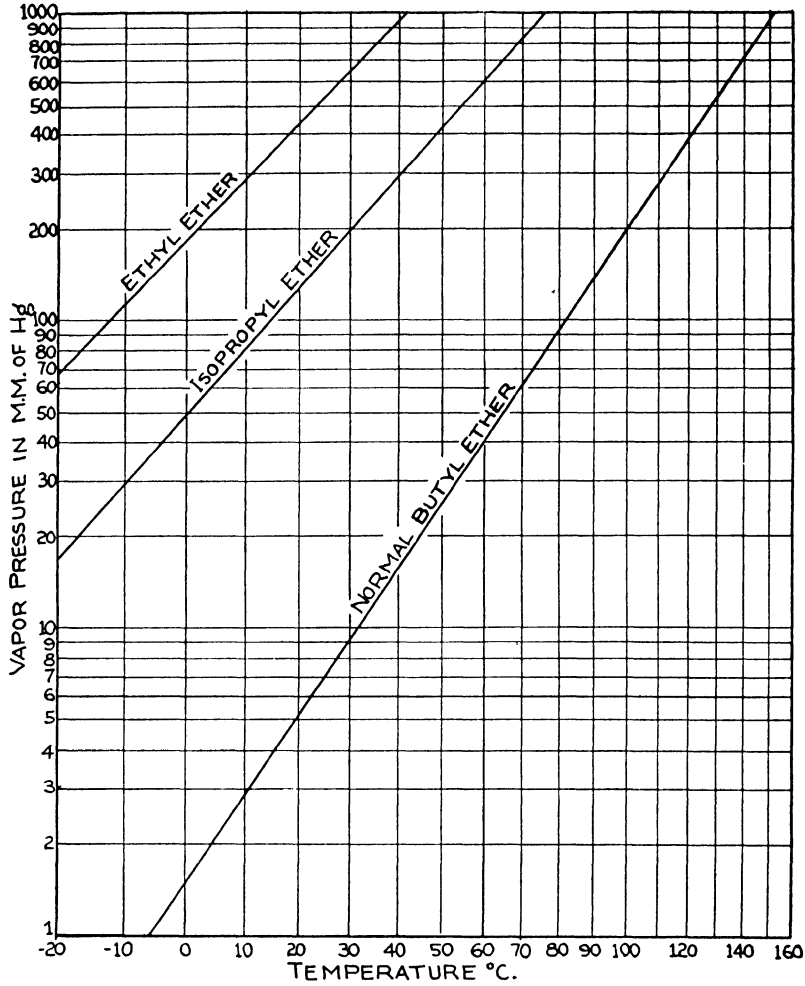


FIGURE 150. Vapor Pressure of Some Ethers at Various Temperatures.[2]

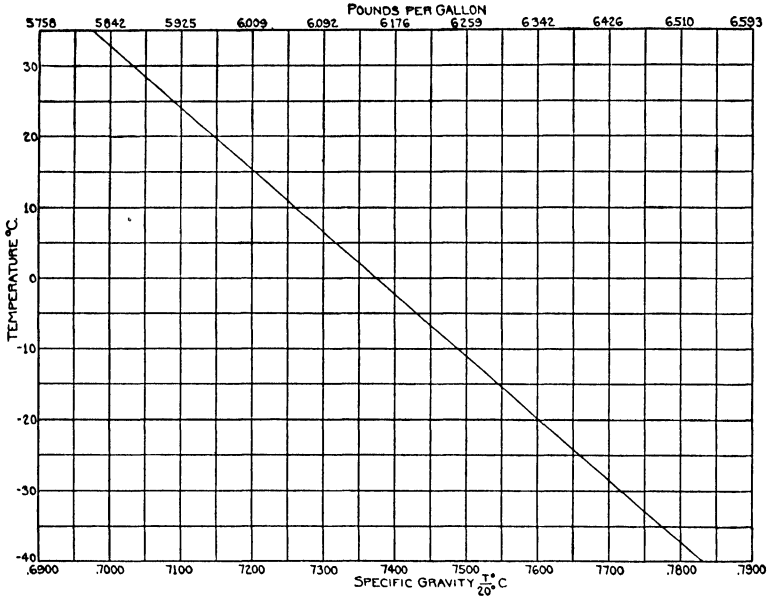


FIGURE 151. Specific Gravity and Weight per Gallon of Ethyl Ether at Various Temperatures.[1]

Isopropyl Ether

The properties of isopropyl ether are very similar to those of ethyl ether. It has added qualities of a higher boiling point and lower vapor pressure, which are of distinct advantage for extraction purposes. It is miscible with most organic solvents and is a solvent for most types of oils, fats, waxes and natural and synthetic resins. By adding isopropyl alcohol to this ether its range of solvency is increased, and in consequence it will dissolve dyes, cellulose esters and so forth. It is used in extraction processes owing to the fact that it can be recovered and used over and over again. These processes include dewaxing, and extraction and recovery of acetic acid. It is also used in paint and varnish removers, in spotting compositions and in rubber cements.

Molecular weight	102.11
Boiling point	67.5° C. (760 mm.)
Specific gravity	0.7247 at $\frac{20° \text{ C.}}{20° \text{ C.}}$
Weight per gallon	6.04 (25° C.)
Specific volume	151.6 cc. at B.P.
Refractive index	1.3678 (23° C.)
Surface tension	32 dynes/sq. cm. (23° C.)
Viscosity	0.379 centipoise (25° C.)

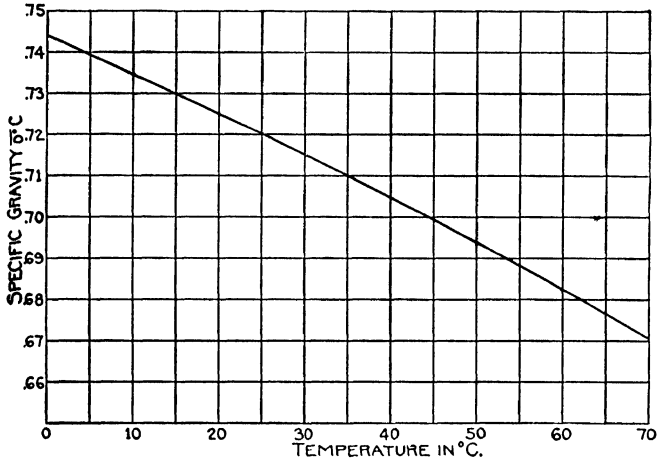


FIGURE 152. Specific Gravity and Weight per Gallon of Isopropyl Ether at Various Temperatures.[2]

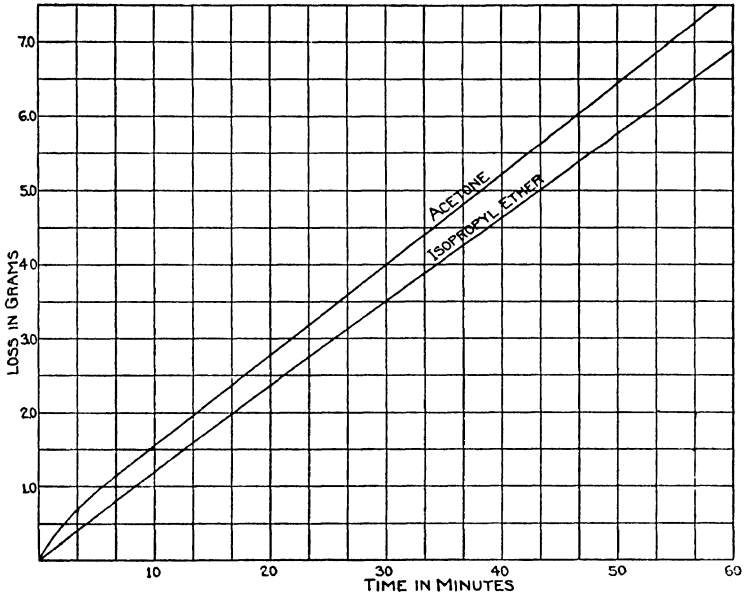


FIGURE 153. Evaporation Rate of Acetone and Isopropyl Ether at Room Temperature.[2]

Vapor pressure	158 mm. (20° C.)
Specific heat	0.526 cal./g. (22°–27° C.)
Flash-point	– 21.5° C. (closed cup)
Solubility	Soluble in most organic liquids. Insoluble in water
Heat of evaporation	68.2 cal./g. at B.P.
Freezing point	– 60° C.

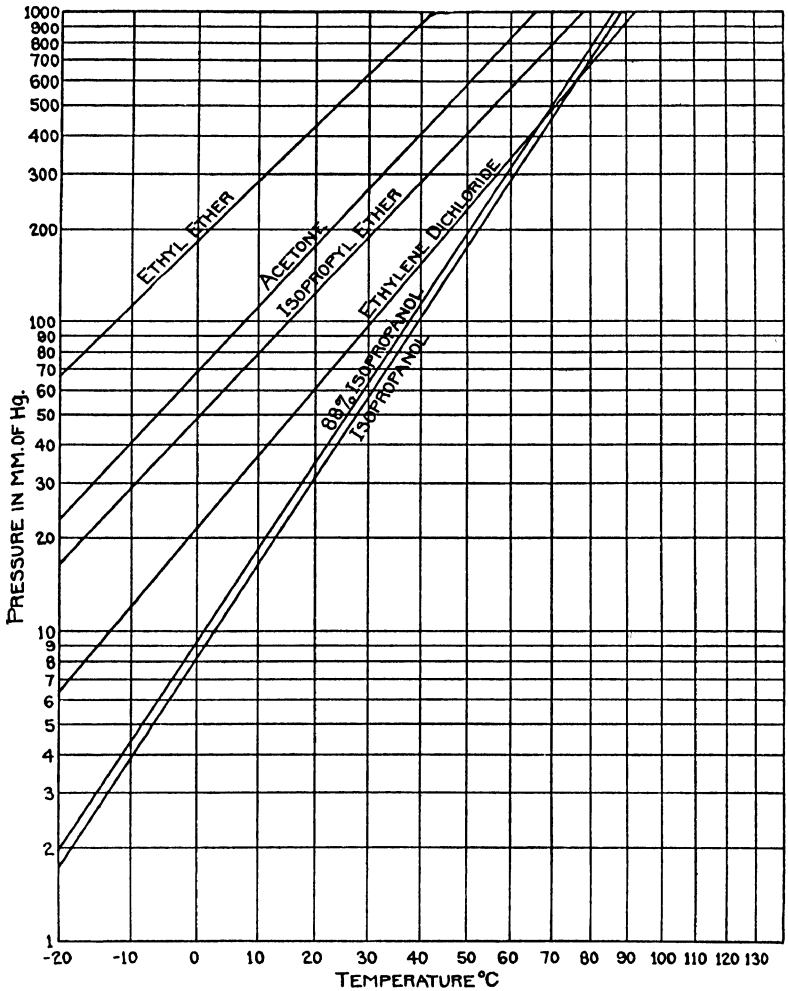


FIGURE 154. Vapor Pressure of Various Solvents at Different Temperatures.[2]

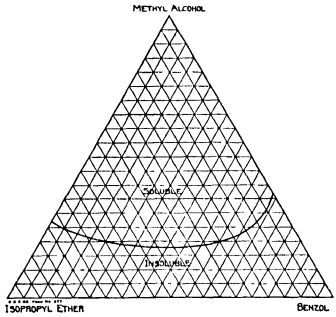


FIGURE 155. Solubility of ½-Second R S. Nitrocellulose in Mixtures of Methyl Alcohol, Isopropyl Ether and Benzene.[2]

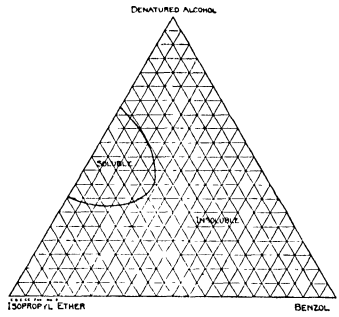


FIGURE 156. Solubility of ½-Second R.S. Nitrocellulose in Mixtures of Denatured Alcohol (C. D. No. 1), Isopropyl Ether and Benzene.[2]

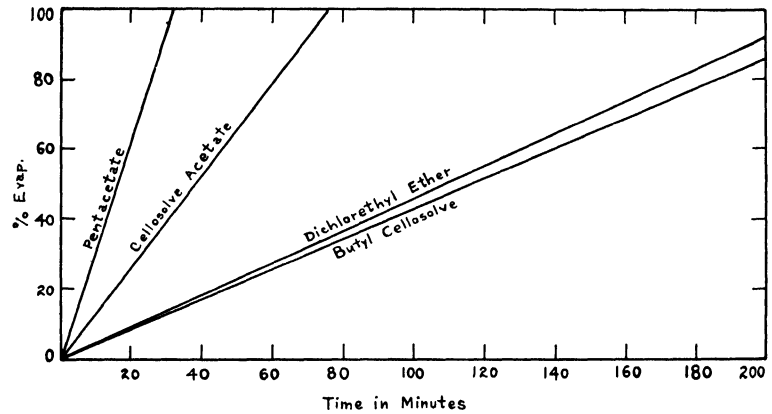


FIGURE 157. Evaporation Rate of Various Solvents at 25° C. in Circulating Air.[2]

Normal Butyric Ether

Butyric ether $[(CH_3)_3CHOCH(CH_3)_3]$ is a colorless, stable liquid. It is a solvent for oils, fats and natural and synthetic resins; and at higher temperatures it will dissolve waxes. It is used in extraction processes owing to its solvency, high boiling point and stability.

Acidity	0.03% butyric acid (max.)
Boiling range	137–143° C. (760 mm.)
Specific gravity	0.756–0.771 at $\frac{20° C.}{20° C.}$

Acetal*

Acetal $CH_3CH\begin{matrix}O \cdot C_2H_5 \\ O \cdot C_2H_5\end{matrix}$ (M.W. 118.1, diethyl acetal, α-α,diethoxy-

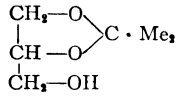
*The Acetals are cyclic ethers of polyvalent alcohol and are made by condensing ketones or aldehydes with polyhydric alcohols.

ethane, ethylidene diethylic ether, diethyl aldehyde) is a colorless, mobile, quite stable liquid of agreeable odor. The solvent properties of acetal resemble those of a mixture of alcohol and ether. Owing to its property of taking up water and forming acetaldehyde and anhydrous alcohol, it can be used in places where anhydrous alcohol is required.

Acetal	97% min.
Boiling point	103.6° C.
Boiling range	97°–112° C.
Metal, chlorine and sulfates	None
Wt. per gallon	6.87 lbs.
Specific gravity	0.823–0.826 (20° C.)

Isopropylidene Glycerol

The condensation of glycerol and acetone yields isopropylidene glycerol:



Ethylidene Glycerol

Ethylidene glycerol is made by the adsorption of acetylene by glycerol. The acetals in the presence of water will dissolve cellulose ethers and esters, gums and resins.

Various Proposed Ethers

Amyl ether
Benzoic ether
Oxalic ether
Sebacic ether
Valeric ether
..... Solvents for nitrocellulose

Ethyl isoamyl ether
Ethyl isobutyl ether
Methyl isoamyl ether
Methyl isobutyl ether
..... Solvents for cellulose acetate

Dicresyl glyceryl ether
Diphenyl glyceryl ether
Ethyl phenyl ether
Clyceryl benzyl ether
Methyl phenyl ether
β-Naphthyl ether
..... Solvents for cellulose esters and ethers

Diphenyl ether
Ethyl naphthyl ether
Pentaerythrite ether
Phenyl benzyl ether
..... Stabilizers for gelatinous explosives

Amylidene diethyl ether
Amylidene dimethyl ether
Catechol methyl ether
Methyl benzyl ether
Pyrocatechol ethyl ether
..... These are advocated as camphor substitutes for nitro- and acetyl cellulose

Acetyl diphenyl ether
Amylidene diethyl ether
Amylidene dimethyl ether
..... Camphor substitutes

Alkyl benzyl ether Aryl benzyl ether	.....Solvents for cellulose ethers
Benzylidene glycerol	Methylene ethylenic ether
Ethylidene glycollic ether	Methylene glycerol
Dibenzyl glycol	Ethylene butylidene ethers
Dichlorbenzyl glycol	Ethylene ethylidene ethers
Dixylylglycol	Tribenzyl glyceryl ethers

Monomethyl Ether of Ethylene Glycol

Monomethyl ether of ethylene glycol $\begin{matrix}CH_2OH\\|\\CH_2OCH_3\end{matrix}$ ($CH_2OHCH_2OCH_3$, methyl "Cellosolve," methyl glycol, methoxy ethanol) is a colorless, limpid, stable liquid having a bland odor. It is miscible with water, aliphatic and aromatic hydrocarbons, alcohols, ketones, glycols and so forth. It is a solvent for essential oils, lignin, dammar, elemi, ester gum, kauri, mastic, rosin, sandarac, shellac, zanzibar, nitro- and acetylcellulose, alcohol-soluble dyes and many synthetic resins. Carroll[3] has proposed a mixture of aromatic hydrocarbons, glycols and glycol ethers as a solvent for ethyl cellulose. Its solvency for cellulose esters is augmented when a ketone or a halogenated hydrocarbon is added to monomethyl ether of ethylene glycol. The uses for methyl "Cellosolve" are as a solvent in quick-drying varnishes and enamels, in conjunction with aliphatic, aromatic and halogenated hydrocarbons, alcohols, ketones and so forth; in solvent mixtures and thinners for lacquers and dopes; and as a penetrating and leveling agent in dyeing processes, especially in the dyeing of leather, animal and vegetable fibers. Other uses are as a fixative in perfumes and as a solvent in odorless nail-polish lacquers. Methyl "Cellosolve" should not be added to nitrocellulose lacquers containing albertols, cumar resins or ester gum owing to the fact that it will cause incompatibility between these substances.

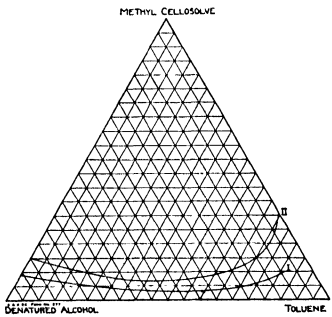


FIGURE 158. Solubility of ½-Second R.S. Nitrocellulose in Mixtures of Methyl "Cellosolve," Denatured Alcohol and Toluene. I denotes solution commences, II a 10% solution easily made.[2]

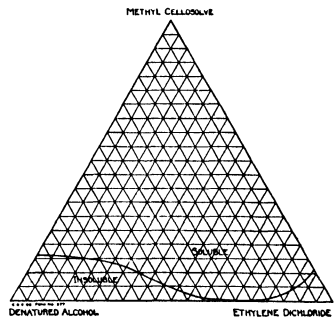


FIGURE 159. Solubility of ½-Second R.S. Nitrocellulose in Mixtures of Methyl "Cellosolve," Denatured Alcohol and Ethylene Dichloride.[2]

Molecular weight	76.06
Boiling point	124.5° C. (760 mm.)
Specific gravity	0.9748 at $\frac{15° \text{ C.}}{15° \text{ C.}}$
Weight per gallon	8.11 lbs (15° C.)
Refractive index	1.4028 (20° C.)
Surface tension	35 dynes/sq. cm. (20° C.)
Viscosity	1.6 centipoises (25° C.)
Vapor pressure	7.5 mm. Hg. (20° C.)
Specific heat	0.534 (20°–25° C.)
Latent heat of evaporation	135 cal./g. (124.5° C.)
Flash-point	32° C. (89.6° F.)
Apparent ignition temperature in air	288° C. (551° F.)

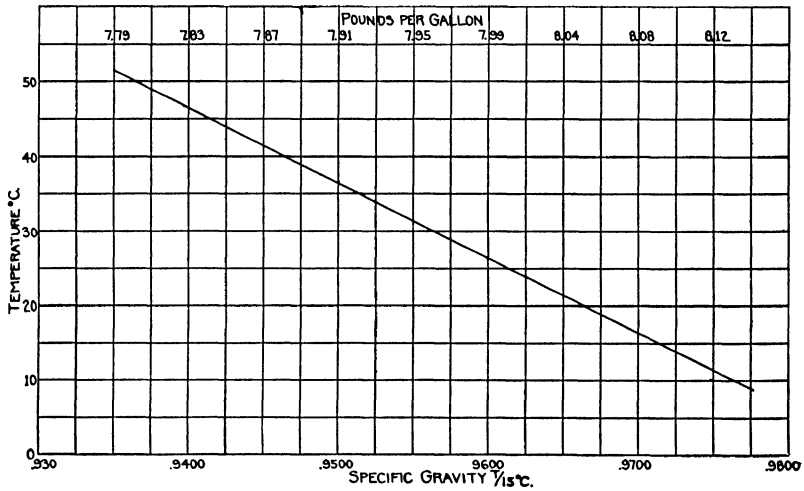


FIGURE 160. Specific Gravity and Weight per Gallon of Methyl "Cellosolve" at Various Temperatures.[2]

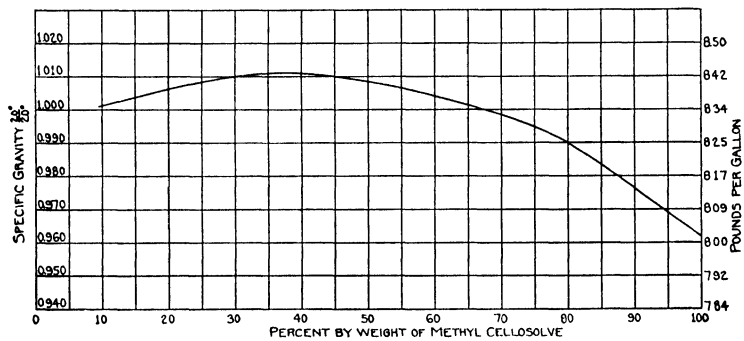


FIGURE 161. Specific Gravity and Weight per Gallon of Aqueous Solutions of Methyl "Cellosolve."[2]

Electrical Conductivity	1.09×10^{-6} recip. ohms
Solubility	Miscible with water and most organic liquids

Dilution ratios
(approx. 8% cellulose ester)

	Water	Toluene	V.M. & P Naphtha
Nitrocellulose	0.25	4.75	0.50
Cellulose acetate	0.15	1.24	0.25

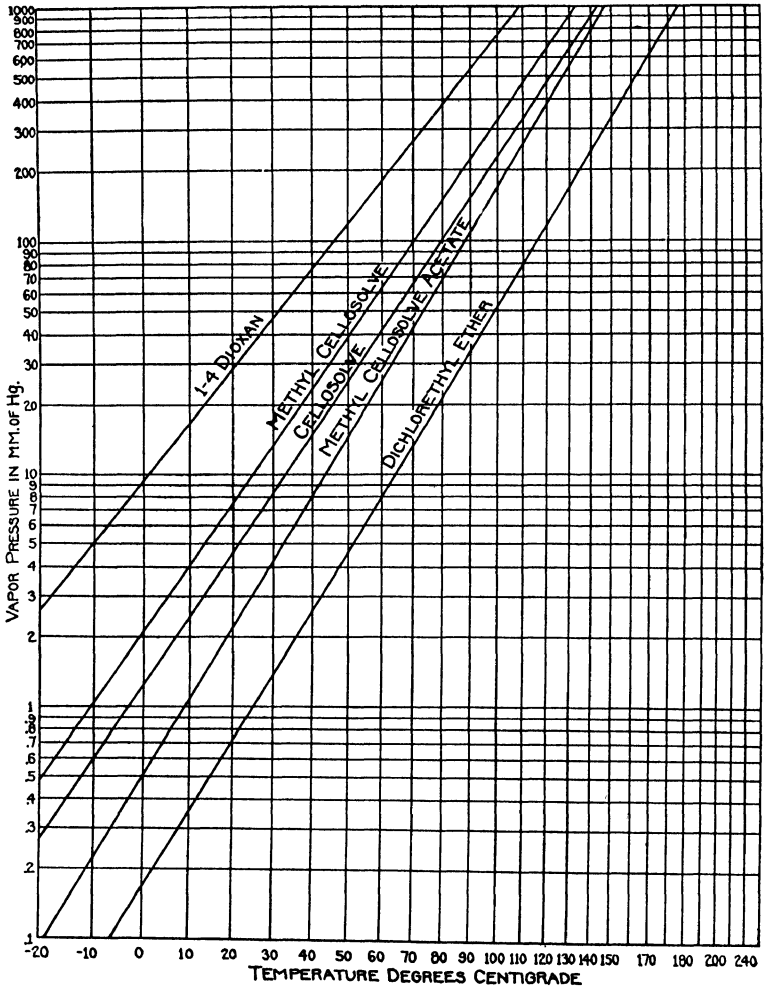


FIGURE 162. Vapor Pressures of Various Solvents at Different Temperatures.[8]

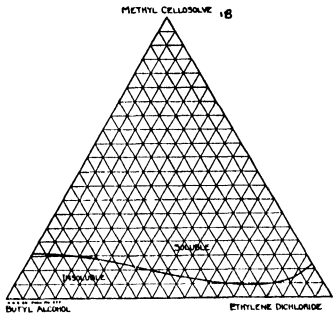


FIGURE 163. Solubility of ½ Second R. S. Nitrocellulose in Mixtures of Methyl "Cellosolve," Butyl Alcohol and Ethylene Dichloride.[2]

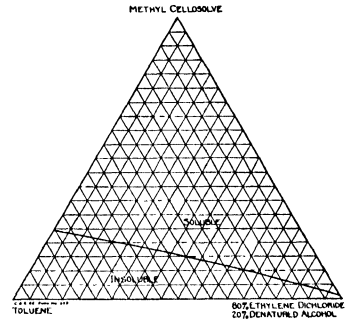


FIGURE 164. Solubility of ½ Second R. S Nitrocellulose in Mixtures of Methyl "Cellosolve," Toluene and 80% Ethylene Dichloride + 20% Denatured Alcohol.[2]

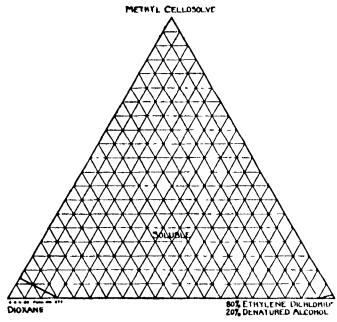


FIGURE 165. Solubility of ½ Second R S. Nitrocellulose in Mixtures of Methyl "Cellosolve," 1-4 Dioxane and 80% Ethylene Dichloride + 20% Denatured Alcohol.[2]

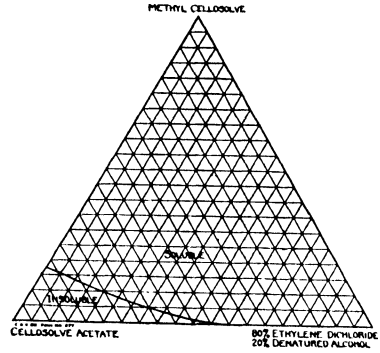


FIGURE 166. Solubility of Low Viscosity Cellulose Acetate in Mixtures of Methyl "Cellosolve," "Cellosolve" Acetate and 80% Ethylene Dichloride + 20% Denatured Alcohol.

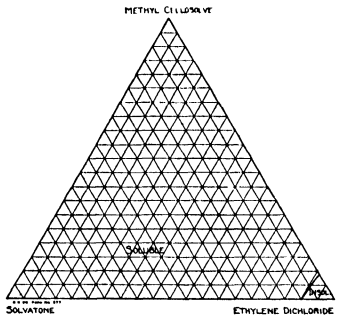


FIGURE 167. Solubility of Low Viscosity Cellulose Acetate in Mixtures of Methyl "Cellosolve," Solvatone and Ethylene Dichloride.[2] (Solvatone—80% Acetone, 10% Isopropanol, 10% toluene.)

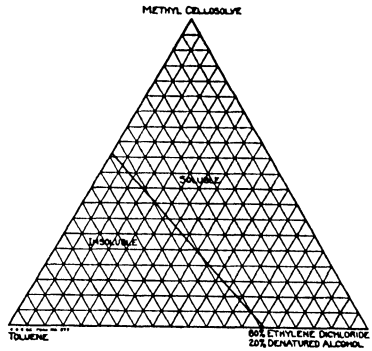


FIGURE 168. Solubility of Low Viscosity Cellulose Acetate in Mixtures of Methyl "Cellosolve," Toluene, and 80% Ethylene Dichloride + 20% Denatured Alcohol.[2]

Monoethyl Ether of Ethylene Glycol

Monoethyl ether of ethylene glycol $\begin{matrix}CH_2OH\\|\\CH_2OC_2H_5\end{matrix}$ (ethyl glycol, "Cellosolve," Solvulose) is a colorless, stable, narcotic liquid of faint odor. It is com-

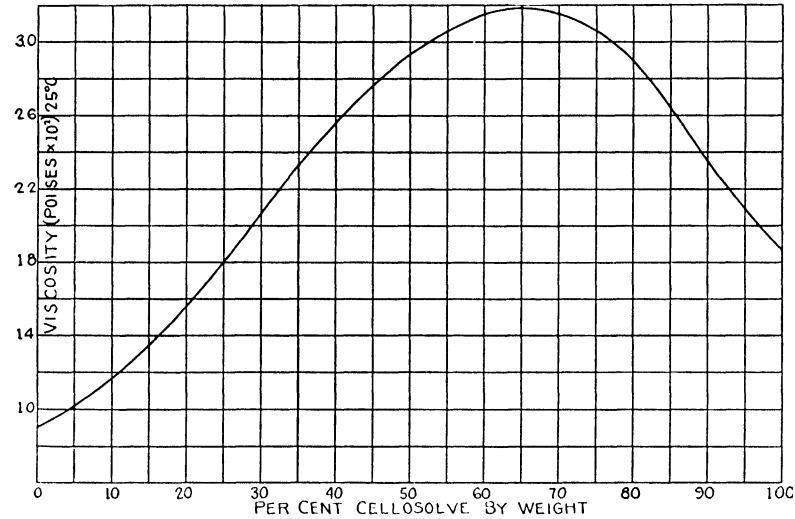


FIGURE 169. Viscosity of Aqueous Solutions of "Cellosolve" (99%) at 25° C.[2]

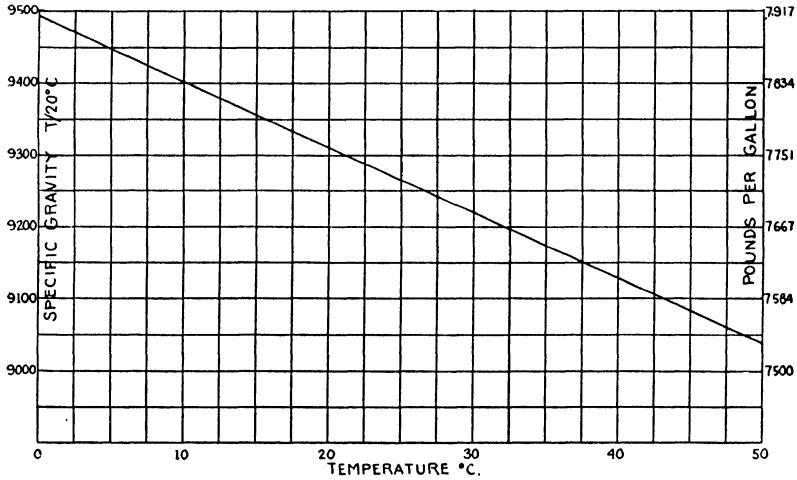


FIGURE 170. Specific Gravity and Weight per Gallon of "Cellosolve" (99%) at Various Temperatures.[2]

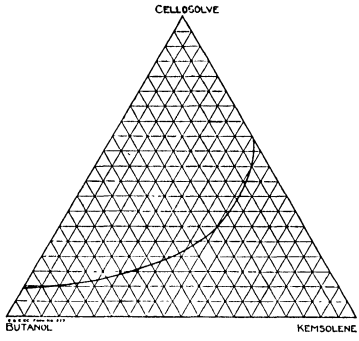


FIGURE 171. Solubility of ½-Second R. S. Nitrocellulose in Mixtures of "Cellosolve," Butanol and Kemsolene.[12]

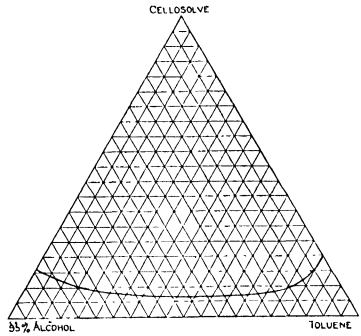


FIGURE 172. Solubility of ½-Second R. S. Nitrocellulose in Mixtures of "Cellosolve," 95% Alcohol and Toluene.

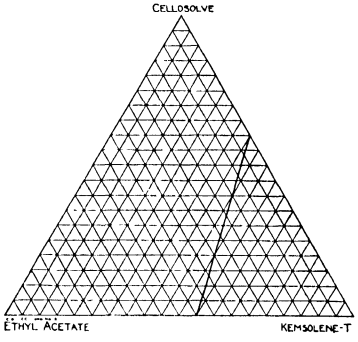


FIGURE 173. Solubility of ½-Second R. S. Nitrocellulose in Mixtures of "Cellosolve," Ethyl Acetate and Kemsolene T.

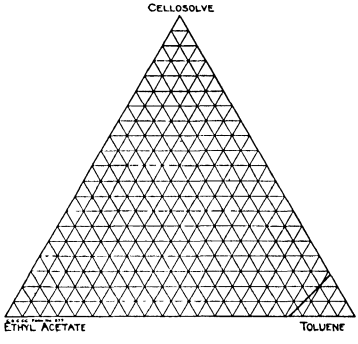


FIGURE 174. Solubility of ½-Second R. S. Nitrocellulose in Mixtures of "Cellosolve," Ethyl Acetate and Toluene.

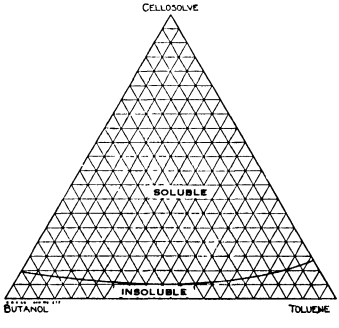


FIGURE 175. Solubility of ½-Second R. S. Nitrocellulose in Mixtures of "Cellosolve," Butanol, and Toluene.[3]

pletely miscible with water and hydrocarbons and is a solvent for natural and synthetic resins, such as benzyl abietate, copal, cumar resins, dammar, ester gum, elemi, mastic, sandarac, glyptols, ketone-aldehyde resins, vinyl resins, cellulose nitrate and some types of cellulose ethers. Cellulose acetate, however, is soluble in hot monoethyl ether of ethylene glycol or in a mixture of the latter with an active solvent. "Cellosolve," owing to its excellent solvent properties for nitrocellulose, its inodorous qualities, and high tolerance for aromatic hydrocarbons, is extensively used in brushing and commercial

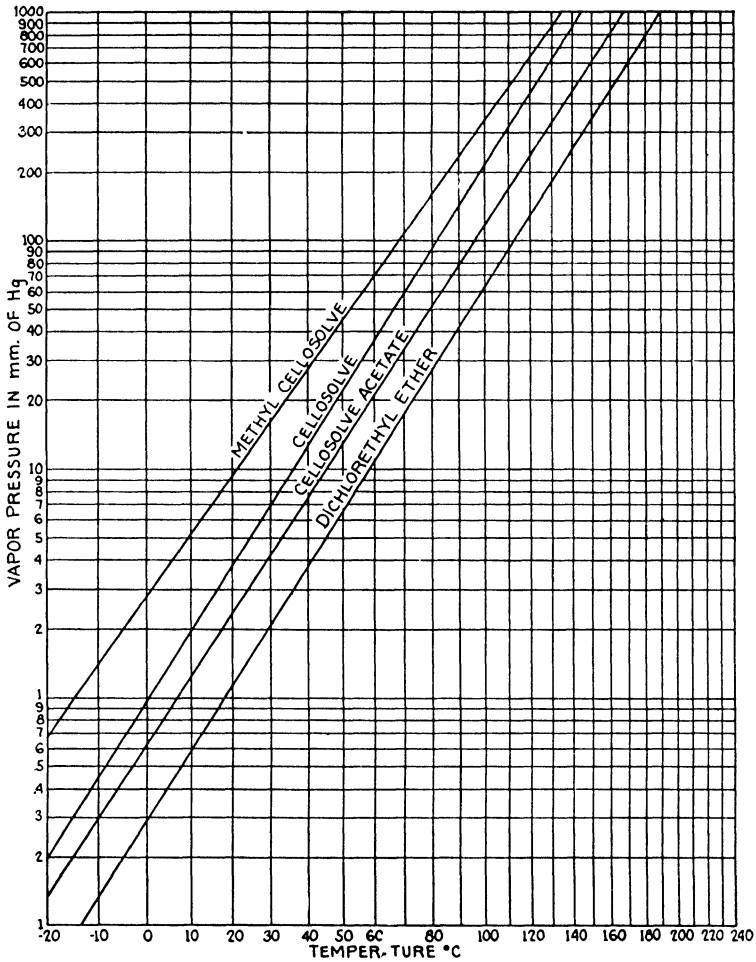


FIGURE 176. Vapor Pressure of "Cellosolves" and Dichlorethyl Ether at Various Temperatures.[2]

lacquers. It is also used as a mutual solvent for some types of nitrocellulose and resins, some of which are dewaxed dammar, rosin, elemi, elemi-rosin ester, bleached shellac, shellac-ester gum, dammar-ester, gum-kauri, pontianac, manila, glyptols and the oxidized rosin-esters. Its solubility and clarity of solution are improved by adding either high-boiling alcohols or esters to monoethyl ether of ethylene glycol. This ether is used in non-aqueous stains, in varnish removers and cleaning solutions; as a penetrating and leveling agent in the dyeing processes of leather, paper and textiles; and as a solvent and plasticizer in inks, films, paints, varnishes and plastics made of cellulose esters and ethers.

Molecular weight	90.08
Boiling point	134.8° C. (760 mm.)
Specific gravity	0.9360 at $\frac{15°\text{ C.}}{15°\text{ C.}}$
Weight per gallon	7.8 lbs. at $\frac{15°\text{ C.}}{15°\text{ C.}}$
Refractive index	1.4060 (25° C.)
Surface tension	32 dynes/sq. cm. (25° C.)
Viscosity	1.861 centipoises (25° C.)
Vapor pressure	3.7 mm. Hg. (20° C.)
Specific heat	0.555 (20°–25° C.)
Flash-point	37.5° C. (99° F.)
Fire point	40° C. (104° F.)
Solubility	Miscible with water and most organic liquids
Dilution ratios	Water 0.30 Toluene 5.3 V.M. & P. naphtha 1 05 Final concentration ½-sec. R.S. nitrocellulose solution, approx. 8%
Electrical conductivity	6.88×10^{-6}

Diethyl Ether of Ethylene Glycol

Diethyl ether of ethylene glycol is a colorless, limpid liquid of faint odor. It is partially miscible with water, and is a solvent for cumar resins, dammar, elemi, ester gum, kauri, mastic, shellac and cellulose nitrate, and will dissolve cellulose ethers when admixed with ethyl alcohol or ethyl acetate. Carbide and Carbon Chemicals Corporation has patented solvent mixtures for cellulose esters composed of monoalkyl glycol ethers, glycol monoacetate or diacetate, diacetone alcohol and benzene.

Mono-*n*-Butyl Ether of Ethylene Glycol

Mono-*n*-butyl ether of ethylene glycol $\begin{matrix}CH_2OH\\|\\CH_2OC_4H_9\end{matrix}$ (butyl "Cellosolve") is a colorless liquid of mild odor and low volatility. It is a solvent for practically all resins, except the Bakelite type, and for nitrocellulose and some types of cellulose ethers its solvency is rather slow. Owing to its high boiling point, low rate of evaporation, and strong dissolvent powers, it is the last portion of the solvent mixture to leave the film and thereby

produces clear and homogeneous films. It is used in dipping lacquers, brushing compositions, in dry-cleaning compounds and in varnish removers. It is also used as a thinner either alone or in combination with petroleum hydrocarbons where rapid drying is not essential and where anti-skinning is desired. Its presence in surface-coating material will both add pliability and reduce viscosity. In vat dyes and pastes it will prevent spotty printing or dyeing.

Molecular weight	118.11
Boiling point	170.6° C.
Specific gravity	0.9188 at $\frac{15°\ C.}{15°\ C.}$
Weight per gallon	7.65 (15° C.)
Refractive index	1.4190 (25° C.)
Surface tension	31.5 dynes/sq. cm. (25° C.)
Viscosity	3.318 centipoises (25° C.)
Vapor pressure	0.12 mm. Hg. (20° C.)
Specific Heat	0.583
Flash-point	60.5° C. (141° F.)
Solubility	Miscible with most organic liquids

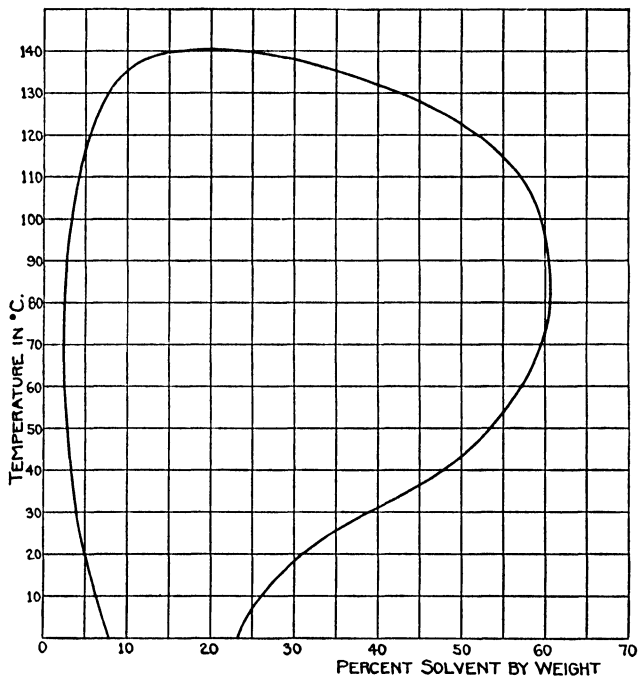


FIGURE 177. Solubility of Butyl "Cellosolve" in Water at Various Temperatures.[2]

Dilution ratios	Toluene 3.5 V.M. & P. naphtha 2.2 Final concentration ½-sec. R.S. nitrocellulose solution, approx. 8%
Electrical conductivity	0.432×10^{-6} recip. ohms

TABLE 105.—Properties of "Cellosolve" and Its Derivatives[2]

	"Cellosolve"	"Cellosolve" Acetate	Butyl "Cellosolve"
Specific gravity (20°/20° C.)	0.930	0.976	0.902
Refractive index (25° C.)	1.4050	1.4051	1.4169
Boiling point, ° C.	134	153	170
Acidity (as acetic acid), per cent		0.02	
Ester content, per cent		95.0	
Dilution ratios:			
Toluene	5.2	3.0	3.5
Turpentine	1.9	2.8	
Petrol (80–130° C.)	0.8	1.5	1.2
Flash-point (open-cup), ° C.	40	53	60

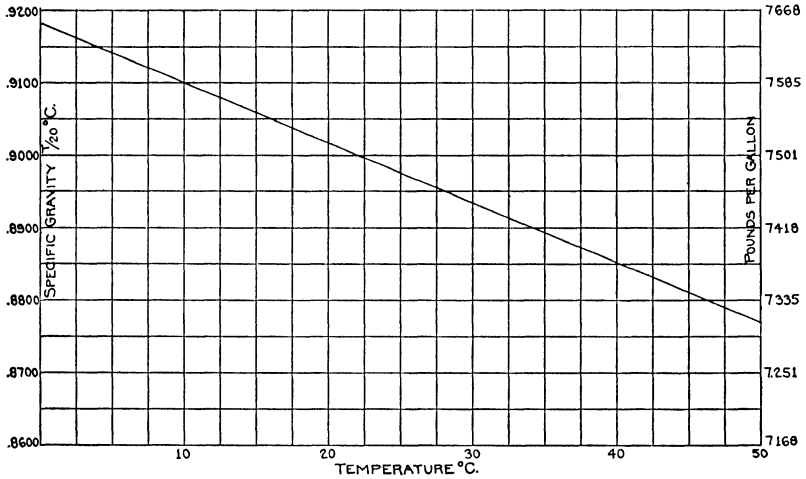


FIGURE 178. Specific Gravity and Weight per Gallon of Butyl "Cellosolve" at Various Temperatures.

TABLE 106.—Composition of Furniture Lacquers[2]

	Figures in pounds			
½-Second nitrocellulose	17	17	17	17
Dibutyl phthalate	3	3	3	3
50% Shellac solution		16	8	
40% Kauri solution				5
50% Resin solution			8	8
Standard dammar solution	18			

TABLE 107—Composition of Automobile Lacquers[2]

	Figures in pounds				
½-Second nitrocellulose (dry basis)	12	12	12	12	12
Dibutyl phthalate	3	3	3	3	3
Blown castor oil (viscosity about 100 to 200 poises)	3	3	3	3	3
50% Ester gum solution (in complete mixed solvent)	6				
50% Elemi solution		6			
40% Pontianac solution (in alcohol)			8		
40% Kauri solution (in alcohol)				8	
Standard dammar solution					10
Solvent, gallons	10	10	10	10	10
Solvent Composition, per cent by Volume					
Toluene	70	65	20	20	70
Ethyl alcohol	5		60	60	5
Ethyl acetate	15	15	10	10	15
Butyl alcohol		10			
"Cellosolve"	5	10	10	10	5
"Cellosolve" acetate	5				5

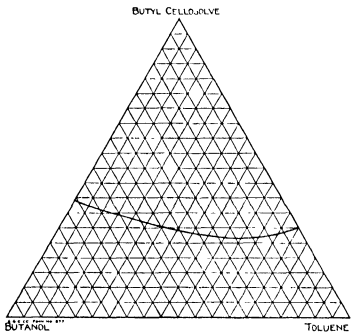


FIGURE 179. Solubility of ½-Second R. S. Nitrocellulose in Mixtures of Butyl "Cellosolve," Butanol and Toluene.[2]

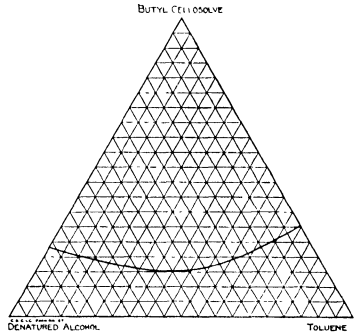


FIGURE 180. Solubility of ½-Second R. S. Nitrocellulose in Mixtures of Butyl "Cellosolve," Denatured Alcohol and Toluene.[2]

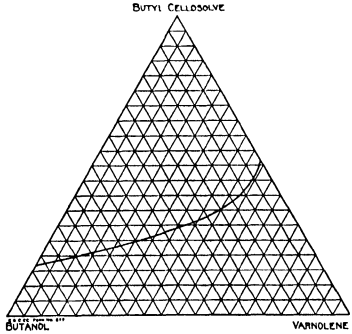


FIGURE 181. Solubility of ½-Second R. S. Nitrocellulose in Mixtures of Butyl "Cellosolve," Butanol and Varnolene.[2]

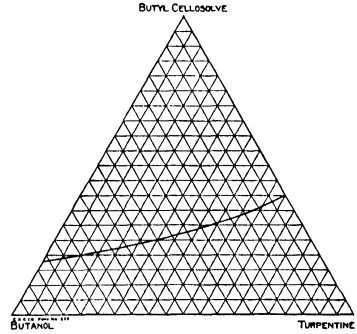


FIGURE 182. Solubility of ½-Second R. S. Nitrocellulose in Mixtures of Butyl "Cellosolve," Butanol and Turpentine.[2]

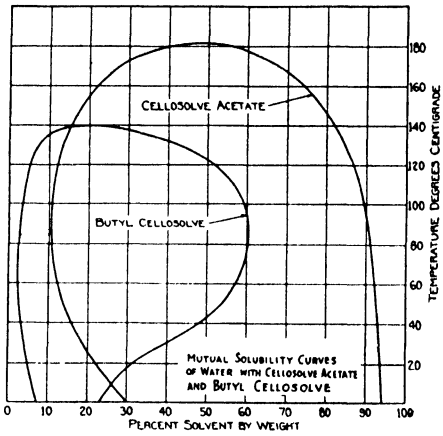


FIGURE 183.

Mutual Solubility Curves of Water with "Cellosolve" Acetate and Butyl "Cellosolve."[4]

TABLE 108 —Composition of Leather Lacquers[2]

"Dope" cotton, 15 to 20 seconds, pounds	12	12	12*	12*
Castor oil, pounds	6–10	6–10	6–10	6–10
Solvent (see below), gallons	10	10	10	10
Solvent Composition, per cent by Volume				
Benzene	65	35		
Toluene		30		35
Petrol (80–130° C.)			50	25
Alcohol	10	10	20	20
Ethyl acetate	15	15	20	20
"Cellosolve"	10	10	10	10

*Non-poisonous

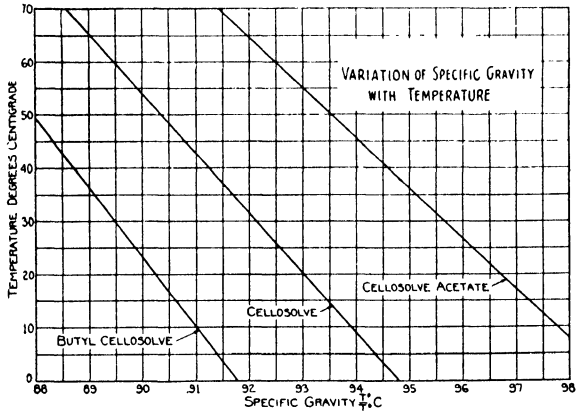


FIGURE 184. Variation of Specific Gravity of "Cellosolves" with Temperature.[4]

TABLE 109.—Composition of Brushing Lacquers[2]

			Figures in pounds		
½-Second nitrocellulose (wet basis, 30% alcohol)	17	21	20	17	17
Blown castor oil				8	
Dibutyl phthalate	8	7	8	3	6
Dammar solution		50	25		
50% Elemi solution	12				
50% Ester gum solution (made in complete brushing lacquer solvent)			15		
40% Kauri solution (in alcohol)					30
Solvent, gallons	10	10	10	10	10
Solvent Composition, per cent by Volume					
Petrol (80–130° C.)	40	40		40	
Xylene (10° C.)	15				
Alcohol		20		20	12
Butyl alcohol	10		15		10
Ethyl acetate	15	15	10	20	15
"Cellosolve"	15	25	10	20	15
Butyl "Cellosolve"	5		15		
Turpentine			10		40
Mineral spirit (substitute turpentine)			40		

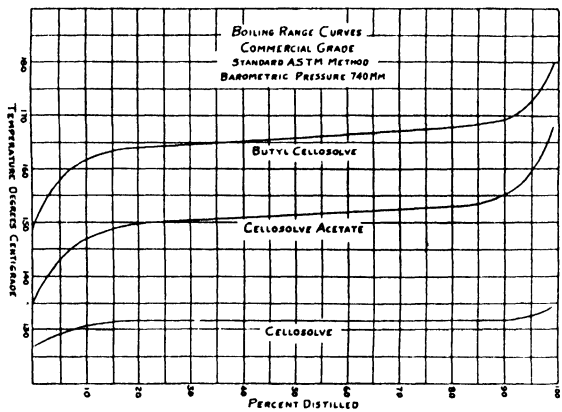


FIGURE 185. Boiling Range of "Cellosolves."[4]

TABLE 110.—Composition of Lacquer Thinners[2]

		Per cent by volume	
Toluene	70		70
Petrol (80–130° C.)		65	
Alcohol	5	5	5
Ethyl acetate	15	20	15
"Cellosolve"			5
"Cellosolve" acetate	10	10	5

TABLE 111—Composition of High-Gloss Lacquers[2]

		Figures in pounds	
½-Second nitrocellulose (wet basis)	17	17	17
Dibutyl phthalate	5	4	4
Castor oil		4	
Dammar solution	50		36
Ester gum solution		20	16
Elemi solution		20	
Solvent, gallons (approx.)	5	6	5
Solvent Composition, per cent by Volume			
Toluene	30	60	70
Petrol (80–130° C.)	30		
Alcohol	10		5
Ethyl acetate	15	10	15
"Cellosolve"	15	5	5
"Cellosolve" acetate		5	5
Butyl alcohol		20	

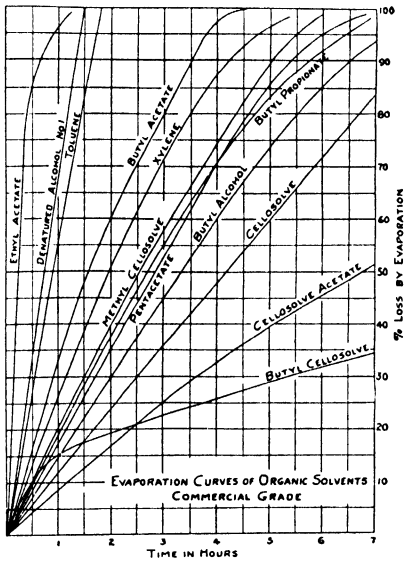


FIGURE 186.

Evaporation Rate of Organic Solvents at Room Temperature.[4]

Diethylene Glycol

Diethylene glycol $\begin{matrix} CH_2OH \\ | \\ CH_2 \\ \quad\diagdown \\ \quad\quad O \\ \quad\diagup \\ CH_2 \\ | \\ CH_2OH \end{matrix}$ (dihydroxy-di-ethyl ether) is a colorless, viscous, non-corrosive, hygroscopic liquid of faint odor. It is freely miscible with water, alcohols, glycols, glacial acetic acid, acetone, furfural, pyridine,

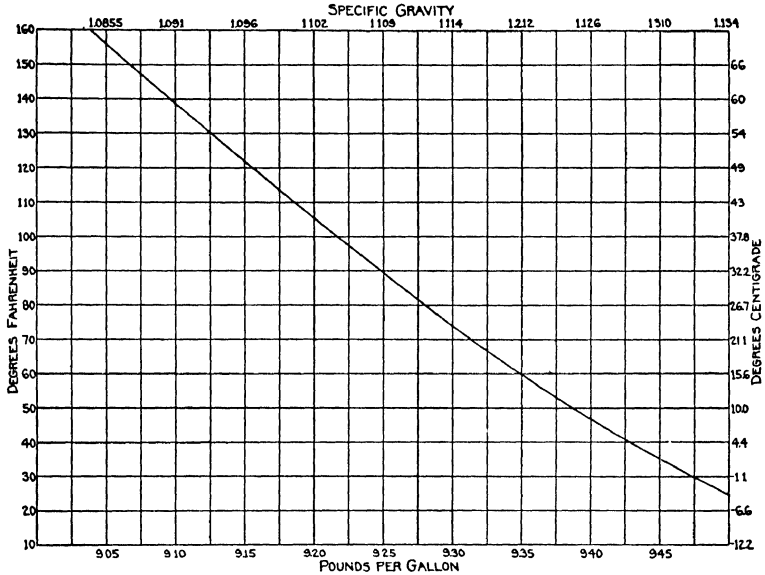


FIGURE 187. Specific Gravity and Weight per Gallon of Diethylene Glycol at Various Temperatures.[2]

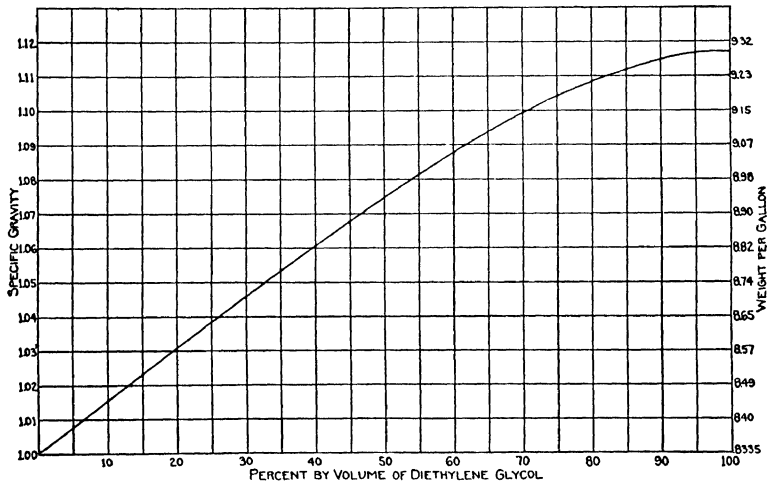


FIGURE 188. Specific Gravity of Diethylene Glycol-Water Mixtures 20°/20°C.[2]

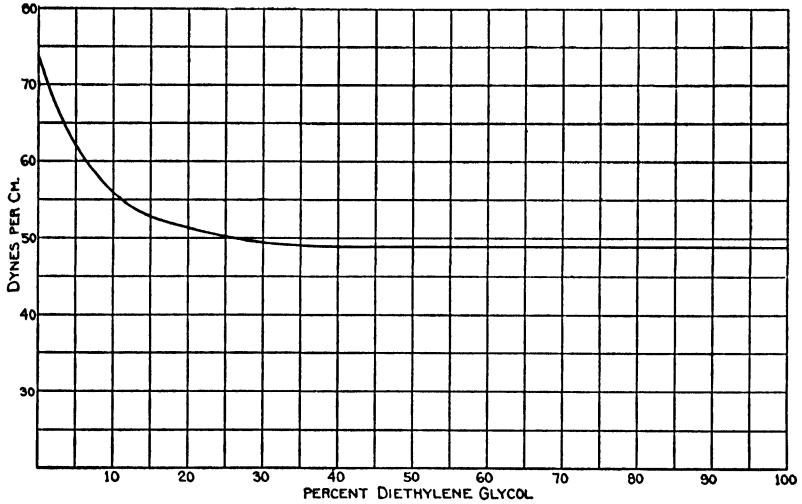


FIGURE 189. Surface Tension of Diethylene Glycol-Water Mixtures[2]
(du Nouy Apparatus. Water=74 dynes/sq. cm.)

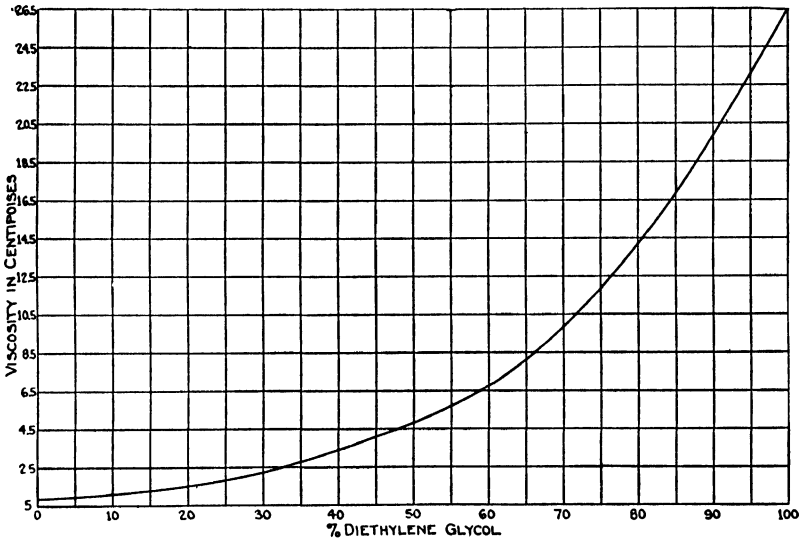


FIGURE 190. Viscosity of Diethylene Glycol-Water Solutions at 25° C.[2]

chloroform, nitrobenzene, aniline and so forth. It is a solvent for dyes, oils, gums, resins, nitrocellulose and many organic compounds. It is a superior solvent to ethylene glycol or glycerin owing to the fact that there are two alcohol groups and one ether group in the molecule. Because it is hygroscopic, non-corrosive and miscible with water, it is used as a lubricant for wool, cotton, rayon, silk and worsted. It is used as a softener and finishing agent, imparting thereby a pleasurable feel to fabric. Other uses are as a mutual solvent in the textile industry for both soaps and textile oils and as a solvent for basic and vat dyes; for printing and dyeing; as a softener and conditioner in glues, gelatin and casein; in cork compositions, in Glassine paper, in cosmetics, in soft greases and soluble oils, in straw products and in vulcanized fiber; and as an antifreeze in refrigerators and sprinkler systems. One of the its most important uses is as an explosive in the form of diethylene glycol dinitrate.

Molecular weight	106.08
Boiling point	244.5° C.
Freezing point	− 6.5° C.
Specific gravity	1.1212 at $\frac{15° \text{ C.}}{15° \text{ C.}}$
Weight per gallon	9.35 (15° C.)
Refractive index	1.446 (25° C.)
Surface tension	48.5 dynes/sq. cm. (25° C.)
Viscosity	0.50 poise (15° C.) 0.38 poise (20° C.) 0.30 poise (25° C.)
Vapor pressure	0.01 mm. Hg. (30° C.)
Specific heat	0.5509 (20° C.)
Flash-point	124° C. (255.2° F.)
Apparent ignition temperature in air	351° C. (663° F.)
Latent heat of evaporation	150 cal./g. at B. P.
Electrical conductivity	0.586×10^{-6} recip. ohms
Solubility	Completely miscible with water and most organic solvents

Monoethyl Ether of Diethylene Glycol

Diethylene glycol monoethyl ether ($C_2H_5OCH_2CH_2OCH_2CH_2OH$, "Carbitol") is a water-white, stable, hygroscopic liquid of a mild, pleasant odor. It is completely miscible with water and most of the commonly known organic solvents. Owing to the fact that it contains an ether, alcohol and hydrocarbon group in the molecule, it has the power to dissolve a wide variety of substances, some of which are oils, fats, waxes, dyes, camphor, natural resins like copal, kauri, mastic, rosin, sandarac, shellac and several types of synthetic resins. "Carbitol" is used as a solvent for synthetic resins and coating compositions, and in lacquers where high-boiling solvents are desired. It is used in safety glass manufacture for its solvency and softening properties, and in dyeing and printing mixtures, textile soaps and in non-aqueous wood stains for its penetrating virtues. Preparations

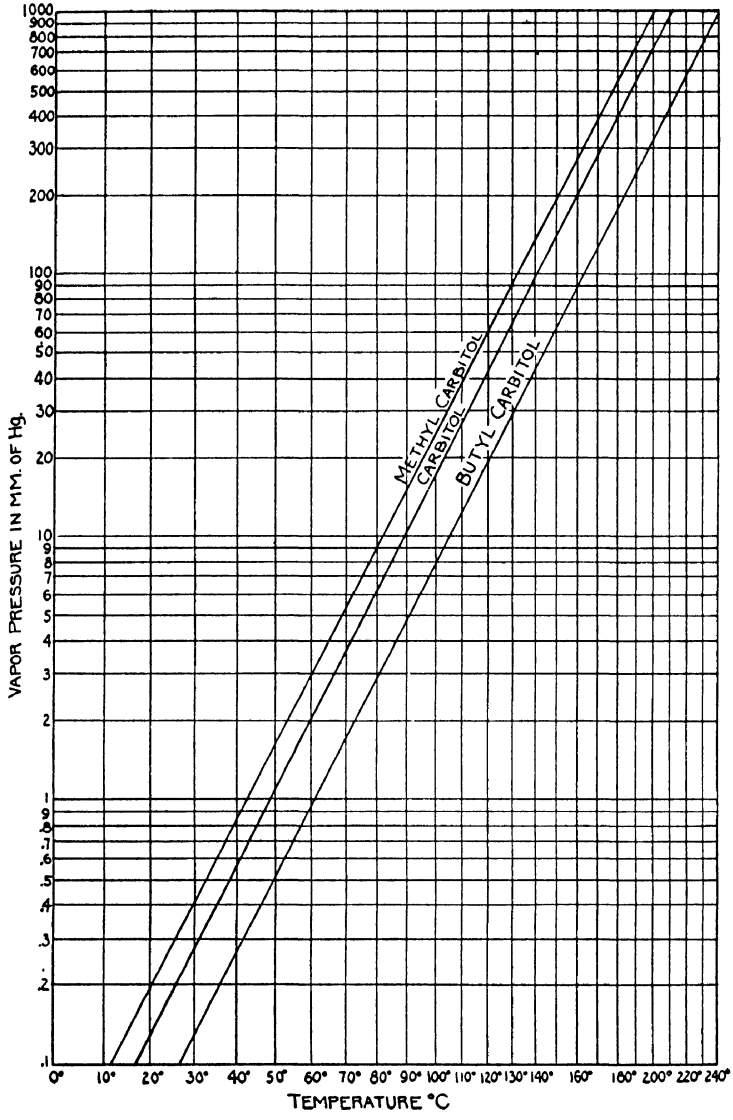


FIGURE 191. Vapor Pressure of "Carbitols" at Various Temperatures.[2]

like after-shaving creams, cleansing creams, cold creams, shampoos and other cosmetics contain "Carbitol" for its cleansing and soothing action. In lacquers it is used both for its solvency and for its softening effect.

Molecular weight	134.11
Boiling point	201.9° C.
Freezing point	< – 76° C.
Specific gravity	0.9902 at $\frac{20° \text{ C.}}{20° \text{ C.}}$
Weight per gallon	8.24 lb. (20° C)
Refractive index	1.4244 (26° C.)
Surface tension	35.5 dynes/cm. (25° C.)
Viscosity	0.0385 poise (25° C.)
Vapor pressure	0.13 mm. Hg. (20° C.)
Specific heat	0.552 cal./g. (20–25° C.)
Latent heat of evaporation	96.3 cal./g. at B.P.
Flash-point	99° C. (210° F.) (A.S.T.M. open cup)
Electrical conductivity	2.5×10^{-8} recip. ohms (25° C.)
Solubility in water	Complete
Dilution ratio	Toluene 1.65 Final conc. ½-sec. nitrocellulose 8%

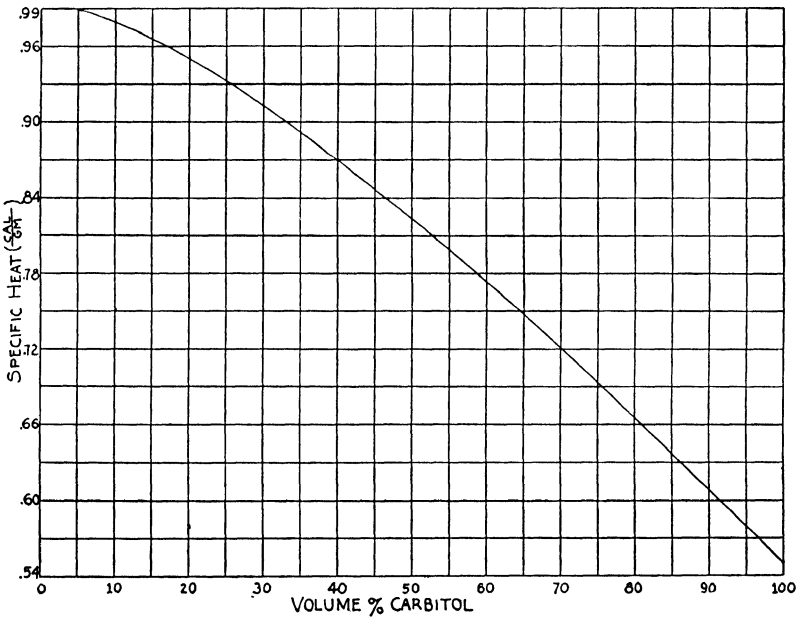


FIGURE 192. Specific Heat of "Carbitol"-Water Mixtures (20-25° C.)[2]

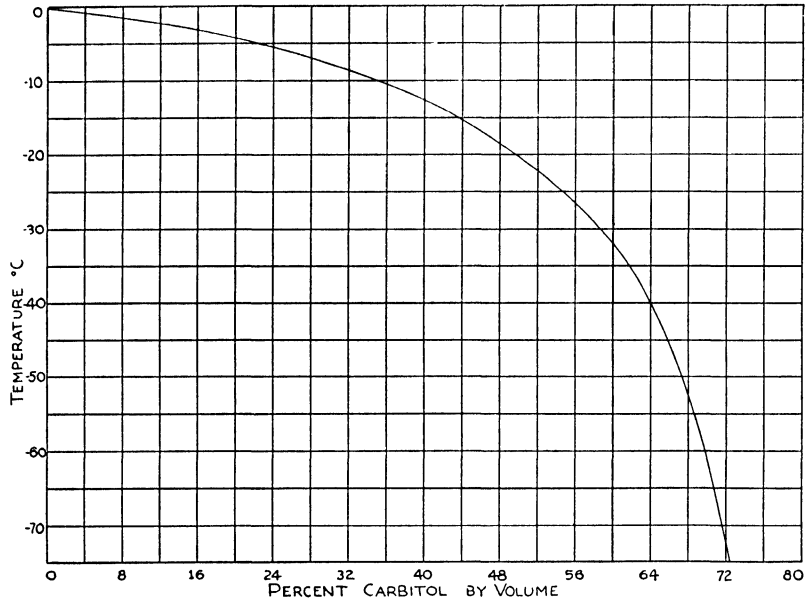


FIGURE 193. Approximate Freezing Point of "Carbitol"-Water Mixtures.[2]

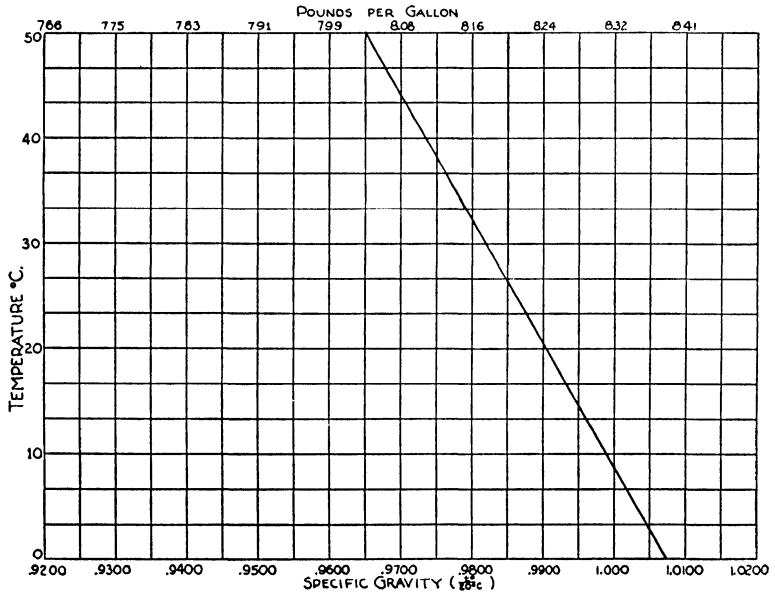


FIGURE 194. Specific Gravity and Weight per Gallon of "Carbitol" at Various Temperatures.[2]

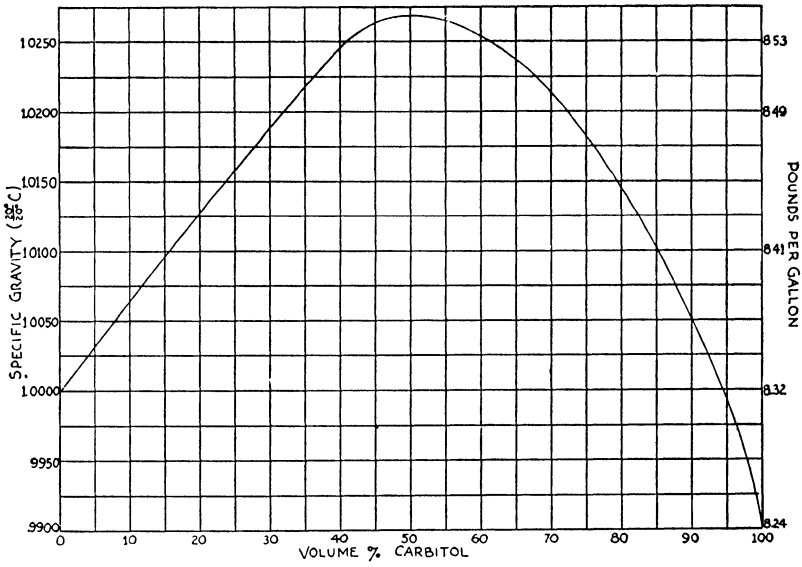


FIGURE 195. Specific Gravity and Weight per Gallon of "Carbitol"-Water Mixtures.[2]



FIGURE 196. Viscosity of "Carbitol" at Various Temperatures.[2]

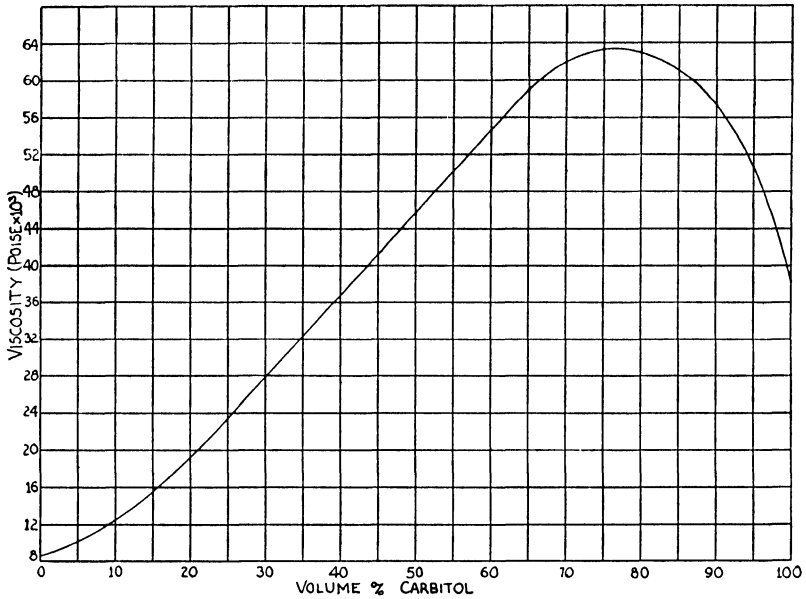


FIGURE 197. Viscosity of "Carbitol"-Water Mixtures at 25° C.[2]

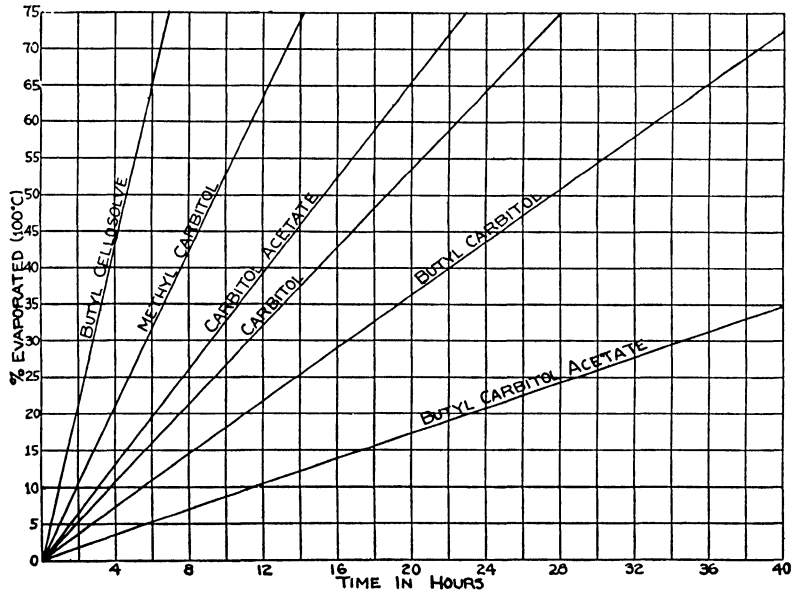


FIGURE 198. Evaporation Rate of Various Solvents at Room Temperature.[2]

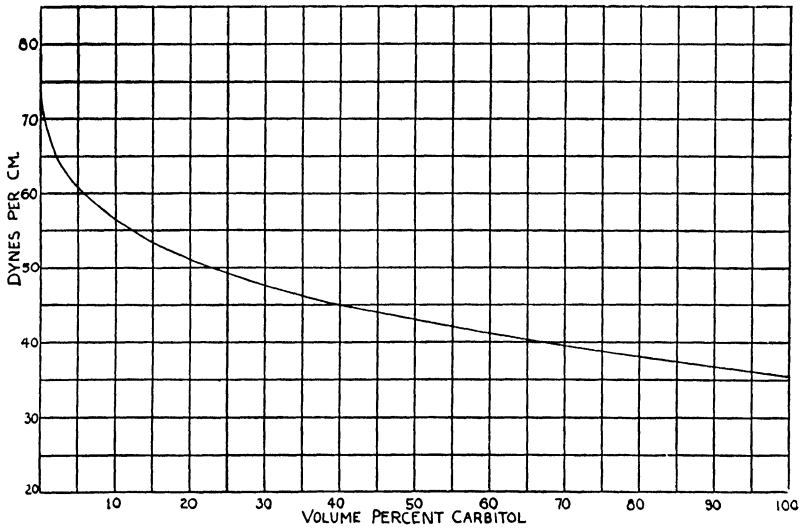


FIGURE 199. Surface Tension of "Carbitol"-Water Mixtures at 25° C.[2] (du Noüy Apparatus—Water=73 dynes/sq. cm.)

Monobutyl Ether of Diethylene Glycol

Monobutyl ether of diethylene glycol ($C_4H_9OCH_2CH_2OCH_2CH_2OH$, butyl "Carbitol") is a colorless liquid of characteristic butyl odor. It is miscible in all proportions with water and many organic solvents. As it is a solvent of the ether-alcohol type, it naturally possesses solvent action for many substances some of which are oils, dyes, gums, and natural and synthetic resins. Butyl "Carbitol" is used as a high-boiling solvent in lacquers, natural and synthetic coating compounds, baking lacquers, printing inks and dye baths. It is especially useful when combining nitrocellulose and resins in lacquers, and oils and soaps in textile processing.

Molecular weight	162.14
Boiling point	231.2° C.
Specific gravity	0.9553 at $\frac{20° \text{ C.}}{20° \text{ C.}}$
Weight per gallon	7.95 lb. (20° C.)
Refractive index	1.4290 (27° C.)
Surface tension	33.6 dynes/cm. (25° C.)
Viscosity	0.0525 poise (20° C.)
Vapor pressure	0.06 mm. Hg. (20° C.)
Specific heat	0.546 cal./g. (20–25° C.)
Latent heat of evaporation	61.9 cal./g. at B.P.
Flash-point	110° C. (230° F.) (A.S.T.M. open cup)
Solubility in water	Complete
Coefficient of expansion	0.00087 (per ° C.) to 20° C.

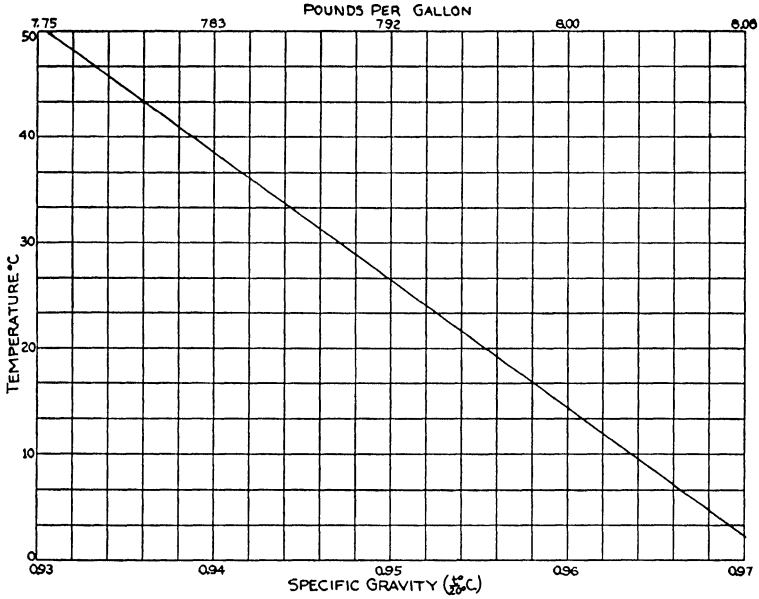


FIGURE 200. Specific Gravity and Weight per Gallon of Butyl "Carbitol" at Various Temperatures.[2]

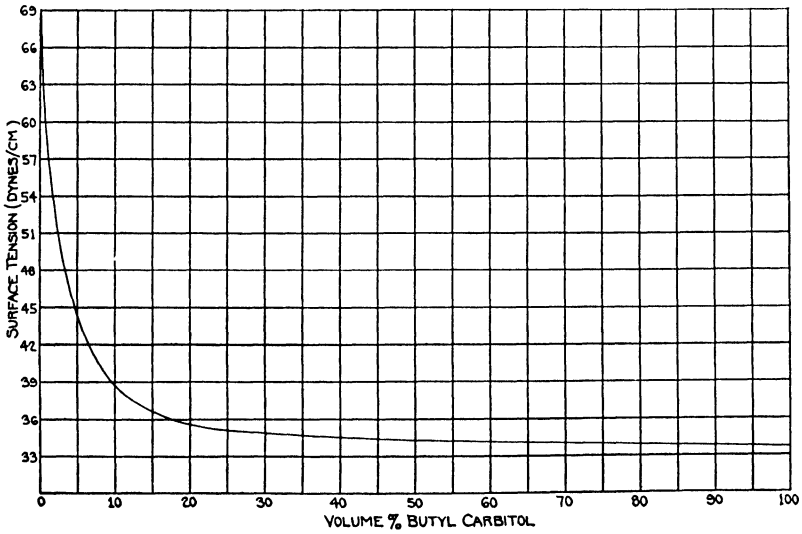


FIGURE 202. Surface Tension of Butyl "Carbitol"-Water Mixtures at 25° C.[2]

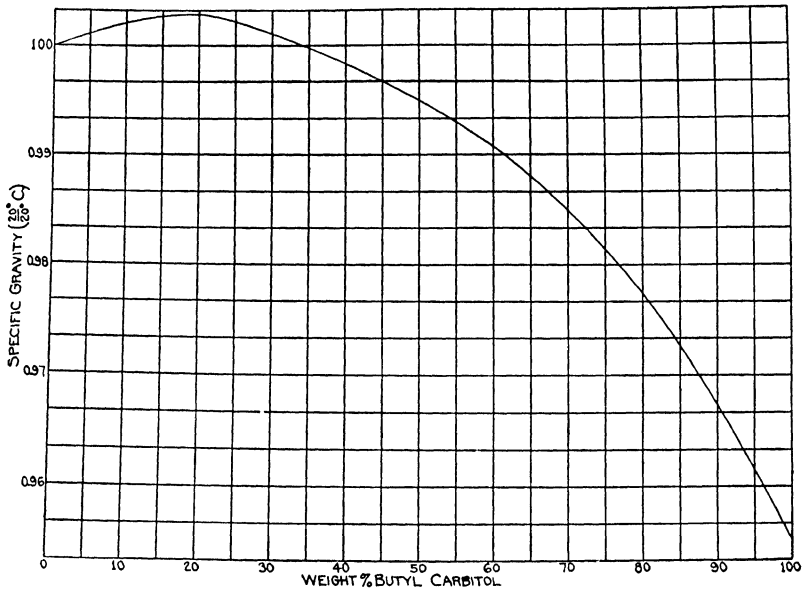


FIGURE 201. Specific Gravity and Weight per Gallon of Butyl "Carbitol"-Water Mixtures.[2]

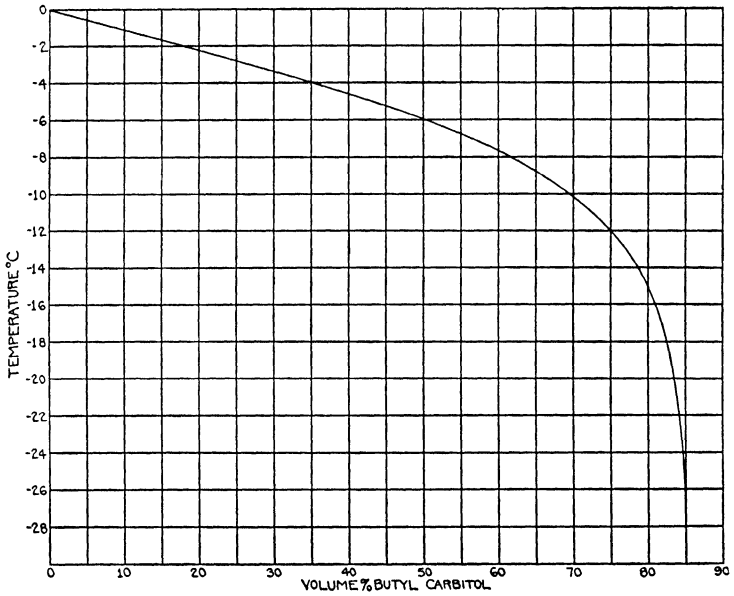


FIGURE 203. Freezing Point of Butyl "Carbitol"-Water Mixtures.[2]



FIGURE 204. Viscosity of Butyl "Carbitol" at Various Temperatures.[2]

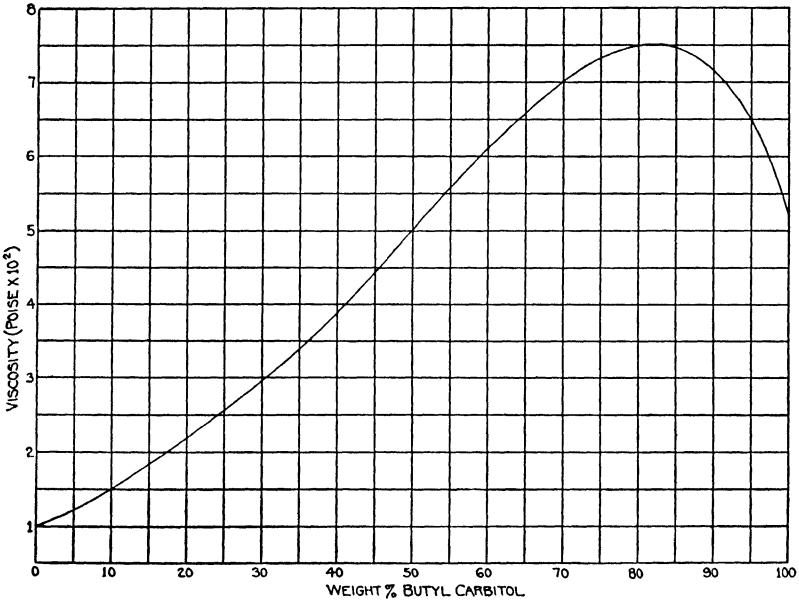


FIGURE 205. Viscosity of Butyl "Carbitol"-Water Mixtures at 20° C.[2]



FIGURE 206. Specific Heat of Butyl "Carbitol"-Water Mixtures (20-25° C.).[3]

Monomethyl Ether of Diethylene Glycol

Monomethyl ether of diethylene glycol ($CH_3OCH_2CH_2OCH_2CH_2OH$, methyl "Carbitol") is a water-white, stable, hygroscopic liquid of agreeable odor. It is completely miscible with most organic solvents and water. It is a solvent for dyes, oils, fats, waxes, many natural and synthetic resins, and acetyl and nitrocellulose. It is used as a high-boiling solvent for printing inks and pastes, and in resin and cellulose derivative protective coatings.

Molecular weight	120 1
Boiling point	193.2° C.
Specific gravity	1.0354 at $\frac{20° \text{ C.}}{20° \text{ C.}}$
Weight per gallon	8.62 lb. (20° C.)
Refractive index	1.4264 (27° C.)
Surface tension	41.3 dynes/cm. (25° C.)
Viscosity	0.0605 poise (20° C.)
Vapor pressure	0.19 mm. Hg. (20° C.)
Specific heat	0.514 cal./g. (23° C.)
Latent heat of evaporation	90.70 cal./g. at B.P.
Flash-point	93° C. (200° F.) (A.S.T.M. open cup)
Solubility in water	Complete
Dilution ratio	Toluene 2.3 Final conc. ½-sec. R.S. nitrocellulose 8%

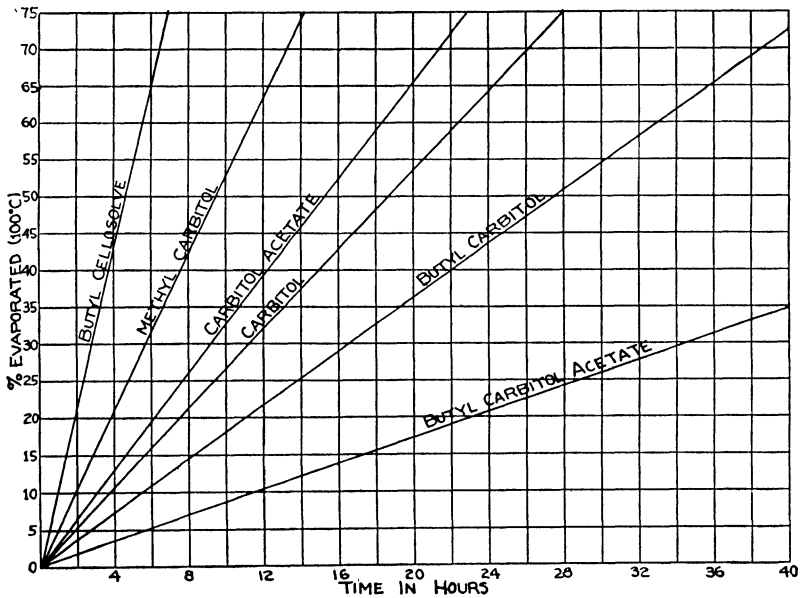


FIGURE 207. Evaporation Rate of Various Solvents at Room Temperature.[2]

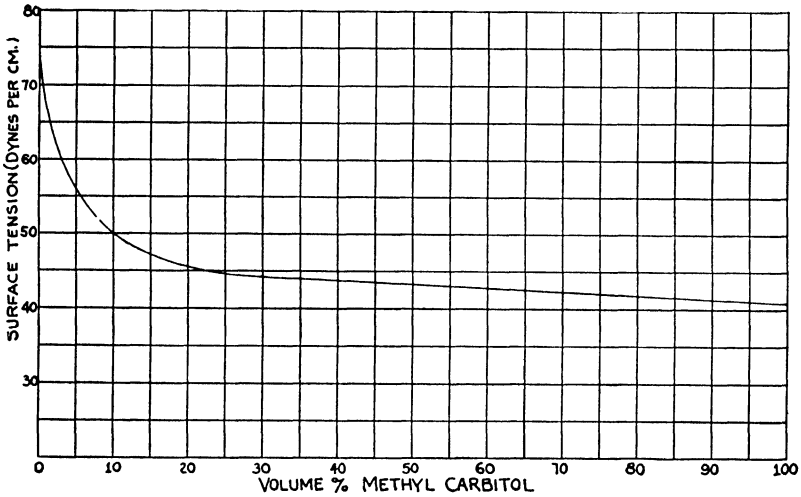


FIGURE 208. Surface Tension of Methyl "Carbitol"-Water Mixtures at 25° C.[2]

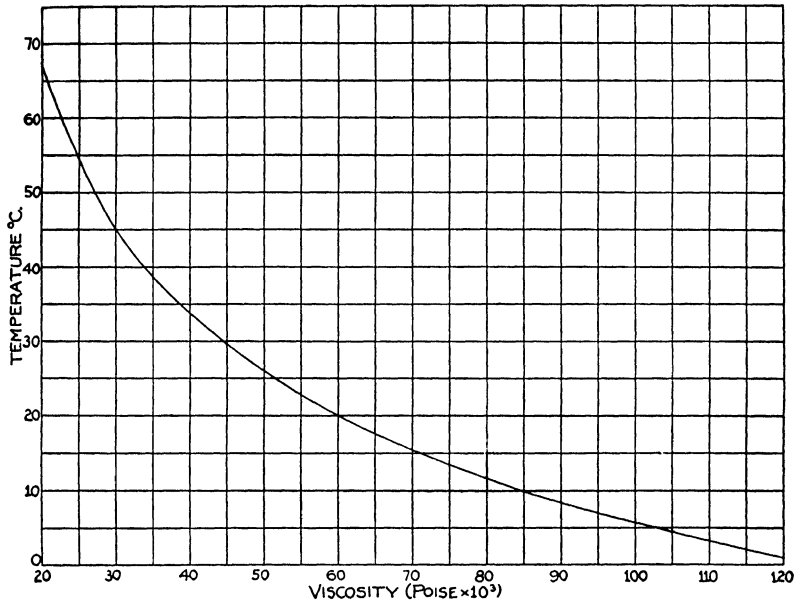


FIGURE 209. Viscosity of Methyl "Carbitol" at Various Temperatures.[2]

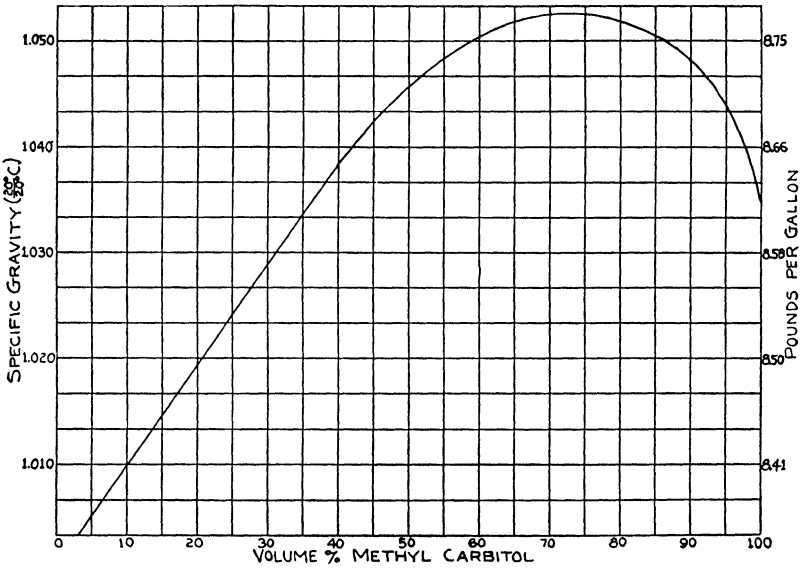


FIGURE 210. Specific Gravity and Weight per Gallon of Methyl "Carbitol"-Water Mixtures.[2]

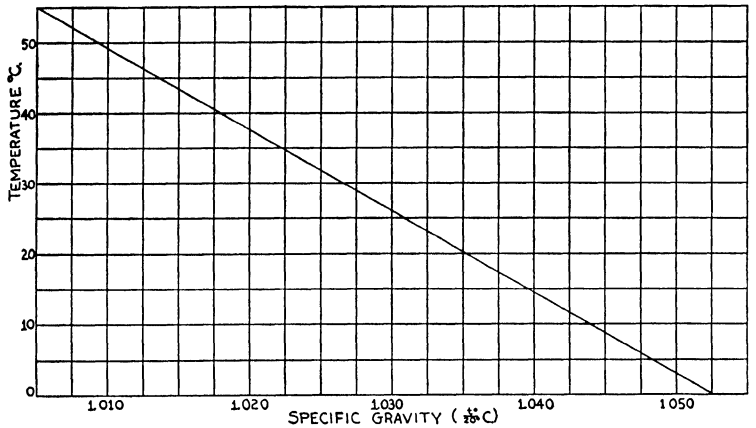


FIGURE 211. Specific Gravity and Weight per Gallon of Methyl "Carbitol" at Various Temperatures.[2]



FIGURE 212. Specific Heat of Methyl "Carbitol"-Water Mixtures (20-25° C.).[2]

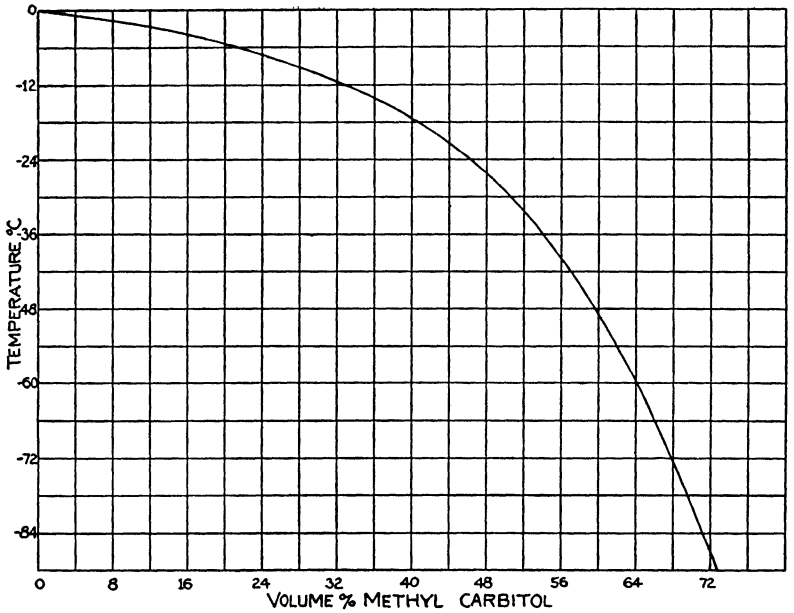


FIGURE 213. Freezing Point of Methyl "Carbitol"-Water Mixtures at Various Temperatures.[2]

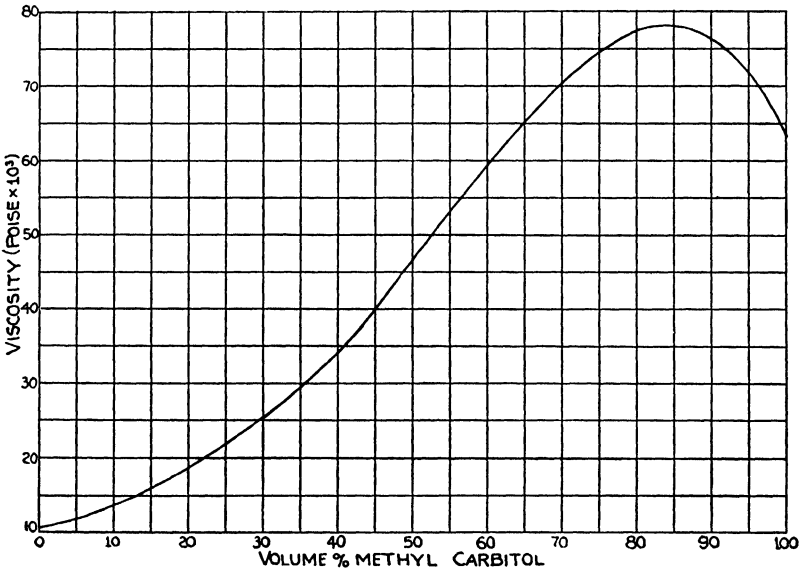
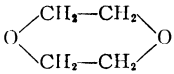


FIGURE 214. Viscosity of Methyl "Carbitol"-Water Mixtures at 20° C.[2]

Dioxan

1,4-Dioxan  (1,4-diethylene oxide, dioxyethylene ether, diethylene oxide, diethylene ether, diethylene dioxide) is a colorless, stable liquid of faint, pleasant odor. Chemically it is a di-ether obtained by the

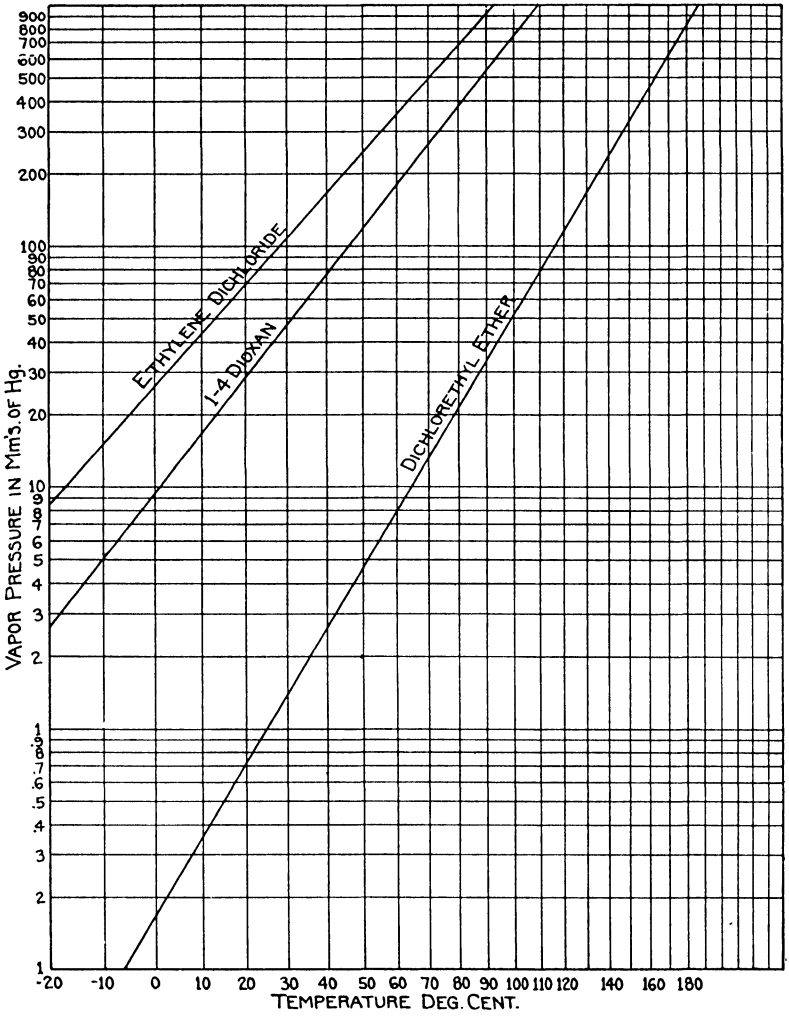


FIGURE 215. Vapor Pressure of Some Organic Solvents at Various Temperatures.[2]

loss of two molecules of water from two molecules of ethylene glycol. It is completely miscible with water and most organic solvents. It is a solvent for mineral, vegetable, blown and heat-bodied oils, and for oil-soluble dyes. Many waxes are soluble in cold dioxan but some require heat for solution. It is a solvent for such substances as natural resins like dewaxed dammar, elemi, guaiac, kauri, manila, mastic, pontianac, rosin and shellac, and for synthetic resins like ester gum, cumar resins, glyptols, some types of vinyl resins, and cellulose ethers and esters.

A mixture of dioxan and alcohol will dissolve a wide variety of organic compounds. Dioxan is used as a solvent for various types of cellulose ester and ether lacquers, as a means of mixing these lacquers with resins, and in molecular weight determinations. As a mutual solvent it is used for fats, oils, greases and water. It is a wetting and dispersing agent in textile processing, dye baths and in stain and printing compositions; and is also used as a degreasing and scouring agent. Other uses for 1,4-dioxan are: in cements, cleaning and detergent preparations, cosmetics, deodorants, fumigants, emulsions, glues, paints, polishing compositions and shoe creams.

Molecular weight	88 06
Boiling point	101.5° C.
Freezing point	11.7° C.
Specific gravity	1.0353 at $\frac{20° \text{ C.}}{20° \text{ C.}}$
Weight per gallon	8.61 lb. (20° C.)
Refractive index	1.4221 (20° C.)
Surface tension	36.9 dynes/cm. (25° C.)
Vapor pressure	29 0 mm. Hg. (20° C.)
Viscosity	0 0120 poise (25° C.)
Specific heat	0.420 cal./g. (20° C.)
Heat of fusion	33.8 cal./g.
Flash-point	18° C. (65° C.) (A.S.T.M. open cup)
Latent heat of evaporation	98.6 cal./g. at B.P.
Heat of combustion	581 kg. cal./mole.
Coefficient of expansion	0.001030 (per ° C.) to 20° C. 0.001070 (per ° C.) to 55° C.
Electrical conductivity	$<2 \times 10^{-8}$ recip. ohms (25° C.)
Solubility in water	Complete

TABLE 112.—Evaporation Rates of Various Solvents[7]

(Amount of solvent used, 3 cc.)

Solvent*	Evaporation Time (Hours)	Solvent*	Evaporation Time (Hours)
n-Butyl acetate	3½	85% *sec*-butyl acetate 15% *sec*-hexyl acetate	3½
25% *sec*-butyl acetate 75% *sec*-amyl acetate	4	Pentacetate	5½
50% *sec*-butyl acetate 50% *sec*-amyl acetate	3¾	Butyl propionate	5½
75% *sec*-butyl acetate 25% *sec*- amyl acetate	3	50% *sec*-butyl acetate 50% *sec*-hexyl acetate	5¼
65% *sec*-butyl acetate 35% *sec*-amyl acetate	3½	60% *sec*-amyl acetate 40% *sec*-hexyl acetate	5½
40% ethyl acetate 60% *sec*-amyl acetate	3¼	33⅓% *sec*-butyl acctate 33⅓% *sec*-amyl acctate 33⅓% *sec*-hexyl acetate	5½

*The proportions used were per cent by volume.

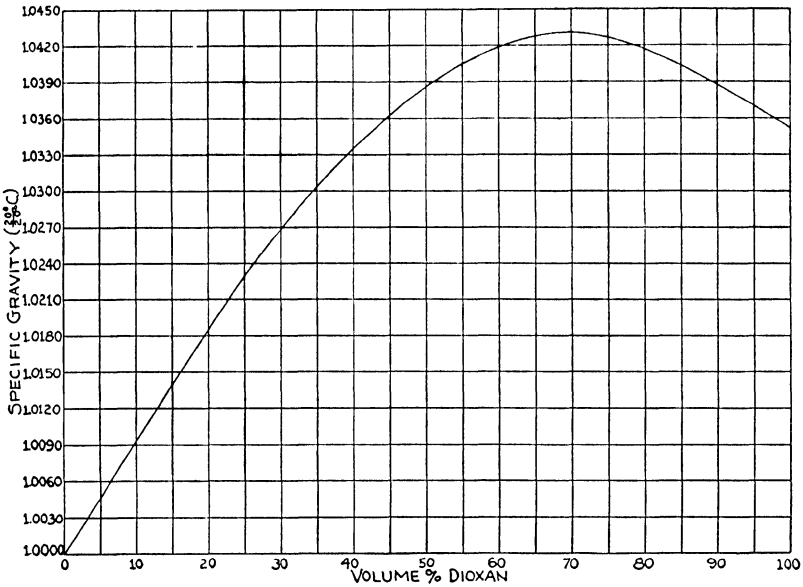


FIGURE 216. Specific Gravity of Water Solutions of 1, 4-Dioxane.[2] Room Temperature.

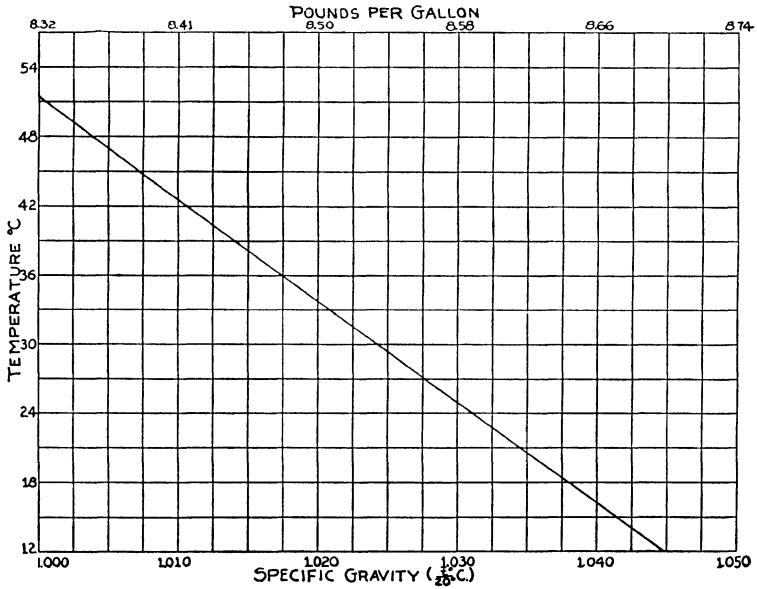


FIGURE 217. Specific Gravity and Weight per Gallon of 1, 4-Dioxane at Various Temperatures.[2]

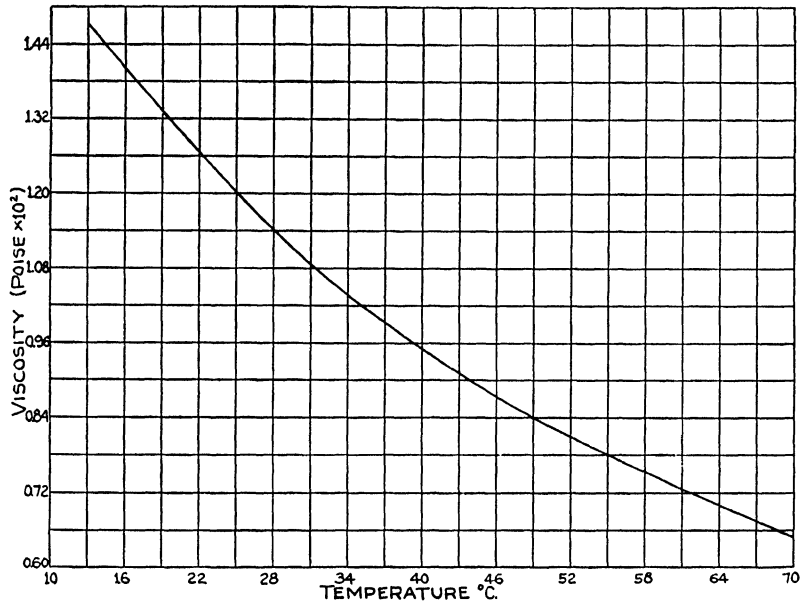


FIGURE 218. Viscosity of 1, 4-Dioxane at Various Temperatures.[2]

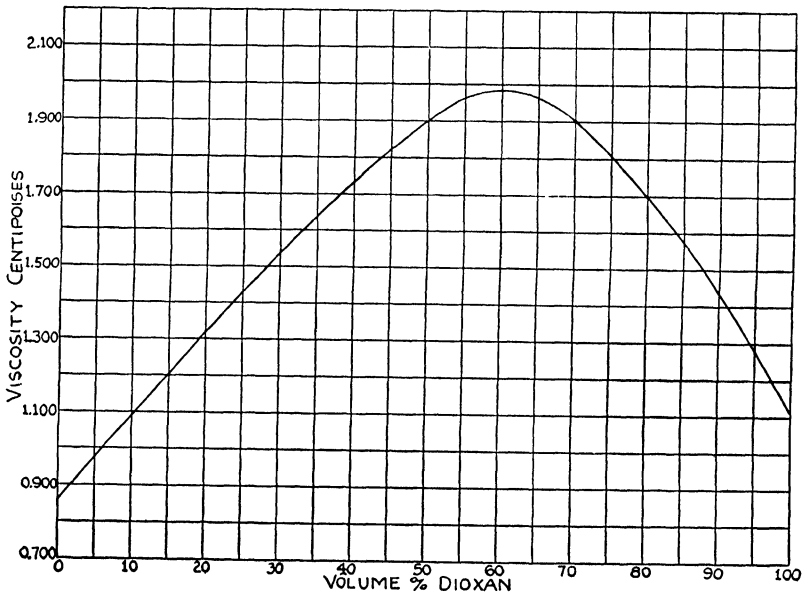


FIGURE 219. Viscosity of 1, 4-Dioxane-Water Mixtures at 25° C.[2]

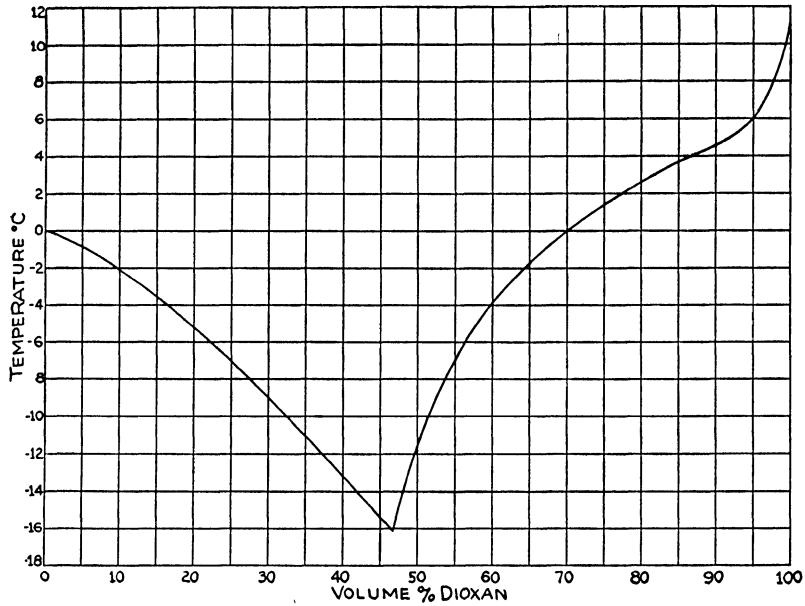


FIGURE 220. Freezing Point of 1, 4-Dioxane-Water Mixtures at Various Temperatures.[2]



FIGURE 221. Surface Tension of 1, 4-Dioxane-Water Mixtures at 25° C.[2]

TABLE 113.—Physical Properties of Some Polyglycols and Their Ethyl Ether Derivatives[2]

Compound	Boiling point (760 mm.) ° C.	Specific gravity 15°/15° C.	Refractive index (n_D) at 26° C.
Diethylene glycol	245	1.132 (0° C.)	
Triethylene glycol	276	1.138	
Tetraethylene glycol	230 (25 mm.)		
Diethylene glycol monoethyl ether	198	0.9996	1.4240
Triethylene glycol monoethyl ether	248	1.0566	1.4389
Tetraethylene glycol monoethyl ether (approx.)	284	1.4389	1.4499

TABLE 114.—Physical Properties of the Monoalkyl Ethers of Ethylene and Propylene Glycols[2]

Monoalkyl Ether	Boiling point* ° C.	Specific gravity 15°/15° C.	Refractive index (n_D) at 26° C.
	Ethylene Glycol		
Methyl	124.5	0.9748	1.4004
Ethyl	134.8	0.9360	1.4042 (24° C.)
Isopropyl	144.0	0.9139	1.4080
n-Propyl	150.0	0.9110	1.4125
Isobutyl	158.8	0.9130	1.4135
n-Butyl	170.6	0.9188	1.4177
Isoamyl	181.0	0 9000	1 4198
	Propylene Glycol		
Methyl	122.8	0.9335	1.4035
Ethyl	133.0	0.9090	1.4061
Isopropyl	141.5	0.8900	1.4062
n-Propyl	150.0	0.8970	1.4102
Isobutyl	161.3	0.8810	1.4112
n-Butyl	170.6	0.8890	1.4151
Isoamyl	183.3	0.8835	1.4182

*Boiling point of monoalkyl ethers of ethylene glycol at 743 mm. pressure, of propylene glycol at 736 mm.

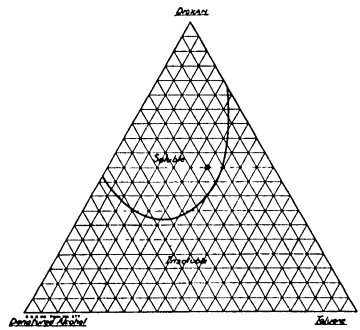


FIGURE 222.

Solubility of Cellulose Acetate in Mixtures of 1, 4-Dioxane, Denatured Alcohol and Toluene. ⊙Good Solvent Mixture for Lacquers *viz.*, 50% Dioxane, 20% Alcohol, 30% Toluene.[2]

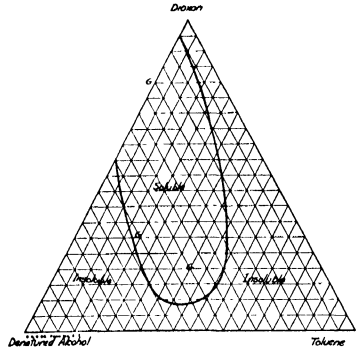


FIGURE 223. Solubility of ½ Second Nitrocellulose in Mixtures of 1, 4-Dioxane, Alcohol and Toluene. G = Solution Gels on Standing.[2]

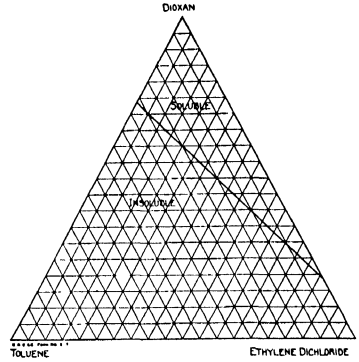


FIGURE 224. Solubility of Low Viscosity Cellulose Acetate in Mixtures of 1, 4-Dioxane, Toluene and Ethylene Dichloride.[2]

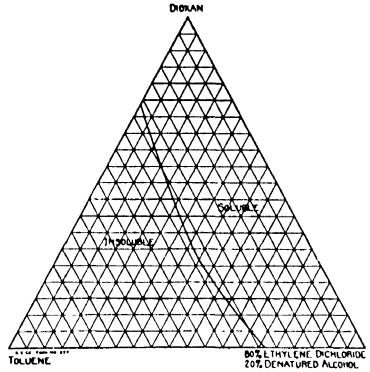


FIGURE 225. Solubility of Low Viscosity Cellulose Acetate in Mixtures of 1, 4-Dioxane, Toluene and 80% Ethylene Dichloride 20% Denatured Alcohol.[2]

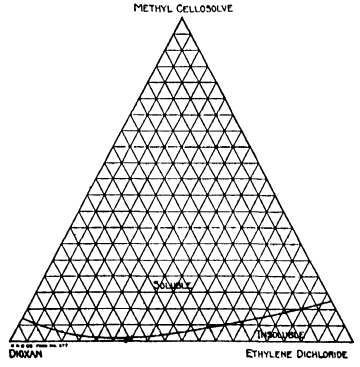


FIGURE 226. Solubility of ½ Second R. S. Nitrocellulose in Mixtures of Methyl "Cellosolve," 1, 4-Dioxane and Ethylene Dichloride.[2]

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[1] U. S. Industrial Chemicals, Inc., New York, N. Y.
[2] Carbide & Carbon Chemicals Corporation, New York, N. Y.
[3] Carroll, S., U. S. Patent, 1,735,157 (Dec. 1929).

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Chapter 15

Esters

Formic Esters

(HCOOR)

Methyl Formate

Methyl formate ($HCOOCH_3$) is a colorless, inflammable liquid. Mork [1] believes it to be a more powerful solvent for cellulose derivatives than is acetone. Methyl formate will dissolve cellulose ethers and esters and will do this more readily when it is mixed with other solvent esters or the less volatile halogenated hydrocarbons. It is used as a fumigant and larvicide in the treatment of tobacco, dried fruit, cereals and so forth. It has also been suggested as an engine fuel when it is first admixed with other combustible materials.

Purity		95% to 100% ester, by weight
Specific gravity		0.950 to 0.980 at $\frac{20° \text{ C.}}{20° \text{ C.}}$
Acidity		Neutral to methyl orange. (Methyl formate hydrolyzes in the presence of water.)
Color		Water-white
Odor		Pleasant, ethereal
Water		No turbidity when 1 vol. is mixed with 19 vols. of 60° Bé. gasoline at 20° C.
Distillation range		
Below 31.5° C.		None
Above 35.0° C.		None
Solubility in water		30% by volume (20° C.)
Melting point		−99.8° C.
Boiling point		31.8° C.
Flash-point		−32° C. (− 25.6° F.)
Vapor pressure	at	16.0° C. = 400 mm. Hg. 25.8° C. = 600 mm. Hg.
Molecular weight		60.031
Weight per U.S. gallon		8.03 lbs. (68° F.)

Ethyl Formate

Ethyl formate ($HCOOC_2H_5$, Formosol) is a water-white, highly volatile, unstable liquid of a pleasant aromatic odor. It is miscible with benzene and is soluble in nine parts of water at 18° C. Ethyl formate is a powerful solvent for cellulose nitrate and acetate and yields solutions of unusually low viscosity which have a tendency to chill. It is used as a solvent for cellulose in combination with solvents of higher boiling points

and lower evaporation rates. It is also used as an acetone substitute, a fumigant and larvicide for the treatment of tobacco, cereals, dried fruit, and similar products, for medicinal purposes and in synthetic flavors.

Purity	95% to 100% ester, by weight
Specific gravity	0.900 to 0.930 at $\frac{20° C.}{20° C.}$
Acidity	Neutral to methyl orange. (Ethyl formate hydrolyzes in the presence of water.)
Color	Water-white
Odor	Pleasant, aromatic
Distillation range	
Below 51° C.	None
Above 55° C.	None
Solubility in water	10% by volume (20° C.)
Melting point	− 80.5° C.
Boiling point	54.3° C.
Flash-point	− 19.5° C. (− 3.1° F.)
Vapor pressure at	20.6° C. = 200 mm. Hg. 30.2° C. = 300 mm. Hg.
Molecular weight	74.046
Weight per U.S. gallon	7.61 lbs. (68° F.)

Butyl Formate

Butyl formate ($HCOOCH_2CH_2CH_2CH_3$) is a colorless liquid, miscible with alcohols, ethers, oils, hydrocarbons and so forth. It will dissolve cellulose nitrate, some types of cellulose acetate, and many cellulose ethers. Butyl formate will also dissolve many natural and synthetic resins such as copals, dammar, elemi, mastic, shellac, benzyl abietate, cumar resins, ester gum and glyptols in the presence of ethyl alcohol. This ester is employed as a solvent in lacquers owing to its virtue of imparting great strength to a film. It is also used as an intermediate and in perfumes.

Acidity	0.02% max.
Ester content	85% min.
Boiling range	96–110° C.
Specific gravity	0.885–0.9108

Amyl Formate

Commercial amyl formate ($HCOOC_5H_{11}$) is an anhydrous, colorless liquid composed of a mixture of isomeric amyl formates with the isoamyl formate in predominance. This mixture is miscible with oils, hydrocarbons, alcohols, ketones and so forth. It is a solvent for cellulose esters, benzyl abietate, cumar, copal, gum esters, mastic, etc. It is able, when mixed with an alcohol, to dissolve shellac and glyptols. It is a less odoriferous and more energetic solvent than amyl acetate, and is consequently more desirable in many industries especially in the manufacture of leather cloth. It also has both a lower boiling point and a greater speed of evaporation. *n*-Butyl acetate and amyl formate have similar volatility and have substantially the same solvent power which permit free interchange of these only as far as these properties allow.

Amyl formate, when in combination with other solvents, is used in film manufacture, as a precipitant for cellulose formate and phosphoformate and in the manufacture of celluloid substitutes.

Acidity	0.05% max.
Boiling point	130.4° C.
Boiling range	110–130° C.
Flash-point	80° F.
Specific gravity	0.880–0.885

Benzyl Formate

Benzyl formate ($C_6H_5CH_2OOCH$) is a colorless liquid with an odor suggestive of leather. It is miscible with alcohols, ketones, oils, aromatic, aliphatic and halogenated hydrocarbons. It resembles benzyl acetate in many respects but differs in its greater volatility. Benzyl formate is a solvent for nitrocellulose, acetylcellulose, and some cellulose ethers, benzyl abietate, ester gum, copal ester, cumar resins, glyptols and so forth.

Glycol Formate

The I. G. Farbenindustrie [2] have proposed a number of glycol and glyceryl formates as solvents and plasticizers for cellulose ethers and esters. Some of these are composed of glycol mono and diformates, glyceryl formates, propylene glycol mono and diformates, and the glyceryl, erythritol, and sorbitol formates, acetates, benzoates, oxalates, succinates and phthalates.

Wolff [4] has suggested Hexalin and Heptalin formates as solvents for cellulose derivatives.

	Specific Gravity	Boiling Range
Hexalin formate	0.973	150–159° C.
Hexalin acetate	0.966	164–180
Heptalin formate	0.959	173–185
Heptalin acetate	0.941	176–193

Acetic Esters

The acetic esters (CH_3COOR) are an important class of liquids used widely as direct and adjuvant solvents. They are colorless, stable liquids of characteristic odor. The solvency of any member of this group decreases as the molecular weight of the alkyl group increases. Other characteristics are dependent upon the kinds of alkyl, aryl or aralkyl groups that are combined with the acetate radical.

Methyl Acetate

Methyl acetate (CH_3COOCH_3) is a water-white, unstable liquid of fragrant odor. It is quite similar to acetone in many respects especially in its boiling-point, solvent-power and miscibility; but it differs from acetone in its instability, which consequently limits its use in the industries. Methyl acetate is used in lacquers, paints, varnishes and enamels, and

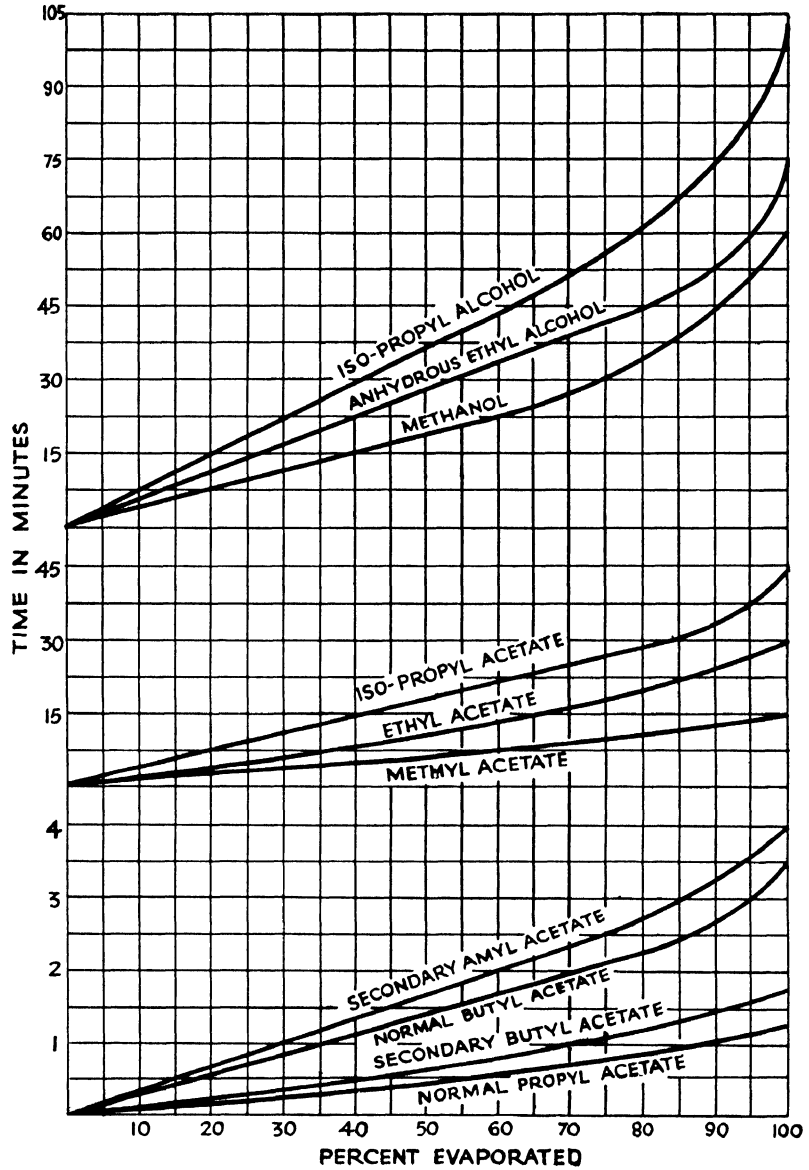


FIGURE 227. Evaporation Rate of Various Solvents at Room Temperature.[8]

as a substitute for acetone in many preparations. It is usually admixed with high-boiling solvents, latent and non-solvents. It is also used in cosmetics, dyes, dopes, flavoring extracts, perfumes, plastics and synthetic finishes. It will completely dissolve cellulose nitrate and acetate, ethyl cellulose, ester gum, rosin, cumar, elemi, amberols, resyls, corn oil, linseed oil, castor oil, neatsfoot oil, chinawood oil and cottonseed oil. It will partially dissolve shellac, manila, dammar, pontianac, Beckacites and glyptols.

	99%	Technical 82-85%
Acidity	0.005% as acetic acid	0.005% as acetic acid
Color	Water-white	Water-white
Non-volatile matter	Not more than 0.005 gram per 100 cc.	Not more than 0.005 gram per 100 cc.
Specific gravity	0.930–0.940 at $\frac{20° \text{ C.}}{20° \text{ C.}}$	0.905–0.910 at $\frac{20° \text{ C.}}{20° \text{ C.}}$
Boiling range	55° C.–58° C. (760 mm.)	53° C.–56° C. (760 mm.)
Boiling point	57° C.	54° C.
Iron	None	None
Chloride	None	None
Average weight per gallon	7.8 lbs.	7.54 lbs.
Solubility in water	24% (20° C.)	Miscible
Solubility in 60° Bé. gasoline	Miscible	Miscible
Toluene dilution ratio	2.3	2.3
Water	None	None

Methyl Chloracetate

Methyl chloracetate has been proposed as a solvent but its instability restricts its wide use.

Ethyl Acetate

Ethyl acetate ($CH_3COOC_2H_5$, acetic ether, vinegar naphtha) is a water-white, inflammable liquid of a pleasant, fruity odor. It is miscible with most organic solvents such as alcohols, ketones, esters, aromatic, aliphatic and halogenated hydrocarbons, and will tolerate a fairly large amount of lacquer diluents. Like methyl acetate it has a wide range of solubilities and possesses the unique property of dissolving nitro and acetylcellulose and cellulose ethers, yielding solutions of low viscosity. Its solvent power for cellulose derivatives is much improved by the addition of a small quantity of alcohol. It is considered one of the best solvents for nitrocellulose. Ethyl acetate will dissolve oils, fats, waxes, gums, and natural and synthetic resins. Owing to its high solvency for nitrocellulose, ethyl acetate is used in the manufacture of artificial hair, leather, silk, cements, celluloid substitutes, dopes, varnishes, transparent wrapping paper, coated paper, polishes, plastics and varnish removers. It is also used in organic synthesis; in making dyes, drugs, flavors, perfumes, esters, phosgene gas, medicinals, smokeless powder, rayon and cleaning preparations for textiles; and in the extraction of acetic acid from aqueous solutions. Other proposed acetates are chlorethyl acetate, ethyl methyl propyl acetate, ethyl propyl methyl acetate, etc.

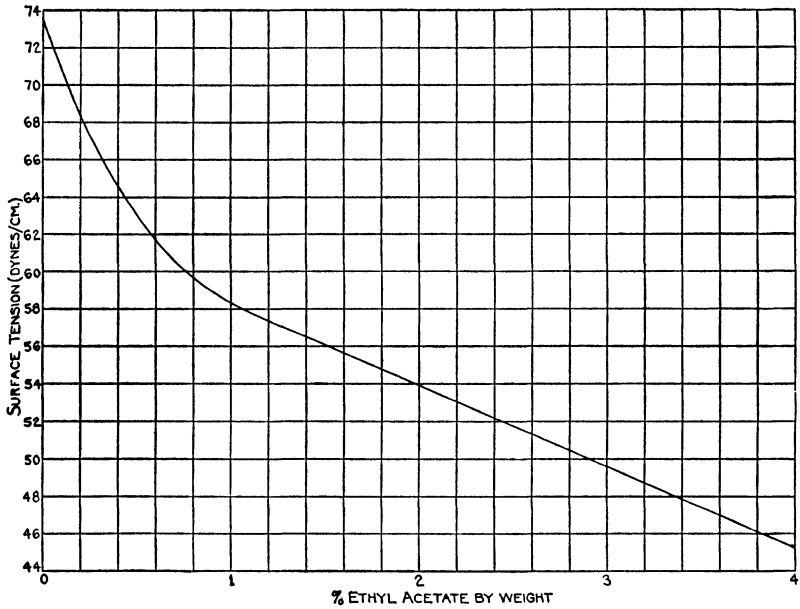


FIGURE 228. Surface Tension of Aqueous Solutions of Ethyl Acetate (20° C.).[5]

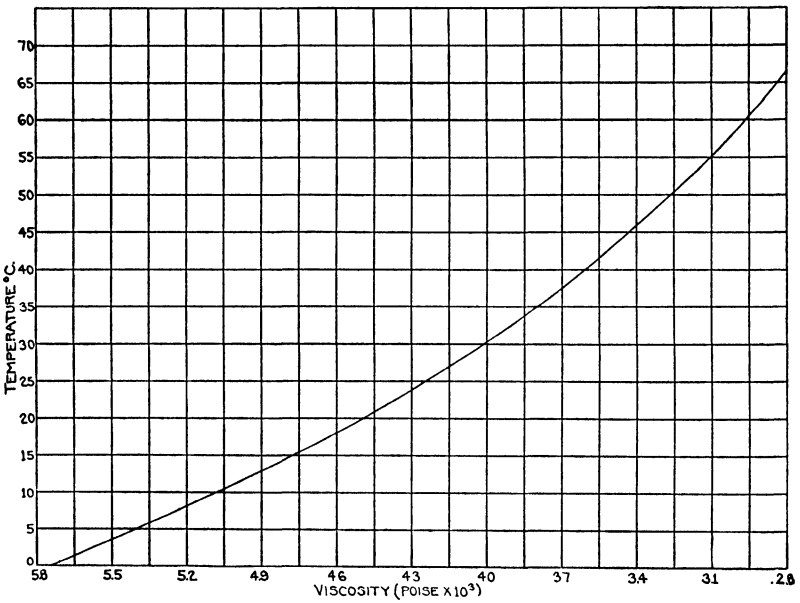


FIGURE 229. Viscosity of Ethyl Acetate at Various Temperatures.[5]

Properties of Ethyl Acetate

	99%	Commercial 85-88%
Acidity	Free acid as acetic, not more than 0.01%	Free acid as acetic, not more than 0.02%
Color	Water-white	Water-white
Distillation range	Below 75° C. ....None Above 80° C. ....None	Below 70° C. ....None Below 72° C. ....Not more than 10% Above 80° C. ....None
Dryness	Miscible without turbidity with 10 vols. 60° Bé. gasoline at 20° C.	Miscible without turbidity with 10 vols. 60° Bé. gasoline at 20° C.
Non-volatile matter	Not more than 0.003 gm./100 cc.	Not more than 0.003 gm./100 cc.
Odor	Mild, non-residual	Mild, non-residual
Purity	Ester content as ethyl acetate, 99–100%	Ester content as ethyl acetate, 85–88%
Specific gravity	0.900–0.904 at $\frac{20° C.}{20° C.}$	0 882–0.886 at $\frac{20° C.}{20° C.}$
Blush resistance at 90° F. (10% ½-sec. R.S. nitrocellulose solution)	Relative humidity: Clear 55% Blush 60%	Relative humidity: Clear 45% Blush 50%
Coefficient of expansion	0.00074/1° F. 0.00133/1° C.	0.00073/1° F. 0.00131/1° C.
Dilution ratio (nitrocellulose solution method)	3.0 with toluene 1.0 with petroleum naphtha	3 5 with toluene 1.1 with petroleum naphtha
Evaporation rate at 95° F.	Per cent: 5 25 50 75 90 95 Minutes: ¼ 1½ 3¾ 6½ 9¼ 10¼	Per cent: 5 25 50 75 90 95 Minutes: ¼ 1½ 3¾ 6¾ 9½ 11¼
Flash-point	26° F. (approx.)	26° F. (approx.)
Viscosity expressed in centipoises (10% ½-sec. R.S. nitrocellulose solution)	33	32
Water solubility	At 25° C., 100 cc. solvent dissolves 3.5 cc. water	At 25° C., 100 cc. solvent dissolves 11.2 cc. water

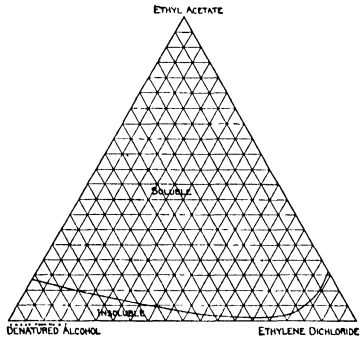


FIGURE 230. Solubility of ½ Second R. S. Nitrocellulose in Mixtures of Ethyl Acetate, Ethylene Dichloride, and Denatured Alcohol.[5]

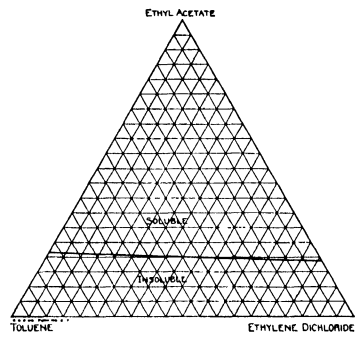


FIGURE 231. Solubility of ½ Second R. S. Nitrocellulose in Mixtures of Ethyl Acetate, Toluene, and Ethylene Dichloride.[5]

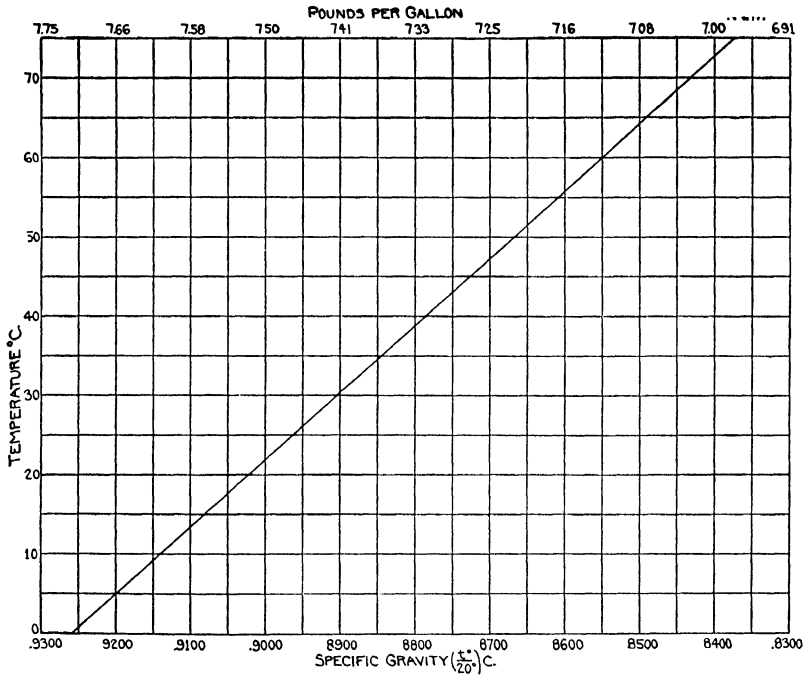


FIGURE 232. Specific Gravity and Weight per Gallon of Ethyl Acetate at Various Temperatures.[5]

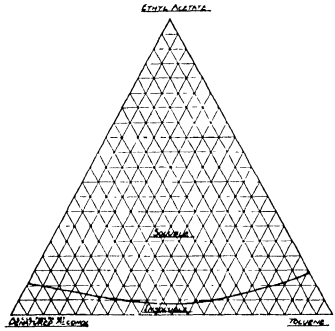


FIGURE 234.

Solubility of ½-Second R. S. Nitrocellulose in Mixtures of Ethyl Acetate, Denatured Alcohol, and Toluene.[5]



FIGURE 233. Specific Gravity of Ethyl Acetate-Ethyl Alcohol Mixtures at Room Temperature.[6]

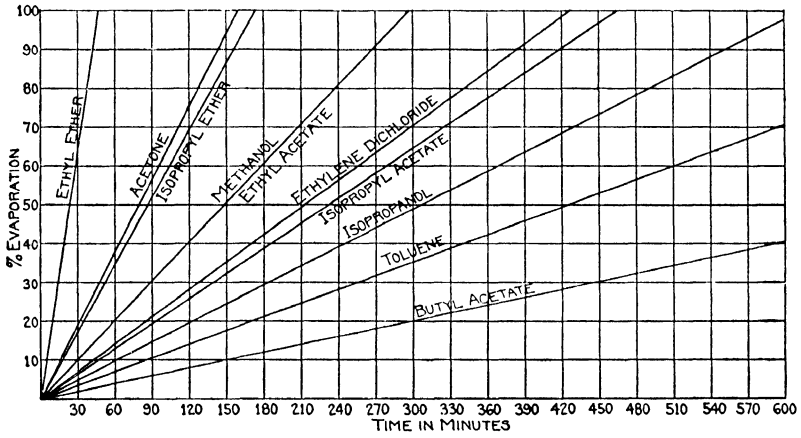


FIGURE 235. Evaporation Rate of Various Solvents at Room Temperature.[5]

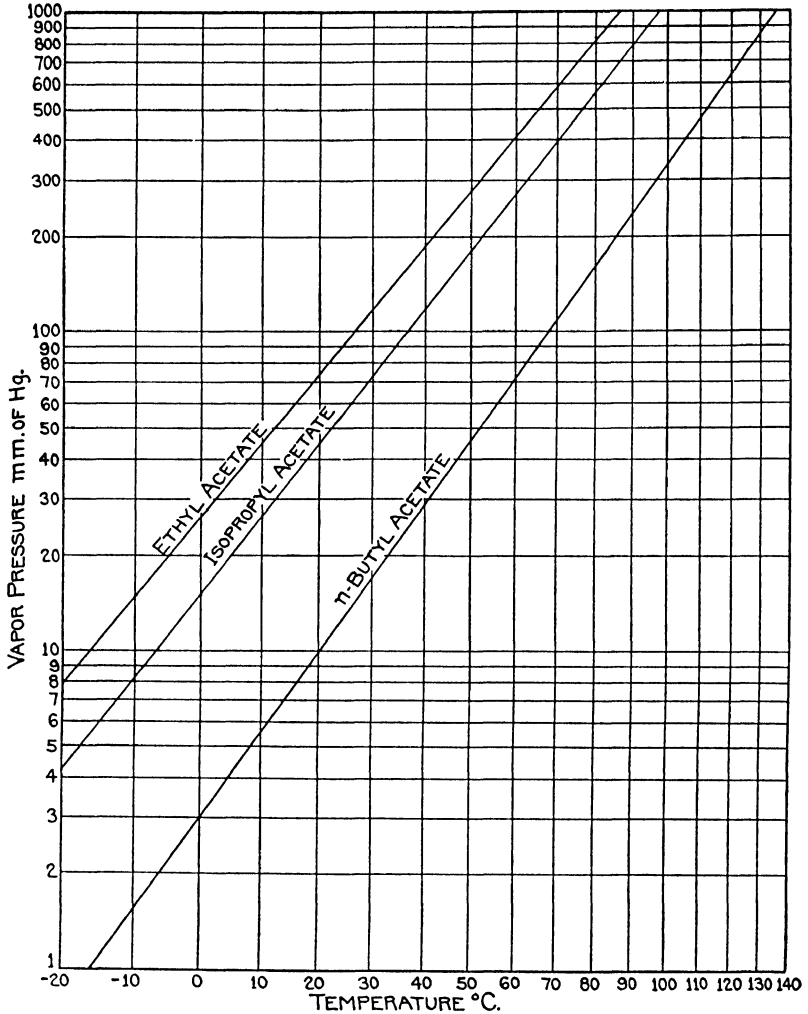


FIGURE 236. Vapor Pressure of Some Esters at Various Temperatures.[5]

n-Propyl Acetate

n-Propyl acetate ($CH_3COOC_3H_7$) in commerce is the acetylated, lighter fraction of fusel oil. It exists as a mixture of propyl, butyl and amyl acetate. The properties of *n*-propyl acetate are, approximately, intermediate between those of ethyl and *n*-butyl acetates. It is miscible with alcohols, ketones, esters, oils and hydrocarbons and is a good solvent for nitrocellulose and a wide range of cellulose derivatives, especially when it is admixed with the aromatic hydrocarbons or the lower aliphatic alcohols. It will also dissolve natural and synthetic resins like benzyl abietate, elemi, cumar resins, ester gum, manila, mastic, rosin and sandarac. It is used in organic synthesis and, in combination with other solvents, in cellulose ether lacquers and plastics. It is a colorless liquid of pleasant odor.

Boiling point	101.6° C.
Flash-point	12° C.
Specific gravity	0 897

Isopropyl Acetate

Isopropyl acetate $CH_3COOCH\begin{matrix}CH_3\\CH_3\end{matrix}$ is a water-white liquid with properties which resemble those of ethyl and butyl acetates but actually it is intermediate between the two. It is miscible with most of the common organic solvents such as alcohols, ketones, esters, oils, hydrocarbons and so forth. It is a solvent for nitrocellulose, cellulose acetate (of low viscosity), and a wide range of oils, fats, waxes, gums, and natural and synthetic resins Isopropyl acetate, like *n*-propyl acetate, responds by an increased solvent-power for cellulose esters when aromatic hydrocarbons or lower aliphatic alcohols are added. It is largely used as a solvent in the manufacture of artificial leather and silk, dopes, films, lacquers and plastics. It is also used in organic synthesis, in synthetic perfumes, and in the recovery of acetic acid from aqueous solutions. The use of chlorpropyl acetate as a solvent for cellulose esters has been advocated.

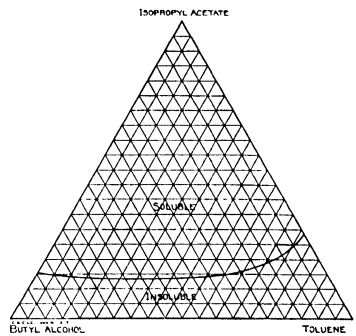


FIGURE 237.

Solubility of ½-Second R. S. Nitrocellulose in Mixtures of Isopropyl Acetate, Butyl Alcohol, and Toluene.[5]

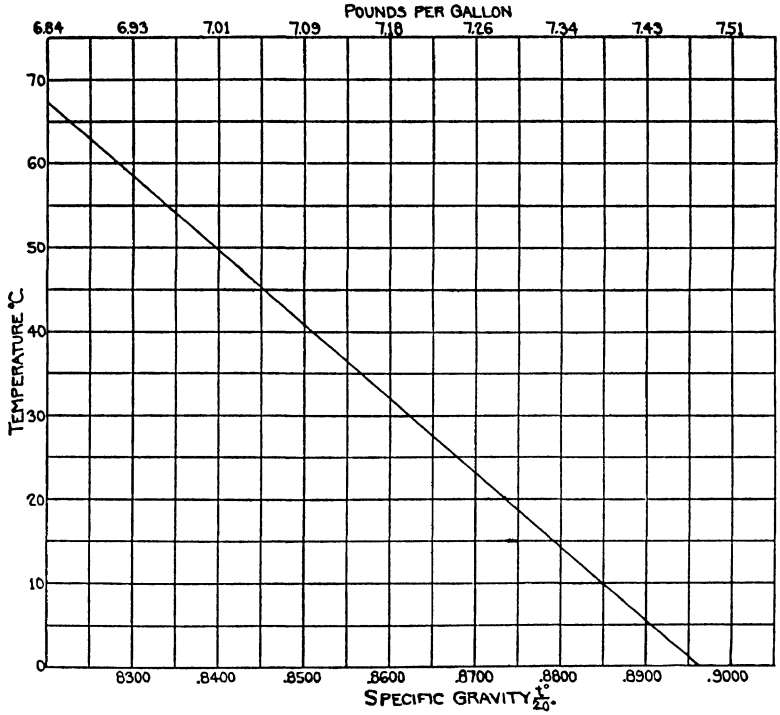


FIGURE 238. Specific Gravity of Isopropyl Acetate at Various Temperatures.[5]

Properties of Isopropyl Acetate

Molecular weight	102.08
Boiling point	88.8° C.
Freezing point	− 73.4° C.
Specific gravity	0.8736 at $\frac{20° \text{ C.}}{20° \text{ C.}}$
Weight per gallon	7.28 lbs. (20° C.)
Refractive index	1.3770 (20° C.)
Surface tension	24.5 dynes/cm. (25° C.)
Viscosity	0.00525 poise (20° C.)
Vapor pressure	48.5 mm. Hg. (20° C.)
Specific heat	0.521 cal./g. (15–25° C.)
Flash-point	8° C. (46.4° F.)
Latent heat of evaporation	78.2 cal./g. at B.P.
Solubility in water	4.5% by wt. (27° C.)
Solubility of water in isopropyl acetate	1.25% by wt. (27° C.)

Electrical conductivity	5.7×10^{-7} recip. ohms (25° C.)
Dilution ratios	Toluene 2.7 V.M. & P. naphtha 0.92 Final conc. ½-sec. R.S. nitrocellulose 8%

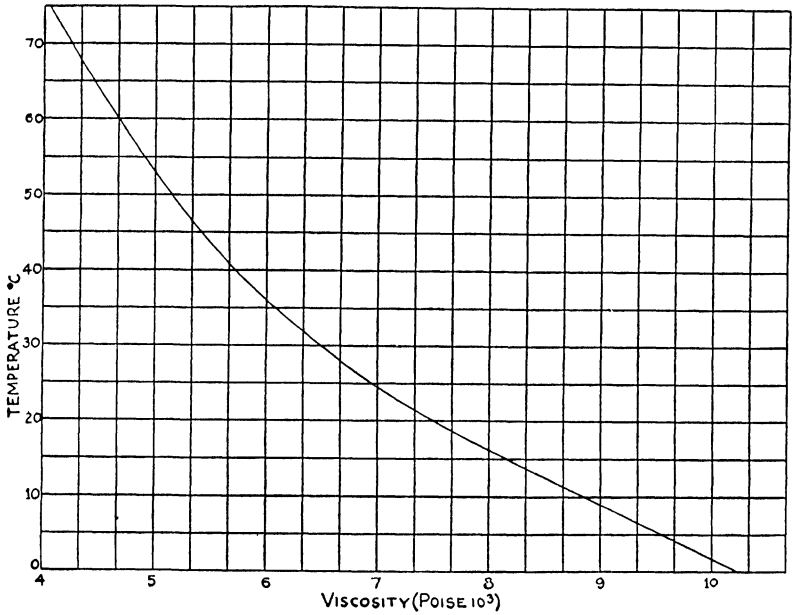


FIGURE 239. Viscosity of Isopropyl Acetate at Various Temperatures.[5]

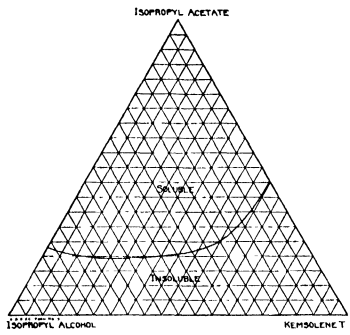


FIGURE 240. Solubility of ½ Second R. S. Nitrocellulose in Mixtures of Isopropyl Acetate, Isopropyl Alcohol, and Kemsolene T.[5]

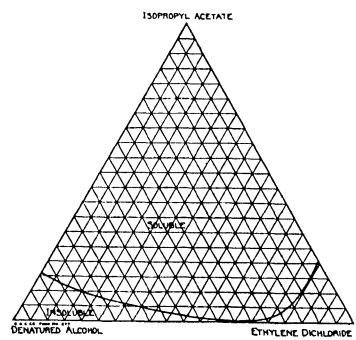


FIGURE 241. Solubility of ½ Second R. S. Nitrocellulose in Mixtures of Isopropyl Acetate, Denatured Alcohol, and Ethylene Dichloride.[5]

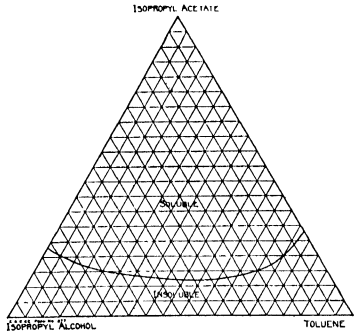


FIGURE 242. Solubility of ½ Second R. S. Nitrocellulose in Mixtures of Isopropyl Acetate, Isopropyl Alcohol, and Toluene.[5]

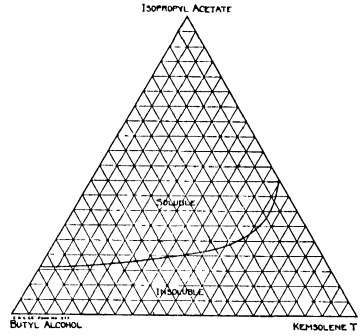


FIGURE 243. Solubility of ½ Second R. S. Nitrocellulose in Mixtures of Isopropyl Acetate, Butyl Alcohol, and Kemsolene T.[5]

Normal Butyl Acetate

Normal butyl acetate ($CH_3COOCH_2CH_2CH_2CH_3$) is a water-white liquid of a characteristic fruity odor which is less pronounced than in amyl acetate. It is miscible with alcohols, ketones, esters and most of the common organic solvents. *n*-Butyl acetate is a solvent for nitrocellulose and cellulose ethers especially when it is previously mixed with active or latent solvents. When it is used in combination with 20 per cent of butyl alcohol the mixture will dissolve the less highly polymerized glyptol resins, and shellac. It will dissolve oils, fats, waxes, metallic resinates, benzyl abietate, camphor, cumar resins, dammar, ester gum, ketone-aldehyde resins, elemi, kauri, manila, mastic, pontianac, rosin, sandarac and vinyl resins. *n*-Butyl acetate is classed among the very good solvents for nitrocellulose owing to its power to impart low viscosity, gum-compatibility and good working qualities. The commercial grade is composed of lower-boiling aliphatic esters which accordingly adds to its solvent power. Its volatility meets the demands for a lacquer solvent in that it is sufficiently high to leave the film readily and at the same time low enough to prevent blushing. When it is used together with butyl alcohol the combination prevents gum-blush, cotton-blush and chilling. The bulk of *n*-butyl acetate is used as a solvent in the manufacture of artificial leather and coatings, enameled leather, coated paper and textiles, films, lacquers, plastics, polishes and safety glass. Other uses are as an extracting solvent for camphor, drugs, mineral and vegetable oils, perfumes, pitches, resins and gum rubber; as an ingredient in perfumes and flavoring materials; and as a dehydrating agent.

Purity	88% to 92% ester, by wt.
Specific gravity	0.872 to 0.880 at $\frac{20^\circ\text{ C.}}{20^\circ\text{ C.}}$

Acidity	Less than 0.03% as acetic acid. Not more than 0.28 mg. KOH required for neutralization of 1 g.
Water	Miscible without turbidity in all proportions with 60° Bé. gasoline at 20° C.
Non-volatile matter	Not more than 0.005 gram when 100 cc. are evaporated and heated to constant weight at 100° C. to 110° C.
Color	None
Distillation range	
Below 110° C.	None
Below 120° C.	Not more than 15%
Above 127° C.	Not less than 70%
Above 145° C.	None
Odor	Mild, non-residual
Flash-point	26° C.
Weight per U.S. gallon	7.30 lbs. (68° F.)
Approx. change in wt.	0.0049 lbs./gal./° F.
Solubility in water	0.5% by vol. (25° C.)
Solubility of water in butyl acetate	1.6% by vol. (25° C.)

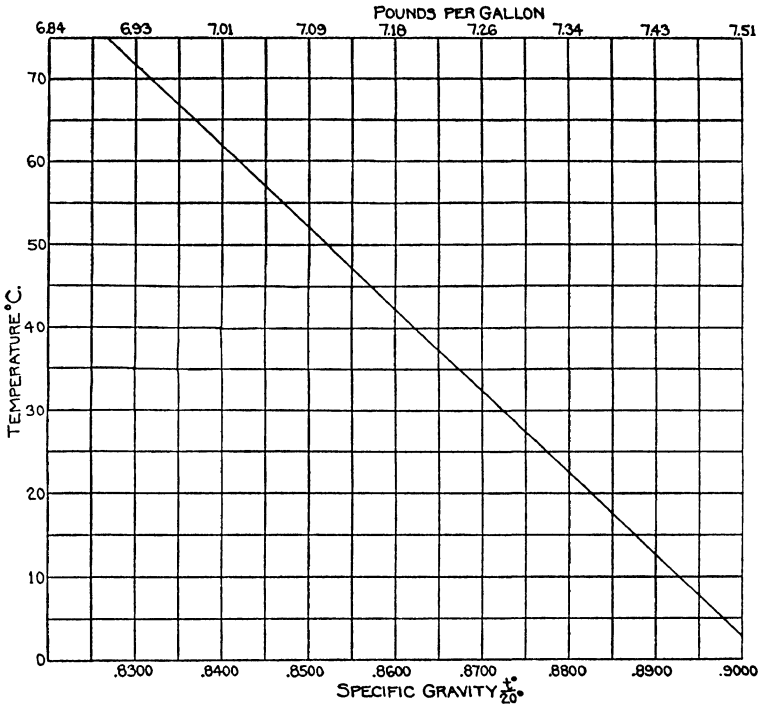


FIGURE 244. Specific Gravity of Butyl Acetate at Various Temperatures.[5]

Molecular weight	116.10
Melting point	− 76.8° C.
Boiling point	126.5° C.
Latent heat of vaporization	73 8 cal./g. (124° C.)
Critical temperature	306° C.
Vapor pressure	3.0 mm. Hg. (0° C.) 15.0 mm. Hg. (25° C.) 45 0 mm. Hg. (50° C.)

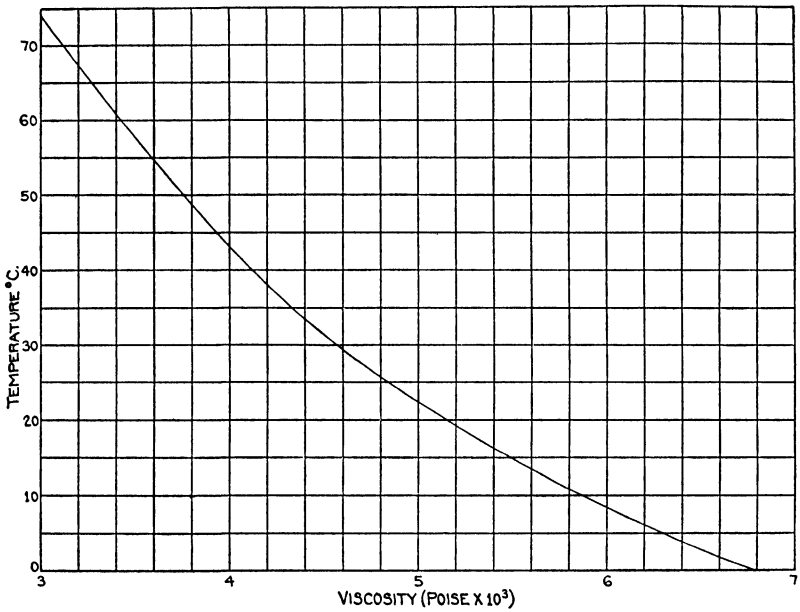


FIGURE 245. Viscosity of *n*-Butyl Acetate at Various Temperatures.[5]

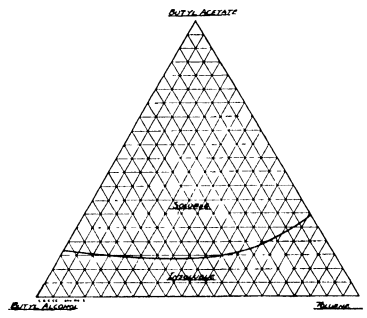


FIGURE 246. Solubility of ½-Second R. S. Nitrocellulose in Mixtures of Butyl Acetate, Butyl Alcohol, and Toluene.[5]

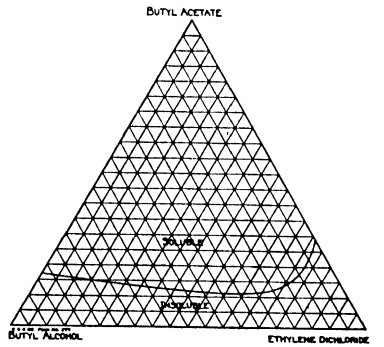


FIGURE 247. Solubility of ½-Second R. S. Nitrocellulose in Mixtures of Butyl Acetate, Butyl Alcohol, and Ethylene Dichloride.

Secondary Butyl Acetate

Secondary butyl acetate $CH_3COOCH\begin{matrix}CH_3\\C_2H_5\end{matrix}$ (acetic acid isobutyl ester) is a colorless, inflammable liquid of a fruity odor. Its miscibility and solubility are similar to those of *n*-butyl acetate. However, it has a lower boiling range, it imparts less blush-resistance and it evaporates with greater rapidity. It can be used in place of *n*-butyl acetate but other solvents must be added to compensate for its quicker rate of evaporation and other differing physical characteristics.

Acidity	Not more than 0.03% free acid as acetic
Color	Water-white
Distillation range	
Below 104° C.	None
Below 111° C.	Not more than 10%
Below 114° C.	Not more than 60%
Below 118° C.	Not less than 90%
Above 130° C.	None
Dryness	Miscible with turbidity with 20 vols. 60° Bé. gasoline at 20° C.
Non-volatile matter	Not more than 0.005 g./100 cc.
Odor	Mild, non-residual
Purity	85–88% ester content (as butyl acetate)
Specific gravity	0.862–0.866 at $\frac{20°\text{ C.}}{20°\text{ C.}}$
Blush resistance at 90° F. (10% ½-sec. R.S. nitrocellulose solution)	
Relative humidity	Clear 75% Blush 80%
Coefficient of expansion	0.00063/1° F. 0.00113/1° C.
Dilution ratio (nitrocellulose solution method)	2.8 with toluene 1.4 with petroleum naphtha
Evaporation rate at 95° F.	
Per cent	5 25 50 75 90 95
Minutes	½ 3¾ 8½ 13½ 16¾ 18
Flash-point	66° F.
Viscosity (10% ½-sec. R.S. nitrocellulose solution)	49 centipoises
Water solubility	100 cc. solvent dissolves 2.5 cc. water (25° C.)

Isobutyl Acetate

Isobutyl acetate $CH_3COOCH_2CH\begin{matrix}CH_3\\CH_3\end{matrix}$ is a colorless liquid of a mild and pleasant odor. It is present in commercial grades of amyl acetate. It has similar properties of solubility and miscibility to normal and secondary butyl acetates. Solutions of nitrocellulose in isobutyl acetate have a lower viscosity than solutions of cellulose nitrate in *n*-butyl acetate. Iso-

butyl acetate owing to its tendency to cause chilling in lacquers should be mixed with amyl acetate.

Ester content	95–100%
Boiling range	110–118° C.
Flash-point	18° C.
Refractive index	1.392 (approx.)
Specific gravity	0.868–0.875

Amyl Acetate

Amyl acetate ($CH_3COOC_5H_{11}$, banana oil, amylacetic ether, isoamyl acetate, pear oil) is a colorless, inflammable liquid of a banana- or pear-like odor. Its objectionable odor is tolerated for its exceptional solvent power. It stands indisputably first for its value to the cellulose nitrate industry. The amyl acetates are made by the acetylation of the alcohols obtained from fusel oil or those made synthetically from the olefin fractions of gasoline. Commercial grades of amyl acetates contain the following esters: *n*-propyl, isobutyl, isoamyl, amyl, *n*-hexyl, and *n*-heptyl acetates. The technical grade of synthetic amyl acetate contains only the isomeric forms of amyl acetate. These mixtures are miscible with oils, hydrocarbons, alcohols, ketones, esters and so forth.

Amyl acetate is a good solvent for cellulose esters and ethers and in combination with ethyl alcohol its solvency is increased. It will also dissolve such substances as albertols, benzyl abietate, camphor, cumar resins, elemi, ester gums, copal ester, copals, dammar, ketone-aldehyde resins, kauri, linoxyn, mastic, rosin, sandarac, tannins, vinyl resins, waxes and zanzibar; and when amyl acetate is mixed with alcohol, it will dissolve glyptol resins. Amyl acetate is used extensively as a solvent for cellulose derivative lacquers owing to its solvency and its power to impart blush-prevention, good flow, gloss and toughness. It is also employed in making gun-cotton, smokeless powder, artificial leather and pearls, waterproofing compositions, varnishes, bronzing liquid, films, celluloid, rayon, linoleum,

	High Test	Commercial	Technical
		Free acid as acetic	
Acidity	Not more than 0.03%	Not more than 0.03%	Not more than 0 03%
Color	Water-white	Water-white	Water-white
Distillation range			
Below 110° C.	None	Not more than 15%	None
Below 120° C.	Not more than 10%	Not more than 30%	Not more than 10%
Below 130° C.	Not more than 40%	Not more than 55%	Not more than 60%
Below 140° C.	Not less than 60%	Not less than 80%	Not less than 90%
Above 150° C.	None	None	None
Dryness	Miscible without turbidity with 20 vols. 60° Bé. gasoline at 20° C.	Miscible without turbidity with 20 vols. 60° Bé. gasoline at 20° C.	Miscible without turbidity with 20 vols. 60° Bé. gasoline at 20° C.
Non-volatile matter	Not more than 0 005 g./100 cc.	Not more than 0.005 g /100 cc.	Not more than 0.005 g./100 cc.
Odor	Mild, non-residual	Mild, non-residual	Mild, non-residual

oil-cloth, fruit flavors, soft drinks, food preparations, confectionery, perfumes, soap solvent and in photoengraving.

	High Test	Commercial	Technical
	Ester content as amyl acetate		
Purity	85–88%	85–88%	90–95%
Specific gravity $\frac{20° C.}{20° C.}$	0.859–0.863	0.857–0.865	0.866–0.870
Blush resistance at 90° F. (10% ½-sec. R.S. nitrocellulose solution)	Relative Humidity		
	Clear 85% Blush 90%	Clear 80% Blush 85%	Clear 85% Blush 90%
Coefficient of expansion	0.00066/1° F. 0.00119/1° C.	0.00066/1° F. 0.00119/1° C.	0.00061/1° F. 0.00110/1° C.
Dilution ratio (nitrocellulose solution method)			
With toluene	2 5	2.7	2.6
With petroleum naphtha	1.4	1.4	1.4
Evaporation rate at 95° F.			
Per cent	5 25 50	5 25 50	5 25 50
Minutes	1½ 8¼ 18½	1 6 15¼	1¼ 7 15½
Per cent	75 90 95	75 90 95	75 90 95
Minutes	30 45 51¾	28½ 41¼ 47½	25¾ 35 40
Flash-point	84° F. (approx.)	63° F. (approx.)	79° F. (approx.)
	Centipoises		
Viscosity (10% ½-sec. R.S. nitrocellulose solution)	61	43	60
Water solubility	100 cc. solvent dissolves 1.8 cc. water (25° C.)	100 cc. solvent dissolves 2.4 cc. water (25° C.)	100 cc. solvent dissolves 1.6 cc. water (25° C.)

Secondary Amyl Acetate

Secondary amyl acetate is made from the secondary amyl alcohols (pentanol-2 and pentanol-3) by acetylation. Its solvent power and other properties are similar to those of amyl acetate with the exception of its lower tolerance for diluents. Its odor, too, is less irritating.

Acidity	Not more than 0.03% free acid as acetic
Color	Water-white
Distillation range	
Below 123° C.	None
Below 126° C.	Not more than 10%
Below 132° C.	Not more than 60%
Below 140° C.	Not less than 90%
Above 145° C.	None
Dryness	Miscible without turbidity with 20 vols. 60° Bé. gasoline at 20° C.
Non-volatile matter	Not more than 0.005 g./100 cc.
Odor	Mild, non-residual

Purity	85–88% ester content (as amyl acetate)
Specific gravity	0.862–0.866 at $\frac{20° \text{ C.}}{20° \text{ C.}}$
Blush resistance at 90° F. (10% ½-sec. R.S. nitrocellulose solution)	Clear Blush
Relative humidity	85% 90%
Coefficient of expansion	0.00060/1° F. 0.00108/1° C.
Dilution ratio (nitrocellulose solution method)	2.1 with toluene 1.1 with petroleum naphtha
Evaporation rate at 95° F.	
Per cent	5 25 50 75 90 95
Minutes	1½ 7½ 15½ 24½ 30½ 33¾
Flash-point	89° F. (approx.)
Viscosity (10% ½-sec. R.S. nitrocellulose solution)	75 centipoises
Water solubility	100 cc. solvent dissolves 0.8 cc. water (25° C)

Pent-Acetate

Pent-acetate is a mixture of five isomeric amyl acetates with some amyl alcohol. These esters are prepared from synthetic amyl alcohol and the solvent power of the mixture is similar to that of amyl acetate.

$CH_3CH_2CH(CH_3)CH_2OH$	128° C.[7]
$(CH_3)_2CHCH_2CH_2OH$	131°
$CH_3CH_2CH_2CH_2CH_2OH$	136°
$CH_3CH_2CH(OOCCH_3)CH_2CH_3$	132°
$CH_3CH(OOCCH_3)CH_2CH_2CH_3$	134°
$CH_3CH_2CH(CH_3)CH_2OOCCH_3$	142°
$(CH_3)_2CHCH_2CH_2OOCCH_3$	142°
$CH_3CH_2CH_2CH_2CH_2OOCCH_3$	148°

Color	Water-white
Specific gravity	0.858–0.866 (20° C)
Acidity	Less than 0.03% free acid as acetic
Water content	None
Ester content	Above 85%
Non-volatile	Less than 0.02% (100° C.)
Petroleum and coal tar hydrocarbons	0.0000%
Weight per gallon	7.2 lbs.
Distillation	
100%	Above 126° C.
95%	Above 130° C.
75%	Above 135° C.
25%	Above 140° C.
End Point	Not above 150° C.

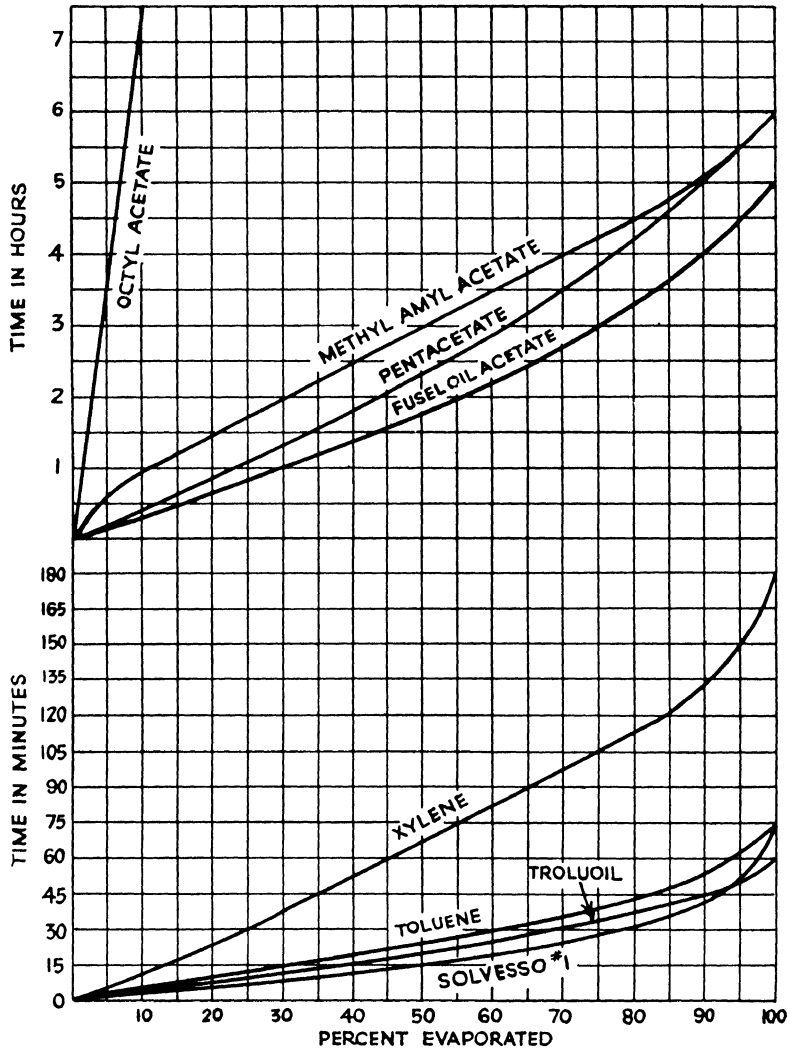


FIGURE 248. Rate of Evaporation of Various Solvents at Room Temperature.[8]

*

TABLE 115.—Dilution Ratios with Nitrocellulose*

Solvent	Diluent Mixture[8] % Butanol / % Toluene 0/100	20/80	40/60	60/40	80/20	100/0
Ethyl lactate	6.0	18.0	30.0	35.0	27.0	22.5
"Cellosolve"	6.0	11.0	19.0	15.0	11.0	9 5
"Cellosolve" acetate	2.5	8.5	22.0	18.0	12.5	8.5
Butyl propionate	2.0	7.5	16.0	17.5	16.0	14.0
Amyl acetate	2.0	5.0	10.0	18.0	15.5	14.0
Butyl "Cellosolve"	5.2	7.4	11.6	8.5	6.0	5.8

Solvent	Diluent Mixture[8] % Butanol / % Dryoline 0/100	20/80	40/60	60/40	80/20	100/0
Ethyl lactate	0.5	2 3	7.0	10.8	15.5	22.5
"Cellosolve"	1.0	2.0	4.2	5.4	7.2	9.5
"Cellosolve" acetate	0.8	1.7	3.2	5.0	7.0	8.5
Butyl propionate	1.0	3.0	3.8	6.0	9.5	14 0
Amyl acetate	1.5	2.6	4.8	6.6	10.0	14.0
Butyl "Cellosolve"	2.0	2 1	2.1	3 8	4.2	5.8

	Lacquer Thinners[8]					
Ethyl lactate	10	5	5	5	5	5% (by vol)
Ethyl acetate	10	15	10	8	20	—
Butyl acetate	—	—	15	6	—	15
Butyl alcohol	10	5	10	10	5	15
Toluene	70	75	—	30	50	—
Petroleum	—	—	60	41	20	65

	Mist Coats[8]					
Ethyl lactate	15	15	10	15	10	15% (by vol.)
Di-acetone alcohol	—	10	—	10	10	—
Butyl acetate	—	—	10	—	5	10
Butyl alcohol	—	—	10	10	10	10
Toluene	85	75	—	—	—	—
Petroleum	—	—	70	65	65	65

* Two-gram portions of ½-sec. nitrocellulose (dry) were dissolved in 20 cc. of the solvent, and diluted until nitrocellulose was precipitated.

The viscosity of solutions of 32 oz. of cotton to one gallon of solvent is given here in relative figures for comparison.

TABLE 116.—Viscosity of Nitrocellulose Solutions[7]

Pent-acetate	100
Butyl acetate	69
Ethyl acetate	21
Refined amyl acetate	100
Secondary butyl acetate	83
Blend 1 part pent-acetate, 1 part ethyl acetate, 2 parts butyl acetate	60

TABLE 116A.—Dilution Ratios of Nitrocellulose with Toluene[7]

2.3 gr. dry ½-sec. nitrocellulose in 25 ml. of the respective solvent:

Solvent	Toluene
Pent-acetate	gelled at 68 cc.
Butyl acetate	gelled at 86 cc.
Ethyl acetate	ppt. at 110 cc.
Refined amyl acetate	gelled at 70 cc.
Secondary butyl acetate	gelled at 70 cc.

Methyl Amyl Acetate

Methyl amyl acetate (methyl isobutyl carbinol acetate) is a colorless liquid having an agreeable odor. It is a solvent for nitrocellulose and for the resins used in lacquer fabrication. It is used in mixtures of solvents and thinners.

Acidity	Not more than 0.02% as acetic acid
Purity	Not less than 95% methyl isobutyl carbinol acetate
Specific gravity	0.855 to 0.860 at $\frac{20° \text{ C.}}{20° \text{ C.}}$
Boiling range	
Below 140° C.	None (760 mm.)
Above 150° C.	None (760 mm.)
Below 143° C.	Not more than 5% distills
Below 148° C.	Not less than 95% distills
Average weight	7.14 lbs./gal. (20° C.)

Octyl Acetate

Octyl acetate is a water-white, stable liquid. It will dissolve nitrocellulose and many of the natural and synthetic resins. It is used in slow-evaporating preparations such as brushing and dipping lacquers, mist coatings and baking finishes.

Acidity	Not more than 0.02% as acetic acid
Purity	88 to 92% 2-ethyl hexyl acetate
Specific gravity	0.870 to 0.876 at $\frac{20° \text{ C.}}{20° \text{ C.}}$
Boiling range	
Below 190° C.	Not more than 5% distills (760 mm.)
Above 198° C.	Not more than 2% distills (760 mm.)
200° C.	End point
Color	Water-white
Dryness	Miscible with 19 vols. of 60° Bé. gasoline at 20° C.
Average weight	7.26 lbs./gal. (20° C.)

2-Ethyl Butyl Acetate

2-Ethyl butyl acetate is a colorless liquid having a mild odor. It is a solvent for nitrocellulose, gums and resins, and is employed as a high-boiling solvent in lacquers.

Acidity	Not more than 0.01% as acetic
Color	Water-white
Specific gravity	0.875 to 0.881 at $\frac{20° \text{ C.}}{20° \text{ C.}}$
Boiling range	
Below 155° C.	None (760 mm.)
Above 164° C.	None (760 mm.)
Purity	Not less than 90% ethyl butyl acetate
Dryness	Miscible with 19 vols. 60° Bé. gasoline at 20° C.
Average weight	7.33 lbs./gal. (20° C.)

Cyclohexanol Acetate

Cyclohexanol acetate $CH_3COO—CH\begin{matrix}CH_2—CH_2\\ \\ CH_2—CH_2\end{matrix}CH_2$ (Hexalin acetate, hexalhydrophenol acetate, cyclohexanyl acetate, hexylin acetate, adronol acetate) is a colorless, non-inflammable, non-explosive, slightly-toxic liquid having an odor resembling that of amyl acetate. It is miscible in all proportions with most of the lacquer solvents and diluents, and with halogenated and hydrogenated hydrocarbons. It has very good dissolvent power for cellulose ethers and nitrocellulose and powerful solvency for basic dyes, blown oils, raw rubber, metallic soaps, driers, shellac, bitumens and a wide range of natural and synthetic resins and gums. It will completely dissolve dammar and unrun congo copal. Cyclohexanol acetate is used in spraying and brushing lacquers to which it imparts blush resistance and good flow.

Methyl Cyclohexanol Acetate

Methyl cyclohexanol acetate (Sextate, methyl Hexalin acetate, hexahydrocresol acetate, hexahydromethylphenol acetate) is a colorless, non-inflammable, non-explosive, non-toxic, non-corrosive liquid having an ester-like odor. Its miscibility and solvent action are quite similar to those of cyclohexanol acetate but its solvent power is slower. It is a solvent for nitrocellulose, basic dyes, rubber, bitumens, oils, fats and waxes, and for such resins as dammar, elemi, manila, mastic, rosin, benzyl abietate, ester gum, Bakelite resins, glyptols, rezyl and vinyl resins. It will dissolve, in a lesser degree, shellac, unrun congo copals, kauri and acetylcellulose. It is used as a high-boiling solvent in nitrocellulose lacquers for both spraying and brushing purposes. Its solvency and slow rate of evaporation impart resistance to blushing and good working qualities and

produce films that are smooth, homogeneous and glossy. Its dilution ratio with

xylene	is 2.5
toluene	is 2.5
benzene	is 2.0
white spirits	is 1.5

It is also used as a mutual solvent for nitrocellulose, resins and oils, and as a solvent in lacquers of the stoving type.

Acidity	0.04% (max.)
Ester content	80%–90%
Boiling range	175°–190° C.
Flash-point	66°–69° C.
Specific gravity	0.95

Benzyl Acetate

Benzyl acetate ($C_6H_5CH_2OOCCH_3$) is a colorless liquid having an odor reminiscent of jasmine flowers. The commercial grade contains benzyl alcohol, chlortoluene, dibenzyl and so forth, which add to its solvency. It is miscible with alcohols, ketones, esters, and aromatic and aliphatic hydrocarbons. It is a solvent for cellulose esters and ethers, natural and synthetic resins, oils and so forth. It exerts both solvent and temporary plasticizing effect, and imparts good flow, high gloss, and working qualities to lacquers. It is used as a solvent in lacquers, dopes, polishes and printing inks and in varnish removers.

Ester content	99–100%
Boiling range	212–216° C.
Refractive index	1.502–1.503
Specific gravity	1.060–1 062

Ethylene Glycol Monoacetate

Ethylene glycol monoacetate $\begin{matrix}CH_2OH\\|\\CH_2OOCCH_3\end{matrix}$ is a colorless, odorless liquid and is structurally a primary alcohol and an ester. It is made by combining a dihydric alcohol and a monocarboxylic acid. It will mix completely with water and many of the lacquer solvents. Ethylene glycol monoacetate will dissolve cellulose esters and ethers and many of the resins.

Boiling point	181° C.
Specific gravity	1.109 (20° C.)
Flash-point	102° C.

Ethylene Glycol Diacetate

Ethylene glycol diacetate $\begin{matrix}CH_2OOCCH_3\\|\\CH_2OOCCH_3\end{matrix}$ is a colorless liquid having a faint odor resembling that of ethyl acetate. It will dissolve a wide range of

cellulose esters, camphor, dammar, ester gum, elemi, mastic, rosin and sandarac. When it is mixed with active solvents its range of solubility is increased for a wide variety of cellulose esters and ethers and for natural and synthetic resins. It is used as a mutual solvent for cellulose derivatives and resins. Its presence in these solutions prevents blushing and imparts pliability.

Specific gravity	1.11
Boiling range	186–190° C.
Refractive index	1.415

Ethylidene acetate and diacetate are direct solvents for nitrocellulose. When admixed with an active solvent such as acetone, they will become a solvent for acetylcellulose.

Monoethyl Ether Acetate of Ethylene Glycol

Monoethyl ether acetate of ethylene glycol $\begin{matrix} CH_2OC_2H_5 \\ | \\ CH_2OC_2H_3O \end{matrix}$ ("Cellosolve" acetate) is a colorless liquid of mild and pleasant odor. It will dissolve

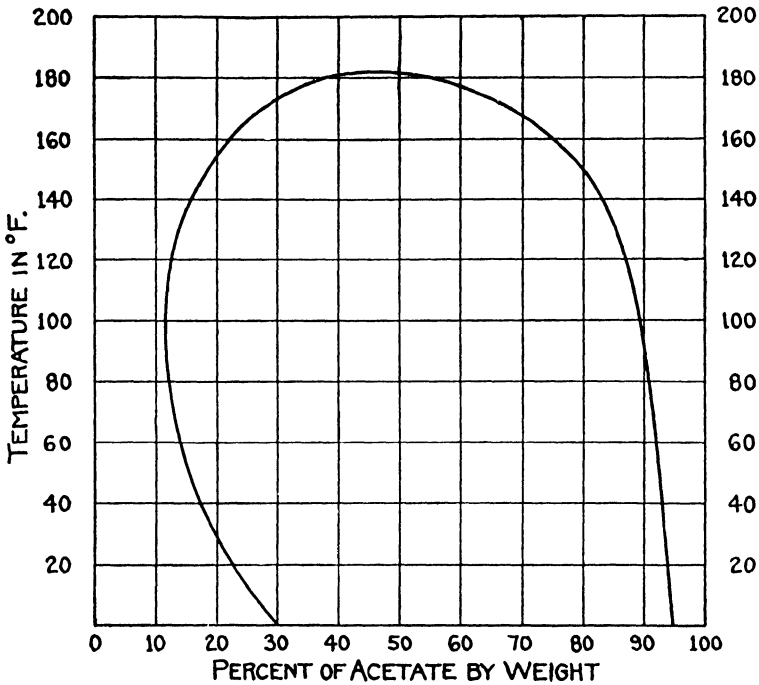


FIGURE 249. Solubility Curve of "Cellosolve" Acetate and Water.[5]

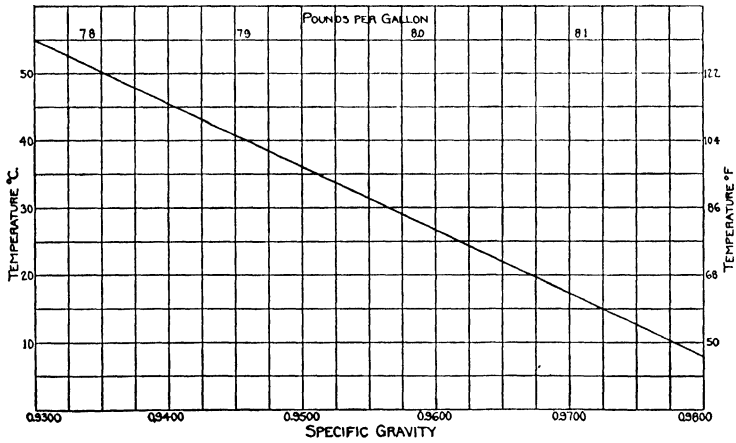


FIGURE 250. Specific Gravity and Weight per Gallon of "Cellosolve" Acetate at Various Temperatures.[6]

practically all resins with the exception of kauri, bleached shellac and unoxidized ester gum, and will also dissolve cellulose nitrate and acetate, dyes, and some types of cellulose ethers. Its most outstanding property is its ability to prevent blushing even in high humidity. It is used as a solvent for oils and resins; in lacquers, in varnish removers, in cleaning and spotting preparations and wood stains; and in finishing and dyeing processes of textiles and leather. It is miscible with aromatic hydrocarbons, and these mixtures are used as thinners for lacquers.

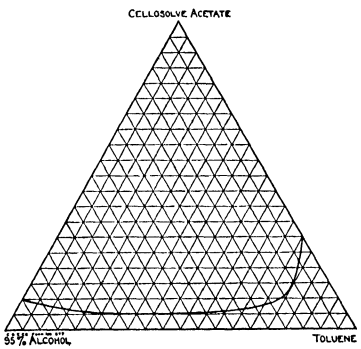


FIGURE 251. Solubility of ½-Second R. S. Nitrocellulose in Mixtures of "Cellosolve" Acetate, 95% Ethyl Alcohol and Toluene.[5]

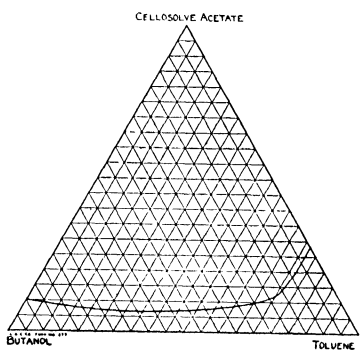


FIGURE 252. Solubility of ½-Second R. S. Nitrocellulose in Mixtures of "Cellosolve" Acetate, Butanol and Toluene.[5]

Molecular weight	132.09
Boiling point	156.2° C.
Specific gravity	0.976 at $\frac{15°\text{ C.}}{15°\text{ C.}}$
Weight per gallon	8.13 (15° C.)
Refractive index	1.4030 (25° C.)
Surface tension	31.8 dynes/sq. cm. (25° C.)
Viscosity	1.205 centipoises (25° C.)
Vapor pressure	2.3 mm. Hg. (20° C.)
Specific heat	0.494 (20°–25° C.)
Flash-point	55° C. (131° F.)
Solubility	Miscible with most organic liquids
Dilution ratio	Toluene 2.6 V.M. & P. naphtha 1.12 Final concentration ½-sec. R.S. nitrocellulose solution, approx. 8%
Electrical conductivity	2×10^{-8} recip. ohm.

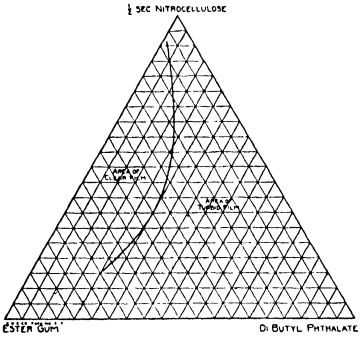


FIGURE 253. Compatibility of ½-Second R. S. Nitrocellulose, Ester Gum and Dibutyl Phthalate in 50% "Cellosolve" Acetate and 50% Butanol.[5]

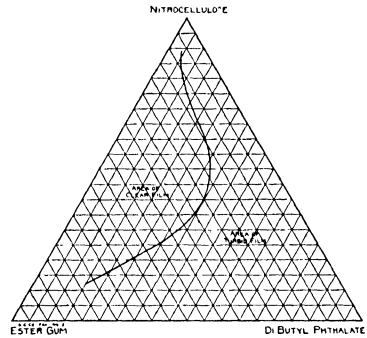


FIGURE 254. Compatibility of ½-Second R. S. Nitrocellulose, Ester Gum and Dibutyl Phthalate in "Cellosolve" Acetate.[6]

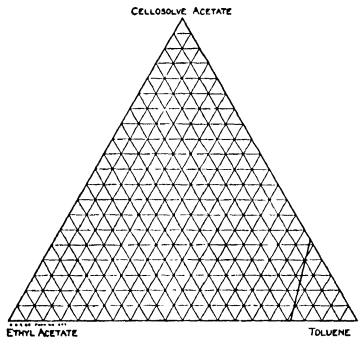


FIGURE 255. Solubility of ½-Second R. S. Nitrocellulose in Mixtures of "Cellosolve" Acetate, Ethyl Acetate and Toluene.[5]

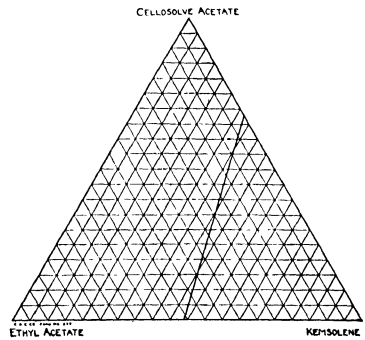


FIGURE 256. Solubility of ½-Second R. S. Nitrocellulose in Mixtures of "Cellosolve" Acetate, Ethyl Acetate[6] and Kemsolene.

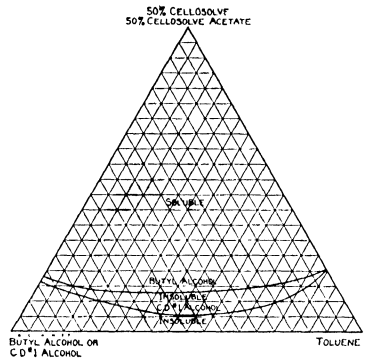


FIGURE 257.

Solubility of ½-Second R. S. Nitrocellulose in Mixtures of 50% "Cellosolve"—50% "Cellosolve" Acetate, Toluene, and Butanol or C. D. No. 1 Ethyl Alcohol.

Methoxy Butyl Acetate

Methoxy butyl acetate (Butoxyl) is a high-boiling, colorless liquid of pleasant odor. It is a solvent for oils, resins, rubber, cellulose ethers and nitrocellulose. Butoxyl will tolerate high dilutions with non-solvents.

ACETO ACETIC ESTERS

(CH_3COCH_2COOR)

Aceto acetic esters are β-ketonic acid esters miscible with water.

Methyl Acetoacetate

Methyl acetoacetate ($CH_3COCH_2CO_2CH_3$) is used in organic synthesis. It is a solvent for cellulose ethers, and in the presence of an active solvent it will dissolve cellulose esters.

Boiling range Below 91° C. From 90 to 95° C.	 Not more than 10% (50 mm.) Not less than 85% (50 mm)
Purity	Not less than 95% methyl acetoacetate
Acidity	Not more than 0.03% as acetic acid
Color	Not more than 5 yellow
Non-volatile matter	Not more than 0.01 g./100 cc.
Specific gravity	1.074 to 1.079 at $\frac{20° \text{ C.}}{20° \text{ C.}}$
Solubility	Miscible in all proportions with alcohol, ether and ethyl acetate
Average weight	8.96 lbs./gal. (20° C.)

Ethyl Acetoacetate

Ethyl acetoacetate ($CH_3COCOOC_2H_5$) is used as an intermediate in the manufacture of a large number of organic compounds. It is also employed in lacquer fabrication, dopes and plastic masses.

Acidity	Not more than 0.5% free acid as acetic
Color	Nearly water-white
Dryness	Miscible without turbidity with 20 vols. 60° Bé. gasoline at 20° C.
Purity	Not less than 96% ester content as ethyl acetoacetate
Specific gravity	1.027–1.030 at $\frac{20° \text{ C.}}{20° \text{ C.}}$
Coefficient of expansion	0.00056/1° F. 0.00101/1° C.
Flash-point	141° F. (approx.)
Boiling range	
Below 96° C.	Not more than 5% (50 mm.)
Above 110° C.	None (50 mm.)
Solubility	Completely miscible with ethyl alcohol, ethyl ether and ethyl acetate
Average weight	8.56 lbs./gal. (20° C.)

Propionic Esters

The propionic esters (CH_3CH_2COOR) are very similar to the acetic esters in physical and chemical properties with the difference that the former have a higher boiling point, lower evaporation rate and a lesser power of solubility. They are miscible with many of the lacquer solvents and diluents and possess a distinctive but not a disagreeable odor.

Methyl Propionate

Methyl propionate ($CH_3CH_2COOCH_3$) has been advocated as a solvent for cellulose derivatives. When it is admixed with other propionates (such as ethyl, propyl, butyl, and amyl) the mixture will dissolve cellulose ethers and esters.

Boiling point	91° C.
Specific gravity	0.937 (4° C.)

Ethyl Propionate

Ethyl propionate ($CH_3CH_2COOCH_2CH_3$, propionic ether, propionic ester) is a colorless liquid having an odor resembling that of pineapples. It is a solvent for cellulose ethers and esters, and for a variety of natural and synthetic resins. It is used as a solvent for cellulose derivatives, as an ingredient for soft drinks and fruit syrups, and as a cutting agent for pyroxylin.

Acidity	Less than 0.02% as free propionic acid
Boiling range	90 to 100% between 80 and 120° C.
Color	Clear white
Dilution ratio	2.5–3.0 with toluene
Ester content	85 to 90% as ethyl propionate
Evaporation rate	Slower than ethyl acetate
Residue on evaporation	None
Specific gravity	0.876–0.886 (15½° C.)

n-Butyl Propionate

n-Butyl propionate ($CH_3CH_2COOCH_2CH_2CH_2CH_3$) is a water-white liquid having an apple-like odor. It is miscible with most of the lacquer solvents and diluents and with oils. It is not miscible with water. It is a solvent for nitrocellulose and many of the natural and synthetic resins. When an active solvent is added to butyl propionate it will dissolve many of the cellulose ethers and esters. It is used as a solvent in lacquer fabrication, and in place of butyl and amyl acetate when lower volatility and slower evaporation are desired. Its presence in a solvent mixture adds solvency and prevents blushing.

Acidity	Not over 0.02% as free propionic acid
Boiling range	120–175° C.; about 60% above 130° C.
Color	Clear white
Dilution ratio	2.4–2.6 with toluene
Dryness	Complete, standing all volumes of gasoline without turbidity
Ester content	85–95% as butyl propionate
Residue on evaporation	None
Specific gravity	0.870-0.880 (15½° C.)

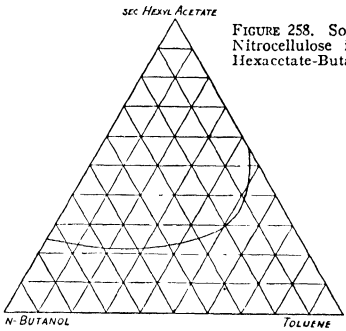


FIGURE 258. Solubility of ½-Second Nitrocellulose in the System *sec*-Hexacetate-Butanol-Toluene.[6]

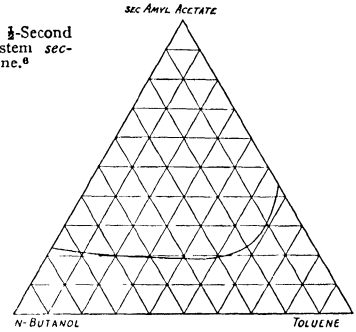


FIGURE 259. Solubility of ½-Second Nitrocellulose in the System *sec*-Amyl Acetate-Butanol-Toluene.[6]

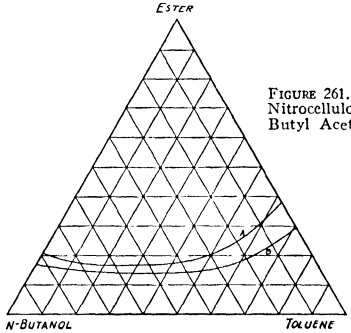


FIGURE 260. Solubility of ½-Second Nitrocellulose in the Systems: (*A*) *n*-Butyl Propionate-Butanol-Toluene; (*B*) *n*-Butyl Acetate-Butanol-Toluene.[6]

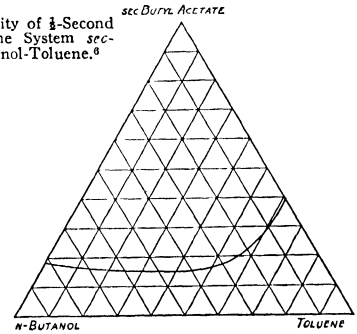


FIGURE 261. Solubility of ½-Second Nitrocellulose in the System *sec*-Butyl Acetate-Butanol-Toluene.[6]

Amyl Propionate

Amyl propionate ($CH_3CH_2COOC_5H_{11}$) is a colorless liquid having an apple-like odor. It is miscible with most lacquer solvents and oils. It will dissolve benzyl abietate, cumar resins, elemi, ester gum, copal and nitrocellulose. It has a sluggish solvent action for cellulose ethers and acts as a latent solvent. This latency can be overcome by the addition of acetone or ethyl alcohol. Its dissolvent properties are quite similar to those of amyl acetate, although it is not as rapid; the resulting solutions are more viscous, and its rate of evaporation is slower and with a less objectionable odor. Its mild odor and solvent power make it a desirable high-boiling lacquer solvent.

Acidity	Less than 0.02% as free propionic acid
Boiling range	120 to 165° C.
Color	Clear white
Dilution ratio	2.4–2.5 with toluene
Dryness	Complete, standing all volumes of gasoline without turbidity
Ester content	85 to 90% as amyl propionate
Evaporation rate	About the same as normal butyl propionate
Residue on evaporation	None
Specific gravity	0.865 to 0.875 (15½° C.)

Some of the other proposed esters are the allyl, isoamyl, crotyl, glyceryl propionates and the methyl, ethyl, propyl, α-ethoxy propionates.

Levulinic Esters

(β-Acetyl propionic esters)

Levulinic esters are high-boiling, colorless liquids and possess solvent properties for cellulose ethers.

	Specific Gravity	Boiling Point	
Methyl levulinate	1.0325	191° C.	solvent for cellulose acetate and starch-ethers
Ethyl levulinate			
Propyl levulinate		215–216° C.	plasticizer for cellulose ethers
Benzyl levulinate			
Propyl butyrate	0.8789 (15° C.)	142.7° C.	
Isopropyl butyrate	0.8652 (13° C.)	128° C.	

These are used with other solvents as dissolving mixtures for cellulose ethers.

Butyric Esters

Butyric esters ($CH_3CH_2CH_2COOR$) are stable, non-toxic liquids of a distinctive odor and their solubility in water is slight. They are solvents for nitro and acetylcellulose. They have a lower speed of evaporation than the propionic, acetic, and formic esters.

Methyl Butyrate

Methyl butyrate ($CH_3CH_2CH_2COOCH_3$) is a solvent for ethyl cellulose and when it is mixed with active solvents it will dissolve nitrocellulose. It is used admixed with plasticizers in the manufacture of celluloid.

Boiling point	102° C.
Specific gravity	0.898 (20° C.)

Ethyl Butyrate

Ethyl Butyrate ($CH_3CH_2CH_2COOC_2H_5$) is a non-toxic liquid having an odor suggestive of pineapples.

Its solvent properties lie between those of ethyl acetate and *n*-butyl acetate, and when mixed with other solvents it will dissolve cellulose esters and ethers, and many of the natural and synthetic resins. It is used in combination with other solvents in lacquer manufacture and in making safety glass.

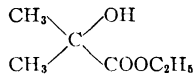
Boiling point	120° C.
Flash-point	23° C.
Specific gravity	0 879 (20° C.)

n-Butyl Butyrate

n-Butyl butyrate [$(CH_3)_2CHCOOCH_2CH(CH_3)_2$, isobutyl isobutyrate] is a water-white, neutral liquid having an apple-like odor. The commercial grade is composed of a mixture of the isomeric esters. It is a solvent for cellulose nitrate, cumar resins, dammar, ester gum, elemi, shellac, plasticizers and metallic resinates. It is added to lacquers for its power to retard evaporation and to impart good brushing, flow, working qualities and gloss. It is also used as a solvent in brushing lacquers.

Flash-point	51° C.
Refractive index	1.405
Specific gravity	0.870–0.880
Acidity	Less than 0.02% as free butyric acid
Boiling range	95–100% between 140–170° C.
Color	Water-white
Dilution ratio	1.8–2.0 with toluene
Ester content	90–95% as butyl butyrate
Evaporation rate	Slower than butyl propionate
Initial and original odor	Characteristic, mild
Residual odor	None
Residue on evaporation	None

Ethyl Hydroxy-Iso-Butyrate

Ethyl hydroxy-iso-butyrate  (Ethyl oxybutyrate) is a water-white, stable liquid of a mild odor. It is a solvent for cellulose nitrate and acetate and when mixed with other solvents it will also dissolve cellulose ethers. Its solvent action is somewhat comparable with that of ethyl lactate, differing in the following aspects:

Its solvent action is slower and requires the presence of an active solvent to accentuate it.
Its solutions of nitrocellulose are more viscous.
Its tolerance for hydrocarbons is about the same as far as it concerns nitrocellulose and is lower in the presence of acetyl cellulose.
Its volatility is higher.

Ester content	96–100%
Boiling range	142–146° C
Specific gravity	0.978–.986 (20° C.)

Ethyl Oxybutyrate

Ethyl oxybutyrate has a low rate of evaporation and therefore will remain in a lacquer film for some time. Its presence in the solvent mixture will impart good brushing, flow, good working qualities and gloss to the film. The residual amount in the film makes it soft and pliable.

Other Butyrates

Amyl butyrate is employed as a solvent and plasticizer for cellulose acetate and in cellulose ether plastics.

Benzyl butyrate is used as a plasticizer in plastic masses and in celluloid substitutes.

Glyceryl butyrate has been proposed as a plasticizer.

Valerianates

Methyl, ethyl, propyl, and butyl valerianates are solvents for nitrocellulose and cellulose ethers. Their solvency is increased by the addition of lower aliphatic alcohols.

Glycollates

Methyl, ethyl, *n*-propyl, *n*-butyl, isobutyl glycollates, acetoglycollates, and thioglycollates have been proposed as solvents for cellulose esters and resins.

Ethyl glycollate ($HOCH_2COOC_2H_5$) and butyl glycollate ($HOCH_2COOC_4H_9$) will dissolve nitrocellulose and many kinds of resins.

Ethyl acetyl glycollate ($CH_3COOCH_2COOC_2H_5$) is a high-boiling, colorless solvent for nitro- and acetylcellulose.

Lactic (Hydroxypropionic) Esters

$[CH_3CH(OH)COOR]$

Ethyl Lactate

Ethyl lactate [$CH_3CH(OH)COOC_2H_5$] is a colorless and almost odorless liquid, which, upon evaporation, will sometimes develop a disagreeable odor. This is owing to the lactides, or inner anhydrides, contained in the lactic acid made by fermentation. It is miscible with water, alcohols, ketones, esters, hydrocarbons, oils and so forth.

Ethyl lactate will dissolve cellulose acetate and nitrate and many of the ethers of cellulose. It is also a solvent for basic dyes, benzyl abietate, glyptol resins, kauri, ketone-aldehyde resins, manila, pontianac, rosin, shellac and the vinyl resins.

This ester is considered as one of the important high-boiling solvents owing to its exceptionally high solvent power and equally high tolerance for non-solvents and diluents. These exceptional properties are accounted for by the existence of both an alcohol and an ester group in its molecule, and by the presence of impurities in commercial grade ethyl lactate.

Its rate of evaporation is slow but this is desirable for brushing lacquers. The presence of ethyl lactate in a solvent mixture imparts good working-qualities and good flow, and permits the application of a thin coat on almost any surface. The resulting films are smooth and uniform, although at times the film will remain soft for a longer period than is anticipated. Its solvent action is slower than that of butyl or amyl acetate and the resulting solution has a high viscosity. However, it will tolerate two or three times as much non-solvent or diluent. In fact, a solution of pyroxylin in ethyl lactate will tolerate the addition of 25 per cent water without precipitation. As far as tolerance is concerned it has no rival in the field of solvents.

Ethyl lactate is employed as a lacquer-solvent for cellulose nitrate, acetate and ethers. It is used in the preparation of stencil sheets, incandescent mantle lacquers, in laminated glass, and as a mutual solvent for nitrocellulose and resins in paints, enamels and varnishes. It is also used as an emollient and gelatinant.

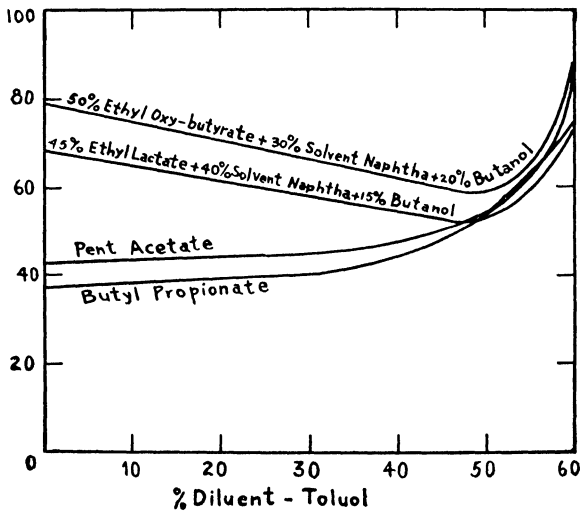


FIGURE 262. Viscosity Curves of 10-Per Cent Nitrocellulose Solutions.[8]

Acidity	Not more than 0.08% free acid as lactic
Color	Water-white
Distillation range	
Below 102° C.	None
Below 139° C.	Not more than 10%
Below 155° C.	Not less than 90%
Above 173° C.	None
Dryness	Miscible without turbidity with 20 vols. 60° Bé. gasoline at 20° C.
Non-volatile matter	Not more than 0.005 g./100 cc.
Odor	Mild, non-residual
Purity	Not less than 96% ester content as ethyl lactate
Specific gravity	1.020–1.036 at $\frac{20° C.}{20° C.}$

Blush resistance at 90° F. (10% ½-sec. R.S. nitrocellulose solution)	Clear	Blush
Relative humidity	80%	85%

Coefficient of expansion	0.00058/1° F. 0.00104/1° C.
Dilution ratio (nitrocellulose solution method)	5.5 with toluene 0.8 with petroleum naphtha

Evaporation rate at 95° F.						
Per cent	5	25	50	75	90	95
Minutes	4	23	47¾	73	92¾	101

Flash-point	129° F. (approx.)
Viscosity (10% ½-sec. R.S. nitrocellulose solution)	195 centipoises
Water solubility	Soluble in all proportions (25° C.)

Butyl Lactate

Butyl lactate [$CH_3CH(OH)COOC_4H_9$] is a brownish, stable, non-toxic liquid having a mild odor. There is no color in the chemically pure grade. The commercial grade contains condensation products and its physical and chemical properties will vary. It is miscible with many of the lacquer-solvents, diluents and oils. It will dissolve such substances as benzyl abietate, cellulose esters, cumar resins, ester gum, copal ester, glyptol resins, mastic, shellac and so forth. It has a high tolerance for non-solvents and it evaporates slowly. Its presence in a solvent mixture will impart brilliance, gloss, adhesion, flexibility and tenacity to the film. It is used as a solvent in lacquers, in stencil manufacture and in lithographic and printing inks. It is also used as a mutual solvent for cellulose derivatives and natural and synthetic resins, as an anti-skinning agent, as an intermediate, and in perfumes and dry-cleaning fluids.

Purity	Not less than 95% ester by weight
Specific gravity	0.974 to 0.984 at $\frac{20° C.}{20° C.}$

Acidity	Not more than 0.15% as lactic acid Not more than 0.93 mg. KOH required for neutralization of 1 g.
Water	No turbidity when one volume is mixed with 19 vols. of 60° Bé. gasoline at 20° C.
Non-volatile matter	Not more than 0.01 g. when 100 cc. are evaporated and heated to constant weight at 120° C.
Color	Water-white
Distillation range	
Below 140° C.	None
Between 155° C. and 195° C.	Not less than 60 per cent.
Between 187° C. and 189° C.	Not less than 90 per cent.
Dry point	Not above 200° C.
Molecular weight	146.11
Odor	Mild (No residual odor.)
Flash-point	71° C. (159.8° F)
Melting point	−43° C.
Weight per U.S. gallon	8.15 lbs. (68° F.)
Solubility in water	3.4% by vol. (25° C)
Solubility of water in butyl lactate	13.0% by vol. (25° C.)
Refractive index	1.42162 (20° C.)
Vapor pressure	0.4 mm. Hg. (20° C.)
Latent heat of vaporization	77.4 cal./g. (20° C.)

Isobutyl Lactate

Isobutyl lactate $CH_3CH(OH)COOCH_2CH\begin{matrix}CH_3\\CH_3\end{matrix}$ is a liquid solvent with properties similar to those of *n*-butyl lactate, with the difference of a higher rate of evaporation.

Boiling range	168–200° C.
Specific gravity	0.974–0.978
Acidity	0.05% max. lactic acid
Ester content	95% min.

Amyl Lactate

Amyl lactate [$CH_3CH(OH)COOC_5H_{11}$] is a non-toxic liquid with a varying composition which contains lacticides among other things. It has an odor like that of brandy. It is miscible with alcohols, ketones, esters, hydrocarbons, oils and so forth. It is a solvent for benzyl abietates, cellulose ethers, cumar resins, copal esters, mastic, nitrocellulose, shellac and so forth; and in combination with alcohol it will dissolve glyptol resins. It is used as a softener for cellulose derivatives.

Other proposed lactates are benzyl lactate, and *n*-butyl, amyl, hexyl and cyclohexyl nitrolactates.

Methyl Cyclohexanol Lactate

Methyl cyclohexanol lactate (Sextol lactate) is a colorless and almost odorless liquid. It is the lactic acid ester of hexahydrocresol which has a tendency to hydrolyze. It is miscible in all proportions with most organic solvents. It is an excellent solvent for nitrocellulose and natural and synthetic resins, and will tolerate a large quantity of diluent. It will also dissolve cellulose ethers, oils, fats, dyes, chlorinated rubber and so forth. Its presence in stoving lacquers of the synthetic resin type assists in the property of flow.

Boiling range	230–255° C.
Specific gravity	1 02
Flash-point	208° F.
Ester content	96% (remainder methyl cyclohexanol)

Oxalic Esters

Oxalic esters $\begin{matrix}\text{COOR}\\ |\\ \text{COOR}\end{matrix}$ have been proposed as solvents for dipping lacquers and penetrating inks. They are chemically unstable.

Diethyl Oxalate

Diethyl oxalate ($C_2H_5OOCCOOC_2H_5$) is a water-white, unstable, combustible but not inflammable liquid of pleasant odor. It is miscible with most organic solvents and will dissolve cellulose esters and ethers and many of the natural and synthetic resins. The addition of a small quantity of active solvent will increase its solvency for a wide range of natural and synthetic substances. Diethyl oxalate is used as a solvent in special lacquers for the purpose of fixing rare-earth salts on the cathode of radio tubes and as an intermediate for the manufacture of dyes and drugs.

Acidity	Not more than 0.05% free acid as oxalic
Color	Water-white
Distillation range	
Below 180° C.	None
Below 182° C.	Not more than 10%
Below 188° C.	Not less than 90%
Above 190° C.	None
Dryness	Miscible without turbidity with 20 vols. 60° Bé. gasoline at 20° C.
Non-volatile matter	Not more than 0.005 g./100 cc.
Odor	Mild, non-residual
Purity	Not less than 99% ester content as ethyl oxalate
Specific gravity	1.075–1.079 at $\frac{20°\text{ C.}}{20°\text{ C.}}$

Blush resistance at 90° F. (10% ½-sec. R.S. nitrocellulose solution)	Clear Blush
Relative humidity	90% ——
Coefficient of expansion	{0.00056/1° F. {0.00101/1° C.
Dilution ratio (nitrocellulose solution method)	3.5 with toluene 0.7 with petroleum naphtha
Flash-point	168° F. (approx.)
Viscosity (10% ½-sec. nitrocellulose solution)	380 centipoises
Water solubility	100 cc. solvent dissolves 1 5 cc. water (25° C.)

Diamyl Oxalate

Diamyl oxalate ($C_5H_{11}OOCCOOC_5H_{11}$) is a colorless, oily liquid miscible with most lacquer solvents, oils and hydrocarbons. It is a solvent for ester gum, copal ester, benzyl abietate, cumar resins, glyptol resins, mastic, nitrocellulose, shellac and so forth. It is used as a plasticizer and in paint and varnish removers. Like other oxalates, it has a tendency to hydrolyze.

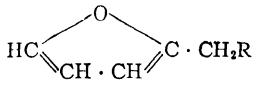
Boiling point	265° C.
Flash-point	116° C.
Specific gravity	0.97

Dibutyl Oxalate

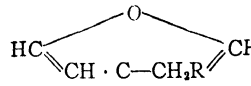
Dibutyl oxalate ($C_4H_9OOCCOOC_4H_9$) is a water-white, high-boiling liquid of mild odor. It is miscible with most alcohols, ketones, esters, oils and hydrocarbons. It is a solvent for benzyl abietate, cellulose esters and ethers, cumar resins, ester gum, copal ester, glyptol resins and mastic. It is used in nitrocellulose lacquers, as a plasticizing solvent, for the purpose of fixing rare-earth salts on cathode elements, and in organic synthesis. It has a tendency to hydrolyze and split off oxalic acid.

Acidity	0 05% (as oxalic acid)
Blush resistance at 90° F. (10% R.S. ½-sec nitrocellulose solution)	Clear at 90% relative humidity
Boiling point	240–250° C.
Coefficient of expansion	0.00095/1° C.
Dilution ratio (nitrocellulose method)	2.3 with toluene 1.0 with petroleum naphtha
Distillation range	
Below 240° C.	Not more than 5%
Below 248° C.	Not more than 90%
Above 255° C.	None
Ester content	99–100° C.
Flash-point	265° F. (approx.)
Refractive index	1.425
Specific gravity	$0.989\text{–}0.993 \frac{20° \text{ C.}}{20° \text{ C.}}$
Water solubility	100 cc. of solvent dissolves 0.5 cc. of water (25° C.)

Furfuryl Esters



alpha



beta

Furfuryl acetate is a solvent for nitrocellulose and some of the ethers of cellulose, elemi, sandarac, gamboge, ester gum, cumar resins and so forth. It is used as a grease and rust remover.

Boiling point	175° C.
Specific gravity	1.1175 (20° C.)

Literature References

[1] Mork, H. S., U. S. Patent 972,464 (Oct. 1910).
[2] Johnson, J. Y., British Patent 311,892 (Aug. 14, 1929).
[3] Commercial Solvents Corporation, New York, N. Y.
[4] Wolff, H., *Farben-Ztg.*, **26**, 647 (1922).
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[6] Park, J. G., and Hopkins, M. B., *Ind Eng Chem.*, **22**, 826 (1930).
[7] Sharples Solvents Corporation, Philadelphia, Pa.
[8] American Cyanamid & Chemical Corporation, New York, N. Y.

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Commercial Solvents Corporation, New York, N. Y.
Franco-American Chemical Works, New York, N. Y.
Niacet Chemicals Corporation, New York, N. Y.
U. S. Industrial Alcohol Company, New York, N. Y.
U. S. Industrial Chemicals, Inc., New York, N. Y.
Carbide & Carbon Chemicals Corporation, New York, N. Y.

Chapter 16

Plasticizers

Abietic Esters

Ethyl, propyl, amyl, phenyl, benzyl and glycol abietate and others ($C_{19}H_{29}COOR$) are liquid or viscous resinous materials miscible with most lacquer solvents or diluents. These esters are solvents for dammar, elemi, mastic, nitrostarch, sandarac and so forth, and are employed in lacquers and varnishes, and in linoleum.

Methyl Abietate

Methyl abietate ($C_{19}H_{29}COOCH_3$) is a yellow liquid resin miscible with most organic solvents. It will dissolve nitrocellulose and many of the natural and synthetic resins. This resinous material hardens by oxidation and will, therefore, harden in films in which it is present. It imparts adhesion, body, gloss and waterproofness to a film.

Acidity	5%
Ester content	95%
Refractive index	1.525–1.535
Specific gravity	1.033–1.043 (20° C.)

Ethyl Abietate

Ethyl abietate ($C_{19}H_{29}COOC_2H_5$) is an amber-colored, viscous liquid which hardens upon oxidation. It is soluble in most anhydrous solvents and will dissolve other resins.

Boiling point	350° C.
Flash-point	178° C.
Melting point	45° C.
Refractive index	1.4980
Specific gravity	1.02

Benzyl Abietate

Benzyl abietate ($C_{19}H_{29}COOCH_2C_6H_5$) is a stable, non-volatile, viscous plasticizer which resembles Canada balsam. It is soluble in most anhydrous solvents. It is employed as a plasticizer in cotton lacquers and in synthetic coating materials. Its presence in nitro- and acetylcellulose lacquers imparts softness, but no tackiness.

Glyceryl Diaceto-Abietate

Glyceryl diaceto-abietate (Plastabrac AA) is a resinous plasticizer and extender. It is soluble in most of the lacquer solvents and is a solvent for

a wide variety of cellulose derivatives and resins. It is used to impart both flexibility and body to nitro- and acetylcellulose films.

ACETATES [1]

(CH_3COOR)

Glyceryl Acetate

Glyceryl acetate $\begin{matrix} CH_2OH \\ | \\ CHOH \\ | \\ CH_2OOCCH_3 \end{matrix}$ (Acetin) is a colorless, hygroscopic liquid miscible with water. It is a direct solvent for nitrocellulose and when mixed with an active solvent it will dissolve cellulose ethers. It is used as a solvent and softener in dopes for coating airplane fabrics, and in celluloid substitutes.

Acidity	50% (as acetic)
Specific gravity	1.20 (20° C.)

Glyceryl Diacetate

Glyceryl diacetate $\begin{matrix} CH_2OOCCH_3 \\ | \\ CHOH \\ | \\ CH_2OOCCH_3 \end{matrix}$ (Diacetin) is a hygroscopic liquid and is miscible with water and benzene. It comprises a mixture of isomers and will dissolve nitro- and acetylcellulose, glyptol resins, shellac and so forth. It is employed as a softening agent in acetylcellulose films and as a means of incorporating dyes in glyptol resins.

Boiling point	259° C. (approx.)
Refractive index	1.44
Specific gravity	1.18

Glyceryl Triacetate

Glyceryl triacetate $\begin{matrix} CH_2OOCCH_3 \\ | \\ CHOOCCH_3 \\ | \\ CH_2OOCCH_3 \end{matrix}$ (Triacetin) is a non-hygroscopic liquid, miscible with many of the lacquer solvents and the aromatic hydrocarbons. It has the unique property of dissolving cellulose nitrate and acetate, and also many of the natural and synthetic resins. It is one of the few widely-used plasticizers. It is both a plasticizer and a means of incorporating synthetic resins into cellulose-ester lacquers and should never be used in quantities exceeding 66 per cent by the weight of the cellulose ester. It is also employed as a camphor substitute and, unlike castor oil, it will not ooze out.

Ester content	95% min.
Acidity	0.5% max. as acetic
Boiling range	200°–268° C.
Color	Water-white
Specific gravity	1.15–1.18 (15° C.)
Weight	9.7 lbs./gal. (20° C.)

Polyglyceryl Acetate

Polyglyceryl acetate is a colorless, viscous liquid composed (mainly) of diglyceryl ether tetraacetate. It is a plasticizer for acetylcellulose in the making of sheets.

Boiling point	340° C.
Refractive index	1.4435
Specific gravity	1.146

Mono-Cresyl Glyceryl Ether Diacetate

Mono-cresyl glyceryl ether diacetate $\begin{matrix}CH_2OC_6H_4CH_3\\ |\\ CHOOCCH_3\\ |\\ CH_2OOCCH_3\end{matrix}$ ("Abracol 777") is a fairly stable liquid miscible with most lacquer solvents and diluents. It is a solvent for cellulose esters and ethers, gums, resins and so forth, and is employed as a plasticizer for cellulose derivatives in quantities ranging from 25 per cent to 50 per cent.

Boiling point	310° C.
Refractive index	1.49
Specific gravity	1.35

Dicresyl Glyceryl Ether Monoacetate

Dicresyl glyceryl ether monoacetate $\begin{matrix}CH_2OC_6H_4CH_3\\ |\\ CHOOCH_3\\ |\\ CH_2OC_6H_4CH_3\end{matrix}$ ("Abracol 888") is similar to cresyl glyceryl ether diacetate in physical properties.

Boiling point	360° C.
Refractive index	1.53
Specific gravity	1.115

Sucrose Octa Acetate

Sucrose octa acetate $[C_{12}H_{14}O_{11}(CH_3CO)_8]$ is a white crystalline material compatible with cellulose acetate and nitrate. It is proposed as a plasticizer for cellulose esters and synthetic resins, and also as a resinous material.

Molecular weight	678.3		
Melting point	About 70° C.		
Decomposes	Above 285° C.		
Boiling point	260° C. (approx.) at .1 mm. Hg.		
Free acidity	Less than 0.05% as acetic		
Specific gravity	1.28		
Viscosity	29.5 poises (100° C.)		
Electrical constants	60 cycles	10^3 cycles	10^6 cycles
Dielectric constant	4.3	4.5	4.7
Power factor	12.3%	5.8%	1.7%
Resistivity	1.5×10^8 megohm. cms.		
Optical rotation in chloroform	+ 59.79° (24° C.)		

Index of refraction	1.4660 (white light, 20° C.)
Ultraviolet light	Increases transparency
Taste	Intensely bitter, between .001 and .002 mg./cc. detectable
Fehling's solution	No action on
Hygroscopicity	None
Rate of hydrolysis	Almost nil

TABLE 117.—Solubilities of Sucrose Octa Acetate[1]

Quantitative

	Grams per 100 grams Solvent at 22° C.		Grams per 100 grams Solvent at 22° C.
Acetal	89	Ethylene dichloride	over 200
Acetic acid	148	Methyl acetate	279
Acetone	over 250	Methyl alcohol	68
Benzene	164	Paraldehyde	14
Carbon tetrachloride	19	Toluene	over 210
Ethyl alcohol (95%)	7	Water	0.14

Qualitative

Soluble in

Acetamide	Carbon tetrachloride	Ethylene dichloride
Acetal	"Cellosolve"	Formic acid
Acetic acid	"Cellosolve" acetate	Furfural
Acetic anhydride	Chlorbenzene	Hexalin
Acetone	Chloroform	Isoamyl alcohol
Amyl acetate	Diacetin	Isopropanol
Amyl levulinate (mixed)	Diacetone alcohol	Methyl alcohol
Aniline	Diamyl phthalate	Methyl "Cellosolve"
Benzaldehyde	Dibutyl phthalate	Methyl ethyl ketone
Benzene	Dichlorbenzene (ortho)	Monoacetin
Benzyl alcohol	Diethyl aniline	Naphthalene (fused)
Benzyl chloride	Diethyl ether	Paraldehyde
Butyl acetate	Dioxan	Phenol
Butyl "Cellosolve"	Ethyl acetate	Pyridine
Butyl crotonate	Ethyl alcohol	Toluene
Butyl lactate	Ethyl benzene	Triacetin
Butyl levulinate	Ethyl crotonate	Troluoil
Butyl oleate	Ethyl lactate	Turpentine (hot)
Butyl propionate	Ethylene chlorhydrin	Xylene
Camphor		

Various Other Acetates

Other acetates proposed as plasticizers for cellulose derivatives are:

Pentaerythritol acetate	Triglyceryl acetate
Glycerylphenyl acetate	Glyceryl aceto caproate
Phenoxyethyl acetate	Glyceryl aceto caprylate
Resorcinol diacetate	Glyceryl aceto laurate
Benzylidene diacetate	Glyceryl aceto palmitate
Hexanol acetate	Propionyl diacetate (glyceryl diacetopropionate)
Naphthyl acetate	
Guaiacol acetate	Glyceryl propionates (propionins)
α, α-Diglyceryl tri- (or tetra-) acetate	Glyceryl butyrate (butyrins)

TABLE 118.—Comparison of the Value of Solvents and Solvent Mixtures With the Value of Normal Butyl Acetate[3]

Solvent or Solvent Mixture	Pounds per gal.	Evap. Rate *n*-BuAc = 1	Tolerance for Naphtha Note 1	Tolerance for Toluene Note 1	Blush Resistance Note 3	Flow Promotion Note 4	Advantages (other than tolerance) compared with *n*-BuAc	Disadvantages (other than tolerance) compared with *n*-BuAc	Comments
Normal butyl acetate	7.3	1.0	1.45	2.8	Excellent.	Excellent.	Combines: Excellent blush resistance. Excellent flow promotion. Optimum evap. rate (neither too fast nor too slow). Stability. Uniformity. Compatibility with gums.	None.	*n*-BuAc combines every possible advantageous characteristic as a solvent for use in spray lacquers with the exception of freedom from odor.
n-Butyl acetate–67% plus butanol 33%	7.12	1.0	1.7	2.8	Excellent. Equal but not superior to *n*-BuAc.	Excellent. Equal but not superior to *n*-BuAc.	Same characteristics as *n*-BuAc plus higher naphtha tolerance. Imparts much lower viscosity to lacquers than does *n*-BuAc alone and increases stability of lacquers on storage.	None.	This mixture is equivalent in all respects—and superior in some—to *n*-BuAc. It costs less.
Amyl acetate from fusel oil	7.17	Slower 0.75	1.5	2.6	Excellent. Equal but not superior to *n*-BuAc.	Excellent. Slightly superior to *n*-BuAc A mixture of 95% AmAc and 5% Et-Ac equals *n*-BuAc.	Slightly better flow promotion	Slow evap. rate, especially of last or "tail-end" portion. Slows up finishing operations and delays sanding and polishing. Quality not uniform. Supply limited. Note 9.	Aside from its slow rate of evap., which retards finishing operations amyl acetate from fusel oil is a very good solvent. It is a by-product material and will always find a market. Note 9.
Secondary amyl acetate	7.2	Slower 0.85	1.15	2.2	Excellent. Equal but not superior to *n*-BuAc.	Good. Only slightly inferior to *n*-BuAc	None.	Objectionable odor. Quality not uniform. Evaps. slowly thus delaying finishing operations. Produces lacquers of slightly higher viscosity than does *n*-BuAc.	The decidedly lower tolerance makes *sec*-AmAc worth much less than *n*-BuAc. Its odor has caused its rejection in many cases.
Secondary amyl acetate 63% plus secondary butyl acetate 37%	7.8	Faster 1.2 Note 5	1.1	2.3	Good, slightly inferior to *n*-BuAc.	Fair Definitely inferior to *n*-BuAc. Equal to a mixture of 90% *n*-BuAc and 10% Ethyl Acetate.	None.	Inferior in flow promotion. Inferior in blush resistance.	This mixture has been claimed to be the equivalent of *n*-BuAc. Its lower tolerance makes it worth less than *n*-BuAc and in all its characteristics it is much inferior to *n*-BuAc.

TABLE 118.—Comparison of the Value of Solvents and Solvent Mixtures With the Value of Normal Butyl Acetate[3]—(*Continued*)

Solvent or Solvent Mixture	Pounds per gal.	Evap. Rate *n*-BuAc = 1	Tolerance for Naphtha Note 1	Tolerance for Toluene Note 1	Blush Resistance Note 3	Flow Promotion Note 4	Advantages (other than tolerance) compared with *n*-BuAc	Disadvantages (other than tolerance) compared with *n*-BuAc	Comments
Secondary butyl acetate	7.15	Faster 1.8	1.2	2.5	Fair. Equal to a mixture of 50% *n*-BuAc and 50% ethyl acetate.	Poor. Equal to a mixture of 50% *n*-BuAc and 50% ethyl acetate.	None.	Inferior in flow promotion. Inferior in blush resistance. Objectionable odor. Quality not uniform.	Evaps. almost twice as fast as *n*-BuAc with consequent bad effect on flow promotion and blush resistance. Odor objectionable.
Pentacetate	7.2	Slower 0.65	1.3	2.1	Excellent. Equal but not superior to *n*-BuAc.	Excellent. Slightly superior to *n*-BuAc. A mixture of 90% Pent-Ac and 10% EtAc equals *n*-BuAc.	Slightly better flow promotion.	Slow rate of evaporation, delays finishing operations.	Pentacetate is inferior to amyl acetate from fusel oil because of its lower tolerance.
Pentacetate 80% plus ethyl acetate 20%	7.23	Faster 1.6	1.3	2.4	Fair. Inferior to *n*-BuAc.	Fair. Inferior to *n*-BuAc. Equal to mixture 89% *n*-BuAc and 11% EtAc.	None.	Inferior in flow promotion. Inferior in blush resistance. Slow evap. rate of the pentacetate delays finishing operations.	This mixture has been claimed to be the equivalent of *n*-BuAc. Such a mixture combines all the bad characteristics of its components. Note 5.
"Cellosolve"	7.8	Slower 0.4	1.0	4 8	Extremely poor.	Excellent. Equal to *n*-BuAc.	Odorless.	Causes blushing. Poorly compatible with gums. Evap. slowly thus delaying finishing operations. Activates alcohols poorly.	Tends to absorb water and so to produce blushing rather than to prevent it. Does not give clear solutions with the gums commonly used in lacquer formulation. Evaps. too slowly for use in spray lacquers.
"Cellosolve" acetate	8.1	Slower 0.25	1.0	2.5	Excellent. Not quite equal to *n*-BuAc.	Excellent. Equal to *n*-BuAc.	Practically odorless.	Very slow rate of evap. Heavy weight per gallon makes it costly on volume basis. Poorly compatible with gums.	This is a solvent for which there is no real use in lacquers. It evaps. too slowly for use in spray lacquers and not slowly enough for use in a truly brushable lacquer At best it can only be used in small percentages

Iso-butyl acetate	7.2	Faster 1.4	1 25	2.6	Excellent. Not quite equal to *n*-BuAc.	Good. Slightly inferior to *n*-BuAc. Equal to a mixture of 90% *n*-BuAc and 10% ethyl acetate.	None.	Inferior in flow promotion.	Isobutyl acetate is just a little inferior to *n*-BuAc in all its characteristics.
Ethyl acetate	7.36	Faster 5.5	1.2	3.4	Very poor.	Very poor.	Imparts lower viscosity to lacquers	Very bad effect on flow. Very poor blush resistance.	Because it evaps. from the drying film so rapidly, the effect of the high tolerance is quickly lost. Cannot be used as the sole solvent in lacquers except where the film is to be dried at elevated temperatures. Not strictly a competitor of *n*-BuAc although it may replace a portion of the *n*-BuAc in a lacquer

1. The "tolerance" of a solvent for a diluent is the number of volumes of the diluent which, when added to one volume of a solution of nitrocellulose in the solvent, will just bring about either a slight precipitation of the nitrocellulose from the solution or else a jelling of the solution. Thus, the greater the tolerance of a solvent, the greater the amount of cheap diluent which can be used. Therefore, "tolerance" is an important factor in determining the relative values of solvents having similar characteristics.

2. Formula for Calculating Value—on the basis of toluene tolerance—of a Solvent from the price of *n*-Butyl Acetate.

X = price of competing solvent per gallon
A = tolerance of solvent
B = price of *n*-BuAc, per gallon
C = price of diluent per gallon.
Tolerance of *n*-BuAc for toluene = 2.8

Formula:

$$X = \left[\frac{(2.8 \times C) + B}{1 + 2.8}\right] \times (1 + A) - (A + C)$$

Example:

n-BuAc at 90.5c per gallon
Toluene at 30.0c per gallon
To determine value of secondary amyl acetate on basis of toluene tolerance.

$$X = \left[\frac{(2.8 \times 30) + 90.5}{1 + 2.8}\right] \times (1 + 2.2) - (2.2 \times 30)$$

X = 80.9c value of *sec*-AmAc.

3. The comparative blush resistance of solvents cannot well be evaluated in money. Most solvents affect blush resistance but slightly. Only ethyl acetate markedly impairs blush resistance.

4. The monetary value of the flow-promoting characteristics of competing solvents as compared with *n*-BuAc is set forth under "Advantages" or "Disadvantages."

5. The evaporation rates of the solvent mixtures shown in this Table are calculated from the rates of the components. They are, therefore, "average" rates. Mixtures do not have an evap. rate which can be truly compared with that of *n*-BuAc In the mixtures the rapidly evaporating component vaporizes during the early stages of drying and the slower evaporating component for the most part vaporizes independently at a later stage of the drying period. There is practically no "blending" of evaporation rates.

6. The value of the high tolerance of "Cellosolve" is offset by its incompatibility with gums. In dry seasons (winter) "Cellosolve" can be used to the extent of about 5 per cent in lacquer solvent formulas. For this limited use it is worth more than *n*-BuAc. In humid weather it should not be used at all.

7. The value of the high tolerance of ethyl acetate is very largely offset by its very rapid rate of evaporation. See Comments.

8. There are several characteristics of solvents to which it is difficult to assign a money value. Such characteristics are: odor, delayed drying, nonuniformity of quality, and poor compatibility with gums. All these factors influence the value of a solvent for special uses but any general estimate of their money value would be misleading.

9. Fusel-oil amyl alcohol is a by-product of the production of ethyl alcohol by fermentation. The amount of refined amyl alcohol so obtained is about 0.2 per cent by vol. of the ethyl alcohol produced. In the U S A. about 140,000 gallons of amyl alcohol are produced annually from fusel oil.

10. At the present differential between the price of *n*-BuAc and EtAc, there may be a partial replacement of EtAc by *n*-BuAc but to secure any very great replacement, the differential would probably have to be 10c per gallon or less. In other words, on a strictly competitive basis, ethyl acetate is worth only about 10c per gallon less than *n*-BuAc. It would not be wholly replaced even if it sold for more than *n*-BuAc.

Acrylic Esters

Acrylic esters ($CH_2CHCOOR$) have been proposed as solvents for a wide range of cellulose derivatives.

Adipic Esters

Of the adipic esters [$ROOC(CH_2)_4COOR$] methyl and ethyl adipate and others have been proposed as cellulose ether solvents to be used alone or in combination with low-boiling, active solvents. Glycol and glyceryl adipates have been suggested as dissolvents for cellulose ethers and resins and are also used as mutual solvents for these substances in the manufacture of lacquers and varnishes. Other adipic esters have been suggested as camphor substitutes for making celluloid.

Dimethyl Cyclohexanyl Adipate

Dimethyl cyclohexanyl adipate [$(CH_2CH_2COOC_6H_{11}CH_3)_2$, Sipalin A.O.M.] is a neutral, stable, colorless liquid having a high boiling point. It is a solvent for nitrocellulose, fats, oils, resin, rubber and so forth.

Boiling point	225–232° C. (12 mm.)
Flash-point	189° C.
Specific gravity	1.011

Amides

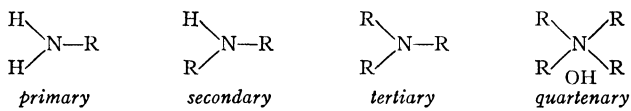
($RCONH_2$)

Acetamide

Acetamide (CH_3CONH_2) is a colorless, mobile liquid. It is a solvent for a wide range of organic and inorganic compounds owing to the presence in the molecule of the hydrocarbon group, carbonyl group and the amino group. Some of the substances it will dissolve are dyes, organic salts and cellulose esters. It is used as an antiacid in lacquers and explosives, as an electroplating plasticizer for acetylcellulose, in soldering fluxes, as a hygroscopic agent, as a wetting and penetrating agent and in organic synthesis.

Acetamide	99%–100%	Color	White
Free acid	Tr. (as acetic)	Melting point	78°–80° C.
Moisture	Tr.	Boiling range	210°–220° C.
Chlorides	None	Specific gravity	1.15
Sulfates	None		

Amines



The amines are solvents and plasticizers for cellulose nitrate and acetate. They are used in combination with active solvents in the printing of artificial silk. Bergstrom, Gilkey and Lung [2] have determined and tabulated the solubility of 288 compounds in a number of amines.

TABLE 119.—Solubilities of Organic Compounds in Aliphatic Amines (at 25° ± 5° C.)[2]

Abbreviation		Approx. Sol'y Range per 100 cc. of Solvent *Grams*
ins	Insoluble or extremely slightly soluble	
ss	Slightly soluble	(0^+ to 10)
s	Moderately soluble	(10^+ to 40)
vs	Very soluble	(40^+ to 70)
vs+	More than vs	(70^+ to 100)
es	Extremely soluble	(100^+ and above)
misc	Miscible (in methylamine column only)	
∞	Miscible in all proportions	
n	Not soluble to an appreciably greater extent in hot solvent	
x	More soluble in heated amine, crystallizes on cooling	
m	More soluble in heated amine (in some cases because of chemical reaction)	
p	Separates into two liquid phases	
r	Solute reacts chemically with solvent. Reaction is rapid enough to be apparent. All acidic substances react more or less rapidly with amines. (The letter *r* has been omitted in these cases)	
a	Swells	
Numerals	Numerals appearing in diethylamine column indicate number of grams of solute (or of its reaction product with diethylamine) per 100 cc. of solution	

		C_2H_5OH	$\begin{matrix}C_2H_5\\C_2H_5\end{matrix}>O$	CH_3NH_2	$\begin{matrix}C_2H_5\\C_2H_5\end{matrix}>NH$	$(C_2H_5)_3N$	$(n\text{-}C_4H_9)_2NH$	$n\text{-}C_4H_9NH_2$	$(n\text{-}C_4H_9)_2NH$	$(n\text{-}C_4H_9)_3N$	$iso\text{-}C_4H_9NH_2$	$C_6H_5CH_2NH_2$	$NH_3(-33°\ C.)$
1	Acenaphthene	ssx	..	..	15	sx	..	sx	s	ssx	s	s	ins
2	Acetaldehyde	.		misc			..	.	..	..	..	..	..
3	Acetamide	s	.	vs	ssx	ins	..	s	ins	ins	s	s	vs
4	Acetanilide	vs	ss		11	ssx	..	vs	ss	ssx	sx	s	..
5	Acetic acid	..	..	vs			..	..	..	..	..	..	..
6	Acetoacetic ester	∞	..	..	∞		..	..	∞	..	..	..	∞
7	Acetone	∞	∞	∞		.	..	..	..	..	..	..	..
8	Acetophenone	∞	..	..	∞		..	∞	..	∞	..	..	s
9	*p*-Acetophenylene diamine	..	..	..	ins	.	..	ssx	ssx	..	ssx	..	..
10	*p*-Acetotoluide	ss	s	..	ss	.	..	..	..	ssx	ssx	..	ss
11	Acetylene	s		s	.	.	..	..	.	.	.	..	.
12	Acetylene tetrabromide	s	∞	..	r	..	..		..	..	..	..	s
13	Acetylsalicylic acid	vs	ss	..	s	s	s	vs	s	ss	vs	s	..
14	Agar-agar	..		..	.	..	..	..	..	..	insn	..	ins
15	Alanine	ss	ins	..	.	..	..	..	..	..	insn	..	..
16	Aldol	∞	s	..	∞	..	..	∞	..	..	..	..	..
17	Alizarin	..	..	s	..	..	..	..	..	..	..	..	..
18	Allyl alcohol	∞	∞	..	∞	..	..	..	..	..	..	..	..
19	1-Aminoanthraquinone	ss	ss	..	ss	ss	ss	ssm	ss	ssx	ssm	ss	..
20	*p*-Aminobenzoic acid	s	ss	..	ins	ins	isn	ss	ins	insn	ss	ssx	..

TABLE 119.—Solubilities of Organic Compounds in Aliphatic Amines (at 25° ± 5° C.)—(*Continued*)[a]

		C_2H_5OH	$\frac{C_2H_5}{C_2H_5}>O$	CH_3NH_2	$\frac{C_2H_5}{C_2H_5}>NH$	$(C_2H_5)_3N$	$(n\text{-}C_4H_9)_2NH$	$n\text{-}C_4H_9NH_2$	$(n\text{-}C_4H_9)_3NH$	$(n\text{-}C_4H_9)_3N$	iso-$C_4H_{11}NH_2$	$C_4H_9CH_2NH_2$	$NH_3(-33°\ C.)$
21	*m*-Aminophenol	s	s	..	vs+	ss	..	s	s	ss	vs	s	..
22	*o*-Aminophenol	ss	ss	..	vs	ins	s	vs+	sx	ssn	s	s	vs
23	Aminosulfonic (sulfamic) acid	..	..	..	.	..	..	ssn	..	..	ssx	..	..
24	Ammonium benzoate	..	..	..	ss	..	..	vsr	..	..	vsr	..	vs
25	Ammonium citrate	..	..	..	ss	..	..	..	..	..	..	..	..
26	Amyl alcohol (iso)	∞	..	∞	..	..	..	∞	..	..	..	∞	..
27	*n*-Amyl formate	∞	∞	..	..	..	..	..	..	∞	..	..	..
28	Anethole	∞	∞	..	∞	..	..	..	..	.	..	..	ss
29	Anhydroformaldehydeaniline	ss	ss	..	ssn	ssx	ins	ss	ss	ssx	ssx	ssx	..
30	Aniline blue	..	..	..	ss	ins	..	ss	ins	ins	ss	ss	..
31	Anthracene	ss	ss	..	ss	ssx	..	ssx	ss	ssx	ssx	ssx	ins
32	Anthranilic acid	s	s	..	ss	ins	ssx	s	ss	ss	s	s	..
33	Anthraquinone	ss	ss	ss	..	..	..	ssx	..	..	ssx	..	ins
34	Atoxyl	..	..	..	ins	ins	..	ss	ins	ins	ss	ins	..
35	Azobenzene	ss	s	vs	vs	vsx	vs	vs	vs	s	vs	s	s
36	Azoxybenzene	s	s	..	es	..	..	..	..	..	es	..	s
37	Beeswax	..	..	..	s	s	..	s	s	ssm	s	ssm	..
38	Benzalacetophenone	ss	vs	..	vs	..	..	es	..	ssx	..	..	..
39	Benzaldehyde	∞	∞	misc	∞	..	..	..	..	..	..	..	es
40	Benzamide	s	vss	..	ss	ins	s	s	ss	ins	s	s	vs
41	Benzene	∞	∞	..	∞	..	..	∞	∞	∞	..	∞	s
42	Benzidine	s	ss	..	ss	ss	..	s	ssx	ins	sx	s	..
43	Benzil	vs	vs	vs	vs	ss	sx	es	ss	ss	es	es	s
44	Benzoic acid	vs	vs	vs	ssx	ssx	..	vs	s	ssp	s	sx	vs+
45	Benzoic sulfinide (Saccharin)	ss	ins	r	..	..	..	..	..	..	ss	..	..
46	Benzoin	s	..	..	..	..	..	vs	..	..	..	..	..
47	Benzophenone	s	s	vs	es	es	..	es	vs+	sx	es	es	s
48	Benzyl acetate	∞	∞	..	∞	..	..	..	∞	..	..	∞	s
49	Benzyl alcohol	∞	∞	..	∞	..	..	..	..	∞	..	..	∞
50	Borneol	vs	vs	..	es	..	..	..	..	..	..	..	s
51	*o*-Bromoacetanilide	..	..	vs	..	..	..	..	..	..	..	..	..
52	*p*-Bromoaniline	vs	vs	..	esx	vs+	esx	vs+	vs	ssx	vs	vs+	..
53	Bromcamphor	s	vs	..	vs+x	s	..	vs+x	vs+	ssx	vs	vs	..
54	Bromocresol green	..	..	..	ss	ins	..	s	ssn	ins	s	s	..
55	1-Bromonaphthalene	∞	∞	..	∞	..	..	..	..	∞	..	..	..
56	*p*-Bromonitrobenzene	s	s	..	s	..	..	..	..	..	..	..	..
57	*o*-Bromotoluene	s	..	..	∞	..	..	..	∞	∞	..	∞	..
58	*p*-Bromotoluene	s	s	..	es	..	..	..	es	..	..	..	..
59	*n*-Butyl alcohol	∞	..	..	∞	..	..	..	..	..	∞	∞	∞
60	tert-Butyl alcohol	..	..	∞	..	..	..	..	..	..	..	..	..

61	*n*-Butyl xyanide	∞∞	s	..	∞	..	..	∞	..	..	∞	..	s
62	*n*-Butyl ether	∞∞	∞	..	∞	..	..	∞	∞	∞	∞	..	..
63	*n*-Butyl formate	∞	∞	..	∞∞	..	..	..	∞∞	..		..	..
64	*n*-Butyl stearate	.	..	..	∞	..	..	∞	∞	∞	∞	rss	.
65	Caffeine	ss	ss	..	ss	..	..	ssx	..	..	ssx	..	ss
66	Calcium acetate	ins	..	..	insn	..	..	..	..	..	..	..	..
67	*n*-Calcium butyrate	..	..	..	..	..	..	insn	..	..	.	..	..
68	Calcium formate	ins	.	..	..	..	..	..	..	.	insn	..	.
69	*d*-Camphor	es	vs	..	es	es	..	es	vs	vsx	es	es	vs
70	Carbon disulfide	∞	∞	..	r	..	..	esr	..	∞	..	..	r
71	Casein	..	..	..	ins	ins	..	ins	ins	ins	ins	ins	..
72	Cellulose	ins	ins	..	ins	ins	.	ins	ins	ins	ins	insa	ins
73	Cellulose acetate	..	..	..	ss	ins	ins	es	ins	ins	s	s	es
74	Cellulose nitrate	..	..	..	s	ins	..	vs	ss	ins	vs	vs	s
75	Cerulein	..	..	vs	..	..	..	..	..	..	..	.	..
76	Cetyl alcohol	s	s	vsx	..	..	..	es	..	s	.	..	ins
77	Chloroacetic acid (mono)	s	s	..	srx	vsxp	..	sx	ssxr	ssp	vs	ssrm	vs
78	*p*-Chlorodiphenyl	s	s	..	vs+	vs+x	..	vs	vs	sx	vs	vs	.
79	Chloroform	∞	∞	∞r	∞	..	..	..	..	..	..	..	sr
80	Cholesterol	ssx	s	..	..	..	vs+	..	..	..	vs+	..	ins
81	Chromotropic salt	..	..	..	..	..	..	insn	..	..	..	..	..
82	Cinchonine	ss	ss	..	..	.	..	ssn	..	..	ssx	..	ins
83	Cinnamic acid	s	vs	..	s	ss	..	sx	ss	ssx	s	ssx	s
84	Coconut oil	..	..	..	∞	∞	..	∞	∞	∞	∞	∞	..
85	Copal	..	..	..	.	..	..	..	..	..	insn	.	ss
86	Crystal violet	..	..	..	ins	ins	..	vs	ins	ins	s	s	s
87	Cyclohexanol	s	s	..	∞	..	..	..	..	..	..	..	..
88	*o*-Dianisidine (bianisidine)	s	vs	..	ss	ins	..	sx	ss	ins	s	s	..
89	Diazoaminobenzene	s	vs	..	vs	..	..	..	..	.	es	..	vs
90	*p*-Dibromobenzene	s	..	..	40	vs+x	..	vsx	vs	sx	vs	vs+	ss
91	2,3-Dibromopropyl alcohol	vs	∞	..	..	..	..	..	..	..	..	..	..
92	Dichloramine-T	..	..	..	vsr	sr	..	vsr	ssr	r	vsr	vs+r	r
93	*p*-Dichlorobenzene	es	vs	..	53	esx	..	es	ves	vs+x	esx	es	ss
94	Dichlorogallein	..	..	s	..	..	..	..	..	..	..	..	s
95	Dichlorohydrin	∞	∞	..	∞	..	..	..	..	..	..	..	..
96	2,3-Dihydroxyquinoxaline	..	..	..	..	.	..	insn	..	..	..	..	s
97	Dimethylaminoazobenzene	x	..	..	sx	ssx	ssx	sx	s	ss	s	s	..
98	*p*-Dimethylaminobenzaldehyde	s	s	..	..	..	..	sx	..	..	..	..	..
99	Dimethylaniline	s	∞	..	∞	..	..	..	..	..	..	..	ss
100	Dimethylethylcarbinol	s	s	..	∞	.	..	..	∞	..	∞	∞	..
101	Dimethylglyoxime	vs	vs	..	ssx	s	ssx	vs	ss	ssx	vs	s	..
102	2,6-Dimethylquinoline	vs	vs	..	vs	..	..	..	..	..	..	..	..
103	2,2-Dinaphthylamine	ss	..	..	ssx	ssx	ssx	sx	ssx	ssx	s	ss	..
104	2,4-Dinitroaniline	ss	..	vs	..	..	..	.	..	.	..	..	..
105	*m*-Dinitrobenzene	ssx	..	vs	9.3	ss	..	s	ss	ssx	s	s	..
106	3,5-Dinitrobenzoic acid	vs	ss	..	ss	ss	ssx	s	ss	ssx	vs	sm	..
107	4,4'-Dinitrodiphenyl	ss	vs	..	ss	ss	..	ssx	ssx	ssx	ssx	ssx	..
108	2,4-Dinitro-1-naphthol-7-sulfonic acid	..	..	..	ss	..	..	.	..	..	..	..	..
109	2,4-Dinitrophenol	ss	vs	..	ss	..	..	sx	..	ssn	vs	..	vs
110	2,4-Dinitrotoluene	ss	..	vs	sx	..	..	sx	ssx	ssx	..	..	ss

TABLE 119.—Solubilities of Organic Compounds in Aliphatic Amines (at 25° ± 5° C.)—(*Continued*)[2]

		C_2H_5OH	$\begin{matrix}C_2H_5\\C_2H_5\end{matrix}>O$	CH_3NH_2	$\begin{matrix}C_2H_5\\C_2H_5\end{matrix}>NH$	$(C_2H_5)_3N$	$(n\text{-}C_4H_9)_2NH$	$n\text{-}C_4H_9NH_2$	$(n\text{-}C_4H_9)_3NH$	$(n\text{-}C_4H_9)_3N$	$iso\text{-}C_5H_{11}NH_2$	$C_6H_5CH_2NH_2$	$NH_3(-33°\ C.)$
111	Diphenyl	ss	s	..	41	s	..	vs	s	sx	vs	vs	ss
112	Diphenylamine	vs	vs	..	es	vs	es	es	vs	sx	es	es	..
113	Diphenylbenzamide	..	..	..	ss	..	..	..	..	..	ssx	..	..
114	Diphenylguanidine	..	..	..	ss	ins	..	vs	s	ssx	vs	s	..
115	Diphenyl ketoxime	..	..	vs	..	..	..	..	..	..	..	..	..
116	Diphenyl sulfone (phenyl sulfone)	ss	s	..	ssx	ssx	..	ssx	ss	ssx	ssx	sx	..
117	Diphenylurea (sym.)	s	s	..	ss	ins	..	ss	ss	ssx	s	ssx	s
118	4,4'-Dipyridyl (bipyridine)	vs	..	..	..	..	..	vsx	..	..	sx	..	vs
119	Di-*p*-tolylselenide	..	..	..	..	..	..	es	..	..	..	..	..
120	Eosin	s	..	..	ss	ins	..	vs	ss	ins	vs	s	s
121	Ethyl alcohol	∞	∞	..	..	..	..	..	∞	..	..	∞	..
122	Ethyl carbonate	s	.	..	ssr	..	..	∞	..	..	..	∞	sr
123	Ethyl cyanoacetate	∞	..	..	..	..	..		..	..	..	..	..
124	Ethylene dibromide	s	∞	spr	∞	..	.	..	∞	..	..	∞	..
125	Ethylene glycol	∞	ss	..	∞	..	∞	..	..	..	∞	..	..
126	Ethyl iodide	s	s	..	∞	..	..	..	..	∞	..	esr	s
127	Ethyl malonate	∞	∞	..	∞	..	..	..	∞	..	∞	..	..
128	Ethyl oxalate	s	..	..	∞	..	..	.	∞	..	..	ssr	..
129	Ethyl sulfate	.	.	..	r	.	.	..	rs	..	..	..	..
130	Fluorene	ss	vs	..	13	ssx	sx	s	s	ssx	s	s	ins
131	Fluorescein	vs	ss		ss	ins	..	s	ins	ins	s	s	s
132	Galactose	ss	.	vs	..	.		.	..	..	..	..	..
133	Gallein	.	.	ss	..	..	..	..	..	..	..	..	..
134	Gallic acid	s	ss	..	insn	insn	..	s	insx	insn	s	ssm	s
135	Gelatin	..	.	..	ins	ins	..	insn	ins	ins	ins	ins	..
136	Glucose	ss	ins	vs	ss	ins	ssn	vs+	ins	ins	s	s	vs
137	β-Glucose pentaacetate	ss	ss	..	..	..	..	es	..	..	..	..	..
138	Glycerol	∞	ins	vs	..	..	..	..	..	..	..	..	..
139	Guaiacol	∞	∞	..	∞	..	..	..	..	..	..	..	..
140	Guanidine nitrate	..	..	.	ss	..	..	..	..	..	..	..	vs
141	Gum arabic	..	..	..	insn	ins	..	ins	ins	ins	ssn	ss?	..
142	H acid	ss	ss	..	..	..	..	insn	..	..	..	..	..
143	Hemoglobin	.	.	..	ins	..	..	insn	..	..	..	..	ss
144	Hexaethylbenzene	s	vs	.	.	..	..	ssx	..	..	ssx	..	..
145	Hexamethylenetetramine	ss	ins	..	ssn	..	..	ssn	..	..	..	..	..
146	Hippuric acid	ss	vss	vs	ssx	..	..	..	..	..	vs	..	vs
147	Hydrazine sulfate	ins	.	..	ins	..	..	..	..	..	..	..	insr
148	Hydroquinone	vs	vs	vs	35	ss	s	s	s	ss	s	ssx	vs
149	Hydroxylamine hydrochloride	s	ins	vs	.	.	..	..	..	..	..	..	..
150	Indigotin	ins	ins	vs	ins	ins	..	ss	ss	ss	ins	ss	ss

151	Indole	vs	vs	..	es	..	..	es	..	..	..	..	vs
152	Isatin	s	ss	..	..	..	..	vs	..	..	..	..	s
153	Isoquinoline	∞	∞	..	∞	..	..	.	∞	..	∞	..	s
154	Lactose	ss	ins	..	ss	ss	..	ss	ins	ins	es	ins	vs
155	Lanolin	..	..	..	es	es	..	es	es	es	es	es	..
156	Linseed oil, raw	..	..	..	∞	∞	..	∞	∞	∞	∞	∞	..
157	Lysol	..	..	..	∞	..	..	..	..	..	..	..	..
158	Maleic acid	s	ss	..	ins	ins	..	ssn	ins	ins	sex	insm	..
159	Malic acid	vs	ss	..	ins	ins	ins	ssn	ins	ins	ssn	ssx	ss
160	Malonic acid	s	ss	..	ins	insn	insx	ss	ins	ss?	ss	ins	ins
161	Mannite	ss	ins	..	ss	ins	..	ss	ins	ins	ssn	ins	ss
162	*d*-Menthol	vs	vs	..	es	es	es	es	es	es	es	es	es
163	Mercuric acetate	ss	..	..	insr	ins	s	vs	ss	ins	ss	ins	s
164	Mercuric cyanide	s	..	vs		.	..	es	..	ssn	..	..	vs
165	Mercury diphenyl	ss	..	..	ss	ins	ss	ss	ss	ins	ss	ins	..
166	Mercury di-*p*-tolyl	..	..	..	..	..	..	ssx	..	ssx	ssx	..	..
167	Methanol	∞	∞	∞	..	..	..	∞	..	∞	..	..	..
168	*meso*-Methyl acridine	vs	vs	..	..	..	..	..	..	..	es	..	..
169	Methylene aminoacetonitrile	..	..	..	ss	ss	..	ss	ins	ssx	ss	ins	..
170	Methylene dianiline	..	..	..	insn	ss	..	ss	ss	insx	ss	ss	..
171	Methyl orange	ss	ins	ss	ins	ins	ins	ssn	ins	ins	ss	ss	..
172	Mucic acid	ins	.	..	ins	ins	insn	ss	ins	ins	ss	ins	s
173	Naphthalene	ss	vs	..	27	sx	..	vsx	s	sx	vs	sx	ss
174	Naphthionic acid	ss	ins	..	ss	ins	.	s	ins	ins	s	ss	..
175	1-Naphthol	vs	vs	vs	..	..	..	..	..	..	..	..	..
176	2-Naphthol	vs	vs	vs	es	vs+	..	es	es	vs	es	es	ss
177	Naphthol yellow	..	..	..	ins	ins	..	ss	ins	ins	ins	ins	..
178	Night blue	.	.	..	s	s	..	s	s	s	s	s	..
179	*p*-Nitroacetanilide	s	ss	..	ss	.	..	.	..	..	.	..	..
180	*m*-Nitroaniline	s	ss	..	sx	ssx	..	s	ss	ssx	s	s	s
181	*p*-Nitroaniline red	..	..	..	ss	ss	..	s	ssx	ssx	s	s	..
182	*m*-Nitrobenzaldehyde	vs	vs	vs	..	..	..		..		..	..	..
183	Nitrobenzene	∞	∞	∞	..	..	..	∞	..	∞	..	..	vs
184	*m*-Nitrobenzenesulfonamide	..	.	vs	..	..	..	..	.	..	..	..	..
185	*o*-Nitrobenzoic acid	s	s	vs	..	..	..	..	.	..	..	..	..
186	*p*-Nitrobenzoic acid	ss	ss	..	ssx	insn	ssx	vsx	ss	ss	s	sx	ss
187	*p*-Nitrobromobenzene	ss	.	..	ss	ss	ssx	sx	ss	ssx	s	sx	..
188	*o*-Nitrophenol	vs	vs	vs		..		..	..	.	..	..	..
189	*p*-Nitrophenol	vs	s	..	13	ss	ssx	vs	ss	ssm	vs	s	s
190	*p*-Nitrophenylhydrazine	..	..	..	..	..	..	vs	..	ssx	..	..	..
191	*o*-Nitrotoluene	∞	∞	vs	.	..	..	..	..	..	..	..	..
192	*p*-Nitrotoluene	s	s	..	vs+x	..	..	..	..	sx	vsx	..	..
193	3-Nitro-4-toluidine	vs	.	..	sx	..	..	vsx	..	ssx	.	..	s
194	Nitrourea	vs	vs	..	ins	..	..	.	..	..	.	.	vs
195	Oleic acid	∞	∞	..	∞	∞	..	∞	∞	∞	∞	∞	ins
196	Olive oil	..	..	..	∞	∞	..	∞	∞	∞	∞	∞	..
197	Orange IV	..	..	..	ss	ins	..	ss	ss	ins	ssn	ss	..
198	Oxalic acid.$2H_2O$	s	ss	..	ins	ins	..	insn	insn	ins	ins	ins	ins
199	Oxanilide	ss	ss	..	0.5	..	..	..	..	..	..	..	..
200	Palmitic acid	ss	..	vs	..	..	..	..	..	..	..	..	..

TABLE 119.—Solubilities of Organic Compounds in Aliphatic Amines (at 25° ± 5° C.)—(*Continued*)[2]

		C_2H_5OH	$\begin{matrix}C_2H_5\\C_2H_5\end{matrix}>O$	CH_3NH_2	$\begin{matrix}C_2H_5\\C_2H_5\end{matrix}>NH$	$(C_2H_5)_3N$	$(n\text{-}C_3H_7)_2NH$	$n\text{-}C_4H_9NH_2$	$(n\text{-}C_4H_9)_2NH$	$(n\text{-}C_4H_9)_3N$	$iso\text{-}C_5H_{11}NH_2$	$C_6H_5CH_2NH_2$	$NH_3(-33°\ C.)$
201	Paraffin	..	..	..	ss	sx	..	s	sm	sx	s	ssx	ins
202	Paraffin oil	..	..	..	..	..	..	..	..	..	..	..	..
203	*n*-Pentane	∞	..	∞	..	..	..	..	..	..	..	..	..
204	2-Pentene	..	..	..	∞	..	..	..	..	..	..	..	..
205	Penacetin	ss	ss	..	ss	ins	ssx	s	ss	ssx	s	ss	..
206	Phenanthrene	ss	s	..	s	..	..	..	..	..	..	vs	ins
207	Phenol	∞	∞	vs	es	..	..	..	..	..	es	..	vs
208	Phenolphthalein	s	ss	vs	s	ss	..	s	ss	ss	s	s	..
209	Phenylacetic acid	es	vs	vs	..	..	..	vsx	..	..	..	..	..
210	*meso*-Phenyl acridine	ss	s	..	..	..	..	..	..	..	ssx	..	..
211	Phenylazo-1-naphthylamine	..	..	..	..	..	..	..	..	ssx	s	..	..
212	o-Phenylenediamine	vs	vs	..	..	..	..	sx	..	..	sx	..	vs
213	Phenylglucosazone	ss	..	..	..	..	..	sx	..	..	vs	..	vs
214	Phenylhydrazine	∞	∞	∞	..	..	..	..	..	..	.	..	..
215	Phenylmercuric bromide	..	..	..	..	..	..	ssx	..	..	ssx	..	..
216	2-Phenylquinoline	vs	vs	..	vs	..	..	vs	..	..	s	..	..
217	Phenyl-*p*-tolyl sulfone	..	.	..	6 3	ins	ins	ss	ss	ssx	ssx	ss	..
218	Phenyl urea	vs	vs	..	ss	ss	ssn	s	ss	ssx	vs	s	s
219	Phthalic acid	s	ss	ins	ins	ins	..	ins	ins	insx	..	ssx	ins
220	Phthalic anhydride	s	ss	ins	sm	ss	..	s	ss	ins	s	ssm	..
221	Phthalimide	s	ss	..	s	ss	ss	s	sx	ssm	s	s	vs
222	Picric acid	s	ss	vs	ssp	ss	vs	vs+	s	ssx	vs	s	es
223	Potassium amide	r	ins	..	ins	..	..	insn	..	..	..	..	vs
224	Potassium ethyl sulfate	..	..	..	ins	..	..	.	..	..	..	..	vs
225	Potassium quinaldine	r	vs	..	..	..	..	vs	..	..	..	..	es
226	Potassium triphenylmethyl	r	s	..	..	..	..	s	..	..	..	..	..
227	Pyridine	∞	∞	∞	.	..	..	..	..	..	..	..	∞
228	Pyrogallol	vs+	vs+	vs	ssm	ss	..	s	s	ss	s	sm	es
229	Pyrrole	vs	vs	..	∞	..	.	.	..	..	..	..	..
230	Quinaldine	vs	vs	..	∞	..	.	∞	..	∞	∞	..	s
231	Quinaldine picrate	ss	..	..	es			es	vsx	ss	..	..	..
232	Quinine	es	vs+	.	s	ssm	s	vs	ssm	ss	vs	s	insol
233	Quinoline	s		.	∞		.	∞	∞	∞	..	∞	∞
234	Quinoline methiodide	..	..	..	.		..	vsx	..	..	vs	..	vs
235	Quinoline yellow (water soluble)	..	..	..	ins	ins	..	ss	ss	ins	ssn	ss	..
236	Quinone	vs	vs	sr	vsr	..	..	.	..	..	..	..	..
237	Resorcinol	es	vs	vs	s	.	.	vs	..	..	..	..	es
238	Rosaniline	s	ins	vs	ins	ins	..	ss	ins	ins	ss	ss	s
239	Rosin	vs	vs	..	s	s	..	vs	vs	ins	s	s	insr
240	Rosolic acid	ss	s	..	ss	ss	..	s	ss	ss	s	s	ss

241	Rubber, vulcanized	ins	ins	..	a	a	..	a	a	a	a	ins	ins
242	Salicylic acid	vs	vs	..	vs	sp	sx	vs+	ss	ssm	es	s	..
243	Selenium	ins	ins	..	ins	ins	..	ins	ins	ins	ins	ins	ins
244	Shellac, white	..	..	..	ins	ins	..	ins	ins	ins	insn	ins	..
245	Skatole	s	..	..	es	..	..	..	..	es	..	..	s
246	Soap	..	..	..	..	.	..	ins	..	..	ins	..	ins
247	Sodium alizarin sulfonate	..	..	..	ss	ins	..	s	ss	ins	s	s	ins
248	Sodium benzoate	ss	..	..	insn	..	..	insn	..	..	..	..	..
249	Sodium indigo sulfonate	..	..	..	ins	ins	..	ss	ins	ins	ss	ss	..
250	Sodium-*p*-nitrophenylantidiazotate	..	..	..	..	..	..	vs	..	..	..	..	s
251	Starch (corn)	ins	ins	..	ins	ins	..	ins	ins	ins	ins	ins	insa
252	Stearic acid, tech.	ss	s	..	es	vs+	es	es	vs+	vs	vs	ssx	ins
253	Strychnine	ins	ins	..	..	..	..	ss	..	..	.	..	..
254	Succinic acid	s	ss	ins	insn	ss	ssx	ins	ins	ins	ins	ssx	..
255	Succinimide	s	..	..	ss	ins	s	vsx	ss	ssx	sx	ss	..
256	Sucrose	ss	..	vs	ss	ss	..	vs	ins	ins	s	vs	vs
257	Sulfanilic acid	ss	ss	..	ssn	ss	..	s	ss	ss	s	ss	vs
258	Sulfonal	ss	ss	..	..	..	..	ssx	..	..	ssx	..	s
259	Sulfur, rhombic	ins	ins	..	s	s	..	vs	ss	ssx	s	s	s
260	Tallow	..	..	..	vsx	..	..	..	..	..	es	..	..
261	Tannic acid	ss	ss	..	ss	ins	insn	ss	ins	ins	ss	ss	ss
262	Tartaric acid	s	ss	ins	ins	ins	..	ss	ss	insn	ss	ssx	ins
263	Tetraethylammonium iodide	.	.	..	ins	ins	..	ins	ins	insn	ins	ins	ss
264	Tetraethyl lead	∞	∞	..	∞	..	..	∞	.	..	..	..	..
265	Tetrahydronaphthalene	vs	vs	..	∞	..	..	∞	..	∞	..	..	..
266	Tetramethyldiaminobenzophenone	vs	vs	..	0.6	ss	ssx	ss	ss	ssx	ssx	ssx	ss
267	Tetraphenyl lead	..	..	..	..	..	..	ssx	..	..	ssx	..	..
268	Tetraphenylmethane	.	.	.	ss	ss	ss	ssx	ssx	ssx	ssx	ssx	ss
269	Thymol	vs	vs	vs	es	es	es	es	es	vs	es	es	vs
270	*o*-Tolidine	vs	..	..	s	ss	ssx	s	ss	ssx	s	s	vs
271	Toluene	∞	∞	∞	..	..	..	..	.	∞	..	..	..
272	*p*-Toluenesulfonamide	..	..	..	vs	ss	vs	vs+	s	ssx	vs	s	s
273	*p*-Toluidine	s	s	..	es	vs+	..	es	vs+	sx	es	es	vs
274	Trichlorogallein	..	..	ss	..	..	..	..	..	.	..	..	..
275	2,4,6-Trinitroaniline	ins	..	es	..	..	..	..	..	..	..	..	..
276	1,3,5-Trinitrobenzene	ss	vs	..	es	ss	sp	s	ss	ss	s	s	vs
277	2,4,6-Trinitrotoluene	ss	vs	..	s	ss	sp	vs	ss	ss	s	s	s
278	Triphenylmethane	ss	vs	..	25	s	sx	s	s	ss	s	s	..
279	Triphenylselenonium iodide	.	..	..	.	..	..	ssn	.	..	ssn	..	..
280	Tyrosine	ins	ins	..	ss	ins	ins	ss	ins	ins	ss	ins	..
281	Urea	ss	ss	vs	ins	ins	..	ss	ins	ins	ss	ss	s
282	Uric acid	ins	ins	ins	..	..	..	..	..	insn	insn	..	ins
283	Wax, carnauba	..	..	..	ss	..	..	..	..	..	..	..	..
224	Wax, Japan	.	.	.	vs	..	..	.	..	..	..	..	..
285	*m*-Xylene	vs	vs	∞	..	..	..		..	..	..	..	..
286	1,3,5-Xylenol	s	..	..	es	vs+	..	es	vs	vs	es	es	..
287	Xylose (crude)	ins	ins	..	es		..	s+	..	.	s	..	..
288	Zinc stearate	..	..	..	ss	ins	ss	vs?	ss	ins	s?	s	..

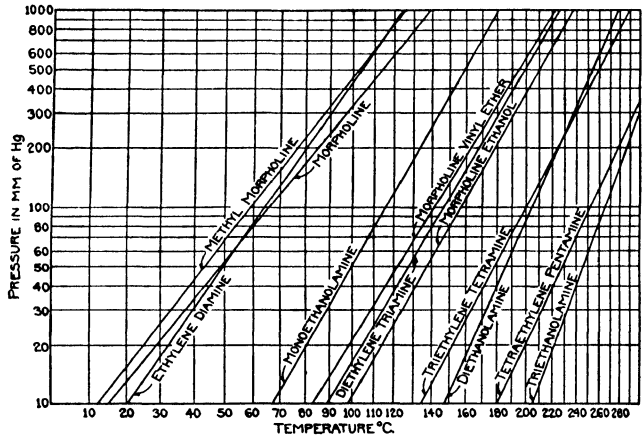


FIGURE 263. Vapor Pressure of Amines at Various Temperatures.[5]

TABLE 120.—Solvent Properties of Amines[5]

	Ethylene diamine	Propylene diamine	Triethylene tetramine	Morpholine	Morpholine ethanol	Morpholine ethyl ether
Water	M	M	M	M	M	M
Alcohol	M	M	M	M	M	M
Glycols	M	M	M	M	M	M
Glycol ethers	M	M	M	M	M	M
Acetone	M	M	M	M	M	M
Methyl butyl ketone	S	S	S	M	M	M
Ethyl ether	S	S	S	M	M	M
Butyl ether	SS	S	SS	M	M	M
Naphtha	S	S	SS	S	I	M
Benzene	M	M	S	M	M	M
Turpentine	I	I	I	M	M	M
Pine oil	M	M	M	M	M	M
Paraffin oil	I	I	I	I	I	M
Castor oil	M	M	M	M	M	M
Linseed oil	I	I	I	M	S	M
Paraffin wax	SH	SH	SH	SH	SH	SS
Beeswax	I	I	SH	I	I	SS
Shellac	S	S	S	S	S	S
Rosin	S	S	S	S	SS	S
Ester gum	SS	SS	SS	S	S	S
Dammar gum	I	I	I	PS	PS	S
Copal gum	S	S	S	S	S	S
Sulfur	VS	VS	S	SS	SS	SS
Vinylite A	G	G	G	S	G	SS
Vinylite N	S	S	S	S	S	S
Vinylite 0200	G	G	G	S	G	S
Cellulose acetate	G	G	G	S	S	I
Cellulose nitrate	S	S	S	S	S	S
Benzyl cellulose	SS	SS	SS	S	S	S
Water-sol. dye	S	S	SS	I	I	I
Alcohol-sol. dye	S	S	S	S	S	S
Oil-sol. dye	S	S	S	S	S	S
Satd. brine	M	M	M	M	M	S

M = miscible in all proportions
S = sol. to over 5%
SS = sol. from 1 to 5%
PS = sol. in part
I = sol. to less than 1%
SH = sol. hot
VS = very sol.
G = gels

TABLE 121.—Physical Constants of Amines[5]

Amine	Formula	Mol. Wt.	Sp. Gr., 20°/20° C.	Boiling Point, 760 Mm. °C.	Vapor Pressure, 20° C. *Mm.*	Melting Point °C.	Flash-Point °F. (°C.)
Ethylene diamine	$NH_2CH_2CH_2NH_2$	60.08	0.8994	116.2	10.0	11.0	93 (33.9)
Propylene diamine	$NH_2CH(CH_3)CH_2NH_2$	74.10	0.8723	119.3			
Diethylene triamine	$NH_2C_2H_4NHC_2H_4NH_2$	103.13	0.9586	207.1	0.16		
Triethylene tetramine	$NH_2(C_2H_4NH)_2C_2H_4NH_2$	146.18	0.9839	277.9	0.01		257 (125)
Tetraethylene pentamine	$NH_2(C_2H_4NH)_3C_2H_4NH_2$	189.22	0.9994	333	<0.01		
Piperazine	$NH(C_2H_4)_2NH$	86.10		146		104	
Morpholine	$NH(C_2H_4)_2O$	87.08	1.0016	128.3	13.2		77 (25)
Methylmorpholine	$CH_3N(C_2H_4)_2O$	101.10	0.9051	115.4	16		
Phenylmorpholine	$C_6H_5N(C_2H_4)_2O$	163.11		260		58	
Morpholine ethanol	$HOC_2H_4N(C_2H_4)_2O$	131.11	1.0724	225.7	0.11		207 (97.2)
Morpholine ethyl ether	$C_2H_5OC_2H_4N(C_2H_4)_2O$	157.14	0.9648	206.2			
Morpholine vinyl ether	$C_2H_3OC_2H_4N(C_2H_4)_2O$	155.13	1.0023	210.1	0.3		180 (82.2)

Monomethylamine

Monomethylamine (CH_3NH_2) is an inflammable gas soluble in water, alcohol and ether. Liquid monomethylamine is a good solvent for many organic substances and is used in the tanning industry, in the manufacture of dyestuffs, and in synthetic products.

Purity	Not less than 98 mol. % of total amines
Concentration	30–35% by wt. in water
Molecular weight	31.047
Boiling point	− 6.0° C. to − 5.5° C. (768 mm. Hg.)
Specific gravity	0.699 at $\frac{-10.8° \text{ C.}}{15° \text{ C.}}$

Dimethylamine

Dimethylamine [$(CH_3)_2NH$] is a gas soluble in water, alcohols and in many organic solvents. It is used as a dehairing agent in the tanning industry.

Purity	Not less than 98 mol. % of total amines
Concentration	25–30% by wt. in water
Molecular weight	45.11
Specific gravity	0.6865 (− 6° C.)
Boiling point	7.2° C. to 7.3° C. (764 mm. Hg.)
Solubility	Soluble in water, alcohol, ether, and many organic liquids
Flash point	(27% solution) approx. − 6.25° C. (20.8 ° F.)

Trimethylamine

Trimethylamine [$(CH_3)_3N$] is sold as a 25 per cent aqueous solution. It is used in organic synthesis, as a warning agent for gases, and as an insect attractant.

Color	Colorless
Odor	Pungent ammoniacal
Molecular weight	59.10
Specific gravity	0.662 (− 5° C.)
Boiling point	3.2° C. to 3.8° C. (765 mm. Hg.)

Monoethanolamine

Monoethanolamine ($HOCH_2CH_2NH_2$, 2-hydroxyethylamine) is a colorless, viscous liquid of ammoniacal odor. It is a strong base and is chemically active. It will combine with fatty acids to form soaps and with acids to form salts. It is used in making soap and in the extraction of carbon dioxide.

Boiling point	171° C. (757 mm.)
Color	Water-white
Specific gravity	1.0170 to 1.0270 at $\frac{20° \text{ C.}}{20° \text{ C.}}$
Boiling range	Not less than 90% over between 165° and 173° C. (760 mm.)
Average weight	8.55 lbs./gal. (20° C.)

Diethanolamine

Diethanolamine [$(HOCH_2CH_2)_2NH$, di(hydroxyethyl) amine] is a faintly colored, viscous liquid. It is miscible with water and most common solvents and is used for the absorption of acid gases, as a softening agent and in organic synthesis.

Boiling point	217° C. (150 mm.)
Specific gravity	1.088 to 1.095 at $\frac{30° C.}{20° C.}$
Water	Not more than 1.5%
Monoethanolamine	Not more than 2%
Diethanolamine	Not less than 95%
Triethanolamine	Not more than 2%
Color	Not more than 3 yellow and 1 red (100 mm. tube)
Average weight	9.08 lbs./gal. (30° C.)

Triethanolamine

Triethanolamine [$(HOCH_2CH_2)_3N$, tri(hydroxyethyl)amine] is a viscous, faintly colored liquid of ammoniacal odor. It is soluble in water, alcohol and many other solvents but only slightly soluble in hydrocarbons. The commercial product contains both diethanolamine and monoethanolamine. It is used as an absorbent for acid gases. It will form soaps with fatty acids which are soluble in water and hydrocarbons and are used in dry-cleaning, textile scouring and cosmetic preparations. Soaps of triethanolamine are emulsifying agents and are used in making "soluble oils," cutting oils and textile lubricants. This amine is both a solvent and plasticizer for nitrocellulose, cellulose acetate, textiles, glues and so forth, and is also used in organic synthesis.

Specific gravity	1.1240 to 1.1300 at $\frac{20° C.}{20° C.}$
Boiling point	277° C. (150 mm.)
Water	Not more than 1.0%
Heavy ends	Not more than 2.5%
Purity	2.5% monoethanolamine 15% diethanolamine 80% triethanolamine
Color	7.0 yellow and 2.0 red
Average weight	9.40 lbs./gal. (20° C.)

Ethylene Diamine

Ethylene diamine [$C_2H_4(NH_2)_2$] is a water-soluble liquid of ammoniacal odor. It is used in the organic synthesis of rubber accelerators, dyes, drugs and so forth.

Specific gravity	0.8994 at $\frac{20° C.}{20° C.}$
Change in specific gravity	0.0007/° C.
Weight	7.50 lbs./gal. (20° C.) 899 gm./liter (20° C.)

Molecular weight	60.08
Boiling point	116.2° C.
Vapor pressure	10.0 mm. (20° C.)
Melting point	11.0° C.
Flash-point	93° F. (33.9° C.)
Viscosity	0.0154 poise (13) (25° C.)
Refractive index	1.4540 (7) (26° C.)
Dielectric constant	16.0 (37) (18° C.)
Ionization constant	7.1×10^{-5} (6) (25° C.)
pH of 25% solution	11.9 (25° C.)
Latent heat of vaporization	167 cal./gm. (calc.)
Latent heat of fusion	77 cal./gm. (0° C.)
Heat of solution	7.6 cal./mole. (9) (15° C.)
Heat of combustion	452.6 cal./mole. (34)

Aromatic Amines

A number of carbocylic and heterocylic amines and their derivatives have been proposed as solvents and plasticizers for cellulose esters and ethers.

Anilids

(C_6H_5NHR)

Acetanilid

Acetanilid ($C_6H_5NHCOCH_3$, phenylacetamide, antifebrin, acetylamidobenzene) occurs as odorless, crystalline scales. It is soluble in alcohol, ether, chloroform and acetone, and is a solvent for celluloid, nitro- and acetylcellulose, cellulose ethers and ethylstarch. It is used in the manufacture of cellulose acetate varnish, phonograph records and so forth.

Boiling point	295° C.
Melting point	113–115° C.

Ethyl Acetanilid

Ethyl acetanilid [$C_6H_5N(C_2H_5)COCH_3$, (Mannol)] is a white, crystalline solid of faint odor and is soluble in most organic solvents. It is used as a substitute for camphor in the nitrocellulose industry.

Boiling point	258° C.
Flash-point	124° C.
Melting point	54° C.
Specific gravity	1.087

p-Toluene Sulfanilid

p-Toluene sulfanilid ($CH_3C_6H_4SO_2C_6H_4NH_2$) is a white, crystalline solid having a melting point at 103° C. It is soluble in most lacquer solvents and is used as a softener for acetylcellulose in quantities up to 50 per cent.

Other Anilids

Some of the other anilids proposed are methyl acetanilid, trichlorethyl acetanilid and so forth.

Anisic Esters

Anisic esters ($CH_3OC_6H_4COOR$) are cellulose ether solvents.

Benzoic Esters

(C_6H_5COOR)

Methyl Benzoate

Methyl benzoate ($C_6H_5COOCH_3$, Oil of Niobe) is a liquid of fragrant odor. It is miscible with alcohols, ethers, ketones and esters, and will dissolve cellulose esters and ethers, resins, rubber and so forth.

Boiling point	199° C.
Melting point	– 12° C.
Specific gravity	1.026 (0° C.)

Ethyl Benzoate

Ethyl benzoate ($C_6H_5COOC_2H_5$) is a pleasant-smelling liquid. It is miscible with most lacquer solvents and will dissolve a wide variety of cellulose derivatives and natural and synthetic resins. It is used in solvent mixtures imparting good working qualities to lacquers and high gloss to films.

Boiling point	211 2° C.
Ester content	98%
Specific gravity	1.0502 (16° C.)

Butyl Benzoate

Butyl benzoate ($C_6H_5COOC_4H_9$) is a colorless liquid and is used as a solvent for cellulose ether.

Boiling point	247.3° C.
Specific gravity	1.00 (20° C.)

Amyl Benzoate

Amyl benzoate ($C_6H_5COOC_5H_{11}$) is a water-white liquid of mild odor. It is miscible with alcohols, ketones, esters, oils and hydrocarbons. Its sluggish solvency for cellulose derivatives is improved and augmented by adding an active solvent. When its solvent power is increased it will dissolve many of the natural and synthetic resins. It is used as a plasticizer in film production.

Boiling point	261° C.
Refractive index	1.4945
Specific gravity	0.994–1.01

Benzyl Benzoate

Benzyl benzoate ($C_6H_5COOCH_2C_6H_5$) is a water-white, stable liquid of pleasant odor. It is miscible with alcohols, esters, ketones, oils and hydrocarbons. It is a solvent for many of the cellulose ethers and a wide range of natural and synthetic resins. When employed as a cellulose ester plasticizer it is mixed with equal parts of nitrocellulose or with 66 per cent

of the weight of the acetylcellulose present. Films containing this plasticizer are strong and flexible.

Boiling range	323–324° C.
Melting point	18.5–19° C.
Refractive index	1.568–1.569
Specific gravity	1.120–1.126

The Seldom Company has proposed some 72 benzoate ester plasticizers.

Naphthyl Benzoate

Naphthyl Benzoate is a plasticizer for pyroxylin and cellulose esters.

Glyceryl Benzoate

Glyceryl benzoate $\begin{matrix} CH_2OOCC_6H_5 \\ | \\ CHOOCC_6H_5 \\ | \\ CH_2OOCC_6H_5 \end{matrix}$ (tribenzoin) is a colorless, non-hygroscopic, crystalline solid plasticizer. It is soluble in most anhydrous lacquer solvents with the exception of petroleum hydrocarbons. It is used with nitrocellulose in quantities not exceeding 20 per cent on the weight of the cellulose nitrate present. It imparts flexibility to films.

Melting point	71° C.
Specific gravity	1.25

Other Benzoates

Phenyl, glycol and glyceryl benzoates have been advocated as solvents and colloiding agents for the derivatives of cellulose.

Boric Esters

The alkyl boric esters (R_3BO_3) are fire-retardants and, consequently, their presence in lacquers reduces inflammability.

Amyl Borate

Amyl borate [$(C_5H_{11})_3BO_3$] is a stable, high-boiling liquid miscible with most lacquers and diluents. It is a solvent for oils, benzyl abietate, cumar resins, ester gum, mastic and so forth. Its presence in cellulose-derivative films imparts adhesion between the film and metallic surfaces and reduces inflammability. It will also prevent gelling of nitrocellulose bronze lacquers. Its poor solvent power for cellulose nitrate requires the addition of active and plasticizing solvents.

Triphenyl Borate

Triphenyl borate is used as a solvent for cellulose esters and ethers.

Carbamic Esters

Carbamic esters (NH_2COOR) are used in the pyroxylin industry as solvents and gelatinizers.

Carbanilic Esters

Carbanilic esters ($C_6H_5NHCOOR$) have been proposed as pyroxylin plasticizers and camphor substitutes.

Carbonic Esters



Diethyl Carbonate

Diethyl carbonate [$(C_2H_5)_2CO_3$, diatol, contains 90 per cent of diethyl carbonate] is a colorless liquid of pleasant odor. It is miscible with alcohols, ketones, esters, aromatic hydrocarbons and some aliphatic solvents. It will dissolve many of the natural and synthetic resins, nitrocellulose and cellulose ethers. The addition of an active solvent such as acetone or an ester, or a latent solvent such as alcohol, will increase its solvent power. It has a rather low tolerance for hydrocarbons. It is employed in lacquer formulation and in special lacquers for coating the cathode of radio tubes with rare earths.

	Pure	90%
	Free acid as carbonic	
Acidity	Not more than 0.02%	Not more than 0.02%
Color	Water-white	Water-white
Distillation range	Below 120° C. . . None Below 128° C. . . Not less than 90% Above 130° C. . . None	Below 100° C. . . Not more than 15% Below 125° C. . . Not more than 50% Above 130° C. . . None
Dryness	Miscible without turbidity with 20 vols. 60° Bé. gasoline at 20° C.	Miscible without turbidity with 20 vols. 60° Bé. gasoline at 20° C.
Non-volatile matter	Not more than 0.005 g./100 cc.	Not more than 0.005 g/100 cc.
Odor	Mild, non-residual	Mild, non-residual
Purity	Ester content as diethyl carbonate, 98–100%	Ester content as ethyl carbonate, not less than 90%
Specific gravity $\frac{20°\,C.}{20°\,C.}$	0.973–0.977	0.967–0.971

	Relative humidity	
Blush resistance at 90° F. (10% ½-sec. R.S. nitrocellulose solution)	Clear 85% Blush 90%	Clear 75% Blush 80%
Coefficient of expansion	0.00066/1° F. 0.00119/1° C.	0.00063/° F. 0.00113/1° C.
Dilution ratio (nitrocellulose solution method)	0.6 with toluene 0.4 with petroleum naphtha	1.2 with toluene 0.6 with petroleum naphtha
Evaporation rate at 95° F.		
Per cent	5 25 50 75 90 95	5 25 50 75 90 95
Minutes	1¼ 7¼ 14½ 24 31¾ 34¾	¾ 5¾ 14 23¾ 31¼ 35
Flash-point	89° F. (approx.)	68° F.(approx.)
	Centipoises	
Viscosity (10% ½-sec. R.S. nitrocellulose solution)	141	69
Water solubility	100 cc. solvent dissolves 1.4 cc. water (25° C.)	100 cc. solvent dissolves 3.0 cc. water (25° C.)

Ethyl Butyl Carbonate

Ethyl butyl carbonate $\begin{matrix} C_2H_5 \\ C_4H_9 \end{matrix}\!\!>\!CO_3$ is a colorless liquid. It has a sluggish solvency for nitrocellulose requiring the addition of ethyl alcohol to activate it. However, it will dissolve quite a number of natural and synthetic resins.

Boiling point	135–175° C.
Flash-point	50° C.
Specific gravity	0.92 to 0.93 (20° C.)

Ethyl Chlorcarbonate

Ethyl chlorcarbonate ($ClCO_2C_2H_5$) is a colorless liquid. Its vapors are irritating to the eyes. It is used mainly in organic synthesis and as a flotation agent in ore refining.

Color	Water-white
Dryness	Miscible without turbidity with 20 vols. 60° Bé. gasoline (20° C.)
Free chlorine	None
Odor	Irritating, tear-producing
Purity	Not less than 96% ester content as ethyl chlorcarbonate
Specific gravity	1.135 to 1.139 at $\frac{20° C.}{20° C.}$
Coefficient of expansion	0.00070/1° F. 0.00126/1° C.
Flash-point	61° F. (approx.)
Toxicity	Poisonous, corrosive. Handle with care

Various Other Carbonates

Diphenyl, tricresyl and trinaphthyl carbonates have been proposed as nitrocellulose gelatinizers. Dichlorethyl carbonate and dichlorpropyl carbonate are good solvents for cellulose esters and ethers, and for some synthetic resins, and impart transparency to cellulose ether lacquers. Resorcinol dicarbonate is a good solvent for cellulose ethers and it will impart to the film flexibility, transparency and adhesiveness. Its boiling point is from 298 to 302° C.

Cinnamic Esters

Of the cinnamic esters ($C_6H_5CHCHCOOR$) methyl and ethyl cinnamate have been proposed as solvents for cellulose esters.

Citric Esters

Citric esters $\begin{matrix} CH_2COOR \\ | \\ CH(OH)COOR \\ | \\ CH_2COOR \end{matrix}$ are solvents for cellulose derivatives.

Triethyl Citrate

Triethyl citrate $\begin{matrix} CH_2COOC_2H_5 \\ | \\ CH(OH)COOC_2H_5 \\ | \\ CH_2COOC_2H_5 \end{matrix}$ is a colorless, mobile liquid of bitterish taste. It was first proposed as a solvent for nitrocellulose in 1889. It is a solvent for cellulose nitrate, acetate and ethers, dammar, ester gum, glyptols, phenol-formaldehyde-rosin resins, starch ethers, shellac and so forth. Triethyl citrate is used as a plasticizer for nitro and acetylcellulose in quantities not exceeding 100 per cent on the weight of the cellulose ester. It is also employed as a plasticizer and mutual solvent for acetylcellulose and shellac, as a softener for starch ethers, as a paint remover and as an agglutinant.

Tributyl Citrate

Tributyl citrate is a liquid plasticizer of fruity odor. When employed as a plasticizer for cellulose acetate 20 per cent is the permitted maximum and 75 per cent is the maximum permissible with nitrocellulose.

Specific gravity	1.046 to 1.047

Crotonic Esters

Crotonic esters ($CH_3CHCHCOOR$) have been proposed as solvents for a wide range of cellulose derivatives.

ETHERS

A number of ethers (ROR) and ether-alcohols have been proposed which are made by combining a polyatomic alcohol such as glycerin, erythrite and pentaerythrite with ethylene oxide in the presence of boric acid. These are solvents and plasticizers for cellulose ethers. Middleton and Rocker [3] have made an elastic lacquer-varnish by the addition of glycol methyl ether, glycol dimethyl ether and glycol trimethyl ether as plasticizers. The alkyl ethers of glycolchlorhydrin are good solvents for cellulose ethers.

Monocresylglyceryl Ether

Monocresylglyceryl ether [$CH_3C_6H_4OCH_2CH(OH)CH_2OH$, Abracol 101] is a colorless, stable, neutral liquid miscible with most organic solvents. It is used as a plasticizer for some of the cellulose ethers.

Boiling range	210–230° C.
Refractive index	1.535
Specific gravity	1.124

Dicresylglyceryl Ether

Dicresylglyceryl ether ($CH_3C_6H_4OCH_2CH(OH)CH_2OC_6H_4CH_3$, Abracol 234) is similar to monocresyl glyceryl ether in properties and uses.

Boiling range	328–340° C.
Refractive index	1.549
Specific gravity	1.136

Dibenzyl Ether

Dibenzyl ether ($C_6H_5CH_2OCH_2C_6H_5$, Erganol) is an unstable liquid of faint almond odor. It is soluble in most solvents and is employed as a plasticizer for nitrocellulose.

Boiling point	298–300° C.
Flash-point	115° C.
Specific gravity	1.035

Various Cyclic Oxides

A number of cyclic oxides [3] have been proposed as plasticizers for cellulose nitrate and acetate, and as camphor substitutes. Some of these are:

Acetone glycerol
Arabite
Benzylidene glycerol
Cineol
Diacetone
Diacetone adonite
Ethyl glycid ether
Ethylidene propylene ether
Glyceryl ether oxide
Glycid
Glycid acetate
Glycidol
Isopropylidene glycerol
Mannite
Methyl glycerol
Methylene glycid ether
Paraldehyde glycid
Pinol

Various Ethers and Ether-Esters

Kessler and Helfrich [6] have proposed a number of ethers and ether-esters as plasticizers for cellulose esters and ethers. The ethers comprise methyl, ethyl, propyl, butyl, and amyl ethers of diethylene glycol, triethylene glycol, dipropylene glycol, and ethylene-propylene diglycol. The ether-esters are made by the esterification of the ethers just mentioned with capric, caproic, lauric, palmitic, oleic, linoleic or ricinoleic acids.

Various Glycerol Derivatives

Some of the glycerol derivatives, proposed as acetylcellulose plasticizers, are:

Glyceryl acetate	Glyceryl diaceto-monophenyl-acetate
Glyceryl acetobenzoate	Monobenzoyl diacetyl-glycerol
Glyceryl benzoate	Nitro-isobutyl glycerol trinitrate

GLYCOLLATES

Methyl Phthalyl Ethyl Glycollate

Methyl phthalyl ethyl glycollate (Santicizer M-17) is a faintly colored liquid having a fruity odor. It is miscible with most lacquer solvents except oils and petroleum hydrocarbons. This liquid is used as a plasticizer for cellulose esters, chlorinated rubber and a number of synthetic resins.

Boiling point	189° C. (5 mm.)
Specific gravity	1.223 (25° C.)
Refractive index	1.505 (25° C.)
Acidity	0.02% max. (as acetic)

Butyl Phthalyl Butyl Glycollate

Butyl phthalyl butyl glycollate (Santicizer B-16) is a colorless, nontoxic liquid. It will dissolve nitrocellulose and most of the resins used in lacquers. It is used as a plasticizer for cellulose ester products, chlorinated rubber and synthetic resins.

Boiling point	219° C. (5 mm.)
Specific gravity	1.009 ± 0.001 (25° C.)
Refractive index	1.489 ± 0.001 (25° C.)
Acidity	0.02% max. (as acetic)
Odor	Slight, fruity

Ethyl Phthalyl Ethyl Glycollate

Ethyl phthalyl ethyl glycollate (Santicizer E-15) is a faintly colored liquid. It is miscible with most lacquer solvents except the hydrocarbons. It will dissolve cellulose esters and most resins and is used as a plasticizer in these.

Boiling point	190° C. (5 mm.)
Specific gravity	1.181 ± 0.001 (25° C.)
Refractive index	1.498 ± 0.001
Acidity	0.02% max. (as acetic)
Odor	Slight, fruity

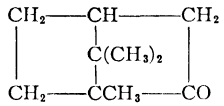
Aromatic Ketones

Acetophenone

Acetophenone ($C_6H_5COCH_3$) is a narcotic, unstable liquid of strong but pleasant odor. It is miscible with oils, hydrocarbons and most solvents. It is a powerful solvent for cellulose esters and ethers, cumar resins, glyptol resins, shellac and so forth. Acetophenone imparts elasticity and flexibility to films but its action is not permanent.

Boiling range	200–202° C.
Melting point	19–22° C.
Refractive index	1.534 to 1.537
Specific gravity	1.0295 (20° C.)

Camphor



The discovery of the solubility of nitrocellulose in camphor gave birth to the celluloid industry. It is the most outstanding plasticizer for nitrocellulose plastics despite the fact that it has such serious faults as strong odor, high vapor pressure and volatility. It is soluble in most of the organic solvents and when mixed with a small quantity of aliphatic alcohol it becomes an energetic solvent for nitrocellulose.

The immense importance of camphor to the plastics industry, as a plasticizer, cannot be overestimated from either the technical or the commercial point of view. Prior to the World War, Japan, through its control of Formosa, was able to dictate prices and quantities to the rest of the world. Germany, even before 1914, appreciating the importance of camphor, made desperate efforts to produce it synthetically. These efforts were finally crowned with success and the German Schering interests became a real competitor of the natural product. No longer was the Japanese monopoly able to raise or lower prices at will. In this country the Monsanto Chemical Works endeavored to fill the breach during the War. Since 1932 the production of synthetic camphor in America has kept pace with the price-fixing of imported natural and synthetic camphor. It is estimated that the output of synthetic camphor in the United States is about 1,500,000 pounds annually.

The synthetic camphor of commerce is by no means built up from simple compounds as the name implies. Technically it is derived from pinene, the principal component of American oil of turpentine, which in molecular structure is similar to camphor. When the pinene molecule is subjected to a few minor chemical changes it is transformed to the camphor molecule.

Camphor is synthesized from turpentine by the following reactions: Turpentine → α-pinene → bornyl chloride → camphene → isobornyl for-

mate → isoborneol → camphor. The numerous patents for making camphor are practically all based on two methods.

"Camphor substitutes" in the plastic and lacquer industries refers to a solvent and plasticizer used in connection with cellulose esters. A camphor substitute need not resemble true camphor chemically or physically; but it must possess those properties which, when added to nitrocellulose, will give a solid solution. This solution when warmed should soften and become plastic, while for lacquer purposes a plasticizer should render the film both plastic and impermeable.

The patent literature reveals that many substances have been proposed, each inventor claiming suitable and efficient plasticizing properties; but only some eight or ten, at the present time, are being used in appreciable quantities. Some of the camphor substitutes have been discarded because they impart color to the finished article or liberate halogens or acids. Others are unsuitable because they lack solvent power for nitrocellulose (10.7% to 11.2% nitrogen content) used in making pyroxylin. Some of these substitutes probably possess solvent power for nitrocellulose which contains higher or lower percentages of nitrogen.

Castor oil was among the first camphor substitutes. Then blown castor oil entered the field. The blown oil has an advantage over the raw oil in that it does not become rancid upon standing and does have the virtue of imparting toughness and durability to a film of cellulose esters. Chemically, castor oil is triglyceryl ricinoleate, and its structure no doubt suggested the idea of forming esters of ricinoleic acid. Recently amyl and butyl ricinoleates and butyl-acetyl ricinoleate have been proposed.

Some of the camphor substitutes less commonly known and used are ethyl lactate, triacetin, ethyl acetanilid, diethyl tartrate; esters of glycollic, acetic, oxalic acids; and glycerin.

The best known and perhaps the most used of camphor substitutes are the esters of phosphoric acid. The solvent power of this class of substances depends upon the $\equiv P:O$ group. These esters lower the combustibility. They are odorless, colorless, very stable, and do not discolor in sunlight. Tricresyl phosphate is the most outstanding member of this class of substitutes. Those of lesser importance are triphenyl, trinaphthyl, tribenzyl and tri-*n*-butyl phosphates. A sub-group of this same class is the arylalphyl phosphates such as diphenyl-ethyl, dibenzyl-ethyl, dicresyl-methyl, dinaphthyl-amyl phosphates and so forth. Another group is the aryl-phosphoric anilide such as dicresyl-phosphoric anilide.

Lately, the esters of phthalic acid have become important. Those that are most outstanding are dibutyl phthalate, diamyl phthalate, diethyl phthalate and dimethyl phthalate. Butyl tartrate has been used for several years and butyl stearate is attracting some attention. Some of the more recent camphor substitutes are the boric acid esters (triphenyl borate) and ethyl abietate.

Chronological List of the United States Patents
Pertaining to Camphor Substitutes

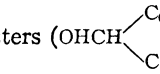
269,340	Esters and ethers
269,341	Essential oils
269,342	Dinitrobenzene
269,345	Essential oils
366,231	Non-volatile gums
410,205	Anthraquinone
410,206–09	Dimethyl-ether, etc.
494,790	Palmitin and stearone
494,791–93	Esters
500,617	Acetanilid
517,987	Acetanilid
528,812	Aromatic amines
542,692	Di-nitro-toluene
543,108	Di-nitro-toluene
543,197	Naphthalene (partial replacement)
551,456	Amyl-acetanilides, etc.
552,209	*P*-nitrotoluene
552,934	Camphene HCl
553,270	Di-nitro-xylene
559,823	Oxidation product of mixed alcohols
559,824	Benzoic esters
561,624	Formic esters
564,343	Antipyrene
568,104–6	Derivatives of fatty alcohols
572,134–35	Derivatives of fatty alcohols
583,516–17	Derivatives of benzene, etc.
587,096	Lanolin
595,355	Aliphatic ketones
596,662	Pinene HCl
597,144	Amyl acetate
598,648	Condensation products of glycerol
604,181	Light coal-tar oils
607,552	Derivatives of phenols
700,471	Casein
700,884	Organic carbonates
700,885	Triphenyl phosphate, tricresyl phosphate, trinaphthyl phosphate
741,554	Esters of alcohols
758,335	Organic compound containing SO_2
831,028	Borneol
831,488	Urea
881,827	Polymerized oil of turpentine
892,899	Amidines
900,204	Cyclohexanone
946,294	Acetins
961,360	Benzyl benzoate
962,877	Halogenated fatty acids
996,191	Cyclic oxide
1,027,617–18	Ethylene chlorohydrine
1,152,625	Oxidized drying oils
1,158,961	Dioxy-diphenyl-dimethyl methane
1,188,356	Dioxy-diphenyl-dimethyl methane
1,191,801	Polymers of coumarone
1,195,040	Chloral hydrate
1,200,886	Amines
1,309,981	Dialkyl oxalate
1,370,853	Tri-benzyl phosphate
1,354,725	Tetra-chloro-naphthalene
1,360,759	Acetin
1,589,608	Tri-*n*-butyl-phosphate

Various Other Aromatic Ketones

Some of the other aromatic ketones proposed as softening and plasticizing agents are:

α-and *p*-Methyl acetophenone
Alkyl-aryl ketones
Alkyl cyclonaphthanone
Alkyl cyclohexanone
Alkyl-naphthyl ketones
Benzophenone
Dinaphthyl ketone
Diaryl ketones
Ditolyl ketone
Ethoxy acetophenone
Hydro-benzyl and naphthyl ketones
Methoxy acetophenone
Methyl naphthyl ketone
Oxy-aryl ketones

Mandelic Esters

Mandelic esters () are solvents for nitrocellulose.

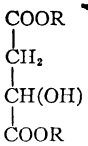
Maleic Esters

Of the maleic esters (ROOCCH : CHCOOR) dimethyl, diethyl, dipropyl and diamyl maleates are used as solvent plasticizers for cellulose esters and ethers.

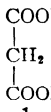
Fumaric Esters

The dialkyl fumaric esters [$C_2H_2(COOR)_2$] are used as plasticizers for cellulose ethers and esters.

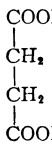
Malic Esters

Of the malic esters  ethyl malate is a good solvent for nitrocellulose and many of the resins used in lacquers. Glyceryl malate is resinous in character and acts as an extender in lacquers and varnishes.

Malonic Esters

Of the malonic esters  methyl, ethyl, diethyl and ethyl-*n*-butyl malonates have been offered as plasticizers for cellulose ethers and esters. They are used in combination with low-boiling active solvents.

Succinic Esters

Of the succinic esters  ethyl succinate has been advocated as a solvent for cellulose ethers, and dibenzyl succinate has been proposed as a plasticizer for cellulose ethers and esters.

Naphthenic Esters

Naphthenic esters or hexahydrobenzoic esters ($C_6H_{11}COOR$) are high-boiling, viscous liquids or semi-solids. They exert both solvent and softening action on cellulose esters and ethers. Some of the esters are used as synthetic varnish material.

Nitrates and Nitrites

A number of alkyl, aryl and aralkyl nitrates and nitrites have been proposed as selective solvents.

Aromatic Nitro Compounds

The general formula for these compounds is $R^1(NO_2)_n$ where R^1 is an aryl radical. The nitro-benzenes, -toluenes and -xylenes are solvents and plasticizers for cellulose esters and ethers. Many have the disadvantage of either imparting color to the finished product or of being toxic.

Mononitrobenzene

Mononitrobenzene ($C_6H_5NO_2$, Oil of Mirbane) is used in making pyroxylin insulating compounds, as a solvent for cellulose ethers, and to modify the esterification of cellulose acetate.

Dinitrobenzene

Dinitrobenzene is a mixture of three isomers employed as camphor substitutes in celluloid production.

Nitrotoluene

Nitrotoluene ($CH_3C_6H_4NO_2$) is a gelatinizing agent for nitrocellulose.

Nitroxylenes

Nitroxylenes are gelatinizing accelerators for pyroxylin.

Nitronaphthalene

Nitronaphthalene is a plasticizer and is used in celluloid manufacture in place of camphor, in plastics, in films, and in waterproofing and ornamenting paper.

Ricinoleates, Oils and Oleates

Butyl Acetyl Ricinoleate

Butyl acetyl ricinoleate is a yellow, oily liquid of mild odor. It is miscible with most lacquer solvents and possesses plasticizing, emulsifying, lubricating and detergent properties. It is used as a plasticizer and as a detergent.

Specific gravity	0.940 at $\frac{20^\circ\text{ C.}}{20^\circ\text{ C.}}$
Acidity	5% approx. (as ricinoleic acid)
Distillation range	220°–235° C. (3–5 mm. Hg.)
Saponification number	235
Freezing point	Indefinite. Becomes cloudy at – 32° C. and solidifies at – 65° C.

Flash-point	110° C. (230° F.)
Saybolt viscosity	123 sec. (100° F.)
Solubility in water	Practically insoluble
Solubility of water in butyl acetyl ricinoleate	2% by vol. (approx.)
Weight per U.S. gallon	7.8 lbs. (68° F.)
Molecular weight	396.47

Castor Oil

Castor oil (*Oleum Ricini*) is a fixed, non-drying oil obtained from the seeds of *Ricinus communis*. It is a greenish-yellow to yellow-to-colorless, transparent, viscid liquid of a faint, mild odor, and a bland taste. Upon standing, it develops an acrid and nauseating taste. Castor oil, which consists principally of triglyceryl ricinoleate, is miscible in all proportions with absolute ethyl alcohol and glacial acetic acid. Equal amounts of 95 per cent ethyl alcohol and castor oil will yield a clear solution; and 90 per cent alcohol will dissolve about one-third of the volume of this oil. It is a solvent for rosin and ester gum. Nitrocellulose will dissolve about 5 per cent of castor oil and the resulting product will be clear. If larger quantities of castor oil are added it will be only dispersed rather than dissolved and will impart a greasy feel. Should pressure be applied to a solid solution of nitrocellulose containing more than 5 per cent of castor oil, the oil will have a tendency to ooze out. The addition of a solvent-plasticizer will retard this oozing.

Blown and acetylated castor oils have been proposed as plasticizers.

Acetyl value	147–150
Acid value	0.12–0.8
Flash-point	285° C.
Iodine value	83–88
Maumené number	46–47
Optical rotation	Not less than + 3.5°
Refractive index	1.4695–1.4730 (40° C.)
Reichert Meissl number	1.1
Saponification number	176–187
Solidifying point	− 10° to − 18°
Specific gravity	0.959–0.968 (15.5° C.)
Unsaponifiable matter	0.6

Various Other Ricinoleates

Some of the proposed alkyl ricinoleates are:

Methyl ricinoleate
Ethyl ricinoleate
Butyl ricinoleate
Methyl acetyl ricinoleate
Ethyl acetyl ricinoleate
Acetylated castor oil
Methyl undecylineate
Acetylated polymerized castor oil
Methyl ester of polymerized ricinoleic acids
Ethyl ester of polymerized ricinoleic acids
Butyl ester of polymerized ricinoleic acids
Methyl ester of acetylated polmerized ricinoleic acids
Ethyl esters of acetylated polymerized ricinoleic acids
Butyl ester of acetylated polymerized ricinoleic acids

Nevillite Oil

Nevillite oil (solvent oil, Nevinol) is an inert, viscous, non-volatile, non-drying, neutral, unsaponifiable, heat-stable liquid. This hydrocarbon polymer is miscible with petroleum solvents, coal-tar naphthas, alcohols, ether and so forth. Nevinol is used as a plasticizer for chlorinated rubber, pyroxylin lacquers, synthetic and natural gums and resins and crude rubber. It is also used in such preparations as adhesives, plastic compounds, caulking compounds, bronze and aluminum paint, aluminum pastes, inks, fly-paper and waterproofing compounds; and with cumar resins, and natural and synthetic resins.

Acid number	1.0 to 0.1
Boiling point	300° C.–370° C.
Flash-point	300° F.
Specific gravity	0.950 to 1.04 at $\frac{15.5° \text{ C.}}{15.5° \text{ C.}}$
Vapor pressure	10–14 mm. (200° C.)

Butyl Oleate

Butyl oleate [$CH_3(CH_2)_7CH:CH(CH_2)_7COOC_4H_9$] is an oily liquid and is miscible with vegetable and mineral oils. It is a solvent for benzyl abietate, cumar resin, copal and ester gum. When it is added to cellulose ester it will impart water-resisting and high-polishing qualities. It requires the addition of a solvent or solvent-plasticizer for incorporation owing to its lack of solubility for nitro- and acetylcellulose, and it consequently cannot be used in large quantities.

Other Oleates

Methyl, ethyl and propyl oleates are softeners and emollients for cellulose ethers. Ethyl oleate is used as a softener in cellulose-ester stencil sheets; and butyl oleate imparts water-resisting qualities to cellulose-ester films and plastics.

Oxystearates and Oxyoleates

Some seventy solvents and softeners have been proposed by Kessler and Helfrick[6] which comprise such types as methyl, ethyl, butyl, glyceryl, phenyl, and naphthyl oxystearates, oxyoleates, ricinoleates and so forth. The solvency of these compounds is augmented by adding a small amount of an active solvent.

Ethyl Sebacate

Ethyl sebacate has been proposed owing to its power to impart softness and pliability without tackiness. As much as 50 per cent of an alkyl sebacate may be added to a cellulose ester or ether.

Ethyl Palmitate

Ethyl palmitate imparts silky and glossy effects to threads of acetyl cellulose.

Stearates

Amyl Stearate

Amyl stearate [$CH_3(CH_2)_{16}COOC_5H_{11}$) when used with an active solvent, imparts a silky feel to cellulose-ester films and plastic bodies and renders the material water-repellant.

Some of the other solvents and plasticizers proposed are methyl-, ethyl-, propyl-, amyl-fluor- (or -chlor-, or -brom-) stearates, palmitates or myristates.

Butyl Stearate

Butyl stearate [$CH_3(CH_2)_{16}COOC_4H_9$] is a stable, water-insoluble liquid. It is miscible with mineral and vegetable oils, dissolves crude rubber and natural and synthetic resins. It is used as a solvent and thermoplasticizer. It is most efficient when dissolved in a solvent-plasticizer and should not be used in quantities exceeding 5 per cent of the weight of acetylcellulose or 2 per cent of the weight of nitrocellulose. As a plasticizer, it imparts lubricating, water-repelling and polishing properties.

Specific gravity	0.855 to 0.862 at $\frac{25° \text{ C.}}{20° \text{ C.}}$
Odor	Faint
Distillation range	220°–225° C. (25 mm. Hg.)
Weight per U.S. gallon	7.14 lbs. (68° F.)
Approx. change in wt.	0 0033 lb./gal./° F.
Solubility in water	0.2% by vol. (25° C.)
Solubility of water in butyl stearate	0.03% by vol. (25° C.)
Freezing point	19° C. (66° F.) (about)
Refractive index	1.44456 (20° C.)
Molecular weight	340.47

Methyl Cyclohexanyl Oxalate

Methyl cyclohexanyl oxalate [$(CH_3C_6H_{10}OOC)_2$, Barkite] is a colorless, odorless, neutral, anhydrous, stable liquid comprising a mixture of isomers. It is miscible with most lacquer solvents and diluents and will dissolve cellulose esters and ethers. Methyl cyclohexanyl oxalate is used with nitrocellulose in quantities up to 150 per cent but with acetylcellulose quantities should not exceed 66 per cent. It is also used as a wetting agent for pigments.

Oxamic Esters

Methyl, ethyl, propyl and amyl oxamates ($NH_2COCOOR$) have been proposed as camphor substitutes and have been used in the manufacture of cellulose-ester thermoplastics.

PHENOLS

(RC_6H_4OH)

p-tert-Butyl Phenol

p-tert-Butyl phenol ($C_4H_9C_6H_4OH$) is a white, crystalline solid of distinctive odor. It has been proposed as a plasticizer for acetylcellulose.

Boiling point	236–238° C.
Melting point	98° C.

Tertiary butyl cresol has also been proposed.

Hexahydro-Ortho-Cresol

Hexahydro-*o*-cresol has been proposed as a plasticizer for cellulose acetate. Its escharotic nature, like that of all other phenols, has militated against its use.

Mannitol

Mannitol [$CH_2OH(CHOH)_4CH_2OH$, Mannite] is a hexahydric alcohol of a sweet taste, odorless and crystalline in character. These white crystals are very soluble in hot water, soluble in hot alcohol, slightly soluble in cold alcohol, and 16 parts are soluble in 100 parts of cold water. They are insoluble in most organic solvents. Mannite is used in making fancy paper and resins, and as a starting point in making ethers, esters, acetals, etc.

Melting point	166–167° C.
Refractive index	1.3454
Neutral to methyl orange	

Sorbitol

Sorbitol [$CH_2O(CHOH)_4CH_2OH$, M.W. 182.1] is a white, odorless, crystalline, hexahydric alcohol of a neutral reaction and pleasant taste. It is made synthetically from dextrose and is available commercially as a thick, viscous, syrupy liquid of honey-like taste and odor. This syrupy liquid contains approximately 85 per cent of Sorbitol, the remainder being water with small amounts of glucose and sodium sulfate.

This hexahydric alcohol is very soluble in water, and soluble to a certain extent in ethyl alcohol, methyl alcohol, acetic acid, pyridine and phenol. An aqueous solution is miscible in all proportions with ethyl alcohol. The physical properties of the 85 per cent and 75 per cent solutions are comparable to those of glycerin and the glycols in very low volatility, specific gravity, viscosity, refractive index and hygroscopicity. It is used as a flexibilizer, as a conditioning and lubricating agent in the manufacture of leather, tobacco, paper, textiles and regenerated cellulose sheets. It is also used to make all-weather print rolls, in printing ink, in fat-liquoring operations, in making resins, antifreeze preparations, cosmetics and pharmaceuticals. It is employed in the synthesis of Vitamin C, ethers, esters, acetals, metallic complexes, etc.

	Pure Chemical	15% Solution	25% Solution
Melting point	93–95° C.		
Specific gravity		1.350	1.310
Viscosity		7400 centipoises (25° C.)	300 centipoises (25° C.)
Refractive index		1.484 (25° C.)	1.462 (25° C.)

Phosphoric Esters

The alkyl, aryl and aralkyl phosphates (R_3PO_4) possess the power to dissolve both cellulose esters and ethers either in the cold or with the aid of heat. They may be classified as follows:

1. Aryl phosphates: composed mostly of triphenyl-, tricresyl phosphates.
2. Haloid aryl-, or alkyl-, or aralkyl phosphates: dihaloid-, or tetrahaloid-, aryl phosphates, or alkyl phosphates, or aralkyl-phosphates.
3. Aryl, or chloraryl, or nitroaryl, or thiophosphates.
4. Di-aryl phosphoric anilid or aryl phosphoric dianilid: examples of these are diphenyl-, dicresyl, dinaphthyl phosphoric anilid and mono-aryl phosphoric dianilids, which are good plasticizers for nitrocellulose and cellulose ethers. Many of these have the disadvantage of imparting color and odor to the finished product.
5. Alkyl esters of aryl phosphoric acid, and aryl phosphoric acid anilid and dianilids.
6. Oxy-aryl phosphates.
7. Alkyl-glycol phosphates. These compounds comprise such substances as:

   Dimethyl-glycol butyl-glycol phosphate
   Dipropyl-glycol butyl-glycol phosphate
   Butyldiethyl glycol phosphate
   Benzyldimethyl glycol phosphate
   Tributyl glycol phosphate

These phosphates are colorless and stable; they possess a high boiling point and low inflammability, and are excellent solvents for cellulose ethers.

Triphenyl Phosphate

Triphenyl phosphate [$PO(OC_6H_5)_3$] is a colorless, odorless, non-inflammable, crystalline solid. It is soluble in most lacquers, solvents and thinners, and oils. It is a more powerful solvent for nitrocellulose than is tricresyl phosphate. It is used as a plasticizer for nitrocellulose in quantities not exceeding 100 per cent of the weight of cellulose ester and with actylcellulose its retentivity is almost 70 per cent. If an excess is used, it has a tendency to crystallize out of the solid solution. This undesirable feature can be overcome by substituting part of the triphenyl phosphate with a liquid plasticizer of high solvent power. Triphenyl phosphate retards inflammability, and imparts flexibility, clearness and toughness to cellulose derivatives. In order to obtain good results with cellulose ethers, triphenyl phosphate should be mixed with dibutyl phthalate and then dissolved in a low-boiling active solvent. This plasticizer is employed in making stencil blanks, dopes, films, varnishes, enamels, plastics and lacquers; as a lubricant, as a camphor substitute in celluloid, and for impregnating roofing paper.

Appearance	White flakes
Odor	Very faintly aromatic
Melting point	48.5° C. min. start
Solution in alcohol (10 gms. in 50 cc.)	
Color	Practically water-white
Turbidity	Not more than faintly opalescent
Permanganate test	Distinct purple color to be present after 30 minutes
Purity	99% min.
Phenol	0.1% max.
Acidity	0.003% max. (as phosphoric acid)

Tricresyl Phosphate

Tricresyl phosphate [$PO(OC_6H_4CH_3)_3$, tritolyl phosphate, Lindol, Kronitex] is a colorless to straw-colored, stable, non-volatile, odorless liquid. It is miscible with oils, hydrocarbons and most of the organic solvents and thinners. It is a solvent and plasticizer for nitrocellulose and cellulose ethers and by adding an active solvent its dissolving power is accentuated. Tricresyl phosphate is one of the few widely used plasticizers. It is extensively used with nitrocellulose in quantities ranging up to 100 per cent by weight of cellulose ester. Acetylcellulose, however, cannot tolerate more than 10 per cent and consequently tricresyl phosphate should be used with solvent-plasticizers and dissolved in an active solvent. Its presence in cellulose ether preparations and ester gum varnishes imparts elasticity; it does not lower the ratio of dilution of the solvent mixtures; and finally its presence in the films imparts tensile strength, flexibility, water-resistance and luster, and permits rubbing and polishing. In addition, it has the property of wetting pigments and is a good grinding medium. Tricresyl phosphate is used as a plasticizer for most types of lacquers, dopes, coating compositions, paper and textile products, synthetic resins and rubber. It is also employed in waterproofing and fire-proofing many preparations.

Acidity	Neutral to methyl orange
Boiling point	275–280° C. (20 mm.)
Color	Practically colorless liquid
Dilution ratio with toluene	3.2 (dibutyl 2.7)
Evaporative residue	At atmospheric pressure, not weighable
Ignition temperature	Non-inflammable (dibutyl 185° C.)
Odor	None (initial and residual)
Phenols	None
Purity	100% as tricresyl phosphate
Refractive index	1.554 to 1.556 (25° C.)
Specific gravity	1.170 to 1.180 (20° C.)
Water	Completely dry with gasoline and insoluble
Congealing point	Liquid at – 20° C.
Weight loss	
at 100° C.	For 100 hrs. less than 0.25% (dibutyl about 4% in 6 hrs.)
at 51° C.	For 56 days, none (dibutyl about 5%)

Tributyl Phosphate

Tributyl phosphate [$PO(OC_4H_9)_3$] is a light-fast, odorless and colorless liquid. It is miscible with most liquid solvents and diluents and will dissolve nitro- and acetylcellulose, shellac and so forth. It is not only a plasticizer but will diminish inflammability.

Boiling point	177–178° C. (27 mm.)
Flash-point	146° C.
Refractive index	1.426
Specific gravity	0.979 (20° C.)

Phthalic Esters

The phthalic esters $C_6H_4\begin{matrix}COOR\\COOR\end{matrix}$ are an important class of compounds which possess a variety of functions. Some are latent solvents, others are direct solvents, and others are softening agents and plasticizers for a wide range of cellulose esters and ethers.

Dimethyl Phthalate

Dimethyl phthalate [$C_6H_4(COOCH_3)_2$] is a colorless, odorless, light-fast, non-toxic liquid. It is miscible with most solvents, plasticizers and resins. Dimethyl phthalate is a good solvent and gelatinizer for cellulose nitrate and acetate, resins and rubber. In cellulose lacquers it is used in proportions up to 75 per cent on the weight of cellulose ester and gives excellent films of good adhesion and flexibility. This plasticizer is used both alone and in combination with other plasticizers for cellulose esters, resins, in rubber sheeting, films, lacquers, transparent paper, molding powder, plastics, laminated glass and so forth. The commercial product, Palatinol, is said to be dimethyl phthalate.

Purity	99% to 100% dimethyl phthalate
Specific gravity	1.192 to 1.194 at $\frac{20° C.}{20° C.}$
Acidity	0.1% (as phthalic acid) 0.68 mg. ≐OH required for neutralization of 1 g.
Molecular weight	194.13
Odor	Very faint
Boiling point	186–194° C. (50 mm.)
Boiling point	282.0° C.
Flash-point	132° C. (270° F.)
Weight per U.S. gallon	9.93 lbs. (68° F.)
Solubility in water	0.45% by vol. (25° C.)
Solubility of water in dimethyl phthalate	1.8% by vol. (25° C.)
Coefficient of expansion	0.00042/1° F. 0.00076/1° C.
Dilution ratio (nitrocellulose solution method)	2.9 with toluene Not miscible with petroleum naphtha

Diethyl Phthalate

Diethyl phthalate [$C_6H_4(COOC_2H_5)_2$] is a water-white, stable, odorless, combustible, but not inflammable liquid of bitter taste. It is completely miscible with alcohols, ketones, esters and aromatic hydrocarbons but only partly miscible with aliphatic solvents. Diethyl phthalate is a solvent for benzyl abietate, cellulose nitrate and acetate, cumar resins, ester gum, copal ester, glyptols, ketone-aldehyde resins, linoxyn, mastic and shellac. It is employed as a mutual solvent and plasticizer for cellulose derivatives and resins and has good retentivity. It is used in cellulose acetate plastics in quantities up to 100 per cent of the weight of acetylcellulose. Nitrocellulose will not tolerate more than 80 per cent of its weight of diethyl phthalate and the retentivity of glyptol resins is 25 per cent. It is also used as a plasticizer for cellulose ethers, as a fixative in perfumes, in insecticidal sprays, as a camphor substitute, in oiling textile fabrics, as a wetting agent in the grinding of pigments and in such preparations as films, stencil sheets, floor coverings and so forth. It imparts to films a transparency to ultra-violet light.

Acidity	0.03% free acid as phthalic
Color	Water-white
Dryness	Miscible without turbidity with 20 vols. 60° Bé. gasoline at 20° C.
Odor	Odorless
Purity	99–100% ester content as diethyl phthalate
Specific gravity	1.117 to 1.121 at $\frac{20°\text{ C.}}{20°\text{ C.}}$
Boiling point	Between 200° and 207° C. at 50 mm. absolute pressure
Coefficient of expansion	0.00042/1° F. 0.00076/1° C.
Dilution ratio	3.8 with toluene 0.7 with petroleum naphtha
Flash-point	325° F. (approx.)
Water solubility	100 cc. solvent dissolves 0.7 cc. water (25° C.)

Dibutyl Phthalate

Dibutyl phthalate [$C_6H_4(COOC_4H_9)_2$] is a water-white, stable, odorless, non-volatile, non-toxic, oily liquid. It is miscible with most of the organic solvents, plasticizers, oils and hydrocarbons. This plasticizer is a solvent for cellulose nitrate and ethers, dyes, oils and resins; and when mixed with ethyl carbonate it will dissolve blown drying oils, metallic resinates, rubber, acetylcellulose and hard copals on heating. Some of the natural and synthetic resins which are soluble in dibutyl phthalate comprise benzyl abietate, cumar resins, ester gum, copal ester, glyptols, mastic, vinyl resins and so forth.

Dibutyl phthalate is perhaps the most generally used plasticizer because it most nearly approaches the ideal plasticizer in its characteristics. It is

colorless, odorless, stable to heat and light, non-toxic and tasteless; it has good solvency and dispersion power, compatibility and high dilution ratio; and it remains permanently in the film. It is employed in nitrocellulose plastics, cements, molding compounds, with cellulose ethers, synthetic resins, molding resins and chlorinated rubber. Owing to its high solvent power it is used in printing inks, dye preparations, perfumes and insecticides. It is also used as a greaseless lubricant in the textile industry because it imparts flexibility and durability to the fibers; as a grinding medium for pigment; as a fixative for perfumes; and as a plasticizing agent in making leather dopes, Cellophane, non-cracking Titanox lacquers, paper, safety glass, shellac and molded products. When it is used together with nitrocellulose its amount will range from 10 to 60 per cent depending upon the desired clarity or pigmentation of the lacquer.

Purity	99–100% dibutyl phthalate
Specific gravity	1.047 to 1.049 at $\frac{20° \text{ C.}}{20° \text{ C.}}$
Color	Water-white
Odor	None
Molecular weight	278.18
Distillation range	227°–235° C. (37 mm. Hg.)
Flash-point	158°–174° C. (316°–345° F.)
Weight per U.S. gallon	8.72 lbs. (68° F.)
Approx. change in wt.	0.0016 lbs./gal./° F.
Solubility in water	0.04% by vol. (25° C.)
Solubility of water in dibutyl phthalate	0 3% by vol. (25° C.)
Refractive index	1.48885 (20° C.)
Coefficient of expansion	0.00042/1° F. 0.00076/1° C.
Dilution ratio (nitrocellulose solution method)	2.7 with toluene 1.7 with petroleum naphtha

Metal Alkyl Phthalates

The metal alkyl phthalates have been proposed as a new phase in plasticizing wherein high solvency, stability, weather-resistance and pigmentation are combined. Lead, cadmium, iron, manganese, nickel, zinc and cobalt butyl or amyl phthalates are used in nitrocellulose lacquers, paints and enamels.

Diamyl Phthalate

Diamyl phthalate $[C_6H_4(COOC_5H_{11})_2]$ is a colorless, stable, combustible, but not inflammable, high-boiling, non-toxic liquid of faint odor. It is miscible with most of the lacquer solvents and diluents, oils and hydrocarbons and is compatible with most resins. It is a solvent for nitro and acetylcellulose and many of the natural and synthetic resins. Diamyl phthalate is used as a plasticizer for cellulose esters in quantities up to 100 per cent on the weight of the cellulose ester. It imparts stability, elasticity, weatherproofness and high tensile strength to the film.

It is also used with resins, in rubber cements, as a foam preventive in glue manufacture and as a medium of heat transfer.

Acidity	0.03% free acid as phthalic
Color	Water-white
Dryness	Miscible without turbidity with 20 vols. 60° Bé. gasoline at 20° C.
Odor	Practically odorless
Purity	99–100% ester content as diamyl phthalate
Specific gravity	1.022–1.026 at $\frac{20° C.}{20° C.}$
Boiling point	Between 247° and 255°C at 50 mm. absolute pressure
Coefficient of expansion	0.00042/1° F. 0.00076/1° C.
Dilution ratio (nitrocellulose solution method)	2.2 with toluene 2.0 with petroleum naphtha
Flash-point	357° F. (approx.)
Water solubility	100 cc. solvent dissolves 0.05 cc. water (25° C.)

Dimethyl Glycol Phthalate

Dimethyl glycol phthalate [$C_6H_4(COOCH_2CH_2OCH_3)_2$, methyl "Cellosolve" phthalate] is a colorless liquid. It is a solvent for cellulose esters but with the reservation that ethyl alcohol or ethyl alcohol-benzene mixture must be added. When employed as a plasticizer for cellulose esters it is used in quantities up to 50 per cent.

Boiling point	230° C.
Specific gravity	1.17
Acidity	0.10%

Diethyl Glycol Phthalate

Diethyl glycol phthalate [$(C_2H_5OCH_2CH_2OOC)_2C_6H_4$, diethoxyethyl phthalate] is a solvent for nitrocellulose and is employed as a plasticizer for cellulose esters in quantities up to 50 per cent.

Specific gravity	1.115 to 1.120 at $\frac{20° C.}{20° C.}$
Weight per U.S. gallon	9.31 lbs.
Color	Water-white to pale straw
Dryness	Infinite with toluene
Acidity	Under 0.10% (as phthalic acid)
Melting point	Completely miscible with toluene and lacquer thinners; completely soluble in large excess of naphtha
Toluene dilution factor	20% higher than that of dibutyl phthalate for nitrocellulose
Evaporation rate	19% of that of dibutyl phthalate at 100° C.
Solvent power	Dissolves nitrocellulose
Purity	98–100% ester content as ethoxyethyl phthalate

Butyl Glycol Phthalate

Butyl glycol phthalate is a high-boiling liquid soluble in most organic solvents. It is employed as a plasticizer for acetylcellulose in quantities up to 33 per cent.

Boiling point	370° C.

Dibutyl Hexahydro Phthalate

Dibutyl hexahydro phthalate (Hydropalat B) has been proposed as a plasticizer for nitrocellulose.

Boiling range	185°–190° C.
Flash-point	152° C.
Specific gravity	1.005

A mixture of similar esters is known as "Hydropalat C.Y." and is recommended as a gelatinizer for cellulose acetate.

Boiling range	130–195° C. (15 mm.)
Flash-point	105° C.

Various Other Phthalates

The following plasticizers are recommended for celiulose esters:

Cyclohexyl phthalate
Cyclohexyl-isopropyl phthalate
Cyclohexyl-*n*-butyl phthalate
Cyclohexyl-amyl phthalate
Cyclohexyl-phenyl phthalate
Cyclohexyl-benzyl phthalate
Cyclohexyl-dicyclohexyl phthalate

Glyceryl phthalate, phenyl phthalate and benzyl phthalate can be employed with nitrocellulose and acetylcellulose.

Halogenated Benzenes, Naphthalenes and Anthracenes

A number of halogenated benzenes have been proposed as plasticizers for cellulose ethers. Usually the solvent power of these substances is improved by the addition of a latent solvent like a lower aliphatic alcohol. Some of these halogenated products are:

Benzyl chloride
Benzyl bromide
Benzotrichloride
Benzotribromide
Benzal bromide
Benzal chloride

Xylene chloride, *p*-xylene dichloride and naphthalene chloride possess plasticizing properties for nitrocellulose.

The di-, tri-, tetra-, penta-, hexa-, hepta-, and octochlornaphthalenes, bromnaphthalenes, or fluornaphthalenes have been advocated as high-boiling plasticizers. The halogenated naphthalenes and anthracenes when mixed with aliphatic alcohols, esters or ketones possess the power to dissolve both cellulose esters and ethers. They are used in the manufacture of stencil sheets and celluloid, and are also used in fire-retarding mixtures.

Tetrahydro Naphthalene Derivatives

Some other naphthalene derivatives proposed as plasticizing agents for cellulose esters and ethers are:

1- or 2-tetrahydronaphthalenesulfo-ethylamide
Tetrahydronaphthalenesulfo-oxyethylamide
Tetrahydronaphthalenesulfomide
Cresyl-1-tetrahydronaphthalenesulfonate
Cresyl-2-tetrahydronaphthalenesulfonate
Tetrahydronaphthalene
Tetrahydronaphthalenesulfoacid cresyl ester

Pyridine, Quinoline and Acridine

Pyridine, quinoline and acridine and their homologues and analogues are solvents for cellulose esters and ethers when used together with other solvents. Pyridine, quinoline and acridine are related to benzene, naphthalene and anthracene respectively with the exception of one CH-group which is replaced with nitrogen.

Salicylic Esters

$[C_6H_4(OH)COOR]$

Methyl Salicylate

Methyl salicylate $[C_6H_4(OH)COOCH_3$, Oil of Wintergreen] is a solvent for cellulose derivatives. It has formerly been used as a solvent in lacquers but it has since been replaced by other solvents.

Boiling point	219–224° C.
Specific gravity	1.18–1.185

Other Salicylates

Esters of acetyl salicylate have been proposed as high-boiling solvents for cellulose ethers and esters. Some other esters proposed are ethyl, amyl, butyl, glycol, phenyl and benzyl salicylates which have a wide range of solvent power.

Alkyl Silicic Esters

Alkyl silicic esters are soluble in alcohols, ethers, ketones and esters. They are solvents for nitrocellulose and possess the added quality of reducing inflammability.

Sulfonamides

The sulfonamides (RSO_2NH_2) are good plasticizers for nitrocellulose and cellulose acetate and are used in making celluloid, films, lacquers, varnishes, thermoplastic bodies and so forth, and as softeners for cellulose ethers.

p-Toluene Sulfonamide

p-Toluene sulfonamide ($CH_3C_6H_4SO_2NH_2$, Abracol 789, Saniticizer 9, New camphrosal) is a white solid which is toxic when taken internally. It is soluble in most organic solvents and many of the vegetable oils, with the exception of the aliphatic and aromatic hydrocarbons. Small quantities are needed to impart good working qualities and gloss to molded products. It is employed as a plasticizer in synthetic resins, molded protein products and cellulose esters; and when used together with other high-boiling solvents it is advocated as a camphor substitute in pyroxylin. When it is used with cellulose esters not more than 30 per cent can be employed. Protein materials, such as casein and glue, will tolerate quantities ranging from 10 per cent to 40 per cent and shellac is improved by the addition of 10 per cent.

Appearance	Fine granular particles*
Melting point	137° C.
Melt	Liquid, clear and light yellow
Acidity	pH 4.6 min. in dilute acetone (2 gram sample in 15 cc. A.R. Acetone and 35 cc. of CO_2 free distilled water)
Reaction to Bromcresol Green	Neutral

*Mixture of *o*- and *p*-toluene sulfonamides.

o- and *p*-Toluene Ethyl Sulfonamide

o- and *p*-toluene ethyl sulfonamide (Santicizer 8) is an amber-colored liquid. It is miscible with most organic solvents with the exception of the aliphatic hydrocarbons. It is a plasticizer for acetylcellulose and nitrocellulose and imparts plasticity, brilliance and polish. However, its instability to light militates against its wider use. When used with cellulose acetate quantities ranging up to 90 per cent are permissible.

TABLE 122.—Tensile Strength Tests* on Plasticizers[4,7]

Plasticizer	Plasticizer in Film: 25 Per cent T. S. *Kg./sq. cm.*	25 Per cent Elongation *Per cent*	50 Per cent T. S. *Kg./sq. cm.*	50 Per cent Elongation *Per cent*	100 Per cent T. S. *Kg./sq. cm.*	100 Per cent Elongation *Per cent*
p-Toluene sulfonamide	408	3				
Benzene methyl sulfonamide	453	7	320	12	80	40
Benzene ethyl sulfonamide	414	10	290	10	115	50
p-Toluene methyl sulfonamide	460	4				
p-Toluene ethyl sulfonamide	380	6	360	8		
Xylene methyl sulfonamide	475	8	350	10	350	10
p-Toluene sulfonanilide	335	10	383	6		
p-Toluene methylene sulfonamide	660	2	408	3	349	5
No plasticizer	355	0				

*Results after 7 days.

TABLE 123.—Sulfonamide Derivatives[4,7]

Derivative	Chemical Formula	Melting Point (° C.)		Solubility in		
		Pure product	Commercial product	Benzene	Acetone	Alcohol
p-Toluene sulfonamide	$CH_3 . C_6H_4 . SO_2NH_2$	137	137	Slight	Fair	Slight
Benzene methyl sulfonamide	$C_6H_5SO_2NHCH_3$	30–31	About 30	Good	Good	Good
Benzene ethyl sulfonamide	$C_6H_5SO_2NHC_2H_5$	57–58	About 45	Good	Good	Good
p-Toluene methyl sulfonamide	$p\text{-}CH_3 . C_6H_4SO_2NHCH_3$	78–79	About 40	Good	Good	Good
p-Toluene ethyl sulfonamide	$p\text{-}CH_3C_6H_4SO_2NHC_2H_5$	63.2	About 45	Good	Good	Good
Xylene methyl sulfonamide	$(CH_3)_2C_6H_3SO_2NHCH_3$		Liquid	Good	Good	Good
p-Toluene sulfonanilide	$p\text{-}CH_3C_6H_4SO_2NHC_6H_5$	103	101–102	Good	Good	Good
p-Toluene methylene sulfonamide	$(p\text{-}CH_3C_6H_4SO_2N : CH_2)n$		70–75	Good	Good	Good

TABLE 124.—Outdoor Exposure Tests[4,7]

Plasticizer	Appearance of Film After:					
	3 weeks	4 weeks	5 weeks	6 weeks	7 weeks	9 weeks
Benzene methyl sulfonamide	Fair	Starting to rust	Poor	Failed		
Benzene ethyl sulfonamide	Good	Good	Fair	Fair	Failed	
p-Toluene methyl sulfonamide	Good	Poor	Failed			
p-Toluene ethyl sulfonamide	Good	Fair	Starting to rust	Quite rusty	Failed	
Xylene methyl sulfonamide	Starting to rust	Quite rusty	Failed			
p-Toluene sulfonanilide	Good	Blistering and rusting	Very dull, rusted in spots	Failed		
p-Toluene methylene sulfonamide	Good	Good	Good	Good	Fair	Fair

TABLE 125.—Retentivity of Plasticizers in 15-Sec. Acetyl Cellulose[4,7]

Plasticizer	Maximum Retentivity *Per cent*
p-Toluene sulfonamide	30
Benzene methyl sulfonamide	100 +
Benzene ethyl sulfonamide	100 +
p-Toluene methyl sulfonamide	40
p-Toluene ethyl sulfonamide	40
Xylene methyl sulfonamide	100
p-Toluene sulfonanilide	70
p-Toluene methylene sulfonamide	200

SULFONATES

(RSO_3R)

Ethyl *p*-Toluene Sulfonate

Ethyl *p*-toluene sulfonate ($CH_3C_6H_4SO_3C_2H_5$) is a toxic, unstable solid and is soluble in many of the organic solvents. It has been proposed as a plasticizer for acetylcellulose.

Melting point	32° C.

Cresyl *p*-Toluene Sulfonate

Cresyl *p*-toluene sulfonate ($CH_3C_6H_4SO_3C_6H_4CH_3$, tolyl *p*-toluene sulfonate) is a brown, oily liquid of faint odor. It is used as a plasticizer for cellulose acetate because of its gelatinizing effect.

Flash-point	184° C.
Specific gravity	1.207

Other Sulfonates

A number of benzene, toluene, and xylene sulfonates have been proposed as plasticizers for cellulose acetate. Some of these are excellent ethers and esters. It is claimed that an aqueous solution of methanesulfonic acid will dissolve cellulose.

SULFATES

Diethyl Sulfate

Diethyl sulfate $\begin{matrix} C_2H_5 \\ \diagdown \\ \diagup \\ C_2H_5 \end{matrix}\!\!>\!SO_4$ is a non-inflammable, non-corrosive, neutral liquid of faintly ethereal odor. It is used as an ethylating agent in the preparation of amines, aromatic ethers, esters, imides and so forth.

Acidity	More than 0.03% (as sulfuric acid)
Purity	Not less than 98% by wt.
Color	Water-white
Specific gravity	1.177 to 1.182 at $\frac{20° \text{ C.}}{20° \text{ C.}}$
Boiling range	95% between 106° C. and 111° C. (25 mm.)
Solubility	Completely miscible with ethyl alcohol and ethyl ether

Sulfones

These stable compounds (R_2SO_2 or RSO_2R) have each of their organic radicals linked to sulfur. These proposed compounds are of the type of dialkyl, alkyl-aryl, diaryl sulfones and are advocated as solvents and plasticizers for cellulose derivatives. Dimethyl sulfone has a melting point of 70° C. and a boiling point of 248° C.

Sulfoxides

Sulfoxides (R_2SO or RSOR) are softeners for cellulose esters and ethers and are used as camphor substitutes.

Tartaric Esters

Tartaric esters $\begin{matrix}CH(OH)COOR\\|\\CH(OH)COOR\end{matrix}$ are neutral in reaction and have a low vapor pressure. The lower members, however, are at a disadvantage by being water-soluble. These esters will dissolve both cellulose acetate and resins. When used together with an active solvent they will dissolve many of the cellulose ethers.

Dibutyl Tartrate

Dibutyl tartrate $\begin{matrix}CH(OH)COOC_4H_9\\|\\CH(OH)COOC_4H_9\end{matrix}$ is miscible with most lacquer solvents, oils and hydrocarbons, and is a solvent for benzyl abietate, nitro and acetylcellulose, cellulose ethers, cumar resins, ester gum, copal ester, glyptol resins, shellac, vinyl resins and so forth. It is employed both as a plasticizer for cellulose esters and ethers in quantities up to 100 per cent, and in transfer inks.

Boiling point	292° to 312° C.
Acidity	0.05% max.
Flash-point	160° C.
Ester content	95 to 100%
Melting point	21.8° C.
Refractive index	1.442
Specific gravity	1.064 to 1.091

Diamyl Tartrate

Diamyl tartrate $\begin{matrix}CH(OH)COOC_5H_{11}\\|\\CH(OH)COOC_5H_{11}\end{matrix}$ is miscible with oils, hydrocarbons and most of the lacquer solvents. It will dissolve Bakelite resins, benzyl abietate, cellulose acetate and nitrate, cumar resins, copal ester, ester gum, glyptol resins, mastic, soft copals, shellac, vinyl resins and so forth; and when mixed with active solvents it will dissolve cellulose ethers. Diamyl tartrate is a good plasticizer for cellulose esters and ethers and glyptol resins and is employed in these products in quantities up to 80 per cent. Not

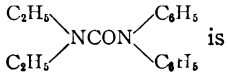
only is it a plasticizer but it functions as a mutual solvent for cellulose derivatives and resins. When used with nitrocellulose the quantity should never exceed an equal weight of the cellulose nitrate.

Boiling point	398° to 400° C.
Refractive index	1.45
Specific gravity	1.04 to 1.06

Ureas

Urea (RHNCONHR or R_2NCONR_2) has been used as a stabilizer for cellulose esters and is usually admixed with other substances. Some of the proposed urea esters are urea acetate, benzoate, butyrate and so forth. The substituted ureas comprise the mono-, di- and trimethyl ureas.

Diethyl Diphenyl Urea

Diethyldiphenyl urea  is a white, crystalline solid of peppery odor and is soluble in most organic solvents. It is used as a plasticizer for acetylcellulose and shellac.

Boiling point	325° to 330° C
Flash-point	150° C.
Melting point	72° to 73° C.
Specific gravity	1.12 (20° C.)

Diethylene Glycol Monoacetate

Diethylene glycol monoacetate is miscible with water and aromatic hydrocarbons. It is a solvent for camphor, rosin acetyl and nitrocellulose.

Amyl Naphthalenes

Monoamyl Naphthalene

Monoamyl naphthalene ($C_{10}H_7C_5H_{11}$) is a neutral, non-toxic, stable, unsaponifiable liquid. This hydrocarbon is miscible with organic solvents and appears on the market as an amber-colored, technical product and also as a water-white, pure liquid of slight odor. Its solvent-power and low vapor pressure make it a valuable plasticizer for rubber, asphaltic material and natural and synthetic resins. Monoamyl naphthalene is used in inks and as coupling agent for mineral and vegetable oils.

Boiling range	279° to 320° C. (760 mm.)
Boiling point	158° C. (20 mm.) 213° C. (100 mm.) 230° C. (175 mm.)
Freezing point	– 60° C.
Flash-point	277° F. (open cup)
Heat of vaporization	63.4 cal./g. (calculated)
Refractive index	1.5727 (20° C.)
Specific gravity	0.96 to 0 97 (20° C.)
Specific heat	0.411 cal./g.
Vapor pressure	0.0098 mm. (20° C.)
Viscosity	0.1195 poise (20° C.)

TABLE. 126.—Solubility of Plasticizers

Solvent	Alkyd Resins	Benzyl Cellulose	Cellulose Acetate	Cellulose Nitrate	Carnauba Wax	Colophony	Congo	Coumarone	Dammar	Ethyl Cellulose	Glyceryl phthalate	Gum Arabic	Gum Blemi	Gum Ester	Gum Ghati	Gum Kauri	Gum Manila (Soft)	Gum Mastic	Hard Copal	Paraffin Wax	Phenolic Resins	Shellac	Sulfonamide Resins	Urea Resins	Vinyl Resins
Acetophenone																									
Alkyl sulfonamide	S	S	S	S																					
Amyl benzoate		PS	PS	PS		S	PS	S		S	S			S					PS			PS			
Amyl borate			S	S		S	SS	S		S	S			S		SS			SS			PS			
Amyl stearate			S	S		S	S	S	S	S	S			PS		S	PS	S				PS			
Benzyl benzoate	S		S	S		S	S	S		S	PS			S		S	S					PS			
Butyl oleate			S	S		S		S		S	S	I	S	S	I				SS		S	SS	S	I	S
Butyl phthalyl butyl glycollate	S		S	S	SH	S		S		S	S			S		SS			SS	HS	S	SH	S	I	S
Butyl stearate		PS	S	S						PS	SS			S					SS			SS			
Camphor			S	S						S															
Cyclohexyl adipate	S			S																					
Diacetin			S	S		SS	SS	SS		S	S			SS		SS		PS	SS			S			
Diamyl phthalate			PS	S				S			PS			S				S				PS			
Diamyl tartrate			S	S		S		S		PS	S			S		SS	PS	PS				S			
Dibutyl phthalate	SH	S	S	S	SH	S		S		S	PS	I	S	S	I		SH	S	SS	SH	SH	SH	S	I	
Dibutyl tartrate		S	S	S		S		S		S	S			S		SH		S	SS			S			
Diethyl phthalate		S	S	S		S		S		S	S			S				PS				PS			
Diethyl diphenyl urea		S	S	S																					
Dimethyl phthalate		S	S	S		S		S		S	S			S								PS			
Ethyl phthalyl ethyl glycollate	S	S	S	S		S				S		I	S	S	I		SH				S	SH	S	I	S
Methyl "Cellosolve" phthalate			S	S		S				S		I	SH	SH	I		SH				S	HS	S	I	SH
Methyl phthalyl ethyl glycollate	S	S	S	S	I	S				S															
Toluene sulfamide			S	S																					
Triacetin	S	S	S	S			PS	PS		S	S			PS		PS		PS							S
Tributyrin	S	S	S	S						S	S														
Tricresyl phosphate	S	S	SS	PS		S		S		S	S			S				PS				PS			
Triphenyl phosphate	S	S	S	S						S	S														

SH Soluble when hot S Soluble SS Slightly soluble PS Partially soluble I Insoluble

Diamyl Naphthalene

Diamyl naphthalene [$C_{10}H_6(C_5H_{11})_2$] resembles monoamyl naphthalene in physical properties and uses.

Boiling range	326° to 375° C. (760 mm.)
Boiling point	198° C. (20 mm.) 258° C. (100 mm.) 275° C (175 mm.)
Freezing point	– 30° C.
Flash-point	326° F. (open cup)
Heat of vaporization	50.6 cal./g. (calculated)
Refractive index	1.5535 (20° C.)
Specific gravity	0.93 to 0.94 (20° C.)
Specific heat	0.417 cal./g.
Vapor pressure	0.0012 (20° C.)
Viscosity	0.9810 poise (20° C.)

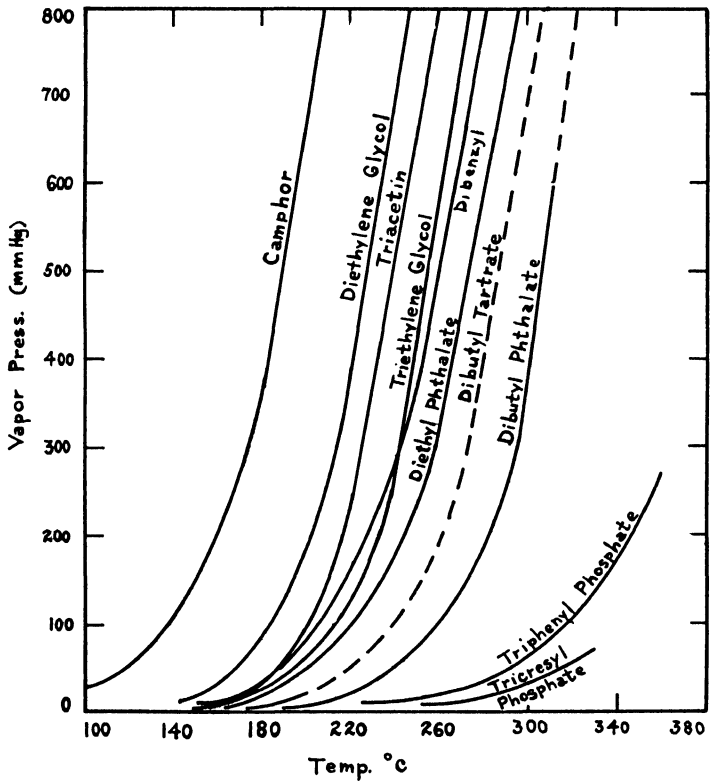


FIGURE 264. Vapor Pressure of Various Plasticizers at Different Temperatures.[9]

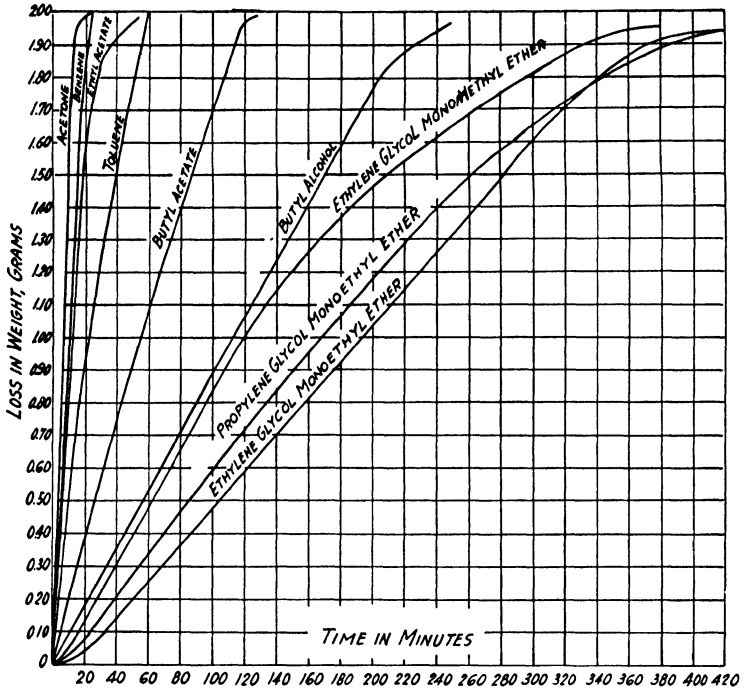


FIGURE 265. Evaporation Rate of Various Organic Solvents at Room Temperature.[9]

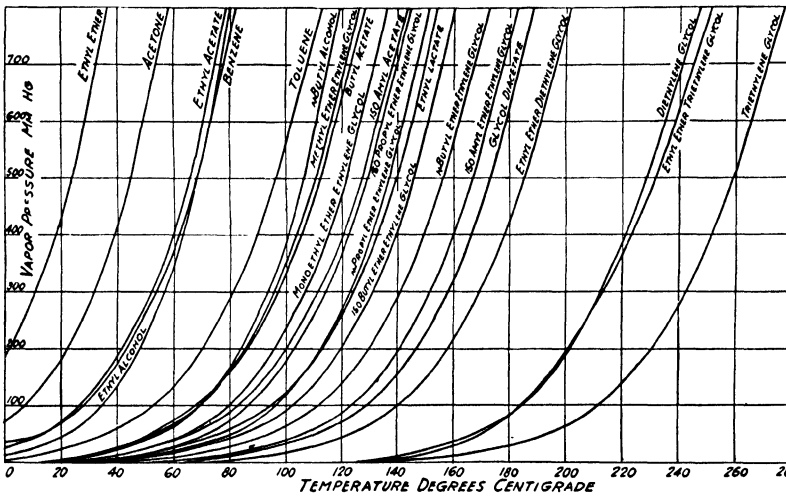


FIGURE 266. Vapor Pressure of Various Organic Solvents at Different Temperatures.[9]

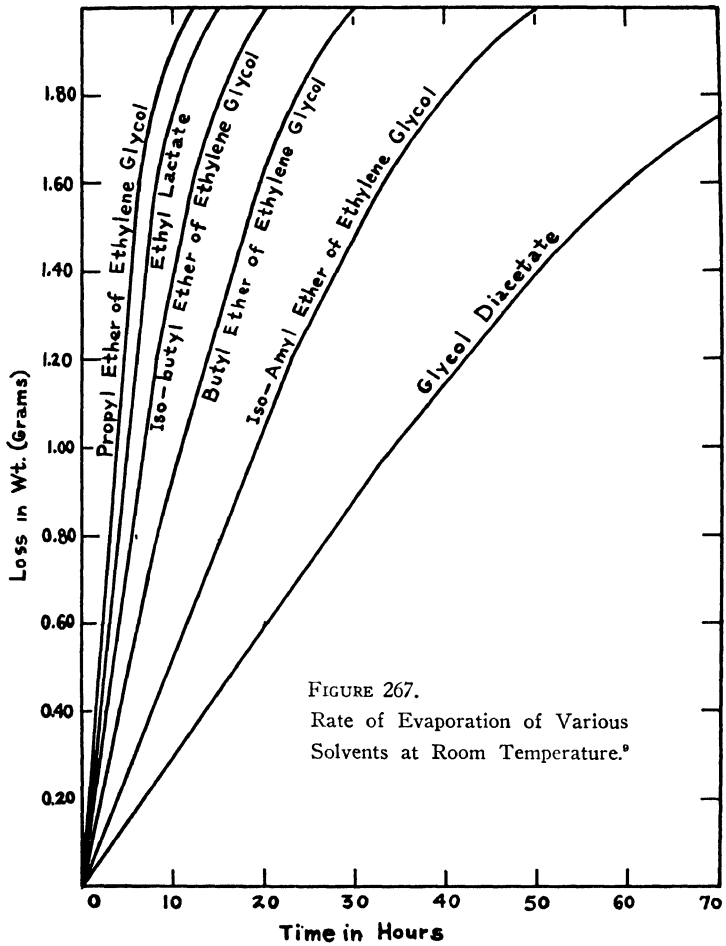


FIGURE 267.
Rate of Evaporation of Various Solvents at Room Temperature.[9]

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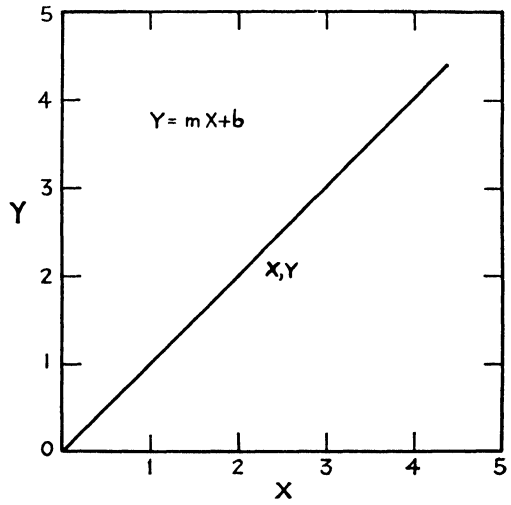
Commercial Solvents Corporation, New York, N. Y.
Franco American Chemical Works, New York, N. Y.
Gilbs, H. D., *J. Am. Chem. Soc.*, **28**, 1395-1422 (1906).
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Chapter 17

Graphical Expression and Interpretation

The physical and chemical properties of matter should be amenable to mathematical or graphical interpretation providing we can control the number of variables and have sufficient data. A variable is a property, or a symbol of a property, the value of which changes during the discussion. If, for example, one gram of a resin will dissolve in 1 cc. of alcohol and 2 grams of resin will dissolve in 2 cc. of alcohol, and so forth, we can say that the two variables are related in such a manner that when the value of one is given the value of the other can be determined. This is true when the other influencing factors are kept constant. The second variable is called a function of the first. The variable and its function can be represented by a graph plotted on rectangular coördinate paper.

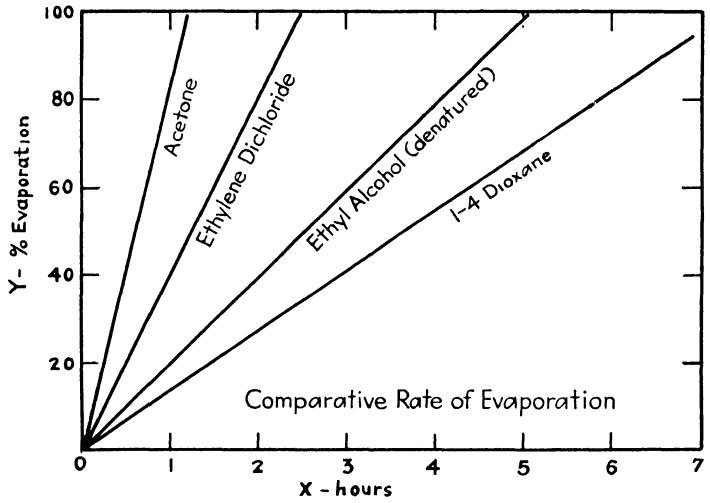
let Y = grams of resin
let X = cc. of alcohol required
when Y = 1 gram of resin then X = 1 cc. alcohol
Y = 2 grams of resin then X = 2 cc. alcohol
Y = 3 grams of resin then X = 3 cc. alcohol
Y = 4 grams of resin then X = 4 cc. alcohol
Y = 5 grams of resin then X = 5 cc. alcohol



Now plot the values and draw a smooth curve passing through or near the plotted points. The fact that a smooth curve can be drawn to represent the values of the variable and their functions leads us to suspect that some relationship exists between the measured values, which may be represented mathematically by the equation for a straight line.

$$Y = mX + b$$

Let us consider the curves representing the evaporation rates in the following graph.



If we apply the equation of a straight line for the 1-4 dioxane curve, we get

$$Y = mX + b$$

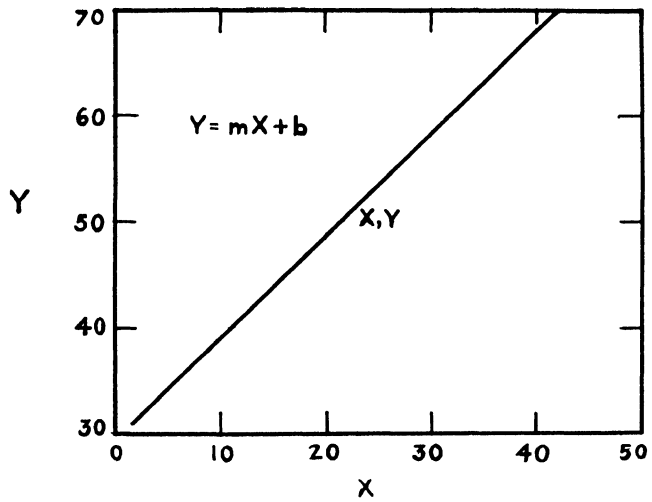
$b = 0$ (because the curve passes through the origin):

$$\text{when } X = 6.66 \text{ hours; } Y = 95.0\%$$
$$95\% = 6.66m$$
$$m = 14.26$$

In other words, when $X = 1$ hour or when 1-4 dioxane is exposed for one hour, 14.26 per cent of it will evaporate.

The following table records the solubility of a salt in a certain solvent at different temperatures.

Y = grams of salt	X = ° C.
31.0	2.0
36.0	7.3
40.0	11.5
48.0	19.8
54.0	26.0
59.5	32.2
67.3	40.0



$$Y = mX + b$$

when $Y = 31.0$; $X = 2.0$

and when $Y = 67.3$; $X = 40.0$

then $31.0 = 2m + b$

$67.3 = 40m + b$

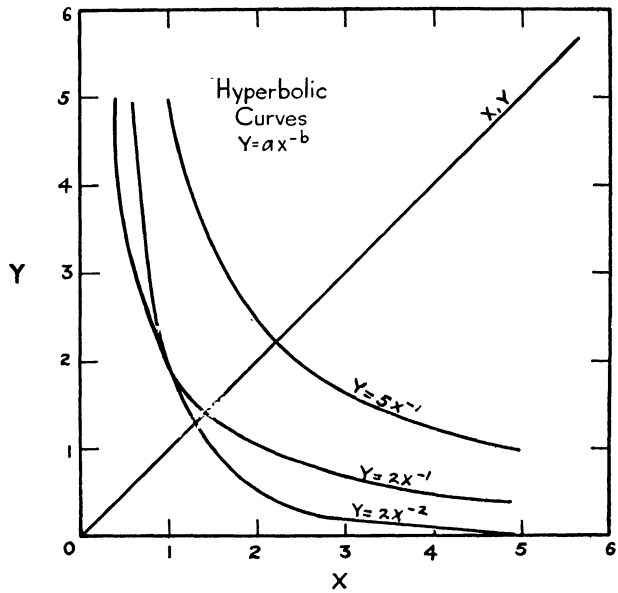
Solving for m and b

$$b = 29.09$$

$$m = 0.955$$

$$y = 0.955X + 29.09$$

Hyperbolic Curves of the Type $Y = aX^b$



In these curves b is negative, therefore

$$Y = ax^{-b} = a\frac{1}{X^b} = \frac{a}{X^b}$$

As one variable increases, the other decreases.

Should we wish to determine if a set of data approximates the equation of the form

$$Y = aX^b$$

we convert the above equation into an equation of the first degree. This is done by taking the logarithms of both members.

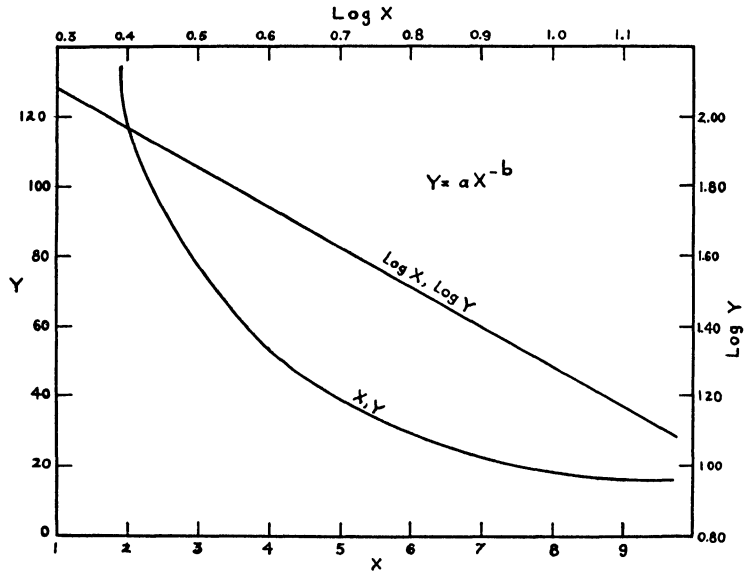
$$Y = aX^b$$
$$\log Y = \log a + b \log X$$
$$\text{let } X^1 = \log X \quad \text{and} \quad Y^1 = \log Y$$
$$Y^1 = \log a + bX^1 \quad \begin{pmatrix}\text{this is an equation of the first}\\ \text{degree in terms of } X^1 \text{ and } Y^1\end{pmatrix}$$

It is interesting to observe that just as the equation $Y = aX^b$ is converted to an equation of the first degree, the plot of $(\log X, \log Y)$ or (X^1, Y^1) will approximate a straight line rather than take on the form of a parabolic or hyperbolic curve.

It has been observed that the volume and pressure of a gas mixture over water varied according to the following experimental data:

X =	Y =	log X =	log Y =
1.91	134.0	0.28103	2.12710
2.3	105.0	0.36173	2.02119
3.4	68.0	0.53275	1.83251
4.9	46.0	0.69020	1.60206
5.8	30.0	0.76343	1.47712
6.81	23.1	0.83315	1.36361
7.30	21.17	0.86332	1.32572
8.82	16.9	0.94547	1.22789
9.56	15.2	0.98046	1.18184

Plot (X, Y) and note that the curve appears to be hyperbolic. Now, plot (log X, log Y) and note that this approximates a straight line.



$$Y = aX^b$$

$$\log Y = \log a + b \log X$$

Divide the data into two groups of five sets:

log X	log Y	log X	log Y
0.28103	2.12710	0.76343	1.47712
0.36173	2.02119	0.83315	1.36361
0.53275	1.83251	0.86332	1.32572
0.69020	1.60206	0.94547	1.22789
0.76343	1.47712	0.98046	1.18184
2.62914	9.05998	4.38583	6.57018

$9.05998 = 5 \log a + 2.62914b$

$6.37018 = 5 \log a + 4.38583b$

Solving for log a and b

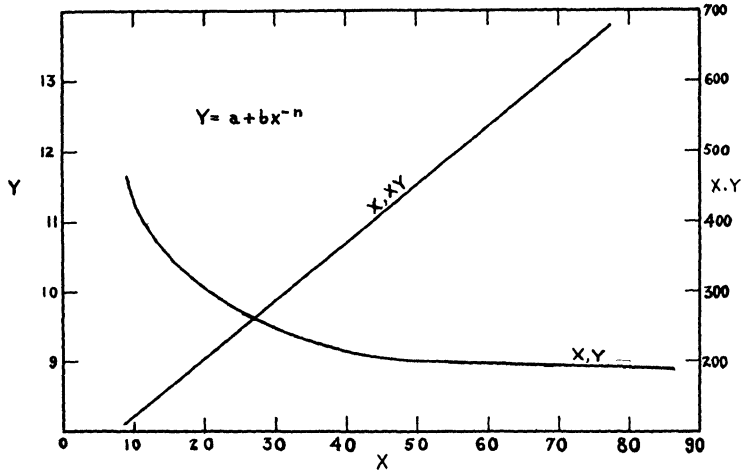
$$b = 1.6242$$
$$\log a = 2.66625$$
$$a = 463\ 7$$
$$Y = 463.7X^{-1.6242}$$

Hyperbolic Curves of the Type $Y = a + bX^n$

The volume of solvent distilled and pounds of steam required vary according to the following tables:

X = volume of solvent distilled	Y = lbs of steam	XY
9.87	11.66	115.09
18.13	10.17	184.38
29.84	9.47	282.59
41.16	9.18	377.85
52.01	9.01	468.61
61.34	8.92	552.15
74.12	8 83	654.44
85.71	8.77	760 48

Plot (X, Y), note that the curve is a hyperbola. Now, plot (X, XY) and note that this will approximate a straight line.



$XY = a + bX$ is a linear relation

therefore $$Y = \frac{a}{X} + b$$

when $XY = 115.09;\ X = 9.87$

and when $XY = 760.48;\ X = 85.71$

$$760.48 = a + 85.71b$$
$$115.09 = a + 9.87b$$

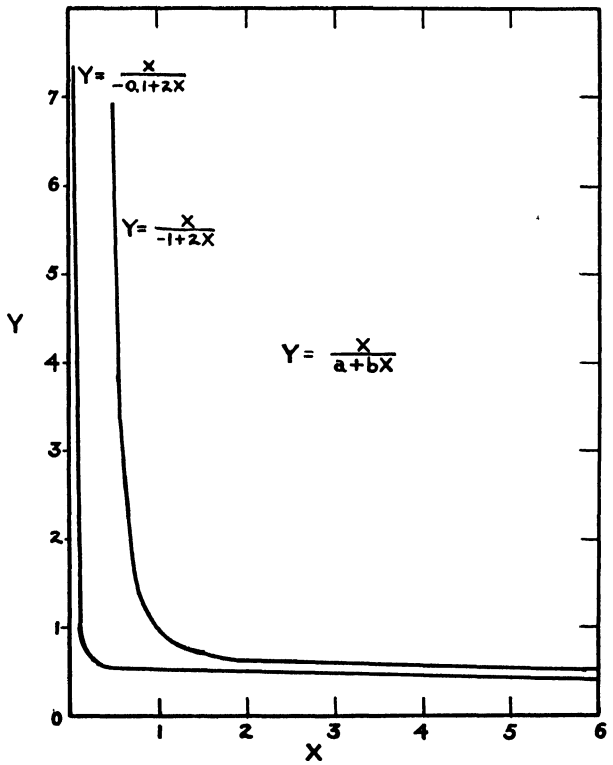
Solving for a and b

$$b = 8.51$$
$$a = 31.1$$
$$XY = 31.1 + 8.51X$$
$$Y = 8.51 + \frac{31.1}{X}$$
$$Y = 8.51 + 31.1X^{-1}$$

Hyperbolic Curves of the Type $Y = \frac{X}{a + bX}$ or $\frac{X}{Y} = a + bX$ or $\frac{1}{Y} = \frac{a}{X} + b$

when	$Y = \frac{X}{-1+2X}$	$\frac{X}{-0.1+2X}$
$X = 1$	1	1/1.9
$X = 2$	2/3	2/3.9
$X = 3$	3/5	3/5.9
$X = 4$	4/7	4/7.9
$X = 5$	5/9	5/9.9
$X = 0.8$	1.33	0.8/1.5
$X = 0.6$	3	0.6/1.1
$X = 0.5$	∞	0.5/.9

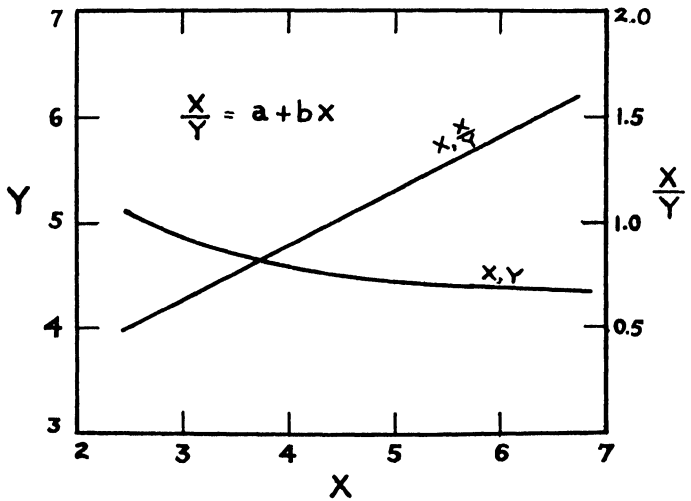
The plot of $Y = \frac{X}{a + bX}$ is a hyperbolic curve. The plot of $\left(X, \frac{X}{Y}\right)$ or $\left(X, \frac{1}{Y}\right)$ will approximate a straight line.



The solubility of a certain type of nitrocellulose decreases with the quantity of active solvent according to the following data:

X = solubility of nitrocellulose	Y = active solvent	X/Y
2.4	5.10	0.47
3.1	4.81	0.64
4.3	4.55	0.94
5.0	4.46	1.12
5.9	4.39	1.34
6.8	4.33	1.57

The plot of (X, Y) is a hyperbola curve. Now, plot $(X, X/Y)$ and note that the curve approximates a straight line.



$$X/Y = a + bX$$

when $X/Y = 0.47;\ X = 2.4$

and when $X/Y = 1.57;\ X = 6.8$

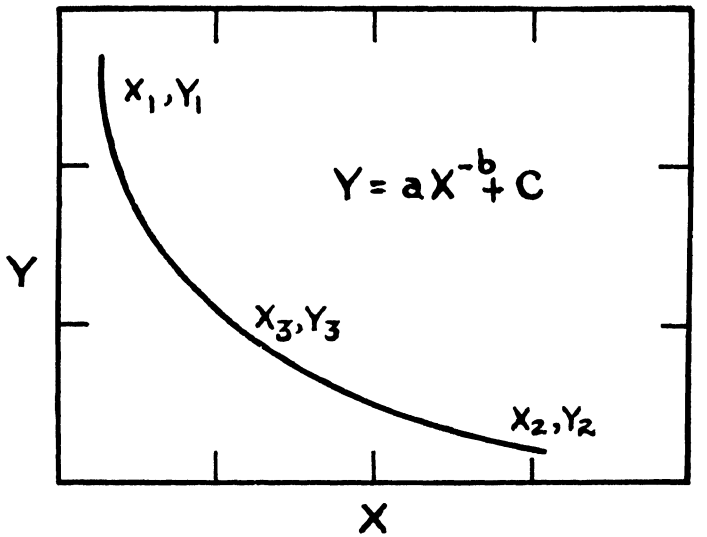
$$1.57 = a + 6.8b$$
$$0.47 = a + 2.4b$$
$$1.1 = 4.4b$$
$$b = 0.25$$
$$a = -0.13$$
$$X/Y = -0.13 + 0.25X$$
$$Y = \frac{X}{-0.13 + 0.25X}$$

Hyperbolic Curves Involving Three Constants

$$Y = aX^{-b} + c = \frac{a}{X^b} + c$$

$$Y = c = aX^{-b}$$

The plot of $Y = aX^b + c$ will be hyperbolic in form if b is negative. The plot of $(Y - c = \log a + b \log X)$ will approximate a straight line. Before we can plot this curve we must first find the approximate value of c. Choose two points on the curve $Y = aX^{-b} + c$ as (X_1, Y_1) and (X_2, Y_2). Then, choose a third point (X_3, Y_3) so that



$$Y_3 = \sqrt{X_1 \cdot X_2}$$

$$Y_1 = aX_1^b + c$$

$$X_3^b = \sqrt{X_1^b \cdot X_2^b}$$

$$aX_3^b = \sqrt{aX_1^b \cdot aX_2^b}$$

$$Y_3 - c = \sqrt{(Y_1 - c)(Y_2 - c)}$$

The tensile strength of a film increased with a decrease in the amount of pigment present according to the experimental data:

X	log X	Y	$\frac{Y-C}{Y-21.98}$	log $(Y-23.35)$
0 5	9.69897–10	27.62	5.64	0.75148
1	0.0	26.0	4.02	0.60423
2	0.30103	24.84	2.86	0.45637
3	0.47857	24.31	2.33	0.36736
4	0.60206	24.00	2.02	0.30535
6	0.77815	23.77	1.79	0.25285
8	0.90309	23.41	1.43	0.15534
9	0.95424	23.33	1.35	0.13033

We must first find the value for c

when $X_1 = 1$; $Y_1 = 26$

and when $X_2 = 9$; $Y_2 = 23.33$

$$X_3 = \sqrt{(X_1)(X_2)} = \sqrt{(1)(9)} = 3.0$$

$Y_3 = 24.31$ (measured)

Calculate the values of c.

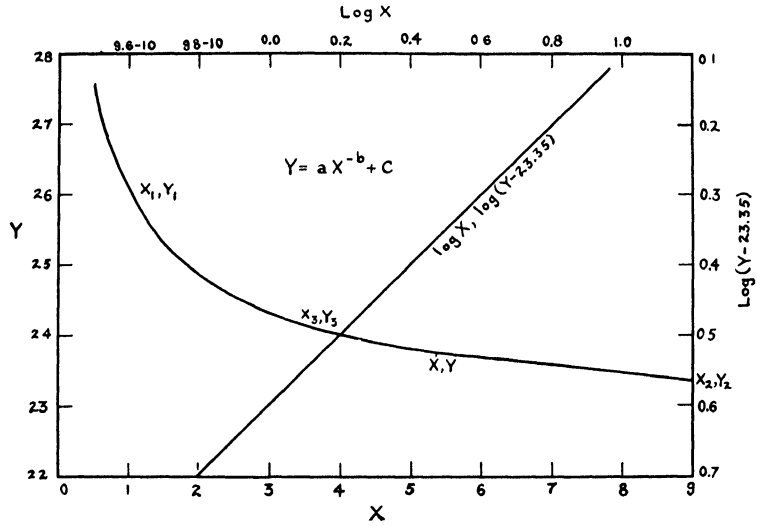
$$c = \frac{(Y_1)(Y_2) - Y_3^2}{Y_1 + Y_2 - 2Y_3} = \frac{(26)(23.33) - (24.31)}{26 + 23.33 - 2(24.31)}$$

$$c = 21.98$$

Plot the (X, Y). The curve is hyperbolic and approaches $Y = 22$ as an asymptote.

Now, plot log X, log $(Y - 21.98)$. The resulting curve approximates a straight line so that the choice of the equation $Y = aX^b + c$ is verified.

Divide the data into two groups:



$$\log (Y - 21.98) = \log a + b \log X$$

$$2.17944 = 4 \log a + b\ (0.47857)$$

$$0.84387 = 4 \log a + b\ (3.43754)$$

$$-0.4513 = b$$

$$a = 3.973$$

$$\log (Y - 21.98) = 0.59885 - 0.4513 \log X$$

$$Y = 21.98 + 3.973X^{-0.4513}$$

Hyperbolic Curves of the Form $Y = \dfrac{X}{a + bX} + C$ when $X = 0$ and $Y = C$

This type of curve is a modification of the form $Y = \dfrac{X}{a + bX}$

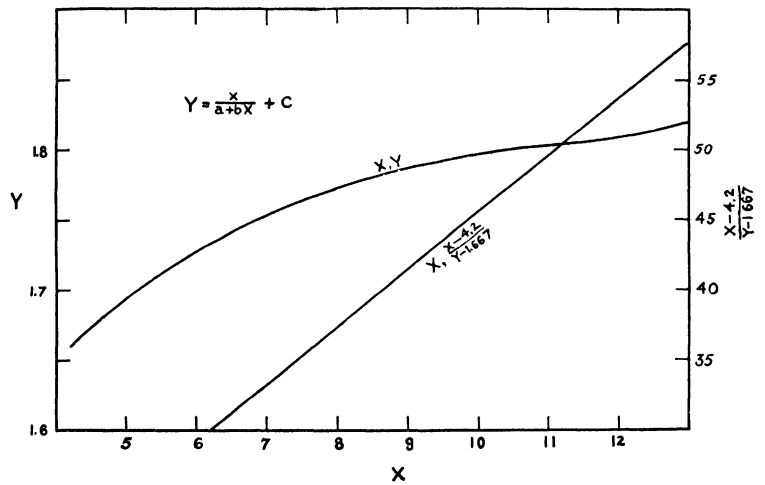
X	Y	$X-4.2$	$Y-1.667$	$\dfrac{X-4.2}{Y-1.667}$
4.2	1.556	0	0	0
6.4	1.738	2.2	0.071	30.9
8.1	1.770	3.9	0.103	37.62
9.7	1.7907	5.5	0.124	44.34
10.2	1.796	6.0	0.129	46.28
12.8	1.817	8.6	0.150	57.3

Plot (X, Y) and note that the curve is hyperbolic in form. Choose any point on the experimental curve Xn, Yn;

then
$$Yn = \frac{Xn}{a + bXn} + C$$
$$Y - Yn = \frac{a(X - Xn)}{(a + bX)(a + bXn)}$$
$$\frac{X - Xn}{Y - Yn} = (a + bXn) + \frac{b}{a}(a + bXn)X$$

This is an equation of the first degree in X and $\dfrac{X-Xn}{Y-Yn}$

Let $Xn = 4.2$ and $Yn = 1.667$ and plot X, $\dfrac{X-42}{Y-1.667}$ and note that this approximates a straight line. Let us assume that the relation



$$\frac{X-4.2}{Y-1.667} = a + bX$$

then
$$30.9 = a + 6.4b$$

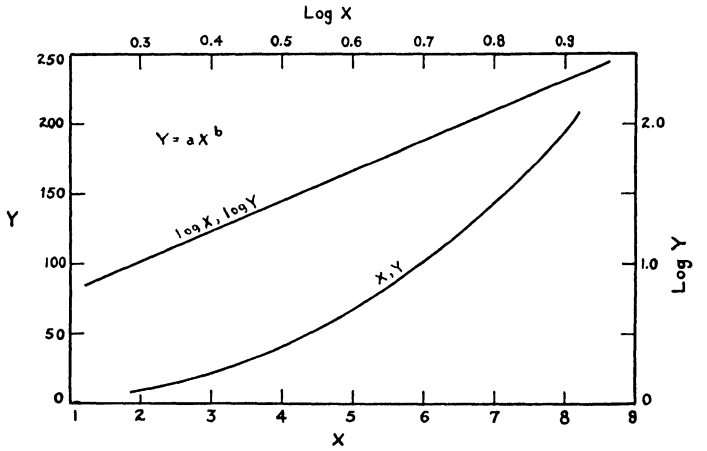
and

$$57.3 = a + 12.8b$$
$$b = 4.12$$
$$a = 4.5$$
$$\frac{X-4.2}{Y-1.667} = 4.5 + 4.12X$$
$$Y = \frac{X}{4.5 + 4.12b} + 1.667$$

The following experimental data give the grams (Y) that will dissolve in 300 grams of a solvent mixture at $X°$ C.

X	Y	log X	log Y
1.8	7.290	0.2253	0.8627
2.1	10.448	0.3222	1.0191
3.6	33.48	0.5563	1.5247
4.9	66.0	0.6902	1.8195
6.4	118.74	0.8062	2.0746
8.2	204.8	0.9138	2.3114

Plot (X, Y), the curve appears to be a parabola of the type $Y = aX^b$. Now, plot (log X, log Y) and note that it approximates a straight line.

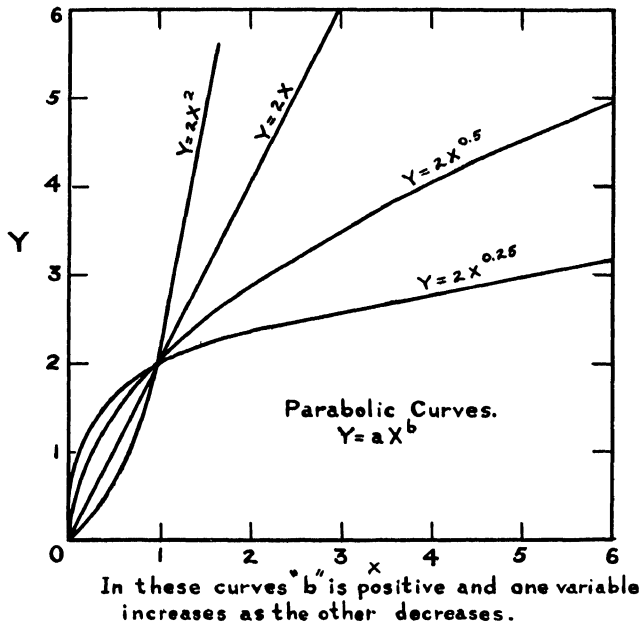


$$Y = aX^b$$
$$\log Y = \log a + b \log X$$

Divide the data into two groups:

$$6.2055 = 3 \log a + 2.4102b$$
$$3.4064 = 3 \log a + 1.1036b$$
$$b = 2.14$$
$$\log a = 0.3492$$
$$a = 2.235$$
$$\log Y = 2.235 + 2.14 \log X$$
$$Y = 2.235\, X^{2.14}$$

Parabolic Curves of the Form $Y = a + bX^{n*}$

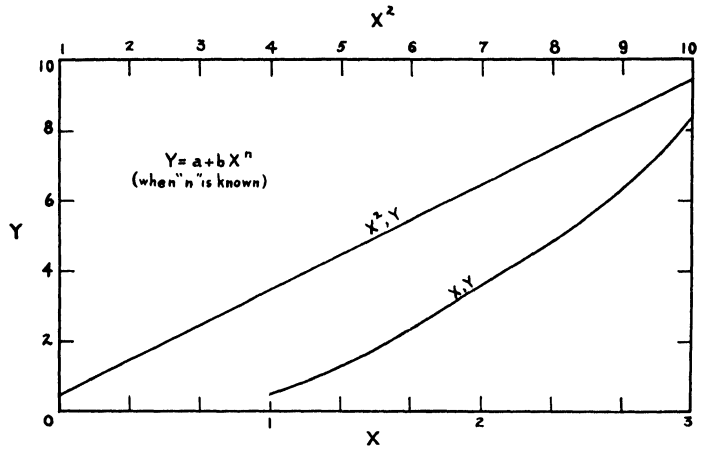


Plot (X, Y) from the following data:

	$n = 2$	
X	Y	X^2
1	2.41	1
1.3	3.18	1.69
1.6	4.14	2.58
2	5.74	4
2.4	7.06	5.76
2.7	8.59	7.29
3	10.3	9

*When n is known

The plot of (X, Y) is parabolic in form. Now, plot (X^2, Y) and note that this approaches a straight line.



let $X' = X^2$

$Y = a + bX'$

Divide the data into two groups:

$$9.73 = 3a + 5.27b$$
$$25.95 = 3a + 22.05b$$
$$b = 0.97$$
$$a = 1.53$$
$$Y = 1.53 + 0.97X^n$$
$$n = 2$$
$$Y = 1.53 + 0.97^2$$

Parabolic Curves of the Form $Y = a + bX + cX^2$

This is an equation for a straight line modified by the addition of a term of the second degree.

X	Y	$X-1$	$Y-5.5$	$\frac{Y-5.5}{X-1}$
1	5.5	0	0	0
2.1	9.92	1.1	4.42	4.01
4.2	26.43	3.2	20.93	6.54
6.3	53.52	5.3	48.02	9.06
8.0	83.2	7.0	77.7	11.1

Plot (X, Y) and try to fit the curve to the equation $Y = a + bX + cX^2$. Choose any point on the experimental curve as

$$(X_p, Y_p)$$

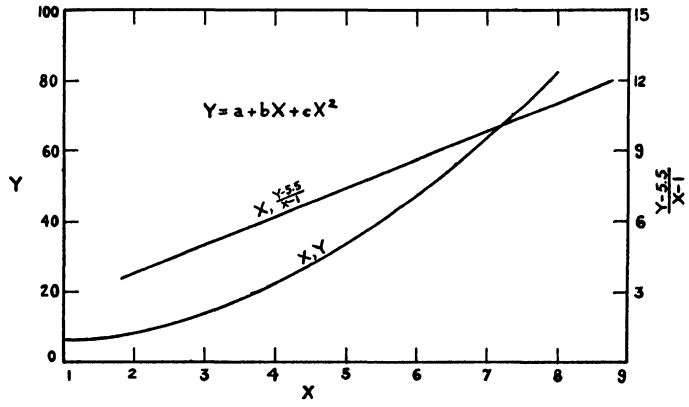
then $$Y_p = a + bX_p + cX_p^2$$

and $$Y - Y_p = b(X - X_p) + c(X^2 - X_p^2)$$

and $$\frac{Y-Y_p}{X-X_p} = b + c(X-X)$$

This is an equation of the first degree so that the plot of X, $\frac{Y-Y_p}{X-X_p}$ should approximate a straight line. Note that the curve passes through (1,5.5) so that the plot of $\left(X, \frac{Y-5.5}{X-1}\right)$ should approximate a straight line.

Plot $\left(X, \frac{Y-5.5}{X-1}\right)$



Let us assume the relationship

$$\frac{Y-5.5}{X-1} = a' + bX'$$

$$11.1 = a' + 8b'$$

$$4.01 = a' + 2.1b'$$

$$7.09 = 5.9b'$$

$$b' = 1.2$$

$$a' = 1.5$$

$$\frac{Y-5.5}{X-1} = 1.5 + 1.2X$$

$$Y - 5.5 = -1.5 + 0.3X + 1.2X^2$$

$$Y = 4 + 0.3X + 1.2X^2$$

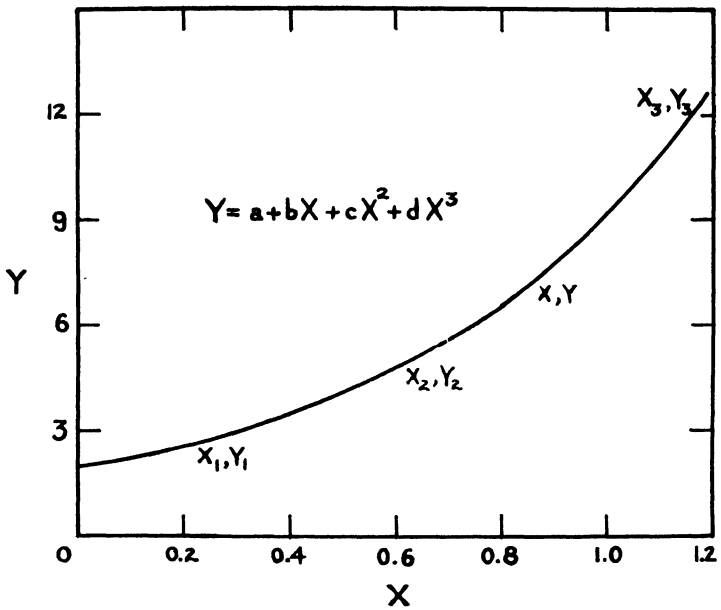
$$a = 4$$

$$b = 0.3$$

$$c = 1.2$$

Polynomials $Y = a + bX + cX^2 + dX^3$

At times the curves representing experimental data may be expressed by an equation of a polynomial.



X	Y
0	2.4
0.2	2.852
0.4	3.552
0.6	4.680
0.8	8.412
1.2	12.832

Plot (X, Y)

Let us assume that the equation is of the form

$$Y = a + bX + cX^2 + dX^3$$

since the curve intercepts the Y axis at 2.4

then $a = 2.4$

and $Y = 2.4 + bX + cX^2 + dX^3$

To determine the constants b, c, d select three points on the curve.

$(0.2, 2.852)$ $(0.6, 4.680)$ $(1.2, 12.832)$

(X_1, Y_1) (X_2, Y_2) (X_3, Y_3)

$$Y = 2.4 + bX + cX^2 + dX^3$$

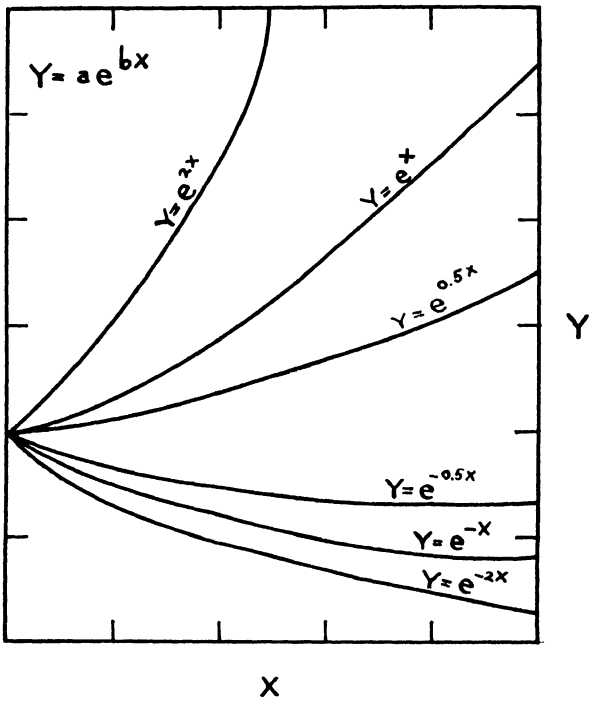
$$12.832 = 2.4 + 1.2b + 1.44c + 1.728d$$

$$5.080 = 2.4 + 0.6b + 0.36c + 0.216d$$

$$2.852 = 2.4 + 0.2b + 0.04c + 0.008d$$

Solve for b, c, and d.

Exponential or Logarithmic Curves of the Form $Y = ae^{bX}$*



Take the log of both members of the equation

$$\log Y = \log a + (b \log e)X$$

let

$$Y' = \log Y$$

$$Y' = \log a + (b \log e)X$$

This is an equation of the first degree in terms of

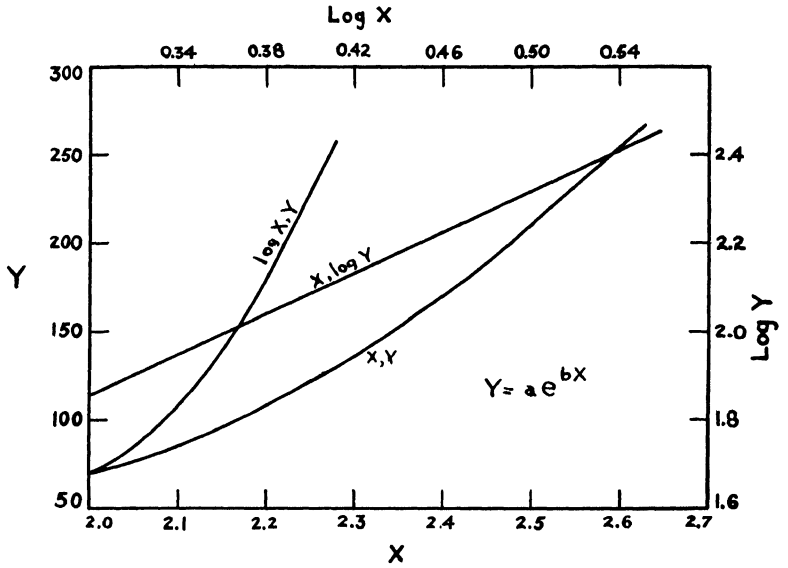
$$(X, Y')$$

Therefore, the plot of (X, Y') should approximate a straight line. Then solve for the constants.

*Where e is the base of the natural logarithms

Plot (X, Y) from the following data:

X	Y	log X	log Y
2	73.46	0.3010	1.8660
2.1	90.31	0.3222	1.9557
2.3	137.77	0.3617	2.1382
2.5	214.5	0.3979	2.3314
2.6	258.64	0.4150	2.4129



The curve appears to be exponential.

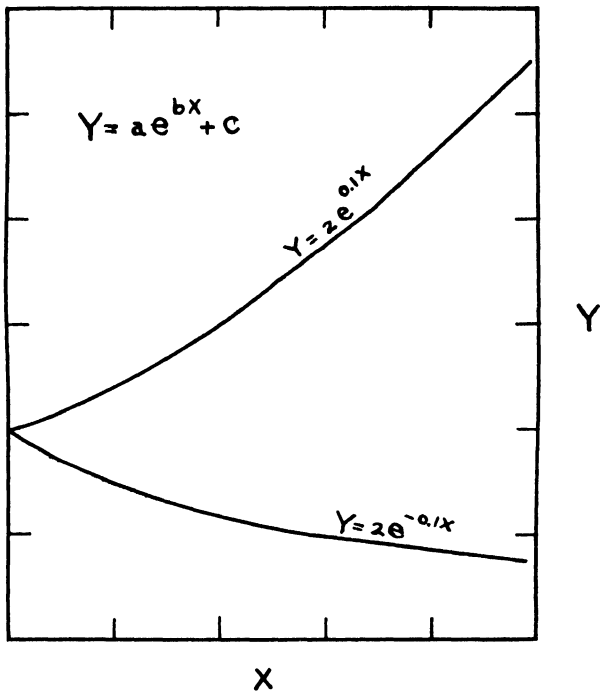
Plot (log X, Y) and note that this does not approximate a straight line. Then plot (X, log Y) and note that this does approximate a straight line.

$$\log Y = \log a + (b \log e)X$$
$$1.866 = \log a + 2(b \log e)$$
$$2.419 = \log a + 2.6(b \log e)$$
$$0.553 = 0.6\,(b \log e)$$
$$0.92 = b \log e$$
$$b = 2.12$$
$$\log a = 0.026$$
$$a = 1.06$$
$$\log Y = 0.026 + 0.92X$$
$$Y = 1.02e^{2.12X}$$

Exponential Curves of the Form $Y = ae^{bX} + c$

This is a modification of the simple exponential equation $Y = ae^{bX}$. The plot of $(X, \log Y - c)$ should approximate a straight line.

$$c = \text{asymptote} = \frac{Y_1Y_2 - Y_3^2}{Y_1 + Y_2 - 2Y_3}$$



Logarithmic Curves of the Form $Y = ae^{bX+cX^2}$

$$\log Y = \log a + (b \log e)X + (c \log e)X^2$$

let $b' = (b \log e)$

$c' = (c \log e)$

$a' = (\log a)$

Then the above equation is equivalent to

$$\log Y = a' + b'X + c'X^2$$

The plot of $X, \dfrac{\log Y - \log Y_p}{X - X_p}$

should approximate a straight line.

Equations Involving Four or More Constants

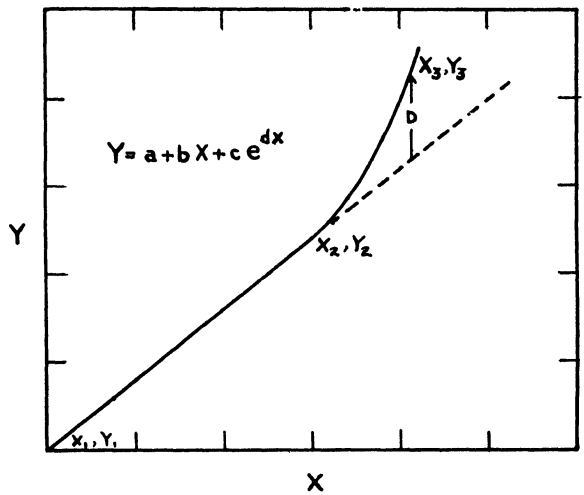
At times the plot of a simple equation will coincide approximately with only part of the experimental curve and requires the addition of one or more terms to make it fit throughout.

Such terms may be: ce^{dX}, or cX^d

$$Y = a + bX$$
$$Y = a + bX + ce^{dX}$$
or $$Y = a + bX + cX^d$$
$$Y = \frac{X}{a + bX}$$
$$Y = \frac{X}{a + bX} + ce^{dX}$$
or $$Y = \frac{X}{a + bX} + cX^d$$

$$Y = ae^{bX}$$
$$Y = ae^{bX} + ce^{dX}$$
or $$Y = ae^{bX} + cX^d$$
$$Y = aX^b$$
$$Y = aX^b + ce^{dX}$$
or $$Y = aX^b + cX^d$$

Curves of the Form $Y = a + bX + ce^{dX}$



If part of this curve is a straight line, it can be expressed by the equation

$$Y = a + bX$$

The deviation from the straight line can be measured.

$$Y_3 - Y_2 = Y - a + bX$$

The plot of $(X,\ Y_3 - Y_2)$ will approximate the exponential

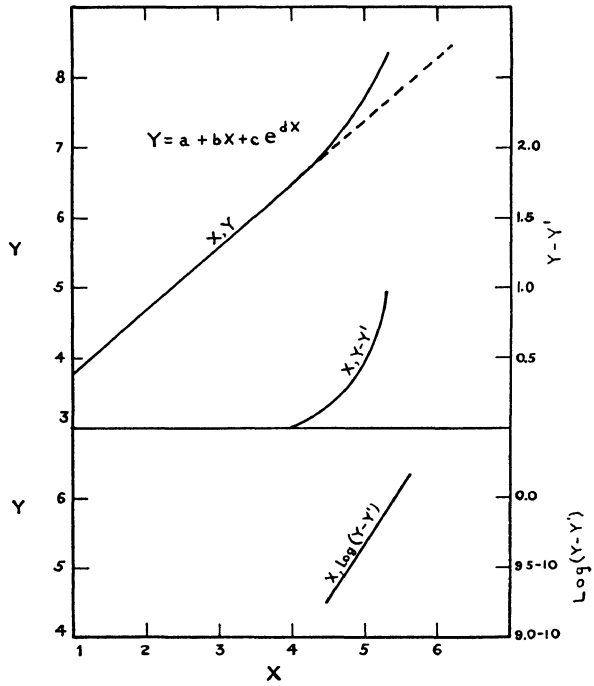
$$Y' = ce^{dX}$$

The entire experimental curve can then be represented by

$$Y = a + bX + ce^{dX}$$

Plot (X, Y) from the following data:

X	Y	Y'	$Y-Y'$	log $(Y-Y')$
1.0	3.824	3.814		
2.0	4.584	4.686		
2.5	5.0	5.122		
3.0	5.444	5.556		
3.5	5.90	5.994		
4.0	6.44	6.43	0.01	8.000–10
4.5	7.05	6.866	0.184	9.26482–10
5.0	7.76	7.302	0.458	9.66087–10
5.3	8.36	7.564	0.797	9.90146–10



Fit the equation

$$Y' = a + bX$$

for the straight line part of the curve.

$$3.824 = a + b$$
$$6.43 = a + 4b$$
$$b = 0.872$$
$$a = 2.942$$
$$Y' = 2.942 + 0.872X$$

Calculate the values for

$$Y'$$

and

$$Y - Y'$$

Plot $(X, Y - Y')$ and note that the curve appears to be exponential of the form

$$Y = ce^{dX}$$

Plot X, log $(Y - Y')$ and note that this approximates a straight line.

$$\log (Y - Y') = \log c + (d \log e)X$$
$$9.26482\text{–}10 = \log c + (d \log e)4.5$$
$$9.90146\text{–}10 = \log c + (d \log e)5.3$$
$$0\ 63664 \quad = (d \log e)0.8$$

since

$$\log e = 0.4343$$
$$d = \frac{0.63664}{0.4343 \times 0.8}$$
$$d = 1.802$$
$$c = 0.00006$$
$$Y - Y' = 0.00006e^{1.802}$$
$$Y = 2.942 + 0.872X + 0.00006e^{1.802X}$$

Curves of the Form $Y = ae^{bX} + ce^{dX}$

A part of this type of curve may be represented by the exponential

$$Y = ae^{bX}$$

The plot of X, log Y for the values of this part of the curve will approximate a straight line. The deviation from the straight line

$$D = Y' - Y = Y' - ae^{bX}$$

The plot of (X, D) will take the form of the exponential

$$D = ce^{dX}$$

and the plot of $(Y, \log D)$ will approximate a straight line.

The values of D are negligible for that part of the curve represented by

$$Y = ae^{bX}$$

The entire equation will be represented by the equation

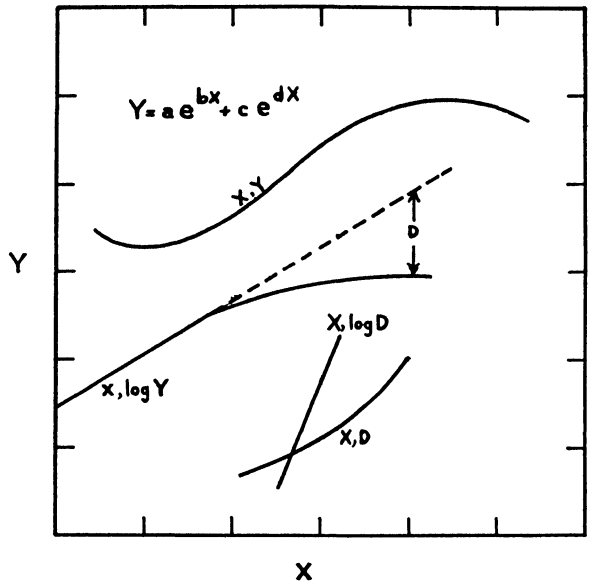
$$Y = ae^{bX} + ce^{dX}$$

Plot (X, Y) and note that the left-hand side of the curve appears to be exponential of the form

$$Y = ae^{bX}$$

Verify by plotting $(X, \log Y)$; this approximates a straight line.

$$\log Y = \log a + (b \log e)X$$



Solve for a and b.

Now, find the value for the derivative, D.

Plot (X, D); this appears to be exponential.

Plot $(X, \log D)$; this approximates a straight line.

assume $D = ce^{dX}$

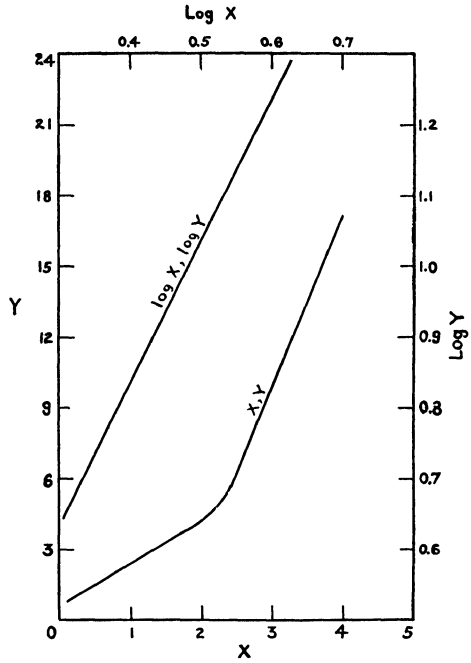
then $\log D = \log c + (d \log e)X$

Solve for c and d.

Two or More Equations

At times it is impossible to represent experimental data by a simple or complex equation of few or many constants. In such cases we represent one part of the plotted curve by one equation, another part by another equation, and so forth. Each equation is, of course, confined to a certain part of the curve. Plot (X, Y) and note that this approximates a straight line.

X	Y	log X	log Y
0	0.4		
1	2.0		
2	4.4		
2	4.4	0.3010	0.6345
2.5	6.87	0.3979	0.8370
3.0	9.9	0.4771	0.9556
3.5	13.475	0.5441	1.1296
4.0	17.6	0.6021	1.2455



$$Y = a + bX$$

Determine the value for a and b

when	$X = 1$	then	$Y = 2$
and when	$X = 2$	then	$Y = 4.4$

$$2 = a + b$$
$$4.4 = a + 2b$$
$$b = 2.4$$
$$a = -0.4$$

Now, try to determine the equation that will fit the remaining portion of the curve.

Try the hyperbolic or parabolic forms

$Y = aX^b$ by plotting (log X, log Y)
$Y = aX^b - c$ by plotting [log X, log$(Y - c)$]

or the exponential forms

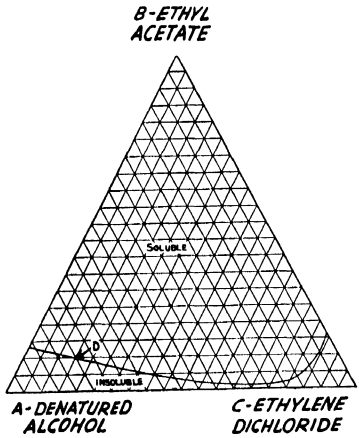
$Y = ae^{bX}$ by plotting (X, log Y)
$Y = ae^{bX} - c$ by plotting [X, log $(Y - c)$]

or their modified forms.

In this particular case the plot of (log X, log Y) approximates a straight line.

$$\log Y = \log a + b \log X$$
$$1.2455 = \log a + 0.6021b$$
$$0.6435 = \log a + 0.3010b$$
$$b = 2.0$$
$$\log a = 0.0413$$
$$a = 1.1$$
$$1.2455 = 0\ 0413 + 2X$$
$$Y = 1.1X^2$$

Where there are more than two variables as in lacquer fabrication, the triangular coordinates of an equilateral triangle lend themselves for expressing variability of a mixture of three solvents. Each side of the triangle is divided into an equal number of divisions.



Solubility of ½-Second Nitrocellulose, in Mixtures of Ethylene Dichloride, Ethyl Acetate and Denatured Alcohol.

In the above triangle, the lines parallel to AC represent parts of ethyl acetate. The line AC represents 0 per cent ethyl acetate and the apex B represents 100 per cent ethyl acetate. The point D refers to a mixture of 10 per cent ethyl acetate, 75 per cent denatured alcohol, and 15 per cent ethylene dichloride.

General References

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Arkin, H., and Colton, R. R., "An Outline of Statistical Methods," Barnes & Noble, Inc., New York, N. Y., 1935.

Liquids for Refractive Index Determinations*

Liquid	N_D at 23° C.
Methyl alcohol	1.3279
Water	1.3328
Acetone	1.3598
Hexane	1.3750
Heptane	1.3868
Ethylene chloride	1.4417
Chloroform	1.4430
Trimethylene chloride	1.4470
Cineol	1.4552
Glycerol	1.4671
Decahydronaphthalene	1.4750
Iso-Amyl phthalate	1.4870
Tetrachloroethane	1.4912
Xylene	1.4957
Benzene	1.4982
Pentachloroethane	1.5006
Anisole	1.5150
Chlorobenzene	1.5218
Trimethylene bromide	1.5220
Ethylene bromide	1.5353
o-Nitrotoluene	1.5440
Nitrobenzene	1.5506
Xylidine	1.5559
Tri-*o*-cresyl phosphate	1.5560
Bromobenzene	1.5578
o-Toluidine	1.5700
Aniline	1.5840
Bromoform	1.5940
Quinaldine	1.6088
Iodobenzene	1.6168
Cinnamaldehyde	1.6190
Quinoline	1.6239
α-Chloronaphthalene	1.6318
α-Bromonaphthalene	1.6569
Methylene iodide	1.74

*Eastman Kodak Company.

Appendix I

Nitroparaffins

The nitroparaffins, manufactured by Commercial Solvents Corporation, constitute a new group of compounds possessing outstanding solvent properties. From these nitroparaffins a wide variety of derivatives possessing interesting properties can be readily prepared.

The nitroparaffins are solvents for the organic esters of cellulose and are of especial interest as cellulose acetate solvents, since solutions of this material in mixtures of nitroparaffins and alcohols have high dilution ratios for coal-tar hydrocarbons. The nitroparaffins are also strong solvents for the co-polymer vinyl resins and tolerate the presence of unusually high proportions of coal-tar hydrocarbons at any given solids content and viscosity.

1-chloro-1-nitropropane has been found to be an excellent anti-gelling agent for use in rubber cements. It has been definitely shown that rubber cements which ordinarily would gel in a period of a few hours to two or three days can be prevented from gelling for months by the addition of a small percentage of 1-chloro-1-nitropropane. This substance is a liquid and is soluble in water.

Some of the physical properties of several of the nitroparaffins are given in the following table.

Compound	Boiling Point (°C)	Specific Gravity	Flash Point (Open Cup) (°F)	Relative Evaporation Rate by Weight (Butanol=100)
Nitromethane	101	1.139	95	400
Nitroethane	114	1.052	82	300
1-Nitropropane	132	1.003	93	208
2-Nitropropane	120	0.992	75	265
1-Nitrobutane	151	0.975	115	110
1-Chloro-1-Nitropropane	141	1.270	102	...

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