

**The chemistry of pharmacy : an exposition of chemical science in its relations to medicinal substances according to a practical and original plan / by R. Rother.**

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THE  
CHEMISTRY  
OF  
PHARMACY.

BY  
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THE  
CHEMISTRY OF PHARMACY

—AN—

EXPOSITION OF CHEMICAL SCIENCE

—IN ITS—

RELATIONS TO MEDICINAL SUBSTANCES

ACCORDING TO A

PRACTICAL AND ORIGINAL PLAN.

—BY—

R. ROTHER,

GRADUATE OF THE UNIVERSITY OF MICHIGAN, DEPARTMENT OF CHEMISTRY,  
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## PREFACE.

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A combination of knowledge derived concurrently from the domains of Chemistry, Physics and Biology constitutes the professional frame-work of Pharmacy. Of these three prime essentials, chemical knowledge takes the first rank, since Pharmacy as a business obtains the greater part of its material and products from the realm of chemistry.

In view of this well recognized fact the further truth seems curiously anomalous, that the study of chemistry, both theoretical and practical, is not prosecuted by pharmacists with the spirit that its importance demands. The principal reason for this condition is that chemical works, as at present extant, yield no proper and practical assistance with special reference to pharmaceutical instruction.

This work, entitled the "Chemistry of Pharmacy," is calculated to supply the want above expressed. It embodies only such portions of chemical science as bear directly and practically on Pharmacy as a business no less than as a science and art.

The author claims for himself the credit of here concisely presenting the subject on a novel and original, yet practical plan. The treatment although in many respects different from conventional methods is nevertheless based on the broad and sound foundation to which modern chemistry has attained.

R. ROTHER.

DETROIT, MICHIGAN.

# CONTENTS.

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## CHAPTER I.

### THE DEFINITIONS AND METHODS OF CHEMISTRY.

	SECTION 1.		PAGE
CHEMICAL PRINCIPLES,	- - - - -		1
	SECTION 2.		
CHEMICAL TERMINOLOGY,	- - - - -		14
	SECTION 3.		
CHEMICAL FORMULÆ, -	- - - - -		36
	SECTION 4.		
CHEMICAL EQUATIONS, -	- - - - -		62



## CHAPTER I.

### THE DEFINITIONS AND METHODS OF CHEMISTRY.

#### CHEMICAL PRINCIPLES.

1. A certain amount of chemical knowledge, if even of the simplest kind, is necessarily associated with some degree of practical efficiency in the calling of a pharmacist. It is ascertained from general experience that augmented knowledge of this nature enhances pharmaceutical proficiency in a corresponding measure. This important observation, therefore, goes to show that, however essential various other kinds of information are to the business of medicinal wares, practical chemical knowledge underlies the really scientific fundament of pharmacy.

The term "practical knowledge," is often erroneously construed into meaning a species of qualification derivable from an order of so-called empirical experience. The special value, presumably attaching to this character of learning, consists in its being gained despite the regulating influence of certain methods based on theory. However, theory is the attendant product of systematized activity, and represents the ideal features of operation, that is, the so-called principles of the subjects in question. Theory is thus seen to be the statement of the rules of action, otherwise termed laws, according to which motive



agencies are governed. Premise, or hypothesis, is a more or less warrantable surmise or assumption regarding the unknown principles underlying certain states of experience; and which, to the extent of its probability, approximates to a true theory, as above defined. Therefore, "practical knowledge" is really such in the degree it banishes vague propositions and aimless empiricism from its province, which distinctly implies that the better the principles are apprehended the greater the efficiency in any course becomes.

One of the commonest facts dwelling on the faculties of observation is the ceaseless change going on about us. While a considerable share of this activity is chargeable to merely physical conditions, a predominant proportion results from so-called chemical transformations. These alterations frequently take place in a seemingly spontaneous manner; but in particular connections the resistance against variation is surprisingly determined.

A familiar and most potent factor of chemical diversity is the mode of energy known as heat. Under its influence either chemical combination or decomposition proceeds in many cases with remarkable facility. When heat causes chemical compounds to vary by decomposition, several new products usually appear. In a sufficiently elevated state of the thermal action, a correspondingly extreme effect of separation may occur. As a legitimate inference from this manner of disintegration, which is powerfully supported by observations upon light, it can be granted that ultra degrees of temperature produce ulterior stages of chemical decomposition. Chemical science at present does not profess to describe this ultimate condition of matter.



The principles of the science, as it is now constituted, do not require its basis to rest upon the proceeds of a last analysis, implying a metaphysical unit. It is sufficient for all its purposes to postulate a chemical unit embodying the properties manifested in the characteristic energy specified as chemical attraction. The physical limit of the material world affords a variety of peculiar forms conventionally designated as kinds of matter. These are termed elements, because their further decomposition, through available means, is found to be impossible. However, this is not the only distinction that characterizes a so-styled elementary substance.

A preponderant number of the elemental bodies possess what is known as a metallic nature. The special property that constitutes a metal is not equally pronounced in all of them. It is observed to diminish gradually, for different kinds, nearly to the vanishing point. Utter absence of metallic features, in an element, brings it in the class of the non-metals. The physical traits of a perfect metal, although extremely marked in bodies of this class, are not exclusive qualities belonging to it. Matter of undoubted complex composition exhibits one or the other property, most conspicuously shown by the metals. The same observation also applies to the non-metallic elements.

A metal may be surpassingly heavy, excessively hard, practically infusible, and difficultly volatile, as osmium; white and lustrous, as silver; ductile, as platinum; malleable, as gold; tenacious, as iron; brittle, as antimony; liquid and volatile, as mercury; combustible, as potassium; and light, as lithium. But a plainly physical faculty solely pertaining to metallic forms of matter is the abso-



lute resistance offered to solution, as such, in any compound or non-metallic medium.

Metals will, in many instances, readily interfuse with one another, thereby generating the curious mixtures called alloys, which, though, are none the less metallic than the constituents were before the union. Yet metals may act in the capacity of solvent media upon elements and compounds that are themselves not metals, but still yield seemingly metallic mixtures analogous to the alloys. Cast-iron and steel are thus formed from iron and carbon; the remarkable compound of palladium and hydrogen and the similar combination of silver and oxygen are further examples; while the very peculiar so-called ammoniacal amalgam is another illustration.

When certain kinds of the non-metals are intimately brought in contact either with one another or with susceptible metallic elements, more or less energetic interaction will ensue. The unions thereby generated differ widely in all important respects from the previous nature of the mutually absorbed components. Products thus resulting are easily discriminated from simple elementary matter in the generality of cases. The coalescence here taking place is distinguished from all other modes of mixture or union by the term chemical attraction, or chemism.

It has been determined by actual experiment that chemical combination always proceeds according to a law of volumes. In cases where the meager volatility of the original components of a chemical compound disbarred such experiment, other means of estimation aided in ascertaining the important fact. This observation extended to the notable result that the so-called combining volumes of all elementary gases are equal, excepting



those of phosphorus and arsenic, which are half, and those of mercury and cadmium, which are double what the rule prescribes. It was incidentally established on a no less certain basis that the resulting chemical compact invariably occupies a volume bearing some simple relation to that of the separate constituents. A large number of these instances present a condensation of the primary volume, but the remainder show no alteration whatever.

As an immediate consequence of this law, it follows that the compound volume resulting from the chemical union of any number of elements in the gaseous state is equal to two volumes of hydrogen gas, if this body is taken as a standard of comparison. In other words, the same number of chemical volumes occupy equal spaces, or equal spaces contain equal numbers of chemical volumes.

The vapor-density of a gaseous body is its specific gravity when referred to hydrogen as unity. Now, since for equal volumes the mass is proportional to the specific gravity, it becomes evident that the quantity of matter, and therefore the weight of a chemical volume, will be represented by twice the specific gravity based upon hydrogen. But specific gravity is the weight of a unit of volume. Hence, if hydrogen is also taken as the chemical standard of comparison, the weight of a unit volume of it will be the weight of its chemical unit. Yet, as a chemical volume equals two unit volumes of hydrogen, it is plain that the weight of chemical volumes in general will be double the specific gravity of the substance when compared with hydrogen as unity; and also that the weight of chemical units in general will equal the specific gravity.



Of course, in accordance with the exception already noted, the weight of the combining volumes of phosphorus and arsenic will be twice, and of mercury and cadmium half their specific gravity with hydrogen as the standard. However, that does not interfere with or vitiate the principle of combination by chemical units.

As a rule, the chemical interchanges of bodies are more conveniently estimated by weight. With this method of determination the results are preferably indicated by means of chemical units, which as already stated are the vapor-densities, or rather the specific gravities of the gaseous bodies as compared with a unit volume of hydrogen taken as the unit of weight.

All elemental matters exhibit a very characteristic property that decides how many chemical units of some particular body of this nature can enter into chemical union with other like susceptible kinds. There are chemical units of a certain order adaptably constituted to unite in single form only. But, again, other kinds possess the power in such enlarged degree as to render solitary units capable of combining with two or more up to at least eight units of the single order. This capacity is variously termed quantivalence, valence and atomicity. In the present connection the term chemical potency will be employed to designate this power. And hence the customary expressions, as univalent, bivalent, trivalent, etc., that is, monadic, dyadic, triadic, etc., or monatomic, diatomic, triatomic, etc., will be replaced by the terms unipotent, bipotent, tripotent, etc., meaning the first, second, third, etc., potency respectively.

All the potencies belonging to an element are not necessarily exerted under all circumstances. This partial



employment of the power gives rise to various so-called unsaturated states. A chemical unit having the control of these limits of saturation is said to be metamerized, when transformed from a lower to a higher manifestation of potency, and conversely, demetamerized, when changed in the reverse order. This circumstance, and likewise various other contingencies, establish the fact that the potencies shown by any one element are not equal in attractive power each to each.

Although the affinities of an element may be completely saturated by corresponding units the compound does not necessarily evince chemical neutrality. It is often still prone to react very energetically with other matters open to attack. Indeed, the very great majority of chemical interactions are brought about by these means. In numerous of such instances there is mutual and complete coalescence. But in the large preponderance of cases the reaction presents a so-called double-decomposition, displaying thus in various forms the principle of substitution.

The mergence of all orders of chemical units results in compound forms, which, whether or not they be enabled to assume the gaseous condition, are none the less the exact equals of chemical volumes. Hence, they are properly designated as such. Now considering that a complex chemical volume is decomposable into various compound chemical units, then each of these separately must display the respective potency exerted in the union where it held a place. These compound units are known as residues, or radicles, but do not commonly exist in the free condition. Their character is usually of a so-called basic nature, when the leading constituent is



a metallic substance. If the characterizing element belongs to the non-metals, the radicle is said to be of an acidic tendency. However, these distinctions are not absolute, because unquestioned non-metallic elements produce most decided radicles of either nature, as for example is the case with carbon and nitrogen. A similar exception obtains with the metallic elements, as manganese and chromium for instance.

Usually the preponderance of oxygen contained in a radicle tends to impart an acidic inclination, whereas the predominance of hydrogen conveys a basic disposition. On mutually uniting, these radicles of opposite qualities neutralize each other chemically in the formation of so-called salts or related compounds. Again, if certain so-styled acid oxides come in chemical contact with so-styled basic oxides the same as the preceding order of compounds will result.

The union of basic oxides with water—hydric oxide—gives rise to basic hydrates, or bases; while acid oxides uniting with water engender acidic hydrates, or acids. Conversely, when bases and acids are deprived of water, the original oxides reappear; and therefore these are also known as anhydrates. As a matter of convenience in some cases and of necessity in others, the elements of water when united under certain conditions are assumed to exist as an oxygenated radicle termed hydroxyl. According to this view hydrates are also properly called hydroxides.

Acids are monobasic, dibasic, tribasic, etc., in accordance with the amount of exchangeable hydrogen or hydroxyl they contain. Bases are monacid, diacid, triacid, etc., on the same account. Both acids and bases



are therefore also described as being monohydric, dihydric, trihydric, etc. By reason of exact analogy alcohols, which are hydrocarbonaceous bases of diverse acidity, are similarly designated to be monohydric, dihydric, trihydric, etc.

Analogous to the differing powers of attraction, in the elements of variable potency, the neutralizing capacity of polybasic acids is not evenly distributed among the several affinities. For instance, orthophosphoric acid is tribasic, but the triammonic phosphate, under gentle heat or on mere exposure in the open air, becomes successively a diammonic and monammonic salt from dissipation of the base. The remaining third of the base can, however, be expelled only at a very elevated temperature.

Sulphuric acid is distinctly of dibasic character. When reacting, with a due proportion of potassic hydrate, it yields normal, that is, neutral potassic sulphate, and water is liberated. The addition of only half the normal proportion of potassic hydrate to sulphuric acid, and evaporation to dryness produces acidic sulphate of potassium, while water is freed. The existence of this salt is also possible in very concentrated aqueous solution, but the presence of much water occasions a separation into the normal potassic sulphate and free sulphuric acid. This result seemingly shows that in sulphuric acid at least the normal form of combination presents the bonds as acting equally. Yet, in many other connections acidic sulphates are the stabler unions, as for example, the acidic sulphates of the alkaloidal radicles.

Several distinctly monobasic acids generate a variety of acidic salts, having considerable stability and definite-



ness. Notable examples of this class are the acidic acetates and valerates of certain monacid bases. In the absence of water these salts can be obtained in a crystalline condition, as for instance, the acidic acetate and valerate of ammonium. There is no evidence of chemical equivalency apparent in this form of combinations, since all the manifest affinities are previously in full exertion. Yet, there is an exhibition of simple proportionality between the acid and saline components of these unions. An exactly analogous, but more numerous, class of such compoundings takes place between various saline substances. The products are a peculiar kind of compound salts not to be confounded with true multiple salts generated from polybasic acids with a diversity of bases, or from polyacid bases with a variety of acids. The chemical union of water, as occurs in the formation of hydrous salts, is a still more frequent and familiar manifestation of this remarkable property. The affinity displayed in these connections, although extremely lax, is undeniably chemical in its nature. A curious trait of this manner of combination is that it offers no discernible means of being explained by the principle of valence, that is, of chemical potency. A plausible, if not wholly satisfactory, explanation is afforded by the substitution of fractional for unit potencies.

Another method of combining closely resembling, if not identical with, the preceding plan of union is noticed to occur between certain neutral salts and various unipotent non-metallic elements. For example, in the presence of a small proportion of water, one chemical volume of potassic iodide forms a brown-red solution with three chemical units of iodine. The result apparently indicates



the formation of tetra-iodide of potassium. But if this compound is mixed with much water, half the iodine is precipitated, leaving a brown-red solution of what is seemingly biniodide of potassium. These results conflict with the so-called "law of even numbers," according to which the sum of the affinities of the perissad elements—that is, those of uneven potency—contained in any strictly chemical compound, must be an even number. However, this rule is powerless to discriminate the true chemical combinations from the anomalous compounds held together by a kind of pseudo-chemical affinity. Many of these latter conform to the law, and numbers do not. Again, if say potassium fluoride is mixed with fluohydric acid, the very stable and definite acidic fluoride of potassium, that is, the fluoride of potassium and hydrogen is formed. This salt agrees with the law of even numbers, but the combination is not based on chemical equivalency, excepting as already stated, subdivided valence is assumed.

Now, if boric acid is treated with solution of fluohydric acid, the so-called fluoboric acid results, which, being a union between fluoride of boron and fluohydric acid, is also producible directly from these constituents. On its neutralization with bases, the corresponding fluoborates are generated. In the fluoborates, and also in the white crystalline solid, resulting from the union of one volume of boron fluoride with one volume of ammonia, it is believed that the usually triadic boron acts as a pentad or quinquepotent element. However, no such explanation is applicable to the combinations of the fluoride of boron with two and three volumes of ammonia respectively.



It was previously said that the chemical interaction taking place between acid oxides and water results in the formation of acids. In many cases an excess of the oxide is likewise absorbed and the curious class of so-called pyro-acids is thereby produced. By permitting the oxides to act on corresponding normal salts, the respective pyro or anhydro-salts are easily obtained. These interesting salts are often formed by the latter method when the acid itself is incapable of a free existence. For illustration, potassium pyro-chromate results from the union of normal chromate of potassium with chromium trioxide. But the common and most practical process for the production of the generality of these compounds consists in the partial or total dehydration of certain acidic salts or the liberation of part of the water from the free acids by means of heat. Thus pyro-boric acid remains when orthoboric acid is caused to part with a portion of its characterizing water; pyrophosphoric acid results in a similar manner.

The numerous class of saline compounds known as sub-salts, basic-salts, oxy-salts and hydroxy-salts are formed in a manner precisely analogous to the anhydro-salts, when basic oxides and hydroxides combine with normal salts. The various salts generated by acids containing oxygen are occasionally called oxy-salts to distinguish them from the salts of the halogen-acids, which contain no oxygen. This ambiguity should be avoided by restricting the name to basic salts, where it is now more often applied.

When the process of dehydrating ortho-acids, of higher basicity than of the second order, is carried beyond the first or pyro-stage, another peculiar group of so-styled meta-acids is engendered. They are usually of unstable



character, and commonly revert to the pyro and ortho forms in the presence of water, especially when heated.

The designations ortho, para and meta are frequently employed to denote the difference among some of the isomeric and polymeric carbon compounds. Where a distinction prevails the ordinary or normal form of the combination is not habitually specified as an ortho compound. But occasionally the common name indicates the prevalent article while ortho signifies departure, usually brought about by some addition. Thus, for instance, union with water converts formic acid into the trihydric orthoformic acid. Then there is cyanogen and paracyanogen; coniine and paraconiine; chloral and metachloral; aldehyde, paraldehyde and metaldehyde, &c.

Yet the most important and systematic application of the terms ortho, meta and para occurs in naming the derivatives of benzene, that is, the so-called aromatic compounds. Owing to the peculiar constitution of benzene its mono-derivatives exhibit no isomerism, because a substituted monad radicle can assume either one of six different positions in the derivation product. But all products resulting from substitution of more than one univalent radicle for hydrogen necessarily present isomeric modifications. When two new radicles are introduced they can hold, relative to each other, either of the positions 1:2, 1:3 or 1:4; the places 1:6 and 1:5 being identical with 1:2 and 1:3. A greater number of substitutions are of course located under the same rule. The positions are named ortho, meta, para in the respective order above given. This manner of distribution and identification of the radicles, in substitution products of benzene, is known as orientation of the radicles. When isomerism occurs in



the radicles that are introduced, the fact has no bearing on the orientation, as it is independently expressed.

### CHEMICAL TERMINOLOGY.

2. Most names of the metallic elements terminate with *um* or *ium*. These endings are characteristic of the Latin form of their nomenclature. Latin names of the non-metals, excepting phosphorus and sulphur, are also ended in this manner. But their English nomenclature is much more varied than that which is used for the metals in the same tongue. Hence, the metals are not distinguishable from the non-metals by any peculiarity about their individual names.

The two divisions of the elements are sometimes classified in accordance with the so-styled quantivalence, or potency. This plan of grouping, although rational and systematic, tends in many ways to connect matters that differ strangely in various other and important respects.

Another mode of arrangement based on apparently closer relationship consists in allying the elements in natural groups presenting a variety of special characters. This method of classification is principally founded on several prominent and clearly chemical traits exhibited by the different orders.

The metallic elements are divided in three orders, namely: the alkalid metals, the earth metals and the heavy metals. The earth metals are further separated into two sub-orders: the alkalid-earth metals and the earth metals proper. Heavy metals are also sub-ordered into simply metals, and heavy metals in the restricted sense. In the true heavy metals a further division takes



place according to which they come under two separate and well-marked tribes.

A distribution of the non-metallic elements is similarly effected into four distinctive orders. These are the halogen elements, or chlorine group; the carbon group; the phosphorus group, and the sulphur group.

In writing out the so-called chemical reactions taking place among elements and their compounds it is convenient and customary to represent the interacting agents by means of suitable symbols. These also incidentally indicate the chemical units of the elements and the chemical volumes of their compounds. As already stated a chemical volume of any kind simple or compound equals two volumes of hydrogen. It was further said that one volume of hydrogen is taken as the physical and chemical unit of comparison; and that consequently the weight of a chemical unit of any kind is its specific gravity referred to hydrogen. Hence, the respective weights of the chemical units are at once the specific gravities of the bodies when in the gaseous state and the combining proportions by weight when existing in any state.

These unit weights are habitually designated as atomic weights; and the weights of the chemical volumes are similarly known as molecular weights. Of course, the molecular weight of any substance is the weight of two unit volumes of that body, that is the molecular weight is double the vapor-density when the matter is in the condition of a perfect gas.

Many simple and compound vaporous matters at an insufficiently high temperature do not exhibit normal vapor-density, that is the volume of gas is not equal to two volumes of hydrogen. However, on augmenting the



heat the density becomes regular. Again, at very elevated degrees of heat certain bodies appear to dissociate into more than the usual two volumes; yet on lowering the temperature the normal two-volume condensation is regained.

To the alkalid metals belong potassium, sodium, lithium, caesium and rubidium. Their hydrated oxides known as alkalis, or caustic alkalis, their sulphides and most of their other salts are very soluble in water.

Potassic hydrate, or potassa was formerly called kali, a term derived from the Arabic *qali*, from *qalaj*, to roast in a pan. This circumstance gave rise to the word kalium, another name for potassium, that furnishes the chemical symbol of the metal, which is K. Potassium is a monad, or unipotent element, and its unit (atomic) weight is 39.04.

The Arabic name of native carbonate of sodium is *natrun*, from this comes the term natron, for caustic soda. Sodium is hence also called natrium, which gives the symbol Na for the metal. Sodium is a monad and its unit weight is 23.

Lithium is a monad, its symbol is Li, and its unit weight is 7. The name is from the Greek *litheios*, of stone, from *lithos*, stone, in allusion to its mineral origin.

Rubidium is a monad, its symbol is Rb, and unit weight 85.4. It derives its name from the Latin *rubidus*, red, from the dark-red color of some of the lines it imparts to light, as exhibited with the spectroscope.

Cæsium is a monad, its symbol is Cs and unit weight 133. It is named from the Latin *cæsius*, sky-blue, owing to the blue lines of its spectrum.

The alkalid-earth metals are barium, strontium, cal-



cium and magnesium. Their oxides, the alkalid-earths, with the exception of magnesia which is practically insoluble, are only moderately or but sparingly soluble in water. Solutions of their salts are not disturbed by sulphydric acid or ammonium sulphide, but are completely precipitated by soluble carbonates. Sulphate of barium is insoluble, sulphate of strontium nearly insoluble, sulphate of calcium sparingly soluble and sulphate of magnesium very soluble in water.

Barium is a dyad; its symbol is Ba and its unit weight 136.8. It is named from the Greek *barys*, heavy, because of the high specific gravity of the native sulphate.

Strontium is a dyad; its symbol is Sr and unit weight 87.2. It is so called from Strontian, the name of the locality where the mineral containing it is found.

Calcium is a dyad; its symbol is Ca and unit weight 40. The name is derived from the Latin *calx*, lime.

Magnesium is a dyad; its symbol is Mg and unit weight 23.94. The term relates to magnesian stone, from magnesia, the name of a place.

The earth metals proper are so to say the asteroids of chemistry. The group as a whole presents a variety of peculiar characters; but in the main it is in a bewildering state of confusion, both as to systematic classification and identity of a number of its members. The oxides of these metals, the earths, are all perfectly insoluble in water. The earths are precipitated from their soluble saline combinations by ammonia, ammonium sulphide, and the caustic alkalis, occasionally redissolving in an excess of the latter. In some cases the precipitate caused by the first two reagents is an ammonium salt, the earth then acting in the capacity of an acid oxide.



To the earth metals belong beryllium, aluminum, chromium, cerium, lanthanum, didymium, samarium, scandium, yttrium, erbium, terbium, ytterbium, titanium, zirconium, thorium, vanadium, tantalum and niobium.

Beryllium is a dyad; its symbol is Be and unit weight 9. The name is modified from beryl, the gem in which the metal exists. The word is originally from the Persian *bulur*, crystal.

Aluminum is a triad; its symbol is Al and unit weight 27.3. It is named from alum its most characteristic salt.

Chromium acts as a dyad, triad and hexad; its symbol is Cr and unit weight 52.4. It gets the name from the Greek *chroma*, color, owing to the various and beautiful colors of its salts.

Cerium is a triad and tetrad; its symbol is Ce and unit weight 141.2. It is named from cerite, the mineral in which it occurs. The term cerite is from the Greek *Ceres*, the name of a mythological divinity.

Lanthanum is a triad; its symbol is La and unit weight 139. It takes its name from the Greek *lanthanein*, to lie hid, because concealed by the presence of cerium.

Didymium is a triad; its symbol is Di and unit weight 145.4. The word is from the Greek *didymos*, double, didymium being the twin metal of lanthanum.

Samarium is a triad; its symbol is Sm and unit weight 150. The name is adapted from samarskite, a remarkable mineral in which the metal was found.

Scandium is a triad; its symbol is Sc and unit weight 44.91. It was named in honor of Scandinavia.

Yttrium is a triad; its symbol is Y and unit weight 89. It is so called from Ytterby, the place where gadolinite the mineral containing it is found.



Erbium is a triad; its symbol is Er and unit weight 169. The name is from a modification of Ytterby.

Terbium is a triad; its symbol is Tb and unit weight 149. This name like the preceding is also modified from Ytterby.

Ytterbium is a triad; its symbol is Yb and unit weight 173. The term is compounded from yttrium and erbium.

Titanium is a tetrad; its symbol is Ti and unit weight 48. The name of the metal relates to the Titans, fabled giants of ancient mythology.

Zirconium is a tetrad; its symbol is Zr and unit weight 90. Zircon is Cingalese for a mineral found in Ceylon that contains the metal and after which this is named.

Thorium is a tetrad; its symbol is Th and unit weight 231.5. It is named from the mineral thorite, after Thor, an ancient Scandinavian divinity.

Vanadium is a pentad; its symbol is V and unit weight 51.2. The term is from Vanadis, a surname of Freyja, of Scandinavian mythology.

Tantalum is a pentad; its symbol is Ta and unit weight 182. Its name is from Tantalus, a mythological personage.

Niobium is a pentad; its symbol is Nb and unit weight 94. It is named from Niobe, the daughter of Tantalus.

The metals proper are gallium, indium, zinc, thallium, manganese, iron, cobalt, nickel and uranium. The acidified solutions of their salts are not precipitated by sulphydric acid. From neutral solutions they are separated by sulphide of ammonium as insoluble sulphides.

The symbol of gallium is Ga; it is a triad; its unit weight is 69.8. The metal is named in honor of France, Gallia being the Latin name of that country.



The symbol of indium is In; it is a triad; its unit weight is 114.4. It received the name on account of the indigo colored lines in its spectrum.

The symbol of zinc is Zn; it is a dyad; its unit weight is 64.9. The name is probably allied to *Zinn*; the German for tin.

The symbol of thallium is Tl; it is a monad and triad; its unit weight is 203.6. It derives the name from the Greek *thallos*, a twig, in allusion to the bright green spectrum line.

The symbol of manganese is Mn; it is a dyad, triad, hexad and heptad; its unit weight is 54.8. Its name is a corruption of the Latin *magnes*, a magnet.

The symbol of iron is Fe; it is a dyad, triad and hexad; its unit weight is 56. Iron is a word probably related to *ferrum*, the Latin name of the metal.

The symbol of cobalt is Co; it is a dyad and triad; its unit weight is 58.8. The term is from the Greek *kobalos*, a knave.

The symbol of nickel is Ni; it is a dyad and triad; its unit weight is 58.8. The word is abbreviated from the Swedish *Kopparnickel*—copper of nick—Nick being the name of a marine monster of northern mythology.

The symbol of uranium is U; it is a tetrad and hexad; its unit weight is 240. It has its name from the Greek *ouranos*, the heaven of Grecian mythology.

To the first sub-order of the heavy metals belong lead, silver, mercury, bismuth, copper, cadmium, palladium, rhodium, ruthenium and osmium. These metals are precipitated from acidified solutions of their salts, by sulphydric acid, as insoluble sulphides, that are insoluble in sulphide of ammonium.



Lead is a dyad and tetrad; the unit weight is 206.4 and the symbol is Pb. Plumbum is the Latin for lead.

Silver is a monad and dyad; the unit weight is 107.66 and the symbol Ag. Argentum is the Latin for silver, derived from the Greek *argyros*, from *argos*, white.

Mercury is a monad and dyad; the unit weight is 199.8 and the symbol Hg. Mercury is probably a modification from the Latin *merces*, wares. The Latin name of the metal is *hydrargyrum*, from the Greek *hydrargyros*, fluid silver, from *hydor*, water and *argyros*, silver.

Bismuth is a dyad, triad and pentad; the unit weight is 210 and the symbol Bi. In the old German the metal was called *wesemot*.

Copper is a monad and dyad; the unit weight is 63.1 and the symbol Cu. The Latin for copper is *cuprum*, from Cyprus, Greek *kypros*, the name of the island where the metal was formerly mined.

Cadmium is a dyad; the unit weight is 112.3 and the symbol Cd. The word comes from the Greek *kadmia ge*, a former name of calamine, a zinc ore in which cadmium occurs.

Palladium is a dyad and tetrad; the unit weight is 106.2 and the symbol Pd. It is named after Pallas, an ancient Greek divinity.

Rhodium is a triad and tetrad; the unit weight is 104.1 and the symbol Rh. Rhodium is from the Greek *rhodon*, the rose, alluding to the rose red color of the salts of the metal.

Ruthenium is a dyad, triad, tetrad, hexad, heptad and octad; the unit weight is 103.5 and the symbol Ru. The name is from the Latin *rutilus*, yellowish-red, in allusion to the golden-yellow color of the tetroxide.



Osmium is a dyad, triad, tetrad, hexad and octad; the unit weight is 198.6 and the symbol Os. It is named from the Greek *osme*, a smell, because of the disagreeable odor of the tetroxide of osmium.

To the second tribe of the heavy-metals belong antimony, arsenic, germanium, tin, gold, platinum, iridium, tungsten and molybdenum. These metals are precipitated from acidified solutions of their salts by sulphydric acid as insoluble sulphides, which are, however, soluble in sulphide of ammonium.

Antimony is a triad and pentad; the unit weight is 122 and the symbol Sb. The name is probably corrupted from the Arabic *al-ithmidun*. Its Latin name is stibium, from the Greek *stibi*, a term denoting the native sulphide of antimony.

Arsenic is a triad and pentad; the unit weight is 74.9 and the symbol As. It is named from the Greek *arrenikos*, masculine, on account of its strength.

Germanium is a dyad and tetrad; the unit weight is 72.32 and the symbol Ge. The metal is named in honor of Germany.

Tin is a dyad and tetrad; the unit weight is 117.8 and the symbol Sn. In Latin, tin is called stannum, from the Cornish *staen*.

Gold is a monad and triad; the unit weight is 196.2 and the symbol Au. The Latin for gold is aurum.

Platinum is a dyad and tetrad; the unit weight is 196.7 and the symbol Pt. The word is from the Spanish *plata*, silver.

Iridium is a dyad, triad, tetrad and hexad; the unit weight is 196.7 and the symbol Ir. It takes its name



from the Latin iris, genitive iridis, the rainbow, because of the variety of colors presented by its different salts.

Tungsten is a tetrad and hexad; the unit weight is 184 and the symbol W. The name is compounded from the Swedish *tung*, heavy and *sten*, stone. It is also called wolframium, from wolfram, an ore of tungsten.

Molybdenum is a dyad, tetrad and hexad; the unit weight is 96 and the symbol Mo. It is named from the Greek *molybdos*, lead, owing to the leaden color of the native sulphide of molybdenum.

The first order of the non-metals is the halogen, or chlorine group. To this belong fluorine, chlorine, bromine, iodine and hydrogen. Hydrogen is united with this group not because of any immediate relationship, but that the difficulty of affiliating it to other orders is still greater. Yet, when it is combined with oxygen, in the state of hydroxyl, the resemblance to the group becomes more intimate.

Fluorine is a monad; its unit weight is 19 and its symbol is F. The name is taken from fluor-spar, the mineral in which fluorine is contained.

Chlorine is a monad; its unit weight is 35.37 and its symbol is Cl. Chlorine is named from the Greek *chloros*, pale-green, in allusion to the color of the gas.

Bromine is a monad; its unit weight is 79.75 and its symbol is Br. The term is adapted from the Greek *bromos*, a stench, because of the noisome odor of the substance.

Iodine is a monad; its unit weight is 126.53 and its symbol is I. It takes its name from the Greek *iodes*, violet-like, from *ion* a violet, and *eidos*, form.

Hydrogen is a monad; its unit weight is 1 and its



symbol is H. The name is from the Greek *hydor*, water, and *genein*, to beget, meaning the generator of water.

The members of the carbon group are boron, silicon, and carbon.

Boron is a triad; its symbol is B and unit weight 11. Its name is a modification of borax, from the Arabic *buraq*, niter, from *baraqa*, to shine.

Silicon is a tetrad; its symbol is Si and unit weight 28. It is named from the Latin *silex*, genitive *silicis*, a flint.

Carbon is a tetrad; its symbol is C and unit weight 12. The name is from the Latin *carbo*, coal.

The phosphorus group comprises only phosphorus and nitrogen. Physically these bodies differ greatly; in certain chemical respects the contrast is also broad; however, in the main the resemblances are close.

Phosphorus is a triad and pentad; its symbol is P and unit weight 30.96. The name is from the Greek *phosphoros*, meaning light-bringer, from *phos*, light, and *phorrein* to bring.

Nitrogen is a triad and pentad; its symbol is N and unit weight 14.01. The word is a modified compound from the Greek *nitron* and *genein*, signifying niter-producer.

To the sulphur group belong sulphur, selenium, tellurium and oxygen. The appearance of oxygen in this connection is somewhat anomalous. But in numerous important points both the analogy and the relationship are so marked that a separation would seem impracticable.

Sulphur is a dyad, tetrad and hexad; its symbol is S and unit weight 31.98. In Latin it is likewise called sulphur.



Selenium is a dyad, tetrad and hexad; Its symbol is Se and unit weight 79. The name is from the Greek *selene*, the moon.

Tellurium is a dyad, tetrad and hexad; its symbol is Te and unit weight 128. It is named from the Latin *tellus*, the earth.

Oxygen is a dyad; its symbol is O and unit weight 15.96 Its name is compounded from the Greek originals *oxys*, sharp, acid, and *genein*, to bring forth, denoting acid-generator.

It is sometimes convenient, though not essential, to employ a special symbol for indicating the potency of chemical units. Commonly, however, it is known from the character of the elements and the nature of the compounds in what degree the potencies prevail. The symbols are as a rule useful only for noting the distinctions of variable valence. The potencies, from the first to the third inclusive, are represented by means of indices. For instance, where copper acts as a monad the fact is expressed by the symbol  $\text{Cu}'$ . Iron as a dyad is symbolized by  $\text{Fe}''$  and as a triad by  $\text{Fe}'''$ . In the case of iron the potency symbols are especially valuable for the characterization of the units where present under several conditions of valency. This advantage is particularly evident in symbolizing the double cyanides of iron. Higher degrees of potency than the third are designated by means of Roman numerals. Thus, nitrogen as a pentad is symbolically represented by  $\text{N}^v$  and sulphur as a hexad by  $\text{S}^vi$ .

Of vastly greater importance and almost constant occurrence are the symbolic forms habitually employed to show how many chemical units of the respective kinds enter into chemical compounds. The Arabic numerals



are used for this purpose by several methods of application. When, for example, more than one chemical unit is required the figure indicating the number is most usually attached to the right and below the symbol of the element. This is the form commonly preferred for associated units of unlike kinds. In certain connections the numeral is placed at the left side of the symbol. This is the conventional method of representing the multiplication of symbol groups. Often the aggregate thus multiplied is put in a parenthesis or inclosed by brackets. In such cases the figure may either precede the compound symbol on the line or succeed it under the line. When a collection of uninclosed unit symbols is preceded by a multiplier the collective expression must be followed by a period or, more correctly, a comma, as only that portion is the multiplicand that goes before the punctuation mark. But in the case of parenthetical symbols all the inclosed portion is affected by the multiplier. The symbols of chemical compounds result from placing together, on a line, the quantified symbols of the chemical units entering into the combination. The group always represents a chemical volume, and is commonly termed the molecular symbol.

The various methods of notation here presented find illustration in the following examples: If, say, two chemical units of hydrogen are under consideration, as a separate item, the expression will take the form  $2\text{H}$ , but when occurring in conjunction with other units it will be written  $\text{H}_2$ . A chemical volume of water is  $\text{H}_2\text{O}$  and four volumes are  $4\text{H}_2\text{O}$ . Hydrogen dioxide, or peroxide of hydrogen is  $\text{H}_2\text{O}_2$ .

Potassium oxide is  $\text{K}_2\text{O}$ ; potassic hydrate, or potassium



hydroxide, is  $\text{KOH}$ ; sulphuric oxide is  $\text{SO}_3$ , sulphuric acid is  $\text{H}_2\text{SO}_4$  and potassic sulphate is  $\text{K}_2\text{SO}_4$ . Alumina, or aluminum oxide, is  $\text{Al}_2\text{O}_3$ ; sulphate of aluminum is  $\text{Al}_2(\text{SO}_4)_3, 18\text{H}_2\text{O}$ ; potassium alum, or sulphate of aluminum and potassium, is  $\text{AlK}(\text{SO}_4)_2, 12\text{H}_2\text{O}$ ; ammonium-iron alum, or ferric sulphate of ammonium, is  $\text{Fe}(\text{NH}_4)(\text{SO}_4)_2, 12\text{H}_2\text{O}$ .

Ferrous sulphate, or sulphate of iron, is  $\text{FeSO}_4, 7\text{H}_2\text{O}$ ; sulphate of iron and ammonium, or ferrous sulphate of ammonium, is  $\text{Fe}(\text{NH}_4)_2(\text{SO}_4)_2, 6\text{H}_2\text{O}$ . Chlorhydric acid is  $\text{HCl}$ ; ferrous chloride is  $\text{FeCl}_2, 4\text{H}_2\text{O}$ , and ferric chloride is  $\text{FeCl}_3, 6\text{H}_2\text{O}$ .

Manganous chloride is  $\text{MnCl}_2, 4\text{H}_2\text{O}$ ; potassium manganate is  $\text{K}_2\text{MnO}_4$  and potassium permanganate is  $\text{K}_2\text{Mn}_2\text{O}_8$ .

The volume symbol of nitric acid is  $\text{HNO}_3$ ; of bismuth nitrate  $\text{Bi}(\text{NO}_3)_3, 5\text{H}_2\text{O}$ , and of bismuth oxynitrate  $\text{BiO}(\text{NO}_3), \text{H}_2\text{O}$ .

Sulphydric acid is symbolized by  $\text{H}_2\text{S}$ ; ferrous sulphide by  $\text{FeS}$ ; sulphide of ammonium by  $(\text{NH}_4)\text{HS}$ ; bisulphide of carbon, or carbonic sulphide by  $\text{CS}_2$ ; thiocyanate, or sulphocyanate of potassium by  $\text{KCNS}$ ; thiosulphate of sodium by  $\text{Na}_2\text{S}_2\text{O}_3, 5\text{H}_2\text{O}$ , and sulphite of sodium by  $\text{Na}_2\text{SO}_3, 7\text{H}_2\text{O}$ .

The empirical volume symbol of hypophosphorous acid is  $\text{H}_3\text{PO}_2$ ; of sodium hypophosphite it is  $\text{NaH}_2\text{PO}_2, \text{H}_2\text{O}$ , and of calcium hypophosphite it is  $\text{CaH}_4(\text{PO}_2)_2$ . Phosphorous acid is represented by the symbol  $\text{H}_3\text{PO}_3$ , and calcium phosphite by  $\text{CaHPO}_3, \text{H}_2\text{O}$ . The symbol of orthophosphoric acid is  $\text{H}_3\text{PO}_4$ ; of pyrophosphoric acid  $\text{H}_4\text{P}_2\text{O}_7$ ; of metaphosphoric acid  $\text{HPO}_3$ ; of ordinary phosphate of sodium  $\text{Na}_2\text{HPO}_4, 12\text{H}_2\text{O}$ , and of pyrophosphate of sodium  $\text{Na}_4\text{P}_2\text{O}_7, 10\text{H}_2\text{O}$ .



Carbonous oxide, or monoxide of carbon, is indicated by CO, and carbonic oxide, or dioxide of carbon, by CO<sub>2</sub>.

The symbolical expression for methane, or marsh gas, is CH<sub>4</sub>; for chloroform CHCl<sub>3</sub>; for chloral hydrate C<sub>2</sub>HCl<sub>3</sub>·H<sub>2</sub>O; for glycerin, or glycerol C<sub>3</sub>H<sub>5</sub>(HO)<sub>3</sub>; for alcohol C<sub>2</sub>H<sub>5</sub>(HO); for ether (C<sub>2</sub>H<sub>5</sub>)<sub>2</sub>O; for aldehyde CH<sub>3</sub>(CHO); for acetone (CH<sub>3</sub>)<sub>2</sub>CO, and for phenol, or carbolic acid, C<sub>6</sub>H<sub>5</sub>(HO).

Ammonia is symbolized by NH<sub>3</sub>; ammonium chloride by NH<sub>4</sub>Cl; ammonium sulphate by (NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub>, and ammonium bicarbonate by (NH<sub>4</sub>)HCO<sub>3</sub>.

Trimethylamine is expressed by the symbol N(CH<sub>3</sub>)<sub>3</sub>; its chloride by N(CH<sub>3</sub>)<sub>3</sub>HCl; aniline, or phenylamine, by NH<sub>2</sub>(C<sub>6</sub>H<sub>5</sub>), and its sulphate by (NC<sub>6</sub>H<sub>7</sub>)<sub>2</sub>H<sub>2</sub>SO<sub>4</sub>.

Acetic acid is symbolically represented by HC<sub>2</sub>H<sub>3</sub>O<sub>2</sub>; lactic acid by HC<sub>3</sub>H<sub>5</sub>O<sub>3</sub>; tartaric acid by H<sub>2</sub>C<sub>4</sub>H<sub>4</sub>O<sub>6</sub>, and citric acid by H<sub>3</sub>C<sub>6</sub>H<sub>5</sub>O<sub>7</sub>·H<sub>2</sub>O.

When compound symbols are written without regard to particular forms of arrangement, they are called empirical symbols. But, if some special plan of construction is observed the forms are known as rational symbols.

The structure of rational symbols is not always rigid and invariable for the same substance. As the character of the expression is generally dependent upon the contingencies under which the compound is either generated or decomposed, and as these latter vary according to circumstances, so will the symbol often assume a different aspect. Hence, rational symbols mainly serve to indicate, firstly: the manner in which the formation or decomposition of a compound takes place; secondly: the possible connection of the constituent matters as therefrom in-



ferred, and thirdly: the mutual relations borne by various allied and analogous compounds.

The considerations which aid in and determine the framing of rational symbols are, therefore, correspondingly numerous. From this it is evident that some particular symbol of a certain substance is by occasion preferable to another for the same compound. But, for practical purposes, that form is conventionally chosen whereby the more common traits of the combinations are suitably portrayed. In such cases a partial rationalization of the symbolic form is not alone all-sufficient, but generally more convenient than a greater analytic extension. These rudimentary components of the volume symbols are usually connected with the unrationalized portion and with each other by appropriate devices.

The foregoing examples afford a number of such instances. As a rule, the specialized parts are inclosed in a parenthesis, or distinguished from the remainder by means of a comma or a period mark. The two latter signs are frequently used interchangeably, but wrongly so, as their purposes are not identical.

The comma is rightly employed to denote a distinction among inter-united aggregates, that are not combined on the principle of unit valence. It is, therefore, of common occurrence in connection with the representation of hydrous compounds proper, or hydrites, of which ample illustrations were given above. It is, furthermore, correctly used in case of the anomalous compound salts, such as, for instance, the chloride of ammonium and mercury, or mercuric chloride of ammonium,  $\text{HgCl}_2, 2\text{NH}_4\text{Cl}, \text{H}_2\text{O}$ ; the nitrate of lead and potassium  $\text{Pb}(\text{NO}_3)_2, 2\text{KNO}_3$ , and the



lactate of calcium and sodium  $\text{Ca}(\text{C}_3\text{H}_5\text{O}_3)_2, 2\text{NaC}_3\text{H}_5\text{O}_3, \text{H}_2\text{O}$ .

Cyanide of zinc is insoluble in water, but it forms a deliquescent salt with iodide of potassium, which is represented by  $\text{Zn}(\text{NC})_2, \text{KI}$ ; with iodide of zinc and nitrate of potassium a similar salt is formed. Mercuric chloride and potassium chromate combine to generate a salt having the symbol  $\text{HgCl}_2, \text{K}_2\text{CrO}_4$ .

To this class of compounds also belong the remarkable unions of mercuric cyanide with soluble bromides, chlorides, iodides, nitrates, formates, ferrocyanides, thiosulphates and thiocyanates.

The comma is further applicable in symbolizing basic salts of the hydroxy type, such as, for example, the ordinary carbonate of magnesium,  $4\text{MgCO}_3, \text{Mg}(\text{HO})_2, 6\text{H}_2\text{O}$ ; the common carbonate of lead,  $2\text{PbCO}_3, \text{Pb}(\text{HO})_2$  and the cupric hydroxychloride,  $\text{CuCl}_2, 3\text{Cu}(\text{HO})_2$ .

The employment of the comma can be, and is, legitimately extended to the compounds possible of expression by valence symbols, but whose character is often more comprehensively shown by the undistributed forms. Such are the true oxysalts, as, for example, those of lead, of copper, of mercury, of iron, etc. Thus, the symbol of the salt of Goulard's solution can be written  $\text{Pb}(\text{C}_2\text{H}_3\text{O}_2)_2, \text{PbO}$ , instead of  $\text{Pb}_2\text{O}(\text{C}_2\text{H}_3\text{O}_2)_2$ ; of insoluble verdigris,  $\text{Cu}(\text{C}_2\text{H}_3\text{O}_2)_2, 2\text{CuO}, 3\text{H}_2\text{O}$  for  $\text{Cu}_3\text{O}_2(\text{C}_2\text{H}_3\text{O}_2)_2, 3\text{H}_2\text{O}$ ; of turpeth mineral  $\text{Hg}(\text{SO}_4), 2\text{HgO}$ , in place of  $\text{Hg}_3\text{O}_2(\text{SO}_4)$ , and of Monsel's salt,  $5\text{Fe}_2(\text{SO}_4)_3, \text{Fe}_2\text{O}_3$ , rather than  $\text{Fe}_4\text{O}(\text{SO}_4)_5$ .

The period sign is properly used for indicating the connection between symbol groups presenting single valence only; in all other cases it is ambiguous and misleading. Its application is variously advantageous and finds



illustration in a multitude of forms. Examples are the symbol for water  $\text{H.OH}$ ; for nitric acid  $\text{H.NO}_3$ ; for sulphuric acid  $\text{H.SO}_4.\text{H}$ , or  $\text{HO.SO}_2.\text{OH}$ ; for alcohol  $\text{C}_2\text{H}_5.\text{OH}$ ; for ether  $\text{C}_2\text{H}_5.\text{O.C}_2\text{H}_5$ ; for acetone  $\text{CH}_3.\text{CO.CH}_3$ ; for aldehyde  $\text{CH}_3.\text{COH}$ , etc.

The parenthesis takes an important part in the symbolism of chemistry, owing to its positive and exclusive character, compactness of form and general convenience.

The bracket symbol comes in use only where a symbol fragment containing a parenthetical form requires to be re-inclosed.

An important difference is made in the symbolization of water, when present in the so-called hydrous condition, as contrasted with the more purely chemical or hydric state.

The water, as contained in the strictly hydrous compounds, is customarily represented by the symbol  $\text{Aq}$ , which is an abbreviation of aqua, the Latin name for water. This character always follows the main symbol of the combination and is correctly separated therefrom by means of a comma interposed between them. Thus, hydrous calcium chloride is written  $\text{CaCl}_2,6\text{Aq}$ ; hydrous chlorine, the so-styled cryohydrate of chlorine, is  $\text{Cl},5\text{Aq}$ , and hydrous citric acid  $\text{H}_3\text{C}_6\text{H}_5\text{O}_7,\text{Aq}$ .

In ordinary practice even the empirical symbols of organic compounds are usually too cumbrous. For this reason a secondary symbolization is performed, whereby greater condensation and incidentally a better outline view of the salient traits of the compounds is attained.

This method consists in giving special forms to the radicle portions of the bodies and grouping these charac-



ters in accordance with the mutual affinities of the parts they represent.

Similar to the symbol of hydrous water, above given, these forms are derived from suitably abbreviating the ordinary names of the substances. Thus, the shortened symbol of cyanhydric acid is  $\text{HCy}$ ; of acetic acid  $\text{HAc}$ ; of valeric acid  $\text{HVa}$ ; of oleic acid  $\text{HOl}$ ; of lactic acid  $\text{HLc}$ ; of salicylic acid  $\text{HSl}$ ; of oxalic acid  $\text{H}_2\text{Oc}$ ,  $2\text{Aq}$ ; of succinic acid  $\text{H}_2\text{Su}$ ; of tartaric acid  $\text{H}_2\text{T}$ ; of mucic acid  $\text{H}_2\text{Mu}$ ; of citric acid  $\text{H}_3\text{Ci}$ ,  $\text{Aq}$ , and of meconic acid  $\text{H}_3\text{Mc}$ ,  $3\text{Aq}$ . Basic and certain allied radicles are represented in a similar manner. Thus, alcohol is written  $\text{Et}(\text{HO})$ ; ether  $\text{Et}_2\text{O}$ ; aldehyde  $\text{Me}(\text{CHO})$ ; acetone  $\text{Me}_2(\text{CO})$ , etc. Basic symbols of this kind are very little used and are, therefore, of no special consequence.

But, an important class of basic radicles is derived from ammonia and its substitution products. In these, however, different from the preceding kinds, the symbolization applies to the base directly. Hence, in these cases, the radicles are expressed by joining the basic symbol to that of hydrogen. This peculiarity of construction is due to the fact that the nitrogen in free ammonia is tripotent, whereas in the ammonium salts it is quinquopotent.

In the contracted form the volume symbol of ammonia,  $\text{NH}_3$ , is represented by the single letter  $\text{A}$ ; consequently, the radicle ammonium,  $\text{NH}_4$ , is then expressed by  $\text{AH}$ . On substituting this for a corresponding number of hydrogen units in the volume symbols of acids, or, which is the same thing, associating it with the symbols of acidic chemical units, the volume expressions for ammonium salts result. Then, for instance, ammonium acetate is



AHAc; commercial, or acidic ammonium valerate, is AHVa, HVa; triammonic citrate is  $(\text{AH})_3\text{Ci}$ , and monammonic citrate is  $(\text{AH})\text{H}_2\text{Ci}$ .

The so-called amines are compound ammonias, which result from substituting a part or all of the ammoniacal hydrogen by so-styled alcohol-radicles, that is, non-oxygenated hydrocarbon residues.

The amines, like ammonia, their source and prototype, are of a basic nature, generating definite salts with acids in a perfectly identical manner.

The so-called amides, although derivatives of ammonia, are not compound ammonias in the sense of the preceding group. The amides result from the replacement of the ammoniacal hydrogen through so-styled acid radicles, that is, oxygenated hydrocarbon residues. They are, therefore, according to the amount and kind of substitution that prevails, either acidic, neutral or feebly basic in their chemical deportment.

The group of so-called alkalamides results when the ammoniacal hydrogen is partly replaced by alcohol-radicles and partly by acid-radicles.

The large and important class of alkaloids, or vegetal alkalis, presents the nature of undoubted amines. Like these, they result from the substitution of the ammoniacal hydrogen, though by very complex radicles that are not often of a purely hydrocarbon character.

The alkaloids are, however, in the generality, of a decided basic disposition, neutralizing acids in a perfect manner exactly as ammonia does. With a few exceptions their basic power is inferior to that of ammonia, since this base usually liberates them from their salts.

Owing to the highly complex and cumbrous symbols



of the alkaloids, a properly shortened symbolic form becomes very desirable. Suitable abbreviations, based on the ammonia type, are easily derived from the ordinary names of the alkaloids. Thus, if quinine is represented by Qn, the sulphate will be  $(QnH)_2SO_4, 7Aq$ ; if cocaine is symbolized as Cc, the chloride will become  $CcHCl$ ; with morphine as Mr, the acetate is  $MrHA_2, 3Aq$ ; from strychnine as Sy, the nitrate is  $(SyH)NO_3$ , etc.

The names of the alkaloidal radicles and of the corresponding salts are based on the nomenclature of the ammonium salts. For instance, the quinine radicle,  $QnH$ , is termed quinium, and the respective salts are called quinium salts; as, for example, quinium chloride, quinium sulphate, etc.

The many illustrations, as above exhibited, fore-shadow that the chemical names of compounds are usually formed by the collective fragments of the names of their constituents. Incidentally, however, the specialty of a term is heightened by impressing it with a quantified character. Compounds are thus distinguished whose composition is varied by the numerical relation of their components.

The type of the body confers the characterizing form to its name. In the broad generality chemical names are founded on the peculiarities of type. Perhaps, the commonest class of chemical terms are the names of salts and similar substances. Titles indicating saline matters represent these by the form of the nomenclature as derivatives of acids; the derivation having reference to the introduction of definite proportions of a basic substance.

The substitution here intervening displaces an equivalent amount of hydrogen. In cases where the replacement



is incomplete the salt retains an acidic character, which fact is usually expressed in specific terms.

When halogen elements or other non-metallic units, or even compound radicles, are introduced by substitution, without altering the type or the affinity of the bodies thus affected, the nomenclature assumes a special form. Hence, when chlorine is thus compounded with methane, the chlorinated product is termed a chlormethane; with aldehydes, a chloraldehyde; with acid oxides in general, a chloranhydrate, etc.

When the nitric acid residue,  $\text{NO}_2$ , thus stands in lieu of hydrogen the product is a nitro-compound, and when the nitrous acid residue,  $\text{NO}$ , thus appears the substance becomes a nitroso-compound.

When the radicles, hydroxyl, methyl, methenyl, phenyl, etc., enter in place of hydrogen the respective hydroxyl, or hydroxy, methyl, methenyl, phenyl, etc., compounds are generated.

The names of salts derived from halogen acids, non-oxygenated acids and non-oxygenized chemical units generally terminate with *ide*; thus, chloride, sulphide, phosphide, cyanide, etc.

The names of salts of oxygen acids, derived from certain elements in the normal or most prevalent degree of oxidation are customarily ended with *ate*; thus, chlorate, sulphate, nitrate, etc.

Under a lower degree of oxidation the terms end in *ite*; thus, chlorite, sulphite, nitrite, etc.

With still lower orders of oxidation the ultimate remains *ite*, but the name is supplied with the prefix *hypo*; thus, hypochlorite, hypophosphite, hyponitrite, etc.

Contrarily: at the highest stage of oxidation the ending



remains *ate*, but the prefix becomes *hyper*, or conventionally *per*; thus, perchlorate, permanganate, etc.

Where the constituent radicles, both basic and acidic, of a compound are marked by a plurality in the various kinds the fact is designated numerically. Thus, when the acidic radicles predominate, there will be dichlorides, trichlorides, bisulphides, trisulphides, bisulphates, trisulphates, etc. Similarly, where the base preponderates, there are, for instance, dipotassic, tripotassic, etc., salts.

The ultimate in *yl* is a characteristic of terms signifying radicles, residues and unsaturated compounds generally, that have, as a rule, no separate existence in a free condition. This suffix is an abbreviation of the Greek *yle*, meaning wood, matter, substance, base, and principle. It is usually employed in reference to the latter sense. Thus, methyl implies the substance, or principle of methane. The term methyl is more immediately derived from methylic alcohol, that is, wood-alcohol. Methylic is a modified compound from the Greek *methy*, wine, and *yle*, wood—wine of wood, or wood-alcohol. It is sometimes considered as a derivation from the Greek words, *meta*, after, with, and *yle*, wood—as derived from wood.

### CHEMICAL FORMULÆ.

3. Perhaps the most important property of matter is that upon which the capacity for chemical transformation is founded. The progress and efficiency of chemical science is chiefly based on the successful study of the peculiar relations through which these changes are determined. A prominent feature of the science, therefore, consists in establishing the correlations of the units by



whose mutual interactions the various chemical compoundings are effected.

The results of greatest value are obtained from observations on the chemical phenomena of combination and decomposition. This, naturally, includes the principle of chemical substitution, which in fact is the corner-stone of the science in its present stage of development. For, in their manifest operation, chemical changes are, indeed, nothing more than reciprocal substitutions, or rather inter-substitutions, occurring between the constituents of different chemical volumes or among the components of the same chemical volume. The latter kind of substitution presents the remarkable and important alterations known as allotropy and isomerism.

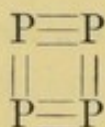
As already stated, a chemical volume equals two volumes of hydrogen gas, hence, also, a chemical volume of hydrogen equals two of its unit volumes, which represent two chemical units of the element. Therefore, a chemical volume of hydrogen contains two chemical units and is consequently symbolized by  $2\text{H}$ , or  $\text{H}_2$ . Since hydrogen is a monad, the simplest manner of expressing the chemical relation subsisting between the two units composing the volume is by the symbol  $\text{H—H}$ .

A chemical volume of water results from the condensation of two volumes of hydrogen with one volume of oxygen, forming two volumes of aqueous vapor. The chemical volume symbol of water, as previously given, is  $\text{H}_2\text{O}$ . This symbol expresses the preceding statement, and also shows that oxygen is here acting as a dyad. The chemical relation existing between the units of this chemical volume is shown by the analytical symbol  $\text{H—O—H}$ .



On now substituting oxygen for hydrogen the form  $O \equiv O$  is obtained as the chemical volume symbol of oxygen. By this process of substitution  $Fe \equiv Fe$  results from  $FeCl_2$ ;  $Fe \equiv Fe$  from  $FeCl_3$ ;  $C \equiv C$  from  $CO$ ;  $C \equiv C$  from  $CO_2$ , etc.

When, however, phosphorus combines with hydrogen half a volume of the former and three volumes of the latter condense to two volumes of  $PH_3$ . The substitution of phosphorus for hydrogen gives the symbol  $P \equiv P$ . But this expression represents only one volume of condensation, whereas  $PH_3$  equals two volumes. Therefore, the chemical volume symbol of phosphorus is  $P_2 \equiv P_2$ . But, as phosphorus is also a pentad the symbolization of its chemical volume can take the expanded form:



Arsenic is analogous to phosphorus in this respect.

Two volumes of mercury vapor and two volumes of chlorine contract to two volumes, and thereby generate mercuric chloride, having the symbol  $HgCl_2$ . Substituting mercury for chlorine, the form  $Hg \equiv Hg$  results. This, however, indicates four volumes of the metal, while  $HgCl_2$  occupies only two volumes. Therefore, the chemical volume symbol of mercury is  $\frac{1}{2}Hg - \frac{1}{2}Hg$  or  $Hg$ . That is, the chemical unit and the chemical volume of mercury take up equal spaces. Cadmium resembles mercury in this regard.

These examples illustrate the interesting fact that the chemical volumes of the elements, in general, contain two chemical units, excepting those of phosphorus and arsenic,



which possess four each, and those of mercury and cadmium, which have only one each.

The combination of two units of hydrogen with two units of oxygen engenders peroxide of hydrogen representable by the symbol  $\text{H—O—O—H}$ . On replacing the hydrogen with oxygen the product is ozone, or the so-called allotropic oxygen. It may accordingly be symbolized by  $\text{O—O—O}$ . This case, apparently, implies the curious circumstance of three chemical units in the chemical volume of an element, that normally presents but two. However, the chemical volume of ozone is not an elementary volume: it is strictly of a compound nature and differs in no particular from compound chemical volumes in general.

The so-called peroxides of the elements are based upon the bivalence of oxygen, although the elements here united with oxygen may appear to be performing the functions of much higher than their normal valence.

Thus, potassium peroxide is  $\text{K}_2\text{O}_2$ ; barium peroxide is  $\text{BaO}_2$ ; manganese peroxide is  $\text{MnO}_2$ ; lead peroxide is  $\text{PbO}_2$ , etc. But these oxides are the analogues of peroxide of hydrogen and of ozone, and should, therefore, be symbolized as  $\text{K—O—O—K}$ ,  $\text{O—Ba—O}$ ,  $\text{O—Mn—O}$ ,  $\text{O—Pb—O}$ , respectively.

The oxides of chlorine exhibit a peculiarly simple relationship by this method of symbolization. If, for instance, chlorine is substituted in a chemical volume of oxygen the product is hypochlorous oxide,  $\text{Cl—O—Cl}$ . No chlorine compound has been obtained, representing a substitution product, from one volume of ozone. But a corresponding chlorous acid exists having the symbol  $\text{Cl—O—O—H}$ . Substitution of chlorine in two chemical



volumes of oxygen yields chloric oxide,  $\text{Cl—O—O—O—Cl}$ . Similar replacement in two chemical volumes of ozone gives perchloric oxide,  $\text{Cl—O—O—O—O—Cl}$ .

The feeble stabilities of these chlorinated bodies characterize the ozone derivatives in particular. It will be noticed that this plan of constructing symbols shows that, while a common bond of union pervades the aggregation of a chemical volume, the various units do not necessarily always stand in immediate relation to each other.

The special advantage of this manner of formulation becomes notably pronounced in the symbolization of compounds distinguished by the conditions of isomerism.

It also incidentally exhibits, the marked difference between the states of true variable valence and those peculiar forms of union simulating real, or normal valence, yet, differing from both this and the former, and hence better described as apparent valence.

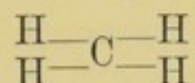
These analytical symbols are indifferently styled graphical formulæ, constitutional formulæ and structural formulæ. However, ambiguous implications are avoided by calling them simply chemical formulæ, as distinguished from chemical symbols merely.

Chemical formulæ are divided into two classes, possessed of marked peculiarities, and known as the open chain and closed chain types. Equally marked contrasts characterize the bodies to which they apply. The so-called inorganic compounds present these features indiscriminately, but the so-styled organic bodies are thereby separated into remarkably characteristic groups.

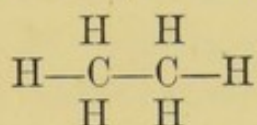
The closed chain type of the carbon combinations is divided into the three, four, five, six, seven, etc., carbon ring groups. The paraffin series of the carbon compounds



yields the most interesting and instructive examples of the open chain variety of unions. The simplest of these combinations is methane, represented by the formula:

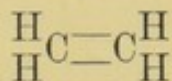


In this expression, the carbon is exhibited as acting by real, or normal valence as a tetrad. Ethane, the next higher member of the series, has the formula:



Here the carbon acts apparently as a tetrad, and likewise throughout the series after this. The state of apparent valence is an essential of the chain formation, since this order of union is largely dependent on the contiguous grouping of like units in the same assemblage.

In ethylene, or dimethylene, of the olefine series, the carbon is also apparently quadrivalent, as may be seen from its formula:



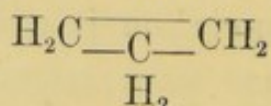
Methylene is incapable of existing in the free condition, yet its oxygen analogue, monoxide of carbon, or carbonous oxide, is a well-known gaseous compound having the formula  $\text{C} \equiv \text{O}$ . But, in this body the carbon is dyadic and thereby affords an illustration of variable valence.

The formula of cyanogen is  $\text{N} \equiv \text{C} - \text{C} \equiv \text{N}$ , in which the carbon is apparently quadrivalent. Cyanides result from this body, by substituting the respective basic radicles in place of the unipotent residue expressed by the form  $\text{N} \equiv \text{C} -$ . Another instance of variable valence, shown by carbon, is displayed in the isocyanides, or carbamines, where the nitrogen is trivalent, as in the cyanides, but

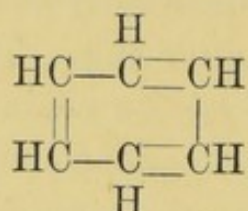


the carbon there is bivalent. Thus, the formula of methyl carbamine is  $\text{H}_3\text{C}-\text{N}=\text{C}$ .

Of the closed chain type of unions the simplest form is the three-carbon ring group. To this belong bodies whose formulæ partake of the trimethylene structure:

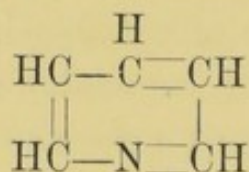


The most curious and significant of the closed chain type is the six-carbon ring group. Its principal member is benzene, the root of the so-called aromatic compounds, whose formula is usually expressed thus:

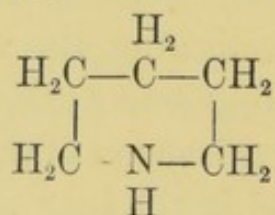


The carbon ring of this group is commonly known as the benzene-nucleus.

On substituting trivalent nitrogen for an  $\text{HC}\equiv$  residue in the benzene volume, the remarkable pyridine results, having the formula:



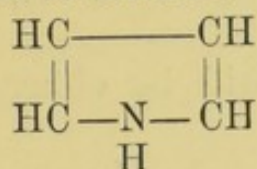
From the hydrogenation of this body, the still more remarkable additive product called piperidine is obtained, which is a hexa-hydropyridine. Its formula is:



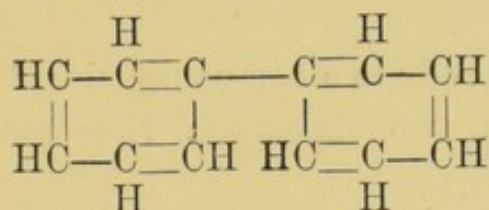
This represents it as an imido derivative of hexamethylene.



The substitution of an imido radicle,  $\text{HN}\equiv$ , for the bivalent residue,  $\begin{array}{c} \text{HC}— \\ || \\ \text{HC}— \end{array}$  in the benzene chain, yields the noted pyrroline, whose formula is:



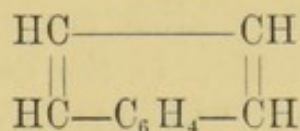
Closed chains in mutually uniting form compound chains. Thus, if two benzene residues of the composition,  $\text{H}_5\text{C}_6—$ , unite, diphenyl will result, having the formula:



The benzene residues, or phenyl groups, can also form a union through the medium of a different group, as in diphenyl-acetylene,  $\text{H}_5\text{C}_6—\text{C}\equiv\text{C}—\text{C}_6\text{H}_5$ .

But the most interesting and important mode of combination is presented by the more intimate union of the benzene-nuclei, as it occurs in naphthalene, anthracene, etc. If, as in the formulation of pyrroline, the bivalent benzene

residue,  $\begin{array}{c} \text{HC}— \\ || \\ \text{HC}— \end{array}$  in the formula of benzene, is replaced by the bivalent benzene residue,  $\text{H}_4\text{C}_6—$ , the expression will represent naphthalene. This formula is:

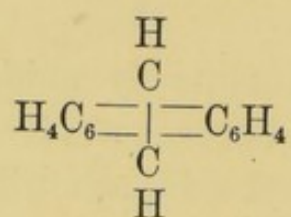


This manner of exhibiting the derivation places naphthalene in the six-carbon ring group. That, however,



does not alter its character as a compound chain, with a six-carbon ring group as a lateral chain. Now, if in a volume of naphthalene the quadrivalent benzene residue,

$$\begin{array}{c} \text{HC} \text{---} \\ | \\ \text{HC} \text{---} \end{array}$$
 is displaced by a second bivalent benzene residue,  $\text{H}_4\text{C}_6 \text{---}$ , anthracene will be obtained. Its formula is accordingly:



This shows the body as a compound closed chain, forming two four and two six-carbon ring groups, mutually dependent.

As previously stated, the principle of substitution, both in practice and theory, is one of the main supports in the study of chemical relations. It is applied with great advantage in the formulation of the hydrocarbons, known as paraffins. For instance, normal paraffins are such whose formulæ show each carbon-unit to be immediately contiguous to at most two other carbon-units; isoparaffins are such in which each carbon-unit is thus contiguous to three other carbon-units; neoparaffins are those in which every carbon-unit thus connects with four other carbon-units, and mesoparaffins are those consisting of a bivalent ethane residue associated with two univalent radicles. The first three kinds are substitution products of methane; the last kind, as the definition implies, are derivatives of ethane. The substitutions, whereby these various complex hydrocarbons result from simpler ones,



are, of course, effected by the replacement of hydrogen through means of hydrocarbon residues.

If hydroxyl is caused to enter as the displacing radicle, the important class of so-called alcohols results. Alcohols are monohydric or polyhydric, according to the number of hydroxyls their respective volumes contain. Thus: ordinary, or ethylic alcohol, is monohydric, as is seen from its formula,  $\text{H}_3\text{C}-\text{CH}_2-\text{OH}$ . Glycerin, glycerol, or propenyl alcohol, is trihydric, as is shown by its subjoined formula,  $\text{HO}-\text{H}_2\text{C}-\text{CH}(\text{HO})-\text{CH}_2-\text{OH}$ .

If, in a multi-carbon residue, the substituting hydroxyl group connects with a carbon unit that is immediately contiguous to only one other carbon unit, the resulting product is called a primary alcohol. When the hydroxyl residue is associated with a carbon unit that is in direct proximity to two other carbon units, the derivative is known as a secondary alcohol. Should the hydroxyl be united to a carbon unit, which stands also in direct relation to three other carbon units, the combination is said to be a tertiary alcohol. These compounds are more comprehensively described in other words, namely: a primary alcohol is such wherein the substitution of hydroxyl has taken place in a methyl residue,  $\text{H}_3\text{C}-$ , thus:  $\text{H}_2(\text{HO})\text{C}-$ ; a secondary alcohol is such wherein the hydroxyl enters a methylene residue,  $\text{H}_2\text{C}-$ , thus:  $\text{H}(\text{HO})\text{C}-$ ; a tertiary alcohol is such wherein the replacement occurs in a methenyl residue,  $\text{HC}-$ , thus:  $\text{HOC}-$ .

When, instead of hydroxyl, the substitution is effected by means of halogen elements, the products are analogous to the alcohols and are named haloid ethers. These are monchaloid or polyhaloid, according to the number of the



replacing units, just as in case of the monohydric and polyhydric alcohols. Similar to the corresponding alcohols these ethers are also primary, secondary and tertiary.

If the substituting units happen to be oxygenated acid radicles, the products are likewise analogous to the preceding compounds. They are called compound ethers, or ethereal salts. These ethers of oxygen acids are somewhat known by the name of esters.

Dehydration of alcohols, in analogy with the removal of water from hydrates, or hydroxides in general, results in the formation of alcoholic oxides, or oxygen ethers.

The abstraction of hydrogen from primary alcohols, through means of oxidation, yields so-called aldehydes having the same number of carbon units as the original alcohols. Thus, from ethyl alcohol,  $\text{H}_3\text{C}-\text{H}_2\text{C}-\text{OH}$ , the product is acetic aldehyde,  $\text{H}_3\text{C}-\text{CO}-\text{H}$ . From dihydric alcohols two classes of aldehydes result corresponding to the extent of the dehydrogenation. They are called first and second aldehydes respectively.

Secondary alcohols when similarly subjected to oxidation give rise to so-styled ketones, possessed of as many carbon units as are contained in the primitive alcohols. Thus, acetone, or methyl ketone, results from the partial oxidation of secondary propyl alcohol,  $\text{H}_3\text{C}-\text{CH}(\text{OH})-\text{CH}_3$ . Its formula is  $\text{H}_3\text{C}-\text{CO}-\text{CH}_3$ . Ketones may be considered as derived from aldehydes, by substitution of the aldehydic hydrogen with a univalent hydrocarbon radicle, which may be like or unlike that existing in the aldehyde.

When aldehydes are submitted to oxidation, bodies of the exceedingly important and numerous class of carboxylic acids are obtained. These can be viewed as



resulting from replacement of the aldehydic hydrogen, by means of hydroxyl. Thus, from acetic aldehyde,  $\text{H}_3\text{C—CO—H}$ , acetic acid,  $\text{H}_3\text{C—CO—OH}$ , is produced. It will be noticed that the characterizing residues of tertiary alcohols and of aldehydes are identical in composition, but not in form. The alcoholic residue is trivalent,  $\text{HO—C}\equiv$ , that of aldehydes univalent,  $\text{H—OC—}$ . Since many aldehydes are formed through the partial oxidation of primary alcohols, it follows that also many acids result from the more advanced oxidation of primary alcohols. The formulæ of carboxylic acids may, therefore, represent these as derivatives of primary alcohols, by substitution of the univalent group,  $\text{HO—CH}_2\text{—}$ , by the univalent so-called carboxyl group,  $\text{HO—CO—}$ .

In general, the derivation of carboxyl acids is conceived as effected from veritable hydrocarbons, by the substitution of carboxyl residues for an equal number of hydrogen units. Thus, ethane,  $\text{C}_2\text{H}_6$ , yields propionic acid,  $\text{H}_5\text{C}_2\text{—CO—OH}$ .

Formic acid is here exceptional, regarding the hydrocarbon origin. It is formulated, as derived, from a chemical volume of hydrogen,  $\text{H}_2$ , by the entry of a carboxyl residue for a hydrogen unit; the formula of formic acid being  $\text{H—CO—OH}$ .

The anomaly extends to carbonic acid, whose formula,  $\text{HO—CO—OH}$ , is from that of water, by the introduction of carboxyl for hydrogen.

Oxalic acid is still more anomalous, since it is not representable as a substitution product of this kind at all, it being a double carboxyl residue,  $\text{HO—CO—CO—OH}$ .

In numerous of the above described oxygen derivatives of hydrocarbons, sulphur, and on occasion selenium,



can take the place and perform the functions of oxygen; many of these analogous compounds are important and interesting.

The formulæ of carboxyl acids usually represent them as hydroxyl derivatives of oxygenated hydrocarbons. The names of the corresponding acido-residues are then conventionally terminated with the syllable *yl*. For instance, an aceto-residue,  $C_2H_3O-$ , is called acetyl; an oxalo-residue,  $C_2O_2-$ , oxalyl; a citro-residue,  $C_6H_5O_4-$ ; citryl, etc. These forms are often essential to the comprehensive exposition of special relations. However, they should not be confounded with the expressions known as acid radicles, properly so-called, and represented by the abbreviated form of notation previously explained.

It is frequently convenient to formulate acids in general as hydroxyl derivatives. This method is particularly useful where some peculiar relationship is to be portrayed. For example, nitrous acid is on occasion formulated as a nitroso-residue,  $NO-$ , termed nitrosyl, in combination with hydroxyl, thus:  $ON-OH$ . In the nitroso-compounds the nitrogen is trivalent.

Nitric acid has a similar formulation as a nitro-residue,  $NO_2-$ , named nitryl, in union with hydroxyl, thus:  $O_2N-OH$ . In the nitro-compounds the nitrogen is quinivalent.

A very curious and interesting case of isomerism results through the union and incident internal transformation of the nitrous-radicle with certain hydrocarbon residues. Nitrogen, as just stated, is a triad in the nitrites. If, however, the nitrous radicle, as contained in silver nitrite, is transferred to a paraffin residue a so-called nitro-paraffin results. Though the composition of nitroparaffins



is the same as that of nitrous ethers, yet, their nitrogen is pentadic. The explanation of this fact is not difficult: for, nitrites are converted into nitrates by direct oxidation, and that is simply the action that has here transpired.

It is seen from the formula of nitrous acid that its hydroxylic oxygen stands in immediate relation to the nitrogen. Likewise is this the case with nitric acid. Now if, say in ethyl nitrite,  $\text{H}_5\text{C}_2\text{—O—N=O}$ , the oxygen is transferred from the ethoxyl group, so as to be wholly in union with nitrogen, then nitroethane,  $\text{H}_5\text{C}_2\text{—N}\begin{smallmatrix} \text{=O} \\ \text{=O} \end{smallmatrix}$  is formed. Therefore, the nitroparaffins, nitrobenzenes, etc., are substitution products of nitric acid in which the hydroxyl is replaced by hydrocarbon residues. But, if only the hydroxylic hydrogen of nitric acid is replaced by such residues, alcoholic nitrates will result. Thus, the formula of ethyl nitrate is  $\text{H}_5\text{C}_2\text{—O—NO}_2$ . This important and remarkable analogy reappears in connection with the interesting compounds that are obtained on replacing the hydroxylic hydrogen of alcohols with simple metallic or compound units. They belong to the class of oxygen ethers. Their nomenclature is the same as that which is applied to salts of oxygen acids. To illustrate: ethylalcohol,  $\text{H}_5\text{C}_2\text{—O—H}$ , yields sodium ethylate,  $\text{H}_5\text{C}_2\text{—O—Na}$ , likewise ethylic ether, or ethyl ethylate,  $\text{H}_5\text{C}_2\text{—O—C}_2\text{H}_5$ ; and glycol, or ethylene alcohol,  $\text{H—O—C}_2\text{H}_4\text{—O—H}$ , gives potassium ethylenate,  $\text{K—O—C}_2\text{H}_4\text{—O—K}$ .

Different from, yet analogous to, the metal alcohols, the oxygen ethers and the haloid ethers, are the metal ethers. These are the products which result from substituting metal units for hydroxyl in the alcohols. The nomenclature of these curious compounds is based on



their analogy with haloid salts, just as that of the metal alcohols is derived from the naming of the salts of oxygen acids. The metal ethers are an important and rather extensive group. For example, there is sodium ethide,  $\text{Na}-\text{C}_2\text{H}_5$ ; zinc methide,  $\text{H}_3\text{C}-\text{Zn}-\text{CH}_3$ ; mercuric amylide,  $\text{H}_{11}\text{C}_5-\text{Hg}-\text{C}_5\text{H}_{11}$ ; aluminum methide,  $\text{Al}(\text{CH}_3)_3$ , and plumbic ethide,  $\text{Pb}(\text{C}_2\text{H}_5)_4$ .

To this group also belong the analogous boron and silicon compounds. It likewise extends to the similarly constituted bismuth, antimony, arsenic and phosphorus combinations with alcohol radicles.

The four elements last named are both triads and pentads, but they unite with alcohol radicles alone only when acting trivalently. The quinquivalent unions contain at most four alcohol radicles combined with some other unit or units, elemental or compound, in addition to the hydrocarbon residues. These combinations of the pentad elements foreshadow the similar nitrogen compounds, namely: the marvelous compound ammonias, alcoholic ammonias, or amines.

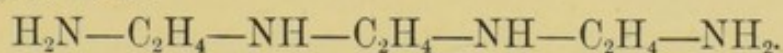
The amines are basic bodies like ammonia. Their nitrogen, as in ammonia, is trivalent. They generate salts with acids on the principle that ammonia does, the nitrogen thereby becoming a pentad. The amines are distinguished as primary, secondary and tertiary, according to the amount of substitution that has taken place in an ammonia volume. For example, methylamine is primary, and is formulated thus:  $\text{H}_3\text{C}-\text{N}-\text{H}_2$ ; diethylamine is secondary, and is represented by  $(\text{C}_2\text{H}_5)_2-\text{N}-\text{H}$ , and triamylamine is tertiary, having the formula:  $(\text{C}_5\text{H}_{11})_3-\text{N}$ .

Amines unite energetically with iodides of univalent radicles, wherefrom saline compounds result, that are con-



stituted on the plan of the ammonium salts. These salts are converted by moist silver oxide into powerful caustic bases. For instance, triethylamine and ethyliodide generate tetrethylammonium iodide, which yields tetrethylammonium hydroxide, having the formula:  $(C_2H_5)_4\equiv N-OH$ .

Amines are further divided into monamines, diamines, triamines, etc., according to the number of ammonia volumes that are represented in a volume of the respective amines. Thus, a monamine is derived from a single volume of ammonia; a diamine from a double volume; a triamine from a triple volume, etc. The formula of triethylene diamine is:  $H_4C_2\equiv N-C_2H_4-N\equiv C_2H_4$ ; of methenyl diamine it is:  $H-N\equiv CH-N\equiv H_2$ ; of guanidine, or carbotriamine, it is:  $H-N\equiv C\begin{smallmatrix} NH_2 \\ NH_2 \end{smallmatrix}$  and of triethylene tetramine it is:



The formulæ of the polyamines show that in these compounds the nitrogen units are not contiguous, but that they are connected through the medium of multivalent alcohol radicles.

There is an interesting and important class of bodies, known as the azo and diazo groups, in which the nitrogen units stand in immediate relation to each other. The azo compounds consist of two univalent benzene residues in combination with two units of trivalent nitrogen. For example, the formula of azobenzene is:  $H_5C_6-N\equiv N-C_6H_5$ .

The diazo group contains bodies consisting of two units of trivalent nitrogen, combined with a benzene residue and a monobasic acid radicle or a haloid unit. Thus, the formula of diazobenzene nitrate is:  $H_5C_6-N\equiv N-NO_3$ .

The hydrazine bases, like the two preceding groups,



represent two immediately united trivalent nitrogen units, combined with two hydrogen units and two alcohol radicles or three hydrogen units and one alcohol radicle. They closely resemble the amines, and may be viewed as derivatives of a hypothetical monamine, represented by the formula:  $\text{H}_2\text{N}-\text{NH}_2$ . In uniting with acids they generate saline compounds analogous to the ammonium salts, one of the nitrogen units, thereby becoming quinquivalent. The formula of phenyl hydrazine is  $\text{H}_5\text{C}_6-\text{NH}-\text{NH}_2$ ; of diethyl hydrazine it is:  $(\text{H}_5\text{C}_2)_2-\text{N}-\text{NH}_2$ .

Hydroxyamines are hydroxyl derivatives of ammonia; when containing hydrocarbon residues they are known as hydramines. The simplest and typical member of the group is hydroxylamine. It is a compound ammonia resulting from the substitution of one hydroxyl group for a unit of hydrogen. Its formulation is therefore:  $\text{H}_2\text{N}-\text{OH}$ .

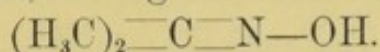
The hydramines, although being compound ammonias containing hydroxyl, are not constructed on the hydroxylamine type. In the hydramines the constituent hydroxyl is an exclusive adjunct of the hydrocarbon residue, and, therefore, does not immediately connect with the nitrogen, which is here believed to be trivalent, as in hydroxylamine. To illustrate, triethylene-hydramine is formulated thus:  $\text{N} \equiv [\text{C}_2\text{H}_4(\text{OH})]_3$ .

The formulation of the hydramines is also consistent with quinquivalent nitrogen, and, indeed, a number of these compounds are represented by such formulæ. The generation of the hydramines, by direct union of certain alcoholic oxides with ammonia or monamines, in the presence of water, favors the view that in the hydramines the nitrogen is quinquivalent.

When hydroxylamine reacts with aldehydes, ketones



and ketonic acids the so-called isonitroso-compounds, or hydroximides, result. Thus, from acetone hydroximido-acetone is obtained, having the formula:

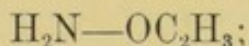


The bivalent residue,  $\text{HO—N—}$ , is known as the isonitroso, or hydroximido-group, being the imide radicle,  $\text{HN—}$ , having its hydrogen replaced by hydroxyl. These interesting bodies are also formed by the reaction of nitrous acid with certain alcoholic derivatives. The nitrous acid interaction results in the replacement of two units of hydrogen by a hydroximide group, whereas in case with hydroxylamine a unit of oxygen is similarly replaced.

Amides, as already alluded to, are, like amines, derivatives of ammonia, with this difference, that the substituting units are acid-residues. Like the amines they are divided into primary, secondary and tertiary amides. They are likewise distinguished as monamides, diamides, triamides, etc.

The simple term, amide, is more especially restricted to primary monamides; they contain the univalent amide-residue, amidogen,  $\text{H}_2\text{N—}$ , combined with a univalent acid-residue. But secondary and tertiary amides of monohydric acids are designated as diacid and triacid amides.

To exemplify: the formula of acetamide is:

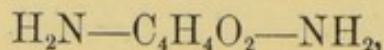


of diacetamide it is:  $\text{HN—(OC}_2\text{H}_3)_2$ , and of triacetamide:  $\text{N—(OC}_2\text{H}_3)_3$ . Secondary monamides containing bivalent acid-residues are commonly called imides. They contain the bivalent imide-residue, or imidogen:  $\text{HN—}$ . Thus, the formula of succinimide is:  $\text{HN—C}_2\text{H}_4(\text{CO})_2$ .

Dibasic acids give rise to primary diamides. For instance, succinamide and oxamide, or oxalamide, are



respectively produced when a succinic acid or oxalic acid residue takes the place of two units of hydrogen in two ammonia volumes. Succinamide is formulated by:



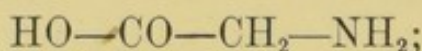
and oxalamide by:  $\text{H}_2\text{N}-\text{C}_2\text{O}_2-\text{NH}_2$ .

If the alcoholic and the carboxylic hydroxyl of dihydric monobasic acids is simultaneously replaced by imidogen, imides of monobasic acids are produced. For

example, the formulation of lactimide is:  $\text{HN} \begin{array}{c} \text{CO} \\ \text{---} | \\ \text{CH}-\text{CH}_3 \end{array}$ .

Dihydric monobasic acids also yield two kinds of amides, alike in composition but unlike in constitution, when either the carboxylic or the alcoholic hydroxyl is singly replaced by amidogen. These amides are, however, isomeric, not identical; the former substitution products are neutral bodies while the latter are acidic substances, described as amic, amidic, or amido acids.

By replacing either a part of the alcoholic hydrogen of monohydric acids, or the alcoholic hydroxyl of dihydric monobasic acids, by means of ammonia residues, the production of amic acids is also attained. This manner of substitution makes it manifest that identical results will be produced from either the original acids or their hydroxyl derivations. For, the residue resulting from the removal of a hydrogen unit from acetic acid is, evidently, the same as that which remains after depriving glycollic acid of its alcoholic hydroxyl. In each case the product will be the residue:  $\text{HO}-\text{CO}-\text{CH}_2-$ . Consequently, acetamic, or amido acetic acid, is the same as glycollamic acid:



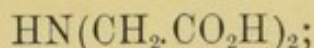
and propionamic acid is only another name for lactamic



acid:  $\text{HO}-\text{CO}-\text{CH}-\begin{smallmatrix} \text{NH}_2 \\ \text{CH}_3 \end{smallmatrix}$  first isomer, and

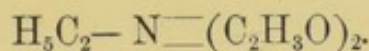
$\text{HO}-\text{CO}-\text{CH}_2-\text{CH}_2-\text{NH}_2$ , second isomer.

There are three acetamic acids analogous to the three acetamides. The formula of diacetamic acid is:



and of triacetamic acid:  $\text{N}(\text{CH}_2.\text{CO}_2\text{H})_3$ . Various other amic acids are obtained from polyhydric and polybasic acids. The amidated derivatives of carbonic acid constitute an interesting and remarkable group of compounds.

Alkalamides, as previously indicated, are derivatives of ammonia containing both alcoholic and acid residues. For example, ethyl acetamide, which is a secondary monamide, has the formula:  $\text{H}_5\text{C}_2-\text{NH}-\text{C}_2\text{H}_3\text{O}$ . Ethyl diacetamide is a tertiary monamide whose formula is:



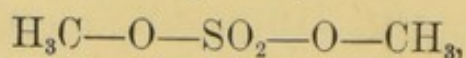
The so-called anilides belong to this group of compounds, from which in their general characters they differ in no particular. As there is no special advantage in the title it is scarcely warranted. The formula of acetanilide, or phenyl acetamide, is:  $\text{H}_5\text{C}_6-\text{NH}-\text{C}_2\text{H}_3\text{O}$ .

In a prior statement the fact was cited that there is a marked difference between the composition and constitution of acid radicles and acid residues respectively. The abstraction of hydrogen yields the former, whilst the rejection of hydroxyl engenders the latter forms. The saline derivatives of acids, resulting from the replacement of the hydroxylic hydrogen, are curiously unlike the products which result when the whole hydroxyl group is replaced.

To illustrate: if in sulphuric acid, represented by the



formula:  $\text{HO—SO}_2\text{—OH}$ , the hydrogen is substituted by methyl, then neutral methyl sulphate:



is obtained. When only half the hydrogen is thus replaced the product is methyl-sulphuric acid, or acid methyl sulphate:  $\text{H}_3\text{C—O—SO}_2\text{—OH}$ . In general, the substitution of alcohol radicles for hydrogen only, in sulphuric acid, results in the formation of normal sulphuric ethers. If but half the hydrogen is thus abandoned the production of acid sulphuric ethers, or alcoholated sulphuric acids is effected.

On wholly substituting the hydroxyl of sulphuric acid by means of hydrocarbon residues, the resulting products are called sulphones. If, however, only half the hydroxyl suffers removal in this manner the new compounds thereby obtained are denominated sulphonic acids.

In general, a sulphonic acid is an unsymmetrical sulphurous acid,  $\text{H—SO}_2\text{—OH}$ , having its unoxxygenated hydrogen unit replaced by various univalent residues. Thus, the formula of nitrosulphonic acid is:  $\text{NO}_2\text{—SO}_2\text{—OH}$ . This remarkable compound results from the interaction between strong nitric acid and sulphurous oxide. It is the product of several other reactions, and constitutes the curious lead-chamber crystals that occasionally form during the manufacture of sulphuric acid.

The alcoholic sulphonic acids are identical with the acid ethers of unsymmetrical sulphurous acid. The sulphonic acids of the methane derivatives are, indeed, prepared by reacting on the haloid ethers of the so-called fatty hydrocarbons with sodium or potassium sulphite. They are likewise obtained by oxidizing the hydrosul-



phides, sulphides and thiocyanates of these hydrocarbons by means of nitric acid.

The sulphonic acids of benzene and its derivatives are also producible in this way, but they are more directly and conveniently procured by acting on these hydrocarbons and their substitution products with concentrated sulphuric acid.

No sulphones of the methane group have been produced, neither can the sulphonic acids of the fatty series be prepared by the sulphuric acid reaction.

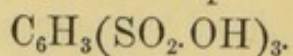
At first appearance, it seems rather strange that bodies of such diverse origins as the sulphonic acids are, should be identical in constitution and likewise in composition, where the alcoholic residues are the same. Their oneness in character is shown by the circumstance of the pronounced all-round stability, and by the further fact that on fusion with potash they yield potassium sulphite and corresponding alcohols.

It was seen that in case of the amic acids, as derived from monohydric and dihydric monobasic acids, the products are identical. This is true for the same reason of the sulphonic acids, whether produced from sulphuric acid or from unsymmetrical sulphurous acid. For, just as glycollic acid is a hydroxyl substitution of acetic acid so is sulphuric acid a similarly substituted derivative of unsymmetrical sulphurous acid. Hence, there can be no chemical difference between the bodies resulting from the replacement of the hydrogen unit in sulphurous acid,  $\text{H}-\text{SO}_2-\text{OH}$ , and a hydroxyl group in sulphuric acid,  $\text{HO}-\text{SO}_2-\text{OH}$ .

When a benzene residue is the replacing agency the substance obtained in each case is benzenesulphonic acid,



having the formula:  $\text{H}_5\text{C}_6\text{—SO}_2\text{—OH}$ . On the same plan the formulation of benzenetrisulphonic acid is:



Owing to the perfectly symmetrical nature of the benzene volume, its mono-derivatives display no isomerism. But the multiple derivatives resulting from the replacement of two or more hydrogen units present isomeric characters. These modifications are represented in the formula of benzene by the relative positions that are assigned to the replacing units. This method of exhibiting the isomeric differences is described as orientation. As previously stated, the respective places are known as the ortho, meta and para positions. Where the substituting units are all alike their relative attitudes, in known compounds, are now mostly ascertained; where, however, an unlikeness prevails the difficulty of location is much greater.

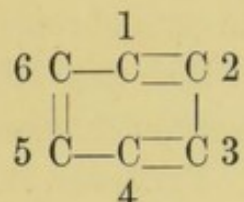
The complication is still further increased where isomerism incidentally occurs in the lateral chains, should such be present in the compound.

The order of succession among the newly incumbent units is described as consecutive, unsymmetrical and symmetrical. To the first belong forms in which the replacing units are contiguous to each other; in the second division they alternate with one hydrogen unit, and in the third two hydrogen units are interposed between them.

As already remarked, the replacement of one hydrogen unit by a foreign unit results in only one modification; but two, three or four newly entering like units admit, in each case, of three possible modifications; whereas five or six such simultaneous replacements can give rise to only one kind of product in each case. These various



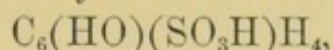
conditions are made more manifest when the positions in the formula of the benzene-nucleus are indicated numerically, thus:



The isomeric states as occurring in the principal chain may also be represented by a more condensed symbolic form, as, for example, in the three dichlorobenzenes,  $\text{C}_6\text{ClClH}_4$ ,  $\text{C}_6\text{ClHClH}_3$  and  $\text{C}_6\text{ClHHClH}_2$ . The first symbol shows the ortho, the second the meta, and the third the para modification.

If in the formation of substitution products only one kind of such product results, the chemical process that supervenes is designated as a clean reaction. In many instances, particularly with high temperature or in the presence of certain very powerful chemical agents, more than one isomeric product is obtained.

Under such circumstances either no ortho-compounds are found or these, when present, are largely contaminated with the para-compounds. The ortho product is doubtless generated first, but is subsequently more or less rapidly and completely converted into the other modifications. For instance, in the preparation of the phenolsulphonic acids the ortho-acid is the sole product at ordinary temperatures; but under heat the para-acid almost entirely results. The rational symbol of the ortho-acid is:



and of the para-acid:  $\text{C}_6(\text{HO})\text{H}_2(\text{SO}_3\text{H})\text{H}_2$ .

While in various connections there appears a peculiar proneness to transition from the ortho to the para state;



the resistance again of the ortho form to certain oxidizing influences is equally remarkable.

In the meta and para position oxidation by means of a mixture of potassium pyrochromate and sulphuric acid is curiously effective. But this mixture exerts no influence on the ortho-compounds, excepting in so far as to utterly destroy them. However, if instead potassium permanganate is here employed the alteration is very satisfactorily effected.

The change of ortho-compounds by oxidation without transforming the orientation of the affected units is well exemplified by the following instances: Toluene, which is monomethyl benzene, is treated with pyrosulphuric acid, whereby it is converted into a mixture of ortho and para toluene-sulphonic acids. The rational symbols of these acids are:  $C_6(CH_3)(SO_2.OH)H_4$ , and

$C_6(CH_3)H_2(SO_2.OH)H_2$ , respectively.

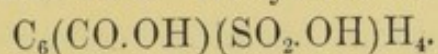
If these mixed acids are diluted with water, then neutralized with potassium carbonate, the saline solution evaporated to perfect dryness and the residue treated with phosphorus pentachloride, a mixture of ortho and para toluene sulphonic chloride will be obtained. The former is a liquid body while the latter is a solid. They are separated by emergence with water and filtration. The liquid chloride passes through the filter along with the water, in which, however, it is insoluble. Its rational symbol is:  $C_6(CH_3)(SO_2.Cl)H_4$ .

On treatment with strong ammonia water this ortho-toluene sulphonic chloride is converted into orthotoluene sulphonamide, whose symbol is:  $C_6(CH_3)(SO_2.NH_2)H_4$ . This body is insoluble in water, but on heating it with a weak solution of potassium permanganate it suffers oxida-

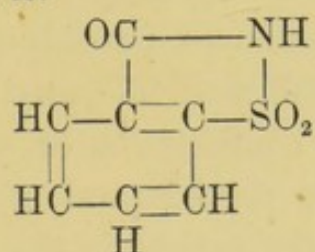


tion, and yields a perfectly colorless solution, after the excess of permanganate has been appropriately reduced and the precipitated peroxide of manganese is separated by filtration.

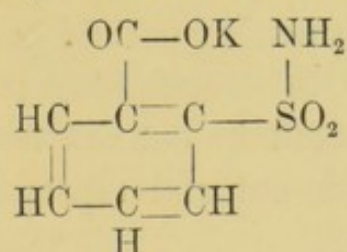
The water-white liquor contains two remarkable substances, in the condition of neutral potassium salts, which are the sole products of the reaction containing benzene residues. One of these is orthobenzosulphonic acid, or ortho-sulphobenzoic acid. Its symbol is:



The other is a far more interesting and peculiar body, that precipitates in a crystalline form when the saline liquor is acidified with chlorhydric acid. The substance is known in commerce as saccharin. Chemically it is an acidic anhydrate presenting the character of an imido-compound; and hence appropriately called benzosulphonimide. Its formula is:



When this curious compound becomes salified the resulting salts are substituted orthobenzoates, not sulphonates. For instance, the formula of the potassium salt is:

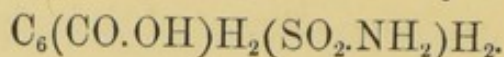


This shows the saline product to be an amido-compound, and hence it is properly called potassium orthosulphon-



amido benzoate. It also indicates it to be the potassium derivative of the hypothetical orthosulphonamido benzoic acid.

The corresponding para-acid, however, has an independent existence and whose rational symbol is:



### CHEMICAL EQUATIONS.

4. Stability in chemical compounds is largely dependent on the maintenance of uniformity in the conditions under which they abide. Beyond certain limits of temperature, especially of a rising degree, an otherwise simple transformation may become extremely complicated.

To illustrate: if, for instance, under prevalent conditions two bodies chemically reacting, generate a single body, at a higher heat they may cause a product consisting of two new substances, possibly differing from both the originals. At still more elevated temperatures, incidentally aided by confinement or pressure, or by the transference of the partial product from the range of further interaction, the variety in the final result is liable to increase, often to an astonishing extent.

Under all circumstances of chemical interchange the sum total of the material undergoing reaction invariably remains the same, it neither partaking of increase or suffering diminution. In all such cases it is, however, essential to know the result in definite form, and hence the reactions are traced out and represented by means of chemical equations.

When the interchange is simply delineated as taking place between the chemical volumes of various bodies, the



representation is merely termed an equation of reaction. It is expressed in the symbols of chemical volumes and often, for convenience sake, in symbols of chemical units, when the reacting bodies are elementary.

Where the quantified nature of a reaction comes into account, the numerical statement involves the unit-weights of the bodies, and the expression, therefore, becomes an equation of product. An equation of product is usually placed in the form of a so-called proportion, or equality of ratios. This is done because these purely mathematical expressions serve to ascertain the amount of product yielded by the interacting substances whose actual quantities and volume-weights or unit-weights are known.

Equations of reaction are not purely mathematical, their validity would remain unimpaired though the volume-weights or unit-weights of the matters were unknown.

The only mathematical requisites to an equation of reaction are the plus sign, +, and the sign of equality, =.

The minus sign, -, is occasionally used to denote the removal of certain constituents from compounds, thereby indicating decomposition. But the employment of the minus sign in this connection is based on a wholly wrong conception of the involved principles. It clashes directly with the most fundamental trait of chemical change, namely: that no matter disappears from the region of the accountable during any chemical transformation. In the application of the minus sign the right hand member of the equation shows less than there was of the original matter started with, and fails to explain its absence. In fact the whole expression, correct enough algebraically, utterly lacks the essentials of a chemical equation. The expression, however, becomes chemically consistent on



transposing the negative symbol also, it thereby becoming positive.

On many occasions a chemical equation, although perfectly accurate for certain conditions, as for instance a given temperature, or the presence of a peculiar medium, determinant of a particular reaction, does not represent the facts when the conditions are changed. In such connection the prevailing state needs always to be designated.

The order in which interacting compounds are successively merged is often a very important consideration, the nature and composition of the products being in respective accordance widely different.

Furthermore, very deep and remarkable chemical changes are effected by the presence, in mere contact, of apparently indifferent bodies. These alterations are seemingly performed through the intermediation of such agents regardless of chemical equivalence. Indeed, a comparatively trivial quantity usually suffices to insure amazingly extensive results. This curious activity, for want of a better knowledge concerning the nature of its mechanism, is known as catalysis, from the Greek *katalyein*, to destroy, dissolve, from *kata*, down, and *lyein*, to loose. No other form, for indicating this agency, is in use than the volume symbol, of the body bearing it, interpolated in both members of the chemical equation which represents the reaction.

Unless otherwise stated, the changes expressed by chemical equations are those taking place in the presence of water as a medium of the interaction. Hence, the water thus acting is never symbolized, its necessary presence being understood.

It is convenient to employ a special sign for denoting

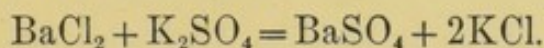


precipitates and gaseous products. For this purpose a dash is placed immediately under the symbol of the precipitated body. When the dash appears just above a symbol it means that the substance thus distinguished is a gas.

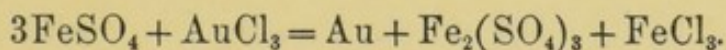
Equations of reaction are illustrated by the following examples: Water brought in contact with sulphuric oxide generates sulphuric acid:  $\text{H}_2\text{O} + \text{SO}_3 = \text{H}_2\text{SO}_4$ .

Potassium carbonate added to dilute sulphuric acid produces potassium sulphate, water and dioxide of carbon:  $\text{K}_2\text{CO}_3 + \text{H}_2\text{SO}_4 = \text{K}_2\text{SO}_4 + \text{H}_2\text{O} + \overline{\text{CO}_2}$ .

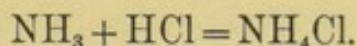
If solutions of barium chloride and potassium sulphate are mixed barium sulphate is precipitated and potassium chloride remains in solution:



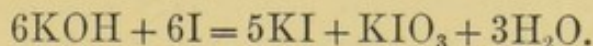
Ferrous sulphate and auric chloride when brought together in solution give rise to metallic gold, ferric sulphate and ferric chloride:



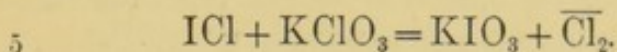
Ammonium chloride is formed when ammonia water and dilute chlorhydric acid are mixed together:



On mixing solution of potassa and iodine, potassium iodide, potassium iodate and water result:

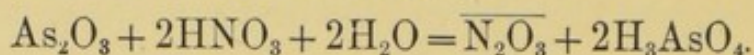


Chlorine passed into water holding iodine, in suspension, dissolves the latter and forms iodine monochloride; its solution when warmed with potassium chlorate yields potassium iodate and free chlorine:

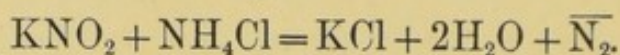




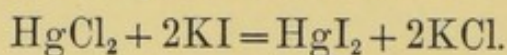
By heating arsenious oxide with slightly diluted nitric acid gaseous nitrogen trioxide, or nitrous oxide is evolved and arsenic acid results in solution:



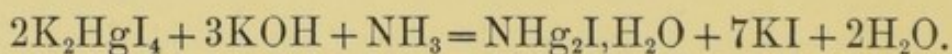
The passage of nitrous oxide into a solution of potassic hydrate produces potassium nitrite; and this when boiled with solution of ammonium chloride gives potassium chloride, water and free nitrogen:



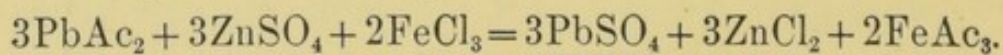
When solutions of mercuric chloride and potassium iodide are mixed together mercuric iodide is precipitated and potassic chloride goes into solution:



Mercuric iodide is readily dissolved by solution of potassic iodide generating potassio-mercuric iodide, or mercuriodide of potassium; this when mixed with solution of potassium hydroxide and ammonia water engenders a precipitate of hydrous dimercurammonium iodide, potassium iodide and water:



The mixture of solutions of lead acetate, zinc sulphate and ferric chloride in the order of succession named gives lead sulphate, zinc chloride and ferric acetate. The product is a pure white, heavy, precipitate and a red liquor gradually becoming turbid and colorless when subsidence of the light-brown flocculent secondary precipitate of ferric oxyacetate is complete:



When the order of union is ferric chloride, zinc sulphate and plumbic acetate, a colorless liquor and a bulky



buff-colored precipitate immediately result. The reaction in this case is difficult to decipher, but the precipitate is probably an indefinite combination of plumbic sulphate and basic ferric acetate.

Equations of product are extremely useful and even necessary aids in the extemporaneous preparation of many compounds. The following are several illustrations: How many grains of salicylic acid and bicarbonate of sodium are required to produce 100 grains of sodium salicylate? The needed amounts are, of course, proportional to the combining weights of the agents that are employed and to the volume weight of the intended product. The volume weight of salicylate of sodium,  $2\text{NaSa}, \text{H}_2\text{O}$ , is 338; of salicylic acid, 138, and of bicarbonate of sodium, 84; hence:

$$338 : 2(138) = 100 : (81.66)$$

and

$$338 : 2(84) = 100 : (49.70)$$

Again, how many grains of quinium sulphate and sodium chloride are required to produce 100 grains of quinium chloride, in the presence of alcohol? The volume weight of quinium chloride,  $\text{QnHCl}, 2\text{H}_2\text{O}$ , is 396.4; of quinium sulphate,  $(\text{QnH})_2\text{SO}_4, 7\text{H}_2\text{O}$ , 872 and of sodium chloride,  $\text{NaCl}$ , 58.4; hence:

$$2(396.4) : 872 = 100 : (110.0)$$

and

$$396.4 : 58.4 = 100 : (14.73)$$

Further, how much hydrous water does 100 grains of crystalline potassium alum contain? The volume-weight of alum,  $\text{AlK}(\text{SO}_4)_2, 12\text{H}_2\text{O}$ , is 474 and the volume-weight of water,  $\text{H}_2\text{O}$ , is 18, hence:

$$474 : 12(18) = 100 : (45.57).$$



From these examples it will be observed that the weight of the factors of product is ascertained by the comparison of equal numbers of either the same kind or correlated volume-weights or unit weights. For instance, in the last example above given, it will be seen that the chemical volume of alum contains 12 volumes of water; consequently the volume-weight of alum is compared with 12 volume-weights of water in order to find by calculation the actual amount of water it contains.

In an extensive practice it is very convenient to record the numerical factors, entering into 100 parts of product, in a tabulated form. Tables of this kind are one of the prime essentials in the systematic application of equations of product in the procedures of operative chemistry.



# INDEX.

## A

Acetone, 46.  
 Acid, 8.  
   acetic, 28, 32.  
   chlorhydric, 27.  
   cyanhydric, 32.  
   fluoboric, 11.  
   fluohydric, 11.  
   hypophosphorous, 27.  
   nitric, 27.  
   nitrosulphonic, 56.  
   orthobenzosulphonic, 61.  
   parasulphonamido benzoic, 62.  
   radicles, 55.  
   residues, 55.  
   sulphydric, 27.  
   sulphuric, 27, 57.  
   sulphurous unsymmetrical, 56, 57.  
 Acidic, 8.  
 Acido-residues, 48.  
 Acids, 12.  
   amic, 54, 57.  
   amido, 54.  
   carboxylic, 46, 47, 48.  
   meta, 12.  
   oxygen, 35.  
   phosphoric, 27.  
   pyro, 12.  
   sulphonic, 56, 57.  
     alcoholic, 56.  
     benzene, 56.  
     phenol, 59.  
 Alcohol, primary, 45.  
   secondary, 45.  
   tertiary, 45.  
 Alcoholic nitrates, 49.  
   oxides, 46.  
 Alcohols, 45.  
   monohydric, 45.  
   polyhydric, 45.

Aldehydes, 46, 47.  
   first, 46.  
   second, 46.  
 Alkalamides, 33, 55.  
 Alkaloids, 33.  
 Allotropy, 37.  
 Alloys, 4.  
 Alumina, 27.  
 Aluminum, 18.  
 Amalgam ammoniacal, 4.  
 Amides, 33, 53.  
 Amidogen, 53.  
 Amines, 33, 50.  
   primary, 50.  
   secondary, 50.  
   tertiary, 50.  
   di, 51.  
   mon, 51.  
   poly, 51.  
   tri, 51.  
 Ammonia, 28.  
 Ammonias, alcoholic, 50.  
   compound, 33, 50.  
 Anhydrates, 8.  
 Anilides, 55.  
 Anthracene, 44.  
 Antimony, 3, 22.  
 Arsenic, 5, 22, 38.  
 Atomicity, 6.  
 Azo group, 51.

## B

Barium, 17.  
 Bases, 8.  
 Basic, 7.  
 Benzene, 13, 42.  
 Benzene-nucleus, 42, 59.  
 Benzosulphonimide, 61.  
 Beryllium, 18.  
 Bismuth, 20.

Boron, 24.  
   fluoride, 11.  
 Bromine, 23.

## C

Cadmium, 5, 20, 38.  
 Cæsium, 16.  
 Calcium, 17.  
 Carbamines, 41.  
 Carbon, 24.  
 Carboxyl, 47.  
 Cast-iron, 4.  
 Catalysis, 64.  
 Cerium, 18.  
 Chains, closed, 40.  
   lateral, 58.  
   open, 40.  
 Chemical attraction, 3, 4.  
   equations, 62.  
   formulae, 36.  
   potency, 6.  
   principles, 1.  
   substitution, 7, 37.  
   symbols, 15.  
   terminology, 14.  
   unit, 3, 5, 6, 15, 37.  
   volume, 5, 15, 26, 37.  
 Chemism, 4.  
 Chlorinated, 35.  
 Chlorine, 23.  
   oxides, 39.  
 Chromium, 18.  
 Clean reaction, 59.  
 Cobalt, 19.  
 Compounds, aromatic, 13, 42.  
   ortho, 59.  
     oxidation, 60.  
   para, 59.  
 Copper, 20.  
 Cyanogen, 41.



**D**

Diazo group, 51.  
Didymium, 18.  
Diphenyl, 43.  
Double-decomposition, 7.

**E**

Elements, 3.  
  perissad, 11.  
Equations, chemical, 62, 63.  
  of product, 63, 67, 68.  
  reaction, 63, 65.  
Erbium, 18.  
Esters, 46.  
Ethane, 41.  
Ethers, compound, 46.  
  haloid, 45.  
  monohaloid, 45.  
  oxygen, 46.  
  polyhaloid, 45.  
Ethyl nitrate, 49.  
  nitrite, 49.  
Ethylene, 41.

**F**

Fluoborates, 11.  
Fluorine, 23.  
Formulae, chemical, 36, 40.  
  constitutional, 40.  
  graphical, 40.  
  structural, 40.

**G**

Gallium, 19.  
Germanium, 22.  
Gold, 3, 22.

**H**

Hydramines, 52.  
Hydrates, acidic, 8.  
  basic, 8.  
Hydrazine bases, 51.  
Hydric, 31.  
Hydrites, 29.  
Hydrogen, 23.  
  peroxide, 26, 39.  
Hydrous, 31.  
Hydroxides, 8.  
Hydroximides, 53.  
Hydroxyamines, 52.  
Hydroxyl, 8, 45, 47.  
Hydroxylamine, 52.

**I**

Imides, 53.  
Imidogen, 53.  
Indium, 19.  
Iodine, 23.  
Iridium, 22.  
Iron, 3, 19.  
Isocyanides, 41.  
Isomerism, 37, 40.  
Isonitroso-compounds, 53.  
Isoparaffins, 44.

**K**

Ketones, 46.

**L**

Lanthanum, 18.  
Law, even numbers, 11.  
Lead, 20.  
Lithium, 3, 16.

**M**

Magnesium, 17.  
Manganese, 19.  
Mercury, 3, 5, 29, 38.  
Mesoparaffins, 44.  
Meta, 13.  
Metal, 3.  
  alcohols, 49.  
  ethers, 49.  
Metals, 14.  
  alkalid, 14.  
  earth, 14.  
  earth, 14.  
  heavy, 14.  
Methane, 41.  
Methyl sulphate, 56.  
Methylene, 41.  
Molybdenum, 22.  
Morphine, 34.

**N**

Naphthalene, 43.  
Natrium, 16.  
Neoparaffins, 44.  
Nickel, 19.  
Niobium, 18.  
Nitrates, 49.  
Nitrites, 48.  
Nitroethane, 49.  
Nitrogen, 24, 32.  
Nitro-compound, 35.

Nitroparaffins, 48.  
Nitroso-compound, 35.  
Non-metals, 14.

**O**

Orientation, 13, 58, 60.  
Ortho, 13.  
Osmium, 3, 20.  
Oxides, acid, 8.  
  basic, 8.  
Oxygen, 24.  
Ozone, 39.

**P**

Palladium, 20.  
Para, 13.  
Paraffins, 44.  
Peroxides, 39.  
Phosphorus, 5, 24, 33.  
Piperidine, 42.  
Platinum, 3, 22.  
Potassium, 3, 16.  
  hydrate, 26.  
  hydroxide, 27.  
  oxide, 26.  
  orthosulphonamido benzoate, 61.  
Potency, 6, 14, 25.  
Pyridine, 42.  
Pyrroline, 43.

**Q**

Quantivalence, 6, 14.  
Quinine, 34.  
Quinium chloride, 34.  
  salts, 34.  
  sulphate, 34.

**R**

Radicles, 7, 36.  
  acid, 33, 48.  
  alcohol, 33.  
  basic, 32.  
Reaction, clean, 53.  
Residue, nitro, 48.  
  nitroso, 48.  
Residues, 27, 36.  
Rhodium, 20.  
Rubidium, 16.  
Ruthenium, 20.



**S**

Saccharin, 61.  
Salts, acidic, 9.  
    anhydro, 12.  
    basic, 12.  
    compound, 19.  
    ethereal, 46.  
    hydrous, 10.  
    hydroxy, 12, 30.  
    multiple, 10.  
    neutral, 10.  
    oxy, 12, 30.  
    pyro, 12.  
    sub, 12.  
Samarium, 18.  
Scandium, 18.  
Selenium, 24.  
Silicon, 24.  
Silver, 3, 20.  
Sodium, 16.  
Steel, 4.  
Stibium, 22.  
Strontium, 17.  
Sulphones, 56.  
Sulphur, 24.  
Symbol, analytical, 37.  
    basic, 32.  
    molecular, 26.  
    volume, 32.

Symbolization, secondary, 31.  
Symbols, compound, 28.  
    empirical, 28.  
    rational, 28.

**T**

Tantalum, 18.  
Tellurium, 24.  
Terbium, 18.  
Thallium, 19.  
Thorium, 18.  
Tin, 22.  
Titanium, 18.  
Toluene, 60.  
    sulphonamide, 60.  
    sulphonic chlorides, 60.  
Tungsten, 22.

**U**

Uranium, 19.

**V**

Valence, 6.  
    apparent, 40, 41.  
    normal, 41.  
    variable, 40, 41.

Vanadium, 18.  
Vapor-density, 5, 15.  
    normal, 15.

**W**

Water, 26, 37.  
Weights, atomic, 15.  
    molecular, 15.  
    unit, 15.  
Wolframium, 23.

**Y**

Ytterbium, 18.  
Yttrium, 18.

**Z**

Zinc, 19.  
Zirconium, 18.





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