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First Step in Chemical Principles

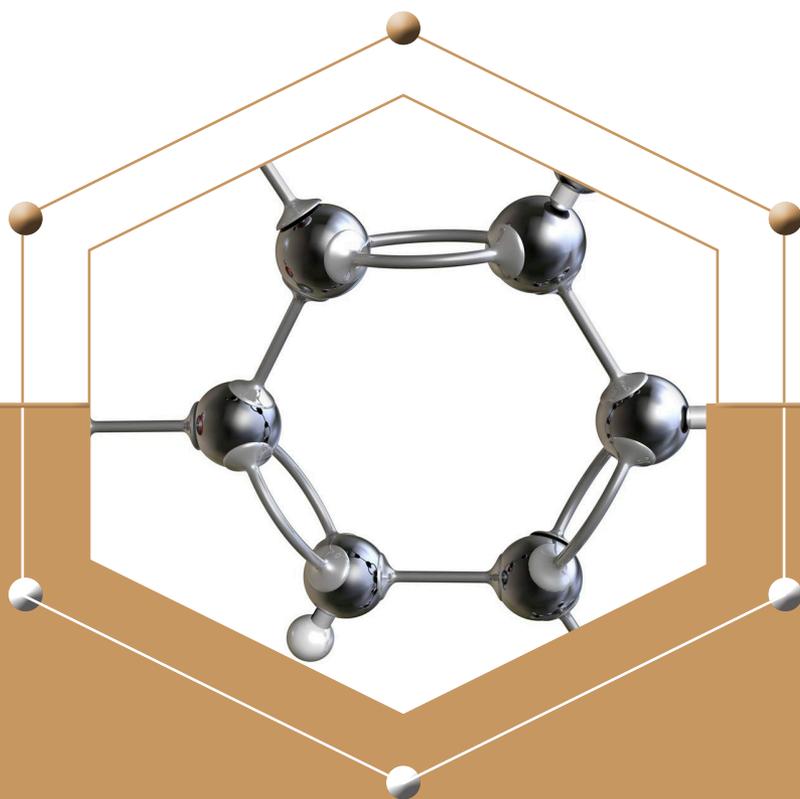
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FIRST STEP IN CHEMICAL PRINCIPLES



By

Henry Leffmann

Chemistry



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PREFACE.

THE following pages contain the substance of the lectures which I have, during the past few years, delivered to my quiz-classes, composed of students at Jefferson Medical College. An experience of ten years in teaching both medical and general chemistry, privately and in classes, during which time I have instructed at least one thousand students, has convinced me that the science is very difficult to acquire, and taxes, as much as mathematical study, the powers of abstract reasoning. I have not sought to make this book a manual of experiment, or practice. Such works are abundant. For medical students, the treatise of Attfield is all-sufficient; for general instruction, that of Eliot and Storer, by far the most philosophical "chemistry" in our language, or the larger work of Bloxam will fulfil ordinary requirements; while, for research and extended reading, the chemist must consult the writings of specialists, or the ponderous volumes that are, by a sort of irony, called "hand books."

My purpose is to make clear, by elaborate explanation and illustration, those points in theory, notation and nomenclature which give trouble to beginners.

Confidence in the system here adopted is derived from the manner in which successive classes have received my teaching. In order to bring the work more nearly to the level of the student, I have had the MS. read by several members of my class, beginners in chemistry, and from suggestions made by them, I have, in many cases, improved the directness and clearness of the text.

H. L.

920 WALNUT STREET.

Philada., September, 1879.

For out of the old fieldes, as men saithe,
Cometh al this new corne fro yere to yere,
And out of old bookes, in good faithe,
Cometh al this new science that men lere.

1. ATOMS AND MOLECULES.

THE material objects around us present an infinite variety of color, form and general qualities. We can, by mechanical action, reduce most of them to fragments, or even to fine powder. The Science of Chemistry has taught us that most bodies are capable of another kind of division, which consists in separating the body into two or more substances unlike each other, and unlike the original substance. Thus, a fragment of common salt may, by mechanical action, be converted into a fine powder, and, by certain other methods, it may be separated into two substances; one, a brilliant metal, and the other a greenish colored gas. The latter transformation is called **DECOMPOSITION**. The two substances obtained from common salt are incapable of further decomposition, and are called **ELEMENTS**. Chemists, by experimenting upon a great variety of bodies, have established the existence of about sixty-five elements, to each one of which a name has been given. A certain force, or form of energy, known as **CHEMICAL AFFINITY**, causes these elements to unite with one another and form **COMPOUNDS**. Before we study the nature of compound bodies it is necessary to explain some points about the elements.

Atomic Theory. If we take a fragment of any element, say a piece of sulphur, we can, as already mentioned, reduce it to a fine powder. Under the microscope the powder will be capable of being further divided, and it would seem as if no limit existed to this division. Chemists, however, are now generally of the opinion that a limit does exist, and that by continued division we would reach particles of infinite hardness, incapable of diminution or destruction, and of being scratched or broken. These have never been obtained. The evidence of their

existence is wholly circumstantial; they are infinitely small, and equally hard no matter what the nature of the mass which they make up. These particles are called *ATOMS* (a word derived from the Greek, and signifying indivisible), and any mass of elementary matter consists of a collection of a greater or less number of these atoms. When, therefore, we divide the piece of sulphur, we merely separate the different atoms from one another. Sulphur is soft; carbon in the form of the diamond is very hard; but this difference in hardness between the two is due simply to the firmness with which the atoms of the two bodies hold together. The atoms of the diamond have a strong affinity, those of sulphur a weak affinity; but, in each body, the atoms themselves are of infinite hardness, resisting all wear and tear. The force which binds together these *similar* atoms is called *COHESION*.

When bodies pass from one physical condition to another, as when a solid becomes a liquid, or a liquid becomes a gas, the atoms are not changed, but merely separated from one another. Hence the atoms of sulphur vapor are as hard and solid as those of solid sulphur, only in the vapor they are separated by greater distances than in the case of the solid. The following will render this point clear :

A A A A	The element in the solid state.
A A A A	„ „ liquid „
A A A A	„ „ gaseous „

This does not represent the proportionate separation, but only the general idea that this change of state is a simple separation of atoms. According to this view, bodies in passing from solid to liquid, and from liquid to gas should increase in volume, and in the reverse processes should decrease ; and this we find to be the case with the vast majority of substances.

Atomic Weights. Chemists have never been able to isolate or render visible any atoms. Their size and weight remain entirely a matter of speculation and theory. Nevertheless, the progress of chemical research, and the application of mathematics, have rendered probable some general principles. These are:—

1st. That the atoms of each element have a constant and definite weight.

2d. That the atom of hydrogen is the lightest of all.

3d. That chemical combination takes place by the union of the atoms, under the influence of chemical affinity.

Starting with the first two principles, a series of numbers has been obtained which represent the weight of each atom compared to the atom of hydrogen. These numbers are called ATOMIC WEIGHTS. A complete table of them is given in the appendix. It is not necessary for the student to commit them to memory.

A combination of atoms, under the influence of chemical affinity, is called a *molecule*.

2. NOTATION.

A CHEMICAL symbol is an abbreviation of the name of an element; it is generally an initial letter, as C for carbon; P for phosphorus. As a number of the elements have names beginning with the same letter the proper distinction is obtained by assigning the single letter to the most common, and attaching small letters to the other initials. Thus, C stands for carbon, Ca for calcium, Cl for chlorine, Cd for cadmium. Certain elements have different names in different languages,

and for these the symbol is formed from the Latin name. Iron, for instance, is represented by Fe, from *ferrum*, lead by Pb, from *plumbum*, silver by Ag (*argentum*), potassium by K (*kalium*.)

Symbols of the more important elements :

H	Hydrogen	K	Potassium.	Zn	Zinc.
O	Oxygen	Na	Sodium.	Cu	Copper.
S	Sulphur.	Ag	Silver.	Sn	Tin.
C	Carbon.	Ba	Barium.	Pb	Lead.
Si	Silicon.	Ca	Calcium.	Au	Gold.
Cl	Chlorine.	Fe	Iron.	As	Arsenic.
Br	Bromine.	Mn	Manganese.	Pt	Platinum.
I	Iodine.	Cr	Chromium.	Hg	Mercury.
P	Phosphorus.	Mg	Magnesium.	Sb	Antimony.

These symbols are absolutely invariable. No symbol represents two elements, no element has more than one symbol.

To express combination between elements, in other words, to express the composition of a compound body, the symbols are to be written together like the letters of a word. Such a collection of symbols is called a FORMULA.

The symbol, however, not only represents the element, but also one indivisible particle of it, that is one atom. Hence, the expression CaO not only shows a compound consisting of calcium and oxygen, but also indicates that the same number of atoms of each element is present. CaO₂ shows that twice as many atoms of oxygen are present as of calcium. In writing these expressions certain rules are followed,

1st. To multiply any single atom, a small number is attached to the lower right hand, as seen above where O₂ indicates two of oxygen. The formula C₂H₄₀₂ shows a combination consisting of two atoms of carbon, four of hydrogen and two of oxygen.

2nd. To multiply several atoms by the same number, we put a large figure in front. Thus 2HClO is equal to $\text{H}_2\text{Cl}_2\text{O}_2$; that is, the large figure multiplies the whole expression. This rule gives much trouble to beginners.

3rd. To multiply a portion of an expression, several methods are in use. We may enclose the part to be multiplied in a parenthesis and attach the proper number to the lower right-hand corner. $\text{Ba}(\text{NO}_3)_2$, for instance, equals BaN_2O_6 ; $\text{C}_6\text{H}_8(\text{NO}_2)_2\text{O}_5$ equals $\text{C}_6\text{H}_8(\text{N}_2\text{O}_4)\text{O}_5$. The effect of the small figure is limited to the part within the parenthesis. This method is especially adapted to multiplying symbols in the middle or at the end of a formula. To multiply the symbols at the beginning of a formula, we usually point off, or punctuate, the part to be affected, and place a large figure in front. Some irregularity prevails as to the particular sign used, the comma and semicolon being both employed. It is sufficient for the student to bear in mind that a punctuation mark, or plus sign, occurring in a formula, will stop the multiplying action of the large figure at the head of the expression. For instance, $2\text{C}_2\text{H}_5, \text{H}_2\text{N}$ is equal to $\text{C}_4\text{H}_{10}\text{H}_2\text{N}$; similarly, in $2\text{FeSO}_4 + \text{HCl}$, the letters following the plus sign are not affected by the figure 2. If we wish to carry the multiplying effect to the end of the expression, we enclose it in parenthesis, thus, $2(\text{FeSO}_4 + \text{HCl})$. Here all the letters are equally influenced.

As these rules are difficult and important, some practical exercises on the use of them will be given further on.

Since the symbol of each element represents one atom, it follows that every symbol carries with it an idea of quantity. If we write HCl the meaning is not merely that hydrogen and chlorine are in combination, but that the amounts by weight are in the proportion of the atomic weights; *i. e.*, 1 (at. wt. H) to

35.5 (at. wt. Cl). When the symbol is multiplied the weight is also multiplied. For instance, H_2O represents 2 parts by weight of H to 16 of O; $HgCl_2$ represents 200 parts of mercury and 71.(35.5 x 2) parts of chlorine. From these examples it will appear that formulæ will give no exact idea of the percentage of the different elements, unless we multiply each symbol by its atomic weight. The following illustration will perhaps make this point clearer. By burning sulphur in air, or in oxygen, we obtain a gas which contains equal parts by weight of S and O. To use the formula SO would be incorrect, for the table of atomic weight shows that the atom of S equals 32, while that of O equals 16; SO, therefore, would show a relation of 32 to 16. The relation is 32 to 32, that is, equal parts; hence, we must use the formula SO_2 , which gives us $S = 32$; $O_2 = 32$ (16x2), the proper proportion. In the same way, we may reduce a more complicated formula. Potassium carbonate is written K_2CO_3 . Referring to the table of atomic weights, we find the following numbers:

K = 39	consequently	$K_2 = 78$
C = 12	„	C = 12
O = 16	„	$O_3 = 48$

The sum of the atomic weights is called the **MOLECULAR WEIGHT**. In the example above given the sum is 138; we cannot reduce this sum in any way, except by taking away one of the atoms; for, by the atomic theory, we cannot remove a portion of an atom. To take away any atom is to change the composition of the body; it is no longer potassium carbonate. Therefore, we say that the smallest portion of potassium carbonate that can exist will be 138 times as heavy as one atom of hydrogen. The same is true of the molecular weight of any body. It will represent the relation between the weight of the

smallest possible quantity of the body, that is, the molecule and one atom of hydrogen. With a number of compound gases, it has been found that the molecular weight is equal to twice the specific gravity compared to hydrogen; and this law has been made the basis of some valuable principles.

3. NOMENCLATURE.

THE names of ordinary chemical compounds are regulated by a system which depends essentially upon the employment of certain terminations.

The names of metals end in "*um*." When the metal combines with oxygen the termination is in a few cases changed to "*a*." Potassium (K), for instance, becomes, by taking oxygen, potassa (K_2O); strontium (Sr) becomes strontia (SrO); magnesium (Mg) becomes magnesia (MgO). This rule is of limited and uncertain application.

Chemical compounds which contain only two elements are called BINARY COMPOUNDS. They are usually named by joining the names of the elements present, and attaching to the non-metallic one the termination "*ide*." This termination may be conveniently regarded as an equivalent of the phrase "nothing else"; that is, wherever it occurs it indicates that nothing else is present except what is expressly mentioned. Potassium *iodide*, for instance, can contain nothing else but potassium and iodine; copper sulphide, can contain nothing but copper and sulphur.

As two elements may combine in several proportions, this termination does not then suffice for proper distinction, and, to obtain this, chemists resort to a system of prefixes, syllables

placed in front of the name of the non-metallic element. These prefixes are Greek or Latin numerals. The bodies Pb_2O , Pb O , PbO_2 , PbO_3 are all correctly entitled lead oxide, (because they are composed of nothing but lead and oxygen), and yet they are clearly different bodies. In this, and in all similar cases, the distinction is as follows:

Pb_2O ,	Lead suboxide.
Pb O ,	„ monoxide.
Pb_{02} ,	„ dioxide.
Pb_{03} ,	„ teroxide.

The second, third and fourth prefixes explain themselves; the first, *sub*, is somewhat difficult to explain. It is applied to cases in which the number of atoms of the metal exceeds that of the other substance. Hence Pb_2Cl , Zn_3I_2 , Cu_4O would be sub-compounds, because in all the atoms of metal exceed those of the other body. The first body would be lead subchloride, the second zinc subiodide, the third copper suboxide.

A number of the metals form binary compounds, containing two atoms of the metal and three of the other element: *e. g.*, Fe_2O_3 , Cr_2O_3 . These are called sesqui-compounds and the above bodies would be called iron sesquioxide and chromium sesquioxide. The word *sesqui* means one and a half and conveys the idea that the relation between the metal and other element is as 1 to $1\frac{1}{2}$ (2 to 3).

When a compound contains three elements, we have no definite system except in the case of salts, bodies consisting of a metal united with an acid. In these oxygen is almost always one of the three elements, and the name is made up by joining the names of the other two elements, and adding to the non-metallic one certain syllables which not only indicate the presence of oxygen but also partly the amount. The syllables

are "ATE" and "ITE." The former indicates the greater quantity of oxygen. Thus, potassium sulphate and potassium sulphite both contain potassium, sulphur and oxygen, but the former (sulphate), contains the most oxygen. Sodium *nitrate* and sodium *nitrite* contain the same elements, but the first mentioned contains a greater quantity of oxygen.

It will aid in the comprehension of the subject and prevent error if we extend the principle which has already been mentioned when speaking of the termination "IDE." It was there pointed out, that this syllable could be regarded as equivalent to the phrase "nothing else." In the same manner, the syllables "ATE" and "ITE" are to be regarded as meaning "something else," and that something else is generally oxygen. With these points in mind, the student will recognize, at a glance, that while in sodium sulphide but two elements are present, sodium sulphate and sulphite will contain three. Illustrations of these matters will be given further on.

These two terminations are not sufficient to distinguish all the salts that may be formed from certain elements. For instance, potassium, chlorine and oxygen will unite in four different proportions, forming KClO_4 , KClO_3 , KClO_2 , KClO . In such cases the important or most common compound is distinguished by the termination "ATE," and the one containing the next lower amount of oxygen by the termination "ITE."

The other compounds are indicated by the use of certain extra syllables, "HYPO" and "HYPER," the latter now generally abbreviated to "PER." The significance and use of these syllables are shown below.

KClO_4	Potassium perchlorate.
KClO_3	„ chlorate.
KClO_2	„ chlorite.

KClO „ hypochlorite.

From this table it is seen that “PER” intensifies the meaning of any termination, that is, indicates more oxygen than if the termination were used alone; while “HYPO” diminishes the power of a termination, that is, indicates a smaller amount of oxygen than would be present if “HYPO” were not used. Several other series of salts show the same principle, although not so perfectly as that above given.

Na_2SO_4	Sodium sulphate.
Na_2SO_3	„ sulphite.
Na_2SO_2	„ hyposulphite.
Ag_2PO_4	„ Silver phosphate.
Ag_2PHO_3	„ phosphite.
AgPH_2O_2	„ hypophosphite.

When, in such compounds, no metal is present, but hydrogen has taken its place, we might use a similar system; but the custom of chemists has decreed that a different method shall be adopted.

Taking the series of chlorine compounds given above, in place of the potassium salts we might have HClO_4 , HClO_3 , HClO_2 , HClO , and these might be called hydrogen perchlorate, hydrogen chlorate, etc.; such names are used by a few persons, but have not become current. The more frequent method is to drop the word hydrogen, change the termination *ATE* into *IC*, the termination *ITE* into *OUS* and add the word *ACID*.

The series would therefore be,

HClO_4	Perchloric acid.
HClO_3	<i>Chloric</i> acid.
HClO_2	<i>Chlorous</i> acid.
HClO	Hypochlorous acid.

Note particularly that the *prefixes* are retained without change, and that the syllable IC is found whenever, in the metallic salt, the termination was ATE, and the syllable OUS is found when the name has come from a compound ending in ITE.

In the same way, we have the following transformations:

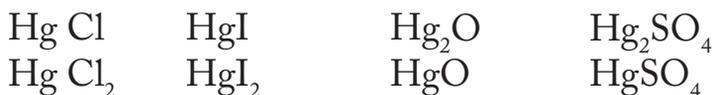
Potassium sulphate		Sulphuric acid.
K_2SO_4	corresponds to	H_2SO_4
Potassium sulphite		Sulphurous acid.
K_2SO_3		H_2SO_3
Potassium hyposulphite		Hyposulphurous acid.
K_2SO_2		H_2SO_2

Strictly speaking, no necessity exists for this variation. The compounds containing hydrogen might well be regarded as salts. They exhibit, however, some incidental properties which distinguish them from the rest of the salts. They have a sour taste, redden vegetable blues, and have, as a rule, a wider range of chemical action. They stand out as a group; and from a very remote period have been called acids. The term is too well established in chemistry to be set aside. Sometimes we have bodies in which the hydrogen is only partly replaced by a metal, and such bodies are, therefore, intermediate between the true acids and the true salts. Thus, $KHSO_4$ is at once a potassium and a hydrogen compound. In such cases the name is a combination of both systems. The above compound $KHSO_4$, is called acid potassium sulphate. Here the word *acid* calls attention to the existence of hydrogen, while the rest of the elements are indicated by the latter part of the expression.

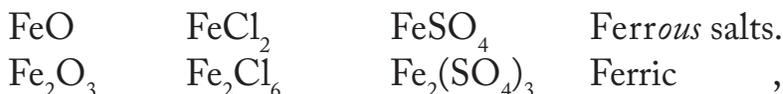
These acid salts are not infrequently called bi-salts. Acid potassium sulphate, for instance, is generally known in commerce as potassium bisulphate; the corresponding acid

carbonate, KHCO_3 , as bicarbonate. This use of the syllable *bi* is improper. If it means anything in this connection, it is that two molecules of acid are present, which is not the case. In a few compounds of exceptional composition the title is used for want of a better one. $\text{K}_2\text{CrO}_4\text{CrO}_3$, for instance, is called potassium bichromate. It is not properly so-called because it does not contain two molecules of chromic acid, CrO_3 being chromium teroxide, but the more scientific title, anhydrochromate, will not be likely to obtain, and the incorrect name will be long used.

Of late years, the terminations *ous* and *ic* have been applied to metallic compounds in which the metal forms two sets of compounds containing the same element, but in different proportions. Mercury forms two chlorides, two iodides, two sulphides, etc. The two series are as follows:



The bodies in the upper row are called mercurous salts, those in the lower row mercuric salts.



Note particularly how these terminations are applied. They indicate not the amount of the metal, but of the other substance; *ous*, as usual, indicates less than *ic*.

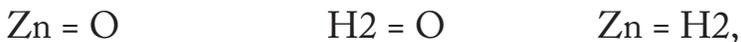
4. ATOMICITY.

THE atom of hydrogen, besides being the standard of the weight of other atoms, is taken as a standard of *capacity* of combination. The elements are arranged in groups, according

to the number of hydrogen atoms with which they combine, or which they will replace in combination. The elements Cl, O, N and C, for instance, form with H, HCl, H₂O, H₃N, H₄C. These are not the only compounds that can be formed from these elements, but they are those which do not show a tendency either to take new atoms, or give up what they already possess. Each element (at least each element of importance) has been examined in regard to the number of hydrogen atoms with which it is capable of combining, and groups or classes have been arranged, in which all the elements having like powers are brought together.

This power is called ATOMICITY. The word QUANTIVALENCE is also sometimes used to express the same idea.

To establish the atomicity of any element, we must determine merely the greatest number of hydrogen atoms which will combine with one atom of the element in question. If the element does not form any hydrogen compound, we may combine it with one of which the atomicity is known, or we may cause it to displace hydrogen from combination and thus get a knowledge of the number of hydrogen atoms to which the substance is equal. Zinc does not form any compound with hydrogen, or at least no definite one. But one atom of zinc will combine with one atom of oxygen, and one atom of oxygen combines with two atoms of hydrogen, We may put our reasoning in this form:



according to the well known principle that things which are equal to the same thing are equal to each other.

By the second method, that of displacement or substitution, we get the same result. Zinc, when put into sulphuric acid, evolves hydrogen and forms zinc sulphate. Careful observation

shows that the change, expressed in symbols, is, $Zn + H_2SO_4 = Zn SO_4 + H_2$; in which the zinc is shown to be equal to H_2 , because it is just sufficient to drive H_2 out of combination. By this demonstration it will be seen that capacity of combining with hydrogen and power of replacing hydrogen are identical.

It is important that the student should bear in mind that atomicity has nothing to do with the energy or activity of the element, It is a measure of capacity only. Bodies of high atomicity are often of weak affinity, while some of the strongest chemical agents are of low atomicity. Chlorine has only one-third the atomicity of nitrogen, but is many times more energetic as a chemical substance.

Chemists have invented terms which indicate the atomicities of the elements, and have also attached certain marks to the different symbols to indicate the atomicity to the eye.

All elements, one atom of which is equal to one atom of hydrogen, are called monads;* when one atom of the element is equal to two hydrogen atoms it is called a dyad; etc., as shown below. The marks used are simply the Roman numerals.

Cl'	marks	Cl	as a	monad,	1 atom = 1	atom	H
O''	"	O	"	dyad,	1 atom = 2	"	H
N'''	"	N	"	triad,	1 atom = 3	"	H
C''''	"	C	"	tetrad,	1 atom = 4	"	H

These little marks are often conveniently used in expressing chemical changes; but they are not often used in formulæ, as they produce confusion.

* In place of the terms given above, some writers use monatomic or univalent, for monad; diatomic or bivalent, for dyad; triatomic or trivalent, for triad; etc. These have no advantage over the terms used in the text.

The following table should be thoroughly committed to memory, since it will enable the student to write correctly the formulæ of many common chemical substances.

Atomicities of the more important elements:

Monads.	Dyads.	Triads.	Tetrads.
Cl	O	N	C
Br	S	P	
I	Ca	As	
F1	Mg	Sb	
K	Ba	Bi	
Na	and all the common		
Ag	metals except Ag.		

The higher grades are called pentads{v}, hexads{v'}, etc. The members of triad group may also act as pentads; some of the dyads become hexads under conditions which will be explained below.

The rule is to unite the different elements in such proportion that their degrees of atomicity shall be equalized. Suppose it should be required to combine sulphur with silver. A reference to the table will show that silver is a monad and sulphur a dyad, therefore one atom of sulphur is equal to two atoms of silver ; the compound will be $\text{Ag}_2 \text{S}$. In further illustration, we may take carbon and chlorine, one a tetrad, the other a monad; the compound will be C Cl_4 . The rule may be expressed formally as follows: in every compound containing two elements, the product obtained by multiplying the degree of atomicity of each element, by the number of atoms of that element, must be equal.

The instances given above are in accordance with this rule, for Ag has an atomicity of one and S of two, and in the formula we have $Ag_2 = 1 \times 2 = 2$ and $S = 2 \times 1 = 2$. So, also in CCl_4 , $C = 4 \times 1$ and $Cl_4 = 1 \times 4$ equaling four in each case. The most difficult application of the rule is where triads and dyads are united, as in the oxides and sulphides of nitrogen, phosphorus, arsenic and antimony. A few trials will show that to make the two products equal, we must multiply the dyad by 3 and the triad atom by 2. For example, $Sb_2 S_3$ must be the formula of antimony sulphide, for it is only in this proportion that we can have the products equal $Sb_2 = 3 \times 2 = 6$ $S_3 = 2 \times 3 = 6$.

Compounds in which the atomicities are equalized, in accordance with this rule, are called *saturated* compounds.

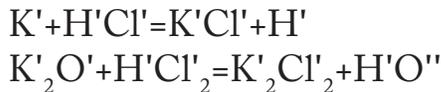
A few formulæ are here appended as additional illustrations:

Monad with monad		H'Cl'	K' Cl'	Na'Br'
“ “ dyad		H' ₂ O''	K' ₂ O''	Cu''Cl' ₂
“ “ triad		H' ₃ P'''	Ag' ₃ Sb'''	
“ “ tetrad		H' ₄ C''''		
Dyad “ dyad		Cu''O''	Zn''S''	Fe''O''
“ “ triad		P''' ₂ O'' ₃	N'''' ₂ O'' ₃	As''' ₂ S' ₃
“ “ tetrad		C''''O'' ₂	C''''S'' ₂	

It must, however, be borne in mind that compounds exist in which the proportion of the atoms differs from what the rule requires; but the essential character of such compounds is, a tendency to change, either by taking new atoms or giving up some that they already possess. The normal compound of oxygen and carbon is, of course, CO_2 , in which the one tetrad C is exactly saturated by the two atoms of dyad O. We are, however, acquainted with a well defined body having the

formula CO. This substance is rather a proof of the rule than an exception to it, for it shows a strong tendency to take up other atoms in order to complete its structure. Heated in the air, it combines with oxygen and forms CO_2 , and it unites with chlorine, forming a definite compound which will, of course, have the formula COCl_2 since it requires two chlorine atoms to perform the function of one oxygen atom.

So also, the student must not fall into the error of supposing that bodies in which the degrees of atomicity are equalized, are necessarily without chemical activity. On the contrary, some of our most active chemical agents are saturated compounds. Hydrochloric acid, HCl is an example of such a substance. It shows no tendency to take new atoms except under the one condition, that it first gives up a portion of its structure. It will dissolve potassium, for instance, but only by first losing its hydrogen, into the place of which the potassium enters. It will dissolve potassa (oxide potassium K_2O), but only by exchanging its hydrogen for the potassium. The changes may be represented as follows:



This is, in fact, the nature of common chemical changes: they are substitutions of one element for another, the substitution always taking place in such a way that the element driven out is exactly equal in atomicity to the one that enters the combination. If, instead of acting on hydrochloric acid with potassium, we use zinc, the quantity of HCl will have to be increased; the reaction $\text{Zn} + \text{HCl}$ cannot take place, since one atom of zinc must drive out two atoms of hydrogen, zinc being a dyad. Therefore, we say $\text{Zn} + \text{H}_2\text{Cl}_2 = \text{Zn Cl}_2 + \text{H}_2$, which is in

strict accordance with fact, as showing that one atom of zinc will set free twice as much hydrogen as one atom of potassium will.

The degrees of atomicity given above are not invariable. The circumstances under which the variation takes place cannot be very well defined, but the extent or rate of variation is governed by a very simple law, to which only a few exceptions need be made. *When an element changes its atomicity, either increasing or diminishing, the change is by two degrees at a time.* Elements of even atomicity remain even, passing, for instance, from hexads to tetrads and finally to dyads, or *vice versa*; elements of uneven atomicity remain uneven, passing from pentads to triads and monads.

The principal exceptions to this law are copper and mercury. These elements are generally dyads, but assume under certain conditions the power of monads ; compounds being formed having the formulæ HgCl ; CuCl .

Theoretical methods have been devised for explaining away these exceptions, but it will burden the mind less to let them stand as unexplained departures from a general rule.

Certain elements vary in atomicity in a way that appears to be exceptional, but in which we can, by a simple and not improbable supposition, account for the change and yet preserve the application of the law. The elements referred to are iron, manganese, chromium, aluminium, and a few other less important metals, and, among the non-metallic bodies, carbon. These have the property of combining with themselves in such a manner as to form double atoms, possessing an atomicity greater than either atom singly, but less than the sum of the atomicities of the two atoms. For instance, iron, which is generally a dyad, becomes in certain compounds a tetrad,

but, instead of forming compounds upon this basis, two atoms of iron unite and form a double atom which then forms compounds with other elements. A moment's reflection will show that this double atom, formed from two atoms each having a capacity of four, will have a power of six, one degree of atomicity in each atom having been consumed in forming the compound. Hence, while ferrous chloride is Fe Cl_2 ; ferric chloride which contains the double atom $(\text{Fe}_2)\text{VI}$ will be Fe_2Cl_6 .

For all these cases of varying atomicity, whether regular or irregular, the terminations *ous* and *ic* are much employed, *ous* indicating the lower degree and *ic* the higher. We have, in this way mercurous (lower atomicity) and mercuric (higher atomicity) salts; ferrous (dyad) and ferric (hexad) compounds. Indeed, in the use of the terminations of the acids, the same principle is carried out, sulphurous acid being the compound in which sulphur has a lower (tetrad) atomicity; sulphuric acid, one in which sulphur has a higher (hexad) power.

In arranging formulæ containing three elements, the application of the law of atomicity becomes somewhat difficult. In many common cases, it will be found that the atomicity of one of the elements is much higher than it is in bodies containing two elements; sulphur, for instance, is a dyad in binary compounds, but in the sulphites and sulphates it is, respectively, a tetrad and hexad. When oxygen is one of the three elements we usually count it against the sum of the other two. Taking an instance of the salts above mentioned, we would get the following formulæ :



In each case the atomicity of the oxygen is equal to the sum of that of the other two elements.

For the student, however, the shortest and safest rule will be to commit to memory, thoroughly, some standard formulæ containing three elements, and from these, by very simple rules, a large number of compounds can be built up.

These formulæ are:

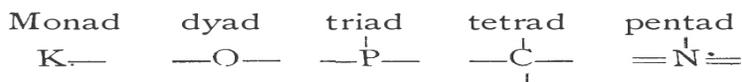
$H_2 SO_4$	Sulphuric acid.
$H_2 SO_3$	Sulphurous acid.
$H_2 CO_3$	Carbonic acid.
$H NO_3$	Nitric acid.
HNO_2	Nitrous acid.
$H Cl O_3$	Chloric acid.
$H_3 PO_4$	Phosphoric acid.

The derivatives from these bodies form a large part of common chemical substances. If we wish to write the formula of any metallic salt, we substitute the proper amount of metal for the hydrogen in the corresponding acid. Let it be required to write the formula of potassium carbonate ; the reasoning would be as follows: Carbonic acid is H_2CO_3 , potassium is a monad; two atoms of potassium will be required to substitute the two atoms of hydrogen, and the formula is K_2CO_3 . By the same reasoning, copper sulphate may be deduced. Sulphuric acid is H_2SO_4 , copper is a dyad; one atom of copper will replace two of hydrogen, therefore, $CuSO_4$. When the standard formula contains too small an amount of hydrogen, we must multiply the expression by some whole number. For instance, the formula of copper nitrate will be deduced in this manner: Nitric acid is HNO_3 , copper is a dyad ; copper will therefore replace the hydrogen of two molecules of nitric acid; hence, $Cu(NO_3)_2$ or CuN_2O_6 .

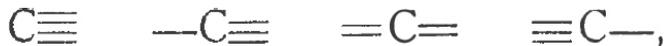
Some chemists, in order to avoid this latter difficulty, use always the double formulas and write as follows:

Nitric acid	$H_2N_2O_6$
Nitrous acid	$H_2N_2O_4$
Chloric acid	$H_2Cl_2O_6$
Phosphoric acid	$H_6P_2O_8$

Graphic Formulæ. A convenient and much used method of indicating atomicities is by GRAPHIC FORMULÆ. These consist of the symbol of each element with bonds or prolongations, the same in number as the degrees of atomicity. Taking some common elements as examples, we have

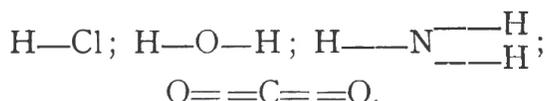


Those bonds may be attached in any position or direction, as long as the proper number is used. Carbon, for instance, may be written as above, or,



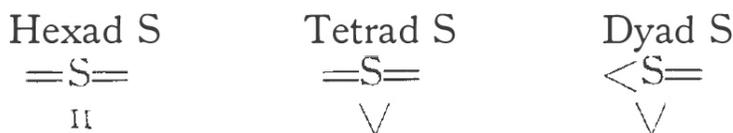
or in any other way, provided four bonds are present.

The practical application of this graphic notation to the writing of chemical formulæ is easy. We link together the bonds of the different elements, and when all the points are joined, the compound is complete, and is a saturated molecule. Two bonds of one atom, however, can never be attached to a single bond of another atom. We cannot have $K=O$, but $K-O-K$ showing us that the composition of potassium monoxide must be K_2O . The following are examples of some common compound written graphically:

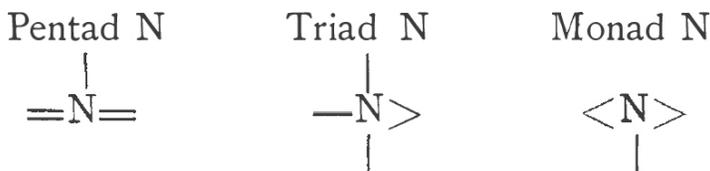


We may, also, indicate *unsaturated* molecules. Thus, $\text{O}=\text{C}=\text{O}$ shows that carbon monoxide is a body having two degrees of atomicity unsatisfied; $\text{O}=\text{C}=\overset{\text{Cl}}{\underset{\text{Cl}}{\text{O}}}$ that two atoms of chlorine have combined and satisfied this free atomicity.

The only objection, perhaps, to the use of graphic formulæ is the danger that the student may think that the atoms actually have spokes, or projections on them, or are arranged in the somewhat architectural manner shown in the formulæ. K—O—H does not mean that, in potassium hydrate the atom of O is flanked on either side by a potassium, and by a hydrogen atom, or that the atoms are connected by hooks or prongs; but merely that the oxygen atom has certain degrees of affinity, which are satisfied by other atoms. A special application of this notation is to explain the nature of those changes in atomicity which have already been mentioned. The atom of sulphur, for instance, is, in some combinations, a hexad, in others a tetrad, in others a dyad. This progressive diminution of capacity may be supposed to arise from the bonds of affinity combining with each other in pairs, thus:



The same principle can be shown with an element of uneven atomicity.

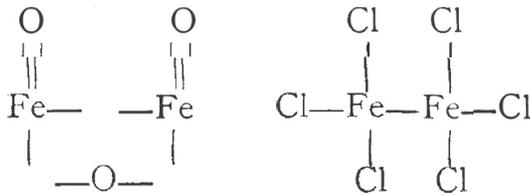


Since such combinations cannot take place unless both points are saturated or neutralized, the decrease of atomicity must take place by two degrees.

The nature of the change by which the iron atom passes from a dyad to a hexad condition, can be very well shown by this method. Dyad iron, graphically represented, would be $\langle \text{Fe} =$, in which two bonds have satisfied each other, leaving two still active. In the higher degree of atomicity, the condition

is , $\overset{|}{\text{Fe}} - \overset{|}{\text{Fe}} -$ one bond of each atom having com-

bined and linked the two in chemical union. Ferric oxide and ferric chloride would be



5. ELECTRICAL RELATIONS OF THE ELEMENTS.

ELECTRICAL excitement exhibits two opposite conditions, called respectively POSITIVE and NEGATIVE. These two conditions are always produced in any apparatus developing electricity. The points at which the electrical excitement is manifested, for instance, the wires OF a battery, are called the POLES. The positive pole is usually distinguished by the sign+, the negative by the sign —.

These have a strong tendency to unite and neutralize each other. On the other hand, positive electricity repels positive, and negative repels negative. Two bodies charged with different kinds of electricity will attract each other, but if charged with the same kind of electricity will repel. The law is generally expressed as follows, *like electricities, repel; unlike, attract.*

These principles have been applied by chemists to the determination of some important electrical relations of the elements. A current of electricity decomposes a large number of compound bodies, and certain elements are strongly attracted to the positive pole and others to the negative. Thus, potassium will always be liberated in contact with the surface negatively charged, while oxygen will be set free in contact with positive surface. This will be the invariable result with these elements, no matter what compounds be taken for the experiment, but with many other elements the effect will depend upon the nature of the compound. With H_2S the sulphur will be attracted by the positive pole, with SO_2 to the negative. This difference is due to the superior attraction which the oxygen has for the positive electricity, by which it seems to compel the sulphur to go to the other point.

Since unlike electricities attract, it follows that elements which are drawn to the positive side must be negative, and those drawn to the negative side must be positive. Very frequently we use the syllable "ELECTRO" in this connection,—thus we say zinc is *electro-positive*; chlorine is *electro-negative*.

A body is not absolutely positive, or absolutely negative, but is simply more positive, or more negative than some other substance. Nevertheless, as the list of elements is limited, we will have two bodies, which, by their high affinities, will stand at the extremes of the scale, one being always negative, the other always positive. Leaving out of consideration some rare elements, we may place potassium as the most positive, oxygen as the most negative.

The following table shows the common elements arranged in the order of their electrical relations:

K	Fe	Hg	S
Na	Ni	H	N
Ba	Pb	Sb	I
Ca	Sn	C	Br
Mg	Cu	As	Cl
Zn	Ag	P	O

It is not necessary to commit this table to memory. The general purpose is met by remembering that hydrogen and the metals are positive, and the non-metallic elements negative.

Each element of this list will be positive when in combination with any element below it, negative when in combination with any above it.

These principles have been explained at some length, because they find an important application in determining chemical changes. The greatest chemical attraction exists

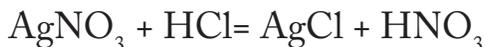
between elements most widely separated in their electrical relations. The student may, by this means, often discover the most probable result of any chemical action, as will be fully shown in an another section.

6. REACTIONS.

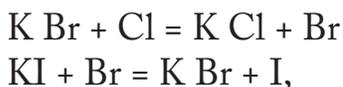
CHEMICAL symbols are employed not only to show the composition of bodies, but also to show exactly the nature of the chemical changes which occur when different bodies are brought in contact. When so used, the expression is called a REACTION. Certain compounds, which are much used for producing reactions, are called REAGENTS, though strictly all the substances present take equal part in a reaction. When we pour vinegar upon a marble table, we say, in ordinary phrase, that the marble is corroded, but, in fact, the vinegar is equally acted upon, both substances are changed in chemical composition, both are rendered unfit for their original uses; in other words, they have not only acted, they have reacted, and are therefore both reagents.

A reaction is substantially an expression of the results of an experiment, and, when correctly written, gives us the proportion in which bodies are to be used and the proportion of the resulting substances. Speaking absolutely, we can never be sure of the correctness of any reaction until we make the experiment and analyze the result; but the progress of chemistry has made known certain laws of change, which enable us to predict, or infer, many results without the necessity of actual observation. Every now and then, however, the analogy fails, and experiment disappoints the suggestions of theory.

Reactions are written by placing in proper proportion and connected by + signs the formulæ of the bodies concerned, then writing the sign = and following this by the formulæ of the resulting bodies. For instance,



expresses that on bringing together silver nitrate and hydrochloric acid, a chemical change occurs by which silver chloride and nitric acid are produced. Students find, in regard to writing reactions, three difficulties: 1st. To know whether a given change will take place. 2d. To know the quantities of the bodies to be used. 3d. To know the nature of the resulting bodies. These difficulties may be taken up in order. 1st. In the simplest cases, the nature of the reaction will be determined by the affinities of the elements as governed by their electrical relations, the change taking place in such a way that the element having the stronger electric affinity will drive out and supplant the element of similar but weaker affinity. A reference to the table of electrical affinities will show that chlorine is more strongly negative than bromine, and bromine than iodine. Accordingly, we find that when chlorine acts upon the bromides they are decomposed, the bromine being expelled, and that bromine, in turn, expels iodine from combination. Therefore, such reactions as



are simply illustrations of the general electrical relations of elements concerned. If these affinities were the only active causes of chemical change, the subject would be quite simple, but, by repeated experiment, chemists now know that the surrounding circumstances may suspend or modify the play of affinities, so as to produce an endless variety of chemical actions.

It is hardly necessary to remark that all the modifying influences are not yet known. Three of them, however, are pretty well understood, and are of such importance as to require the attention of the student.

(a) Insolubility. When in any liquid we bring together substances which are capable of forming a body insoluble in the liquid, that insoluble compound will be produced in spite of the general relations of affinities. This influence of insolubility is the basis of a large number of tests and other chemical operations.

When the formation of the insoluble compound would require a powerful chemical agent to be set free, the change will not take place, unless, of course, the added substance is stronger than the one to be liberated. Carbonic acid forms with calcium a body quite insoluble in water, but this body cannot be formed by passing carbonic acid into calcium sulphate. The reason is shown at once on examining the conditions of the experiment. The reaction would have to be $\text{CaSO}_4 + \text{H}_2\text{CO}_3 = \text{CaCO}_3$ (insoluble) + H_2SO_4 , that is sulphuric acid would be set free. The affinity of H_2CO_3 is, under ordinary conditions, so much below that of H_2SO_4 that the former will not drive out the latter. The condition becomes changed if we assist the action of the carbonic acid by some substance which has an affinity for sulphuric acid and will obviate the necessity of setting it free. $\text{CaSO}_4 + \text{Na}_2\text{CO}_3$ will produce immediate action, resulting in $\text{CaCO}_3 + \text{Na}_2\text{SO}_4$. This reaction illustrates a not uncommon method of keeping the powerful affinities in abeyance, and thus allowing secondary influences full play. Some of the arsenic tests show the principle strikingly. Arsenious acid added to CuSO_4 produces no action because the affinity of the S O_4 is too strong, but by

adding a little ammonia, the strong affinity this has for SO_4 assists in breaking up the copper sulphate and immediately a precipitate of copper arsenite falls.

(b.) Volatility. This is the second influence that disturbs ordinary affinities. If a body is capable of being converted into a gas, this fact will diminish its chemical power; fixed substances that have ordinarily less affinity will drive it out of combination. Boric acid, for instance, is one of the weak acids, yet at a red heat it will drive out even sulphuric acid. The cause is, in the main, that at this temperature sulphuric acid is volatile, while boric acid is fixed. Chemists make, as is well known, much use of the action of heat as a modifier of chemical action, and frequently it is this influence of volatility which is brought into play,

(c.) Mass. Sometimes chemical action seems, to be governed by the quantity of the substances present. If we pass water vapor over red hot iron, iron oxide is formed and hydrogen is set free; if we pass the hydrogen back over the iron oxide, steam is formed and iron set free. In the first case, the water is in excess and exerts an oxidizing influence; in the second, the hydrogen is in excess and exerts a deoxidizing influence. The effect of mass is indefinite and uncertain, and need not enter into the ordinary working of reactions.

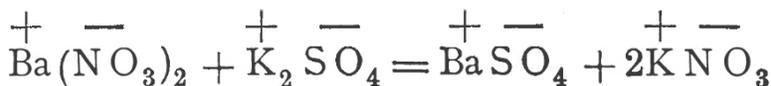
It will be seen to be a deduction from these statements that no substance can be set down as absolutely the strongest in affinity. Chemists cannot determine, for instance, what is the strongest acid or the strongest alkali, except under specified conditions.

2d. The proportion in which bodies react is determined by their atomicities. Let it be required to write the reaction between mercuric chloride and potassium iodide. The for-

mulæ are HgCl_2 and KI , but the bodies will not react in this proportion for the Hg will require I_2 and Cl_2 will require K_2 . The proper reaction is $\text{Hg Cl}_2 + 2\text{KI} = \text{Hg I}_2 + 2\text{K Cl}$. In the same way antimony sulphide and hydrochloric acid can only act upon each other in the ratio $\text{Sb}_2 \text{S}_3 + 6 \text{H Cl}$ because Sb being a triad, Sb_2 will combine with Cl_6 , and S being a dyad, S_3 will require H_6 .

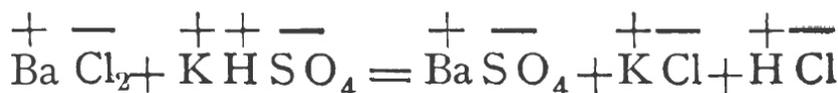
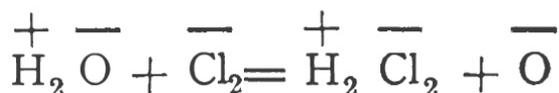
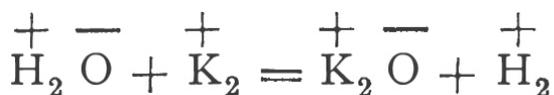
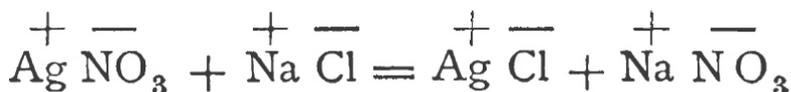
3d. If a chemical change occurs when two given substances are brought in contact, the nature of it will depend principally upon the electrical relations of the elements concerned. In the reaction $\text{Hg Cl}_2 + \text{H}_2 \text{S}$, the only possible result is the combination of S with Hg and H with Cl , as is shown at once by placing the proper signs over the elements, $\overset{+}{\text{Hg}} \overset{-}{\text{Cl}_2} \quad \overset{+}{\text{H}_2} \overset{-}{\text{S}}$ Such

a combination as $\overset{+}{\text{Hg}} \overset{+}{\text{H}_2}$ or $\overset{-}{\text{Cl}_2} \overset{-}{\text{S}}$ could not take place, since it requires like electricities to attract, which is against the rule. In beginning with reactions, the student will do well to place the proper signs over each element, and these signs will be a useful guide and control. When acids or salts, containing three elements, are part of the reaction, the plus sign is put over the hydrogen or the metal and the negative over the oxygen and other element, thus:



The placing of the single sign over the two elements is simply an evidence of the fact that in ordinary reactions, these two elements act as a single element.

The following formulæ will further illustrate the general principle:



In the last reaction, the electro-positives K and H may seem to be in union, but this is not the case. Each is independently united to the SO_4 , which is a dyad. The formula might be written

7. HYDRATES AND ANHYDRIDES.

WATER, H_2O , is known to the chemist as having active affinities. It dissolves many bodies, solid, liquid and gaseous, and is absorbed by many substances. Porous bodies, for instance, exposed to moist air increase in weight considerably by absorbing water. These effects are not generally regarded as due to chemical affinity and need not be considered here.

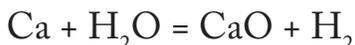
A very large number of substances form, with water, definite chemical compounds, in some of which the water unites directly without losing its identity; in others the molecule H_2O seems to be broken up. Of the first kind of combination, the best instances are in the crystallization of the common metallic salts. Copper sulphate, for instance, has the formula

Cu SO_4 , but the blue crystals sold in the shops as copper sulphate contain, in addition to this formula, a large amount of water. This water is derived from that in which the copper sulphate was dissolved. It is an essential part of the crystal, for, if we drive out all of it, the mass is converted into a white powder. Chemical analysis shows that the composition of the blue substance is $\text{CuSO}_4 + 5\text{H}_2\text{O}$. Water that is in this way part of a molecule and essential to a crystalline form is called WATER OF CRYSTALLIZATION. Substances that do not contain it in such a state of combination, are said to be ANHYDROUS. Some metallic salts form crystals containing large amounts of water; sodium carbonate in its commercial form, $\text{Na}_2\text{CO}_3 + 10\text{H}_2\text{O}$, contains over fifty percent water.

The second form of the chemical action of water is where it is apparently decomposed, its two elements associating themselves independently with the elements of the other body. If we mix water with common quicklime, a violent action, attended with production of much heat, ensues, and if the quantity of water is about one-third that of the lime, a dry powder results, from which no appreciable amount of water can be expelled except by a red heat. If this compound contained water in an unchanged form, a moderate heat would drive it all out; hence, chemists have regarded the compound not as $\text{CaO}, \text{H}_2\text{O}$ but as CaH_2O_2 which is an entirely new body, containing really neither quicklime nor water. A considerable number of oxides are capable of uniting thus with water and forming bodies known as HYDRATES.

Perhaps the most scientific view of these hydrates, is to regard the water as acting the part of an acid (it might indeed be called hydric acid), and just as CaSO_4 is calcium sulphate, CaH_2O_2 will be calcium hydrate. Water, in fact, might be

written HHO, the first H being replaceable by an element according to the usual law of atomicity. A portion of the hydrogen must always remain, or the body would become an oxide. Thus, if potassium were to act upon water, according to the reaction $K_2 + H_2O = K_2O + H_2$; or calcium were to act according to the reaction

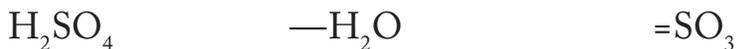


the bodies produced are not hydrates, but oxides.

The oxides, which, by addition of water, produce hydrates, are called ANHYDRIDES. By subtracting H_2O from any hydrate we may reproduce the corresponding anhydride. Many of the common acids may in this way furnish anhydrides, some of which are interesting bodies.

Sulphuric acid.

Sulphuric anhydride.



In the same manner the student may deduce: Sulphurous anhydride SO_2 from Sulphurous acid.

Carbonic

“

CO_2 from Carbonic acid

If the acid contain but one atom of hydrogen, we must, of course, double the formula before subtracting. Hence

Nitric acid

Nitric anhydride



similarly we deduce

Nitrous anhydride N_2O_3 from Nitrous acid.

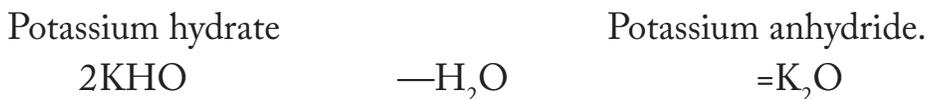
Phosphoric “ P_2O_5 “ Phosphoric “

We may proceed in the same way with the metallic hydrates, Calcium hydrate

Calcium anhydride.



As before, when the hydrate contains but one atom of hydrogen, we double the formula,



These metallic anhydrides are often called BASES.

8. ACIDS AND ALKALIES.

IT has been pointed out in a former section, (p. 16), that the hydrogen salts are generally called *acids*, H_2SO_4 , for instance, being called sulphuric acid rather than hydrogen sulphate. Most acids have a sour taste and a power to change vegetable colors, and these properties are regarded as characteristic of the group. We speak therefore of substances "being acid," or having an "acid reaction," which expressions mean that the bodies in question possess the two properties just mentioned. The taste is frequently unsatisfactory or inconvenient, and in practice we are limited to the test with vegetable colors. A variety of colors have been employed, but the ordinary laboratory method is with *litmus*, which is a blue color that becomes red when in contact with an acid. It is used either in solution in water or in the form of *litmus-paper*, strips of paper soaked in the solution and dried. The test is by no means scientifically accurate. Some metallic salts, as Cu SO_4 are capable of turning it red, and, on the other hand, it sometimes fails to indicate the true condition. Acid sodium carbonate, Na H CO_3 , for instance, will not show any result with *blue* litmus.

Anything which neutralizes the acid will restore the original color of the litmus. Bodies that possess this property are said to be "*alkaline*." This term is also used in an indefinite

sense. A considerable number of salts, especially the carbonates, possess the power of neutralizing acids, and hence turn red litmus blue. Even acid sodium carbonate will do this, and the confused condition of the nomenclature is well shown by the fact that we can correctly say that this body is an acid salt with an alkaline reaction, or that copper sulphate is a "neutral salt with an acid reaction" (Fresenius).

9. QUASI-ELEMENTS.

QUASI is a Latin word meaning "as if." A *quasi-element* is a compound which acts in combination as if it were an element. Of the many examples which chemistry presents, we need here discuss only two, *ammonium* and *cyanogen*.

Ammonium is NH_4 . It must be unsaturated by one degree; for if N be a triad H is in excess, if N be a pentad the H is deficient. Under either supposition N H_4 will show a tendency to take up one hydrogen atom, or the equivalent of one hydrogen atom. We find that, like monad metals, it combines with one atom of chlorine and replaces the hydrogen of the various acids. In short, this body is capable of acting exactly like potassium or sodium, and, while in strictness it cannot be considered a metal, it has received a name which terminates in the syllable *um*, characteristic of the metals. The following formulæ show the comparison between the salts of potassium and ammonium:

K Cl	potassium chloride.
$\text{N H}_4\text{Cl}$	ammonium chloride.
K_2SO_4	potassium sulphate.
$(\text{N H}_4)_2\text{SO}_4$	ammonium sulphate.

KNO_3	potassium nitrate.
NH_4NO_3	ammonium nitrate.
KHO	potassium hydrate.
NH_4HO	ammonium hydrate.

Ammonium, of course, acts as a positive molecule.

As the expression NH_4 makes some confusion in formulæ, it has been proposed to use the symbol Am; ammonium chloride will thus be AmCl ; ammonium sulphate, Am_2SO_4 . This useful method has not received the favor it deserves.

The termination "um" is changed into "a" when the metal is combined with oxygen. Accordingly, ammonium will form ammonia $(\text{NH}_4)_2\text{O}$ or Am_2O , corresponding to potassa K_2O or soda Na_2O . A little confusion occurs here, in consequence of the earlier chemists having given the name ammonia to a body having the composition NH_3 and entirely distinct from Am_2O . This body, NH_3 , for sake of distinction, should be called ammonia gas, or better *amine*. In ordinary chemical language, "ammonia" always refers to the oxide Am_2O , or to the hydrate NH_4HO .

Cyanogen is CN . It shows one degree of atomicity unsaturated, and it may be left as an exercise for the student to prove this fact. Cyanogen is not metallic in character. It is electro-negative and associates itself with such elements as Cl, Br and I. It forms compounds called *cyanides*. In all of these it acts as monad, thus we have hydrogen cyanide HCN , potassium cyanide KCN . Dyad metals require of course two molecules of cyanogen. Calcium cyanide would be CaC_2N_2 or $\text{Ca}(\text{CN})_2$. The syllable Cy is often used in formulæ instead of the symbols CN . Thus we write HCy instead of HCN , KCy instead of KCN , CaCy_2 instead of the formula for calcium cyanide

just given. The two quasi-elements may combine together, giving us NH_4CN , or AmCy, ammonium cyanide, in which, although three elements are present, the nomenclature is that of a binary compound, because the body is regarded as made up of two quasi-elements.

ATOMIC WEIGHTS AND SYMBOLS.

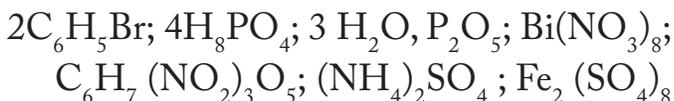
Name.	Symbol	At. Wt.	Name.	Symbol.	At. Wt.
Aluminium	Al	27.3	Mercury	Hg	200
Antimony	Sb	122	Molybdenum	Mo	96
Arsenic	As	75	Nickel	Ni	58.6
Barium	Ba	137	Niobium	Nb	94
Beryllium	Be	9.	Nitrogen	N	14
Bismuth	Bi	210	Osmium	Os	198.6
Boron	B	11	Oxygen	O	16
Bromine	Br	80	Palladium	Pd	106.2
Cadmium	Cd	112	Phosphorus	P	31
Caesium	Cs	133	Platinum	Pt	196.7
Calcium	Ca	40	Potassium	K	39
Carbon	C	12	Rhodium	Rh	104
Cerium	Ce	141	Rubidium	Rb	85.2
Chlorine	Cl	35.4	Ruthenium	Ru	103.5
Chromium	Cr	52.4	Selenium	Se	78
Cobalt	Co	58.6	Silicon	Si	28
Copper	Cu	63	Silver	Ag	108
Didymium	Di	147	Sodium	Na	23
Erbium	Er	169	Strontium	Sr	87.2
Fluorine	F	19	Sulphur	S	32
Gallium	Ga	68.9	Tantalum	Ta	182
Gold	Au	196.2	Tellurium	Te	128
Hydrogen	H	1	Thallium	Tl	204
Indium	In	113	Thorium	Th	231.5
Iodine	I	127	Tin	Sn	118
Iridium	Ir	196.7	Titanium	Ti	48
Iron	Fe	56	Tungsten	W	184
Lanthanum	La	139	Uranium	U	240
Lead	Pb	207	Vanadium	V	51.2
Lithium	Li	7	Yttrium	Y	93.
Magnesium	Mg	24	Zinc	Zn	65
Manganese	Mn	55	Zirconium	Zr	89.6

In rough calculations the fractions of the atomic weights may be disregarded, the nearest whole number being taken.

PROBLEMS.

THE answers to these problems are given on the next page. The method of solving them will be found on the pages noted in each set.

Pages 9 and 10. Give the number of atoms of each element in the following formulæ:



Page II. Determine the molecular weight of copper monoxide; potassium monochloride; Fe_2Cl_6 ; $\text{C}_2\text{H}_4\text{O}_2$; As_2O_3 ; $\text{Pb}(\text{NO}_3)_2$

Pages 13 and 14. Give the names of the following; Cu S ; KI ; H_2O ; CrO_3 ; Sb Cl_8 ; Fe_2O_3 ; Pb Cl_2 ; Hg Br_2 ; As I_3 .

Pages 13-16. What is the essential difference between calcium nitride, nitrate and nitrite; between sodium chloride and chlorate; between potassium manganate and permanganate.

Pages 22-24, Write the formulæ of copper oxide; silver chloride; calcium bromide ; carbon sulphide; hydrogen chloride; carbon oxybromide.

Pages 25 and 26. Write the formulæ of ferric bromide, ferrous chloride; mercurousulphide; mercuric iodide ; cuprous oxide ; cupric chloride ; phosphorous chloride; arsenic sulphide.

Pages 17, 27 and 28. Write the formulas of potassium sulphate ; acid sodium sulphate ; acid potassium carbonate ; calcium sulphite ; silver chlorate; sodium nitrite ; acid silver

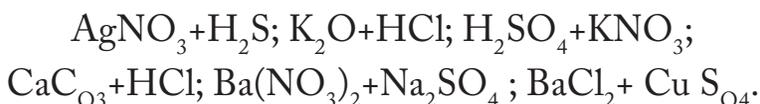
sulphite; 3 different sodium phosphates; 3 different calcium phosphates; ferrous sulphate; ferric sulphate; mercurous sulphate ; mercuric chlorate.

Pages 29, 30 and 31. Represent graphically carbon oxy-chloride ;arsenious bromide ; ferric iodide.

Page 36, Which of the following reactions are possible, and give reasons:



Pages 39, 40. Give the correct proportions and work out the following:



ANSWERS TO PROBLEMS

THE answers are given strictly in the order of the problems.

Pages 9 and 10. $\text{C}_{12}\text{H}_{10}\text{Br}_2$; $\text{H}_{12}\text{P}_4\text{O}_{16}$; H_6O_3 , P_2O_5 ; BiN_3O_9 ; $\text{C}_6\text{H}_7\text{N}_3\text{O}_{11}$; $\text{N}_2\text{H}_8\text{SO}_4$; $\text{Fe}_2\text{S}_3\text{O}_{12}$.

Page II. 79; 84.4; 324.4; 60; 198; 331.

Pages 13 and 14. Copper, sulphide, Potassium iodide, hydrogen monoxide,* chromium teroxide, antimony terchloride, iron sesquioxide, lead dichloride, mercury dibromide, arsenic teriodide.

Pages 13–16. Calcium nitride contains only Ca and N. The nitrate and nitrite contain Ca, N and O, the nitrate containing the greater amount of O. Sodium chloride contains only Na and Cl. Sodium chlorate contains Na, Cl and O. Potassium permanganate contains more O than the manganate.

Pages 22–24. CuO ; AgCl ; CaBr_2 ; CS_2 , HCl ; COBr_2 .

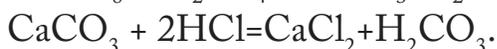
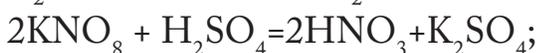
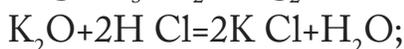
Pages 25 and 26. Fe_2Br_6 ; FeCl_2 ; Hg_2S ; HgI_2 ; Cu_2O ; CuCl_2 ; PCl_3 ; As_2S_5 .

Pages 17, 27, 28. K_2S_{04} ; NaHS_{04} ; KHCO_3 ; CaSO_3 ; AgClO_3 ; NaNO_2 ; AgHSO_3 ; NaH_2PO_4 , Na_2HPO_4 , Na_3PO_4 ; CaHPO_4 , $\text{Ca}_2\text{H}_2(\text{PO}_4)_2$, $\text{Ca}_3(\text{PO}_4)_2$; FeSO_4 ; $\text{Fe}_2(\text{SO}_4)_3$, Hg_2SO_4 , $\text{Hg}(\text{ClO}_3)_2$ or HgCl_2O_6 .

Pages 29, 30, 31.—

Page 36. $\text{ZnCl}_2 + \text{Fe}$ and $\text{HgCl}_2 + \text{I}_2$ will not react because Fe is *less* positive than Zn, and I *less* negative than Cl. $2\text{AgNO}_3 + \text{Cu}$ will produce $\text{Cu}(\text{NO}_3)_2 + \text{Ag}_2$ because Cu is *more* positive than Ag.

Pages 39, 40.—



In the remaining reactions the proportions are correct as given in the problems.

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