

# SCIENTIFIC SECTION

## GENERALITIES OF SOLUTION.\*<sup>1</sup>

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Before introducing the meniscus subject promised in the closing paragraphs of the article titled "Solvents in Pharmacy" (following "Solvents in Pharmacy," *JOUR. A. PH. A.*, 1918, 145<sup>2</sup>) it may be well to consider some of the generalities of solution.

The physical dilution of matter by separation of its molecules through the agency of a solvent is one of the constants of solution. Usually liquids are the diluents or solvents, which in taking up other substances transform them, if liquid, into a more diluted liquid; if solid, into the liquid state. Liquids, gases and solids may thus severally be dissolved in and distributed throughout the liquids. For example, water will dissolve oxygen gas, chloroform or sugar. Such solutions are apparently the result of physical phenomena, the components of the product retaining to a degree their individual characteristics.

The action of a liquid is not, however, essential to liquefaction (solution) of a solid. It is possible to induce two volatile solids to dissolve each other and produce a fluid. Thus, equal amounts of chloral hydrate and camphor, if rubbed together, will form a liquid, the reaction at the start being due to the *vapors* of these substances acting on each other. Combining, these vapors form a liquid film over each solid particle, establishing thus a common solvent, and then as vapor is absorbed the liquid increasingly dissolves both substances. This is illustrated by placing a piece each of chloral hydrate and of camphor near each other under a small beaker glass, when it will be observed that both will gradually liquefy.

Where only one substance is volatile, admixture may liquefy both solids. If di-berberine sulphate (not volatile) in dry powder be triturated with an equal amount of thymol, the two powders form a paste.<sup>3</sup> The chemistry of this phenomenon has not, to my knowledge, been established. A seeming similarity is shown when vapor of water is absorbed by, and ultimately dissolves chloride of calcium or acetate of potassium. In this case chemical reaction seems to be involved, because of the definite hydrates produced.

Another class of solutions may be produced by two non-volatile bodies. When materials containing water of crystallization, capable by re-arrangement of forming

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\* Scientific Section, *A. PH. A.*, Portland meeting, 1928.

<sup>1</sup> These general remarks may seem afar from manipulative plant pharmacy. And yet, do not law and rule apply as directly to vegetable structural complications as to separate definite chemicals? In introducing these general remarks no claim is made to originality, the aim being simply to connect some phases of plant pharmacy with established phenomena. The notes were made in and close following 1879 (written in 1885), the intent now being to make no alterations, even some glaring defects under present views being untouched. In a few cases as where Wolfgang Ostwald and Dr. Seidell have been credited, slight additions have been made.—J. U. L.

<sup>2</sup> Part I of "Solvents in Pharmacy" is printed in *JOUR. A. PH. A.*, VI (1917), 940-949; Part II in VII (1918), 137-149, and a letter from Dr. Wolfgang Ostwald on the subject in XVII (1928), 820.

<sup>3</sup> The ordinary mono-berberine sulphate will not produce this reaction.

an anhydrous salt, are triturated together, liquefaction may result. Thus crystallized acetate of lead and crystallized sulphate of copper, in equal amounts, powdered together, change into a paste consisting of a solution of acetate of copper and suspended sulphate of lead.

These examples illustrate that it is not possible to restrict the term "solvent" to either a liquid dissolving a liquid or a liquid dissolving a solid.

Substances in solution may increase the power exerted by a solvent over other substances. Thus, citrate of potassium added to water increases its solvent power for ferric hypophosphite as well as a few other ferric compounds.

A contrary action sometimes occurs with solutions of other salts, the liquid becoming less a solvent and capable of throwing out of solution materials previously dissolved.<sup>1</sup>

Double salts of different solubilities may be formed, as when slightly soluble corrosive sublimate, and ammonium chloride are triturated with water, the result being a soluble double salt.<sup>2</sup>

As a rule, individual relationships concerning solubilities of different substances in different liquids can at the present time be determined only by experiment, a fruitful opportunity for serviceable investigation.<sup>3</sup>

As a rule, hot liquids are better solvents than cold ones, and heat also usually furthers chemical change, the results being often complicated when viewed from the solution aspect. Physical or simple solution of solids is accompanied by decrease in temperature, as when Glauber's salt dissolves in cold water.<sup>4</sup> Solution complicated with chemical alterations, on the contrary, seems generally to be accompanied by increased temperature, as when calcined magnesia "dissolves" in solution of citric acid. In many cases, the act of solution is accompanied by the molecular combination of some of the water with a solid, as, on dissolving, caustic soda progressively combines with water to form solutions of higher hydrates with the liberation of much heat. Often also the term "solution" is applied to chemical reactions in which solid substances in the presence of reagents, change their conditions chemically, at the same time becoming liquid. Thus, diluted hydrochloric acid is in popular terms said to dissolve iron, when in reality the iron and the acid both disappear, as such, in the ensuing chemical reaction, the result being a solution of

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<sup>1</sup> Possibly another phase of the problem rests in the fact that the terms solid and liquid may depend upon temperature only. Thus water becomes a solid when viewed from a temperature below 32° F.

<sup>2</sup> In 1865 Dr. W. B. Chapman, under whom this writer served as an apprentice, theorized that this solution could replace alcoholic solution of corrosive sublimate as a bedbug poison. To his surprise parties using it decided otherwise.

<sup>3</sup> Again I beg to say that although the pharmacist is in business for a living, that very "business" makes it a necessity for him to perform experiments that come to no other man. To record observed facts, to extend research beyond the business phase of the subject, is both a pleasurable opportunity and a professional duty. It is his right to retain to himself results that would injure his business if published, but the larger share can be given to the world. Even the retention of a private process necessary to his success is a gift to the world. Is it not easier for an imitator to follow where a path is made than to make an original exploration?

<sup>4</sup> To study this subject now (1918) would much change as well as amplify this sentence.

Ostwald: *Decrease* in solubility with *rising* temperature is also known, for instance, with calcium sulphate (above 40° C.) or better still calcium butyrate, calcium caprylate, calcium malonate or water + diethylamine. (Personal letter to the author, 1928.)

chloride of iron, a new substance. Taking it altogether, these illustrations are sufficient to indicate that the term "solution" as employed in pharmacy may be either precise or very elastic.

From the foregoing citations and brief definition of the general term, let us turn to a consideration of the solvent relationships of liquids, which in pharmacy are denominated as *solvents*.

*Inter-action of Liquids as Solvents.*—It is found that the liquids concerned as solvents seem not always to obey a definite rule in their deportment toward each other, but may show unexpected, and as yet unrecorded differences, regardless of their molecular constructions. Some of them will mix in any proportion, but others take each other up in very small amounts. Although they can be formulated into convenient classes that, as a rule, mix with liquids of related compositions, yet here and there, in attempted classifications unexpected exceptions occur.<sup>1</sup> As examples, I am not acquainted with any neutral liquid with which alcohol will mix in all proportions, from which methyl alcohol recoils. Any liquid, so far as I know, that will mix in all proportions with sulphuric ether, will do the same with acetic ether. The exceptions that occur to these rules, if there be any, I have failed to locate, provided both ethers be water-free.<sup>2</sup> Upon the contrary, while glycerin and water are usually paired, they inexplicably and unexpectedly are distinguished by acetone, which affiliates freely with water, and yet refuses to mix beyond a certain proportion with glycerin. And yet acetone in turn mixes in all proportions, so far as I have found, with all other liquids with which glycerin affiliates. This fact seems the more remarkable when we consider that acetone comes nearer to being a "cosmopolitan" liquid solvent (absolute alcohol excepted) than any other liquid known to me.<sup>3</sup> Most neutral liquids, excepting some of the paraffin series, mix with it in all proportions—a problem that furnishes an excellent subject for pharmaceutical investigation.<sup>4</sup>

*Miscibility of Liquid Solvents.*—In studying more carefully the line of solvents cited in this series<sup>5</sup> chemical constitution seems not as yet to offer an opportunity to classify them into systematic groups. Methyl and ethyl alcohol are widely separated in solvent powers from glycerin, which is also an alcohol. Benzol and benzine mix with all hydro-carbons, and yet other members of the hydro-carbon series do not all mix with solvents that unite freely with these liquids, as, witness in the deportment of liquid petrolatum which repels or is repelled by acetone,<sup>6</sup> al-

<sup>1</sup> See "Solvents in Pharmacy," *JOUR. A. PH. A.*, VI (1917), 940.

<sup>2</sup> In the experimentation to follow, this water problem in ethers assumes importance by reason of discordant results otherwise unexplained.

<sup>3</sup> And yet it has destructive powers, as well as solvent. Within a very short period it will utterly destroy the very stable alkaloid sanguinarine. I touch acetone very cautiously in plant pharmacy.

<sup>4</sup> One of these problems is the decomposition of acetone by substances dissolved, as well as the composition of resultant products.

<sup>5</sup> Fourteen liquids are now studied as solvents: glycerin, water, alcohol, methyl alcohol, acetone, chloroform, amylic alcohol, acetic ether, sulphuric ether, benzol and benzine, carbon disulphide, oil of turpentine, petrolatum and liquid petrolatum.

<sup>6</sup> Likes and dislikes are mutual. We are prone to consider the most prominent substance, to the neglect of the "minority."

Ostwald: *Solvent Power of Acetone.*—In the modern electronic theory of matter, especially in the so-called "dielectric theory of liquids" by P. Debye and others, acetone has a rather ex-

though the latter affiliates freely with either benzol or benzin, with both of which liquid petrolatum also mixes, in all proportions. Bisulphide of carbon and chloroform are not related chemically, and yet are close companions in their solvent attributes as concerns the present series of solvents, the companionship extending to many other liquids. Other examples might be cited to illustrate, perhaps even more forcibly, the opportunity for research presented in the solvent relationships or deportments that exist between liquids.

*Attempts at Systematization.*—Is any known alcohol insoluble in ethyl alcohol? Acetic acid dissolves all organic acids I can now recall, with, however, the exception of gentisic acid.<sup>1</sup> The normal nitrates generally, even the nitrates of the alkaloids, are quite soluble in water; but nitrates of berberine, chelidone and sanguinarine to a lesser degree, are exceptions. Watts states that "Solubility in water of the nitrates of the alkali metals decreases as the atomic weight of the metal increases," but yet no rule, so far as I am aware, has been announced by which a quantitative solubility of even one of these nitrates in any untried solvent can be accurately predicted. As examples of our dilemma, it may be stated that strontium nitrate is insoluble in alcohol, while calcium nitrate is soluble. In this direction the following from Mendeleef is pertinent: "The platinochlorides of lithium and sodium are soluble in water; those of potassium, rubidium and caesium are sparingly soluble, and the greater the atomic weight of the metal, the less soluble is the salt. (Note, Watts Concerning Nitrates of Alkali Metals.) *In other cases the reverse is observed.*"<sup>2</sup> The greater the atomic weight, the more soluble are the corresponding salts." These generalizations are scientifically inadequate, as applied to plant structures, for as yet no method has been devised to enable us to arrive by calculation at the *quantitative* solvent power of any organic substance, at any temperature, in any solvent. The statements seem to be applicable only as preliminary generalizations, the details of which must be established experimentally. In this field empiricism dominates, and pharmacy is the field that engulfs the purely scientific man concerned in the study of plant structures.

*Chemical Analogies.*—Chemical analogies, however, sometimes approximately classify chains of solubilities, Wilhelm Ostwald stating that most alcohols dissolve in water more freely as the carbon in their molecules decreases, and also that—

"The replacement of hydrogen by hydroxyl (OH) in the molecule of benzol (benzene 1918)  $C_6H_6$ , increases the solubility of the compound."

Thus he draws attention to the fact—

"Benzol (benzene (1918)  $C_6H_6$ ) is insoluble  
Phenol  $C_6H_5OH$  dissolved in fifteen parts of water  
Hydroquinone  $C_6H_4(OH)_2$  is more soluble."

In this connection it is probably of interest to compare solubilities of hydroxides of metals in relation to their atomic weights.

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ceptional place too. It has an enormous "dipole momentum," by far the greatest of all common solvents, much greater than water, alcohols, ethers, benzol, benzine, chloroform, etc. It is, from the electronic point of view, a very "active" substance. (Personal letter to the author, 1928.)

<sup>1</sup> Accepting that it is a true acid.

<sup>2</sup> Italicized by me.—J. U. L.

The following table for which the data were obtained from Dr. Atherton Seidell,<sup>1</sup> "Solubilities,"<sup>2</sup> indicates a relation the reverse of that stated by Watts for the nitrates of alkali metals mentioned above:

## SOLUBILITIES.

| Hydroxides.         | Atomic wts. | Temp. | 100 Gm. of water plus. | 100 Gm. of solution contain. |
|---------------------|-------------|-------|------------------------|------------------------------|
| LiOH                | 7           | 20°   |                        | 10.99 Gm.                    |
| NaOH                | 23          | 20°   | 109 Gm.                | 52.2 Gm.                     |
| KOH                 | 39          | 20°   | 112 Gm.                | 52.8 Gm.                     |
| Mg(OH) <sub>2</sub> | 24          | 18°   | 0.0008 Gm.             |                              |
| Ca(OH) <sub>2</sub> | 40          | 20°   | 0.165 Gm.              |                              |
| Sr(OH) <sub>2</sub> | 87.6        | 20°   |                        | 0.851 *                      |
| Ba(OH) <sub>2</sub> | 137         | 20°   | 3.89 Gm.               | 3.74 Gm.                     |
| Fe(OH) <sub>3</sub> | 56          |       | Insoluble              |                              |

\* Calculated for Sr(OH)<sub>2</sub>.

It is noted that with molecules having the same number of OH groups, the solubility rises with increasing atomic weight of the metal.

Contrary to the rule Ostwald applies to phenols, the increase in the number of OH groups is marked by decrease of solubility.

May we not, indeed, go a little further, without digressing from our subject? Potassium chloride and platinum chloride are both water soluble, and yet the double chloride of platinum and potassium is practically insoluble. So far as I know, no rule has been evolved to indicate in advance of experiment such exceptions.

But in plant pharmacy, we have even greater exception problems. The "potash" salts are, as a rule, very soluble in water. And yet, in plant textures, potassium is held so tenaciously as to forbid its total extraction by water. This union is shown in corn cobs, which hold a decided percentage of potassium (calculated to KOH) the ashes of corn cobs being largely potash KOH and K<sub>2</sub>CO<sub>3</sub>. Successive boilings of ground corn cobs in large amounts of water fail to extract the final proportion of the potassium textural compound.<sup>3</sup>

As yet the empiricist in this and a multitude of other directions connected with vegetation must accumulate data to be later utilized by the unknown party destined yet to correlate the research fragments and formulate them into a compre-

Ostwald: (Wolfgang), personal letter to author. No question but that the rule given by Willh. Ostwald is meant to be a "Handregel" (rule-of-thumb) for a certain simple set of *organic* compounds. Real extending *laws* are not known even now (cf. V. Rothmund, *Löslichkeit u. Löslichkeitsbeeinflussung*, Leipzig, 1907, 196; J. Hildebrandt, *Solubility*, about 1902; Monographs edited by the Amer. Chem. Soc. or Chem. Catalogue Company, New York); those are the most comprehensive, theoretical treatises on solubility.

<sup>1</sup> Table and term "benzene 1918" added in 1918.—J. U. I.

<sup>2</sup> The research placed by Dr. Seidell on this subject is phenomenal. This publication is one of the greatest offerings made in recent years to connected literature. Had it been attainable in 1879, this writer would have been saved much wandering and, undoubtedly, many errors both of fact and theory.

<sup>3</sup> The term "textural" is employed because, so far as I know, the natural compound is unknown.

hensive whole. But we can make a stagger by considering the qualities of the three classes of liquids given on page 137, JOURNAL OF THE AMERICAN PHARMACEUTICAL ASSOCIATION (1918), reproduced as follows:

The extremes (Classes 1 and 3) being diametrically opposed to each other, neither mix with nor dissolve each other, nor do they dissolve the same classes of bodies. Few substances soluble in the 3rd class will dissolve in the 1st. Hence it is that in galenical pharmacy, if the active principles of a drug are wholly soluble in water, the drug may be freely abstracted of many of its needless extractives by the sixth class of solvents as a preparatory step without detriment to its therapeutical value providing the solution formed be not a solvent for the constituent desired.

Considering that the proximate principles of drugs are admixtures of various constituents, it would seem possible to abstract or exclude one or more of them as we may desire by a study of the application of these natural solvents. Thus, the qualities of menstruums that may be made by a judicious mixing of these classes approach infinity. This object, too, should seemingly be accomplished without the application of any destructive or heroic chemistry. Beginning with the extremes of the classes mentioned, we have liquids that neither affect each other nor dissolve the same substances. Progressing toward the means in each case, we have liquids that as a rule affiliate with those bounding them, but yet present marked characteristics and differences from the further separated classes. There are, however, a few conspicuous exceptions as, for example, the affinity that benzol bears for members of the first class, and the indifference that acetone exhibits for glycerin. These very exceptions may, however, be made to serve a useful purpose in pharmaceutical manipulation.

It should be possible with selections of these liquids to wash out inactive substances from a powdered drug by the judicious adoption of the right menstruum providing the inert and active principles present different solubilities. The operator may, indeed, first abstract the desired principles in connection with others objectionable, and afterward by appropriate solvents and excluders separate those objectionable.

Two or more liquids may be combined so as to enable the product formed to present solvent actions that are very different from either of the originals, and the solvent powers may be altered (graded) time and again by such methods. A percolate made of one solvent may be dissociated by the use of others added in progressive steps and the dissolved matters first abstracted thus broken into fractions by a judicious admixture of other neutral solvents. Thus we may successively throw out of solution or dissolve at will, without using chemicals, the various constituents that are now classed together among plant products under the general name, extractive matter. This, I believe, is the true foundation of a coming study in galenical pharmacy. In this direction we are again led to the phase of the act of solution that confronted us when we considered the value of water as a solvent. So far as the writer can observe, the principle in each is identical with the other. Although well known in its application to mixtures of neutral solvents and definite chemicals, it has been overlooked where successive menstruums operate on a mixture of plant constituents.

To resume. Mix any two solvents, *e. g.*, alcohol and water, and the solvent action of the resultant liquid is different from the original. Add, successively, other

liquids and with each addition the solvent power of the product is altered. Change the proportions of the ingredients and successive alterations in solvent power, that seem to defy calculation, result. It is possible by this means to make a solution of one liquid in another and then by adding a third liquid to throw one or the other out of solution; in other words, to precipitate it. In like manner new liquids may be added and thus liquid precipitate after precipitate may be produced in turn, perhaps to finally all redissolve when the conditions are right. Each new liquid is a menstruum, each menstruum a separate solvent having distinct qualities, as is shown by the successive precipitates.

Now refer to the solution of plant constituents (see page 217). Each substance that the menstruum dissolves becomes a liquid, the new liquid dissolves another body and thus a new liquid results. A third substance now dissolves, and with the change a third solvent springs into existence. We have a complex liquid exactly as though we had mixed various solutions together. This third liquid may not be able to hold in solution a substance that when first dissolved helped to form the first liquid. Part of this body may finally be thrown out of solution and when it is out of solution it resumes the solid form. It precipitates (insoluble) and alters the solvent by so doing. There is no reason why we should draw a distinction between the precipitates in this case and a precipitate that results when water is added to a mixture of alcohol and chloroform whereby the chloroform is precipitated. Thus we are led to the unfolding depths and questionings that now appear before us.

Can the scientific reasoner as yet predict quantitatively in water alone, much less other solvents, the solubility of any newly discovered alkaloid or its salt? He can reason from analogy, arguing that similarly constituted bodies behave so as to make it probable that the substance under consideration behaves likewise. But, can he demonstrate the amounts by any rule? Dare he predict quantitative amounts? Let us cite:

Ammonio-sulphate of copper in water dissolves cellulose. This fact was discovered by experiment, and so far as science is concerned, could not to the present day have been predicted by law or analogy. Pyroxylin (gun cotton), U. S. P., 1860, dissolves in ether. Is there any constitutional or other rule to indicate why it should respond to this agent, and be practically insoluble in alcohol? To follow this thought leads to complications innumerable. And yet we in pharmacy everywhere are confronted by such facts as these. When we search for the undercurrents in many features of solution phenomena as applied to pharmaceutical processes, as has been shown, they spring up and multiply in all directions. We must patiently experiment, fail in result, mistake in theory, err as a rule, and be contented in the passing along if here and there we find a sliver of value.

In this field of empirical exploration, pharmacists by reason of uncertainties are at home. Surely it is a field of entanglements. The problems connected with molecular chemistry are much easier to solve because in the section of galenical pharmacy even a foundation upon which to stand is wanting. The writer ventures to assert that no observer has as yet presumed to record the possibilities that may follow the uses of the several members of the three classes of solvents that are herein classified (see *JOUR. A. PH. A.* (1917,) 11) as they may be applied to any existing drug in any order, beginning with the most simple combination. Reverse the order selected and, as has been shown, the conditions are altered. Can any

mathematician establish the number of possible combinations these menstruums may make with the soluble constituents of a single plant?

And yet, unless an attempt is made at systematization, we will forever remain empiricists, struggling without a law and working without a rule. This we are practically doing now in official galenical pharmacy. Any thread of thought that suggests itself by reflections such as these affords abundant experimental opportunity. Let us then pass into the study of solution as restricted to one phase that confronts pharmacists.

*Plant Constituents.*—In a vial before me an organic<sup>1</sup> proximate principle rests. Following the example of most alkaloids, we would naturally accept that its salts are more soluble than the alkaloid. But this alkaloid, berberine, chances to be one of the exceptions for it is quite soluble in water, its salts variably so, the nitrate especially being unexpectedly quite insoluble. The constitution, the origin, the alkaloidal relationship, throw little if any light concerning its behavior.

Pass to solubilities quantitative as applied to classes of proximate plant principles. Comparisons of different solvents become of no predictive value. Even the most familiar inorganics mystify us. Let us take as an example chloride of sodium to contrast with organic bodies. The relationships that exist between common salt and water could have been demonstrated quantitatively only by experiment. Who, therefore, will venture to predict the solubility quantitatively of this salt, in any other liquid, for example nitrobenzol? Who, from the voluminous literature on the substance, as well as the rules concerning temperature and vapor pressure could establish its quantitative solubility in the following well-known liquids:

Alcohol, Methyl Alcohol, Amylic Alcohol, Glycerin.

Acetone, Acetic Acid, U. S. P., glacial, Acetic Acid, Ammonia Water.

If we are in darkness concerning such a well-established substance as common salt and the most familiar liquids, what can we expect of recondite, organic solutions?

Can any reader of this page take the data at his command by either experimentation or in science reasoning, and therefrom estimate the quantitative solubility of any alkaloidal salt or any other alkaloid, glucoside or organic body, in any untried liquid? In this field is not empiricism yet our master? Those who propose to establish the solvent power of a liquid or the solubility of a solid, must necessarily utilize experimentation. Here the scientist and the empiricist meet on common ground. Here we find an illimitable field for the experimenting pharmacist, with time to devote (waste?) or to utilize, view it as he may.

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<sup>1</sup> This article was written before the pharmacist or physician concerned himself in animal serums. The term organic in this publication refers to vegetable products.—J. U. L. (1918.)

Ostwald: True enough, that no one can to-day "establish the quantitative solubility of NaCl" in the well-known liquids used as solvents. Until now we know only rules of mostly rather limited applicability. One factor which certainly has something to do with solubility is the "dielectric constant" of liquids, another, the "dipole momentum" a value derived from data on dielectric constant, specific gravity and refraction of the liquid.

So-called "polar" substances, for instance, *electrolytes* are frequently dissolved to a greater extent with increasing value of the dielectric constant, for instance:

Tetraethylammonium iodide  $N(C_2H_5)_4I$  at 25° (salt crystallizes, etc.), P. Walden, *Z. physik. Chem.*, 61 (1908), 633.

| Solvent.            | Solubility<br>molar per cent. | Dielectric constant. |
|---------------------|-------------------------------|----------------------|
| Water.....          | 3.32                          | ca. 80               |
| Nitromethane.....   | 1.16                          | ca. 50-40            |
| Acetonitrile.....   | 0.618                         | 36                   |
| Nitrobenzol.....    | 0.203                         | 32                   |
| Propionitrile.....  | 0.214                         | 27                   |
| Ethyl alcohol.....  | 0.201                         | 27-26                |
| Benzonitrile.....   | 0.181                         | 26                   |
| Acetone.....        | 0.0718                        | 21                   |
| Acetophenone.....   | 0.0594                        | 18.6                 |
| Amyl alcohol.....   | 0.0305                        | 15.0                 |
| Paraldehyde.....    | 0.0189                        | ca. 11.8             |
| Methyl-formate..... | 0.00751                       | 8.9                  |
| Bromobenzol.....    | 0.00369                       | 9.8-5.3              |

This does *not* hold at all for "nonpolar" substances like many organic compounds, for instance, naphthalene.

The close connection between dielectric const., dipolemoment, and general character of solvent represented by J. U. Lloyd's experimental series of solvents (JOUR. A. PH. A., VI (1917), 940-949, and VII, 137-149) has been pointed out before (letter from Dr. Wolfgang Ostwald, JOUR. A. PH. A., XVII (1928), 820).

To the data that are being collected as a contribution toward scientifically establishing forthcoming opportunities of him competent scientifically to collate observed facts and phenomena, pharmacists or men of pharmaceutical outgrowth have already contributed liberally, and in this field will surely continue their usefulness if they credit their forebears.

*The Term Soluble vs. Insoluble as Applied to Liquids.*—And now we may well inquire what we mean by the terms *soluble* and *insoluble*, used so freely. Probably every liquid will dissolve traces of all other liquids, even though some solutions may approach emulsion or micro-dispersions. On digesting the fixed oils and fats with water, filtering and then evaporating the transparent filtrate, films of grease remain on the glass. Is there any exception? Carbon disulphide, benzol, turpentine, chloroform and similar liquids, if digested with glycerin, filtered and evaporated, leave films of glycerin. Water and liquid petrolatum (paraffin oil) shaken together and permitted to separate transparent at 70° F., by standing ten or twelve hours, precipitate (turn milky) on cooling, showing that each liquid has dissolved something from the other that is less soluble at a low than a high temperature. Probably if we were to confine ourselves to ultra-fact, we might be unable to use the term *insoluble* in connection with any pair of liquids.

A series of liquid solvents, could we establish the exact location of each member, might progressively pass from such contradictory opposites as liquid petrolatum *vs.* water (practically indifferent to each other), to others like alcohol and water that are miscible in all proportions. It would be difficult to establish a break in the slant of the line that could be drawn between extremes embracing liquids classed as soluble and those called insoluble.

Mutual solubility is markedly characteristic of all neutral liquids that evaporate, it being impossible for such to be insoluble, since the vapors of a volatile liquid penetrate hostile liquids. And yet even here it is necessary to use the two terms. Consequently in our present series of studies, the term *soluble* will be employed

where a liquid perceptibly takes up another, the term *insoluble* being applied where no appreciable amount of a liquid is transferred under ordinary conditions.

*Solution of Gases.*—While a gas will dissolve in or mix with all other gases in any and all proportions providing they do not combine to form new compounds, and is also more or less soluble in most liquids, the amounts taken up depend on the nature of the liquids, the pressure, container and temperature. The relations that exist between the solvents and the gas dissolved thereby, which govern the solvent power of liquids are not yet understood, but science seems gradually to be approaching the solution of the problem. True solutions of gases are those in which chemical combination does not take place and in which removal of pressure or boiling expels the dissolved gas. There seems to be no great distinction between the solution of a gas in a fixed liquid and that of a solid (as sugar in water) in a volatile liquid, excepting that the participants reverse themselves. In the one case the substance dissolved (gas) is the more volatile, while in the other it is the solvent that may be evaporated. In both cases, evaporation of the more volatile substance separates the bodies more or less completely.<sup>1</sup> When, however, as is true of some liquids and gases, a gas unites chemically with the liquid, the result can no longer be considered a solution of the gas.

Two or more gases in solution in liquids seem not to interfere materially with each other, providing they are chemically indifferent. Each appears to be unaware of the presence of the other. Thus it is that when a liquid dissolves several gases, each gas will be dissolved in as great an amount as if no other gas were present. When gases dissolve in liquids, if chemical change occurs, heat is liberated and then (for example, in making ammonia water) the vessel that contains the liquid into which the gas is passing must be cooled.<sup>2</sup> All liquids seem to take up larger amounts of a gas at lower than at higher temperatures, every gas being soluble to a greater or less extent in every liquid.

*Solutions of Volatile Liquids.*—Every volatile liquid is probably soluble at ordinary pressure in every other cold liquid even if it be only to the extent of the vapor absorbed. If there be no chemical change, which point is sometimes difficult to determine, it is possible by distillation to separate the dissolved vapor of a volatile liquid from a liquid fixed or less volatile. In this paper the term *vapor* in these cases is therefore used as being synonymous with the term *gas*.

*Volatile Liquids May Therefore for Our Purpose Be Considered as Condensed Gases.*—If under atmospheric pressure the temperature of our atmosphere were increased to 100° C., water would, under this view, be a gas. If the temperature were 37° C. we would consider sulphuric ether as a gas; at 78° C. alcohol would be a gas; at 47° C. carbon disulphide would be gaseous. It is seen that the physical condition of these bodies becomes for descriptive use, simply a question of pressure and temperature (neglecting the critical point) and as volatile liquids are in this sense condensed gases, their vapors should obey the laws that govern gases. When a gas is liquefied by reduction of temperature, it becomes a volatile liquid and if a volatile liquid is vaporized, it becomes a gas. The ordinary condition of these bodies

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<sup>1</sup> When we reach the surface film under capillarity, problems arise, theoretical phases needless to mention here.

<sup>2</sup> If  $\text{NH}_3 + \text{H}_2\text{O} = \text{NH}_4\text{OH}$  chemistry is involved. If it forms  $\text{NH}_3\text{H}_2\text{O}$ , a solution of  $\text{NH}_3$  results.

determines the manner in which they are classified, the distinctions between the classes being dependent on temperature and pressure.

*Vapors of Volatile Liquids Are Miscible.*—If volatile liquids are gases condensed, the vapors of volatile liquids that do not unite chemically should commingle in all proportions and so far as I am aware, they do so.

As an example of the series of solvents herein considered, water, according to this word, included as a member of Class 1 (see *JOUR. A. PH. A.*, VII (1918), 137) may be considered typical, and described in part as follows:<sup>1</sup>

It mixes in all proportions with glycerin, alcohol, methyl alcohol and acetone, which liquids (excepting acetone and glycerin) affiliate freely with each other and constitute Class 1.

It mixes in varying proportions, but less freely, with chloroform, amylic alcohol, acetic ether and sulphuric ether, which liquids affiliate freely together and constitute Class 2.<sup>2</sup>

It is practically insoluble in benzol, carbon disulphide, benzine, turpentine and liquid petrolatum (paraffin oil), which liquids affiliate freely together and form Class 3.

The fact is, however, that each member of any of the three classes will dissolve more or less, precisely speaking, any member of the entire series, even liquid petrolatum, U. S. P. ("insoluble in water") yielding, under proper manipulation enough of its substance to water to demonstrate that it is not absolutely insoluble in water.

Having in this way briefly, though inadequately, referred to the "generalities of solution," I shall later comment on some of the qualities of the fourteen solvents forming types of the three classes of solvents aforementioned.

#### HOSPITALIZATION BILL CONSIDERED IN COMMITTEE.

The House Committee on World War Veterans' Legislation, in executive session January 15th considered the Luce bill (H. R. 15921), to authorize an appropriation of \$10,000,000 for improvement in hospitalization facilities to care for "the increasing load of mentally afflicted veterans and to enable the Veterans' Bureau to care for its beneficiaries in Veterans' Bureau hospitals." No action was reached.

The bill also provides for acceptance of donations by the Director of the Veterans' Bureau for carrying out the purposes of the bill and the acceptance by the President of the United States of grounds and other equipment from states and other bodies.

#### INTERNATIONAL INDUSTRIAL AND MEDICINAL HERBS CONGRESS, BUDA- PEST, HUNGARY.

According to the Royal Hungarian Ministry of Agriculture there was held in Budapest under its auspices, from September 8 to September 12, 1928, an International Industrial and Medicinal Herbs Congress, at which 18 nations were represented. The meetings of this congress were confined to lectures and discussions. The name of the Hungarian official who supervises the cultivation, preparation and sale of all industrial and medicinal herbs cultivated in Hungary, will be furnished interested American firms upon request. (Consul General William H. Gale, Budapest.)

<sup>1</sup> Some substances absorb water in enormous amounts. Be this capillary or otherwise water becomes *dry as dust*. Seemingly it is no longer water. In other cases quivering jellies result. Here we enter the realm of physics, or pseudo-solutions in which water assumes peculiar qualities.

<sup>2</sup> *JOUR. A. PH. A.*, VII (1918), 137.