CHEMICAL PROBLEMS.

Problem I.—To state the relative weights of constituents entering into a chemical reaction, the equation being given.

Example.—(Take atomic weights to nearest whole number.)

Zn	+ H_2SO_4	= $ZnSO_4$	+ H_2
$Zn = 65$	$H_2 = 2$	$Zn = 65$	$H_2 = 2$
	$S = 32$	$S = 32$	
	$O_4 = 64$	$O_4 = 64$	

Summation $(Zn)\ 65 + (H_2SO_4)\ 98 = (ZnSO_4)\ 161 + (H_2)\ \ 2$

Answer.—Sixty-five parts by weight of zinc and ninety-eight parts of sulphuric acid produce one hundred and sixty-one parts of zinc sulphate and two parts of hydrogen.

We have then merely to add the atomic weights of the elements in each term to obtain the weights of the various substances. This is not, properly speaking, a "problem" at all, but only a restatement of the fact that the molecular weights of compounds are the sums of the atomic weights of the elements composing them, each weight being reckoned as many times as the subscripts indicate.

Note that the equation also illustrates the *Conservation of Mass:*

$$65+98=161+2$$

It is true that the "weights" in this illustration are merely "relative" expressions, but that does not affect the last statement, since any substitution of *actual weights*, in any unit of weight whatever, would bring about the same equation, provided the due proportions were maintained. This brings us to the first real "Stoichiometric" question.

Problem II.—(*a*) The *actual* weight of one substance entering into a chemical reaction being known, to determine the weight of any of the other substances, equation being given. ("Approximate" weights used throughout in Problem II.)

(As either element or compound may take part in the reaction, the word "substance" is used to indicate either. It is to

be taken, however, to mean a "substance" of definite chemical composition and formula.)

Example:

$$KOH + NH_4Cl = KCl + H_2O + NH_3$$

If we have *one pound* of "caustic potash" (KOH), what will be the weights of ammonium chloride, potassium chloride, water and ammonia gas, respectively?

Solution.—The relative weights must be first set down as in Problem I. Now, since these weights are in fixed ratio, if one of them becomes concrete the others may at once be determined by a simple proportion. The same statement applies to so many other chemical problems, that it may be given as a perfectly general rule or principle, viz:

"Combining weights and actual weights are in the same ratio."

In forming the proportion, place the combining (molecular or atomic) weights in the first member, keeping second member for the known and unknown actual weights. Let the unknown come in as the last term.

$K = 39$	$N = 14$	$K = 39$	$H_2 = 2$	$N = 14$
$O = 16$	$H_4 = 4$	$Cl = 35.5$	$O = 16$	$H_3 = 3$
$H = 1$	$Cl = 35.5$			
$KOH = 56$	$NH_4Cl = 53.5$	$KCl = 74.5$	$H_2O = 18$	$NH_3 = 17$

Let it now be required to find the weight of potassium chloride (KCl).

$$KOH : KCl = KOH : KCl$$
$$56 : 74.5 = 1 : x \qquad x = 1.33.$$

Answer.—1.33 pounds of potassium chloride.

Repeating the rule: "Combining weight of potassium hydroxide is to combining weight of potassium chloride, as actual (known) weight of potassium hydroxide is to actual weight of potassium chloride."

In the same way we can get the weight of any other term of the equation.

$$KOH : NH_4Cl = KOH : NH_4Cl$$
$$56 : 53.5 = 1 : 0.9554 \quad \text{(lbs.)}$$

$$KOH : NH_3 = KOH : NH_3$$
$$56 : 17 = 1 : 0.3036 \quad \text{(lbs.)}$$

$$KOH : H_2O = KOH : H_2O$$
$$56 : 18 = 1 : 0.3124 \quad \text{(lbs.)}$$

In short, each term of any chemical equation has a fixed numerical relation to each and every other term, whether the comparison be made in molecular or in actual weights.

We may now extend this illustration a little further. Let us suppose a *series* of reactions, as in the following equations:

$$H_2SO_4 + Zn = ZnSO_4 + H_2 \quad (1)$$
$$CuO + H_2 = Cu + H_2O \quad (2)$$
$$H_2O + SO_3 = H_2SO_4 \quad (3)$$
$$H_2SO_4 + Zn = ZnSO_4 + H_2 \quad (4)$$

Let the molecule H_2 be the same throughout these reactions, or, in actual weights, suppose the hydrogen to be always the same. Then will all the other molecules or weights be present in their fixed relative proportions. The SO_3 of (3) and the Zn of (1) or (4) are in the proportion of 80 to 65. Given any one term in the whole series, we can determine any other term.

Problem II.—(*b*) In a series of connected reactions (equations being given) to determine the weight of any product (final or intermediate) from known weight of any one term, without calculating the intermediate terms.

Solution.—This is a mere variant, and a very trivial one, from Problem II (*a*). Method is exactly the same.

Example:

$$4NaCl + 4H_2SO_4 = 4NaHSO_4 + 4HCl \quad (1)$$
$$MnO_2 + 4HCl = MnCl_2 + 2H_2O + Cl_2 \quad (2)$$

We have ten pounds of salt (NaCl) in (1); what weight of chlorine gas will be produced in (2)?

$$4NaCl = (23 + 35.5) \times 4 = 234$$
$$Cl_2 = 35.5 \times 2 = 71$$

$$4NaCl : Cl_2 = 4NaCl : Cl_2$$
$$234 : 71 = 10 : x = 3.034 \ \textit{Ans.}$$

We could go from term to term, calculating the weight of each and every compound in succession. This indeed would be necessary if the calculation be supposed to indicate some practical manufacturing process. In such a case we should compute the sulphuric acid needed, and the manganese dioxide. So far as the weight of the final product is concerned, such procedure is quite needless.

Problem II.—(*c*) Find weight of a substance "*B*" chemically equivalent to a given weight of a substance "*A*," according to a given or required formula.

The variation from the other forms is very trivial. No equation, however, need be written in this case. It is another application of "Combining and actual weights in the same ratio."

Examples.—(*a*) We have 3 per cent. of copper in an ore. How much sulphur will it take to bring it into matte in the form of Cu_2S?

This ratio being often called for in metallurgical calculations, it is usual to assume copper as four times the weight of the sulphur in the combination Cu_2S. This is merely assuming that the atomic weights are 64 and 32 instead of 63.57 and 32.07 respectively.

We have then

$$Cu_2 : S = Cu_2 : S = Cu_2 : S$$
$$128 : 32 = 4 : 1 = 3 : 0.75$$

So that in one hundred lbs. of ore we should use 0.75 lbs. of sulphur in the formation of the matte which carried all of its copper.

(*b*) We have 20 lbs. of silica. What weight of lime (CaO) is needed to combine with it, so as to form Ca_2SiO_4?

This formula separates into 2CaO and SiO_2. We now have:

$$SiO_2 : 2CaO = \text{silica (lbs.)} : \text{lime (lbs.)}$$
$$60 : 112 = 20 : 37.66$$

(*c*) 100 lbs. of PbS is roasted to $PbSO_4$. What is the gain in weight?

$$PbS : PbSO_4 = \text{lbs. sulphide} : \text{lbs. sulphate}$$
$$239 : 303 = 100 : 126.7$$

(Gain = 26.7 lbs.)

There are cases in which the statement may be facilitated by writing an equation of reaction, *e.g.:*

(*d*) How much potassium cyanide will be destroyed by one pound of sulphuric acid? The equation of this reaction (for solutions) would be:

$$KCy + H_2SO_4 = KHSO_4 + HCy \quad (Cy = 26)$$

Then:

$$H_2SO_4 : KCy = \text{lbs. acid} : \text{lbs. cyanide}$$
$$98 : 65 = 1 : 0.66$$

A variety of stoichiometrical problems, many of which have metallurgical applications, come under the elementary principle illustrated in these variants of Problem II.

As part of this volume is devoted to metallurgical calculations, some problems preliminary to actual furnace or slag calculations are appended, together with others of a more general kind.

(*e*) An ore contains by analysis:

FeS_2	48.00 per cent.
ZnS	24.25 per cent.
Silica	27.75 per cent.
Total	100.00 per cent.

It is roasted, with reactions as below:

$$4FeS_2 + 11\ O_2 = 2Fe_2O_3 + 8SO_2$$
$$ZnS + 2\ O_2 = ZnSO_4$$

Suppose one ton of the ore to be treated. What is weight of the product after roasting? *Ans.* No change in weight.

(*f*) $$2KNO_3 + H_2SO_4 = K_2SO_4 + 2HNO_3$$

(Production of nitric acid from potassium nitrate and sulphuric acid.)

Take 350 grams of the nitrate, what weight of sulphuric acid is required? *Ans.* 169.8 grams.

(*g*) $$Sn + 4HNO_3 = SnO_2 + 4NO_2 + 2H_2O$$

Seven lbs. of the binoxide were produced, what weight of tin was taken? *Ans.* 5.517 lbs.

(*h*) $$PBr_3 + 3H_2O = H_3PO_3 + 3HBr$$
$$3HBr + 3AgNO_3 = 3HNO_3 + 3AgBr$$

Phosphorus tribromide is decomposed by water, and then precipitated with silver nitrate. If 3.3 grams of the tribromide were taken, what is weight of the silver bromide?

Ans. 6.87 grams.

(*i*) We have ore with 30 per cent. silica which is to be combined with enough ferrous oxide to form FeO, SiO_2. What weight of Fe_2O_3 must be added to effect this? Weight of ore one hundred lbs.

$$60 : 72 = 30 : 36$$

We require therefore 36 lbs. of ferrous oxide. Ferric oxide (Fe_2O_3) contains 90 per cent. ferrous oxide by formula. Hence:

$$\frac{36}{.9} = 40 = \text{required lbs. of ferric oxide}$$

(*j*) Ore contains 40 per cent. lead sulphide (PbS). Roasted, this becomes a mixture of lead oxide (PbO) and lead sulphate ($PbSO_4$). One-half of the lead in the ore goes to each form. Take 100 lbs. of ore, what will be the respective weights of oxide and sulphate produced?

Ans. PbO, 18.66; $PbSO_4$, 25.36 lbs.

(*k*) $$4FeS_2 + 11\ O_2 = 2Fe_2O_3 + 8SO_2$$

Three tons of pyrite are roasted to ferric oxide. What will be the weight of the latter? *Ans.* 2 tons.

(*l*) $$2KI + MnO_2 + 2H_2SO_4 = K_2SO_4 + MnSO_4 + 2H_2O + I_2$$

If the iodine produced weighed 9.071 what weight of potassium iodide was taken? *Ans.* 11.857.

(*m*) $$S_2 + 3\ O_2 + 2H_2O = 2H_2SO_4$$

This is an outline of the process of manufacturing sulphuric acid. If we take 500 lbs. of sulphur, what weight of sulphuric acid? *Ans.* 1531 lbs.

(*n*) Tri-calcic phosphate has the formula $Ca_3(PO_4)_2$. What weight of it contains 20 lbs. of phosphorus? *Ans.* 100 lbs.

(*o*) $$2As_2 + 3\ O_2 = 2As_2O_3$$

Take 1350 grams metallic arsenic, what weight of trioxide is obtained? *Ans.* 1782 grams.

(*p*) $$2Ca\ (PO_3)_2 + 5C = 5CO + Ca_2P_2O_7 + 2P$$

Calcium metaphosphate heated with charcoal produces calcium pyrophosphate and phosphorus.

Taking 31 grams of the metaphosphate, what weight of phosphorus? *Ans.* 4.85 grams.

(*q*) $$CaSO_4 + BaCl_2 = CaCl_2 + BaSO_4$$

The $BaSO_4$ resulting from this reaction weighed 11.65. What weight of calcic sulphate was taken? *Ans.* 6.8.

(r)
$$PCl_5 + 4H_2O = H_3PO_4 + 5HCl$$
$$5HCl + 5AgNO_3 = 5HNO_3 + 5AgCl$$
$$5AgCl = 5Ag + 5Cl$$

Weight of the silver from these reactions was 67.5 grams, find weight of the phosphoric acid. *Ans.* 12.25 grams.

(s) $MgCO_3 + H_2SO_4 + 6H_2O = MgSO_4, 7H_2O + CO_2$

Limestone contains 12 per cent. magnesium carbonate. Take forty pounds of it, how many pounds of the crystallized sulphate? *Ans.* 14.05 lbs.

(t) $Cu + 2H_2SO_4 = CuSO_4 + 2H_2O + SO_2$ (Cu = 64)

The SO_2 gas weighs 7.11 grams. What weights of copper and of sulphuric acid were taken?

Ans. Copper 7.11 lbs. Acid 21.73 lbs.

(u) $4FeS_2 + 8H_2O + 15O_2 = 2Fe_2O_3 + 8H_2SO_4$

This represents in outline the production of sulphuric acid from pyrite. Take 1000 lbs. of pyrite, what weight of sulphuric acid is obtained? *Ans.* 1633 lbs.

(v) $NaNO_3 + KCl = NaCl + KNO_3$

Interchange of bases and acid radicals in the manufacture of potassium nitrate (saltpeter) from sodium nitrate and potassium chloride.

Take 17 lbs. of sodium nitrate. What weight must we add of potassium chloride, and what will be weight of potassium nitrate? *Ans.* 14.9 lbs. potassium chloride. 20.2 lbs. nitrate.

(w) $Na_2CO_3 + 2C = 3CO + Na_2$

From this operation 43.4 lbs. of sodium were produced. How many lbs. of sodium carbonate were taken?

Ans. 100 lbs.

(x) $CaCO_3 = CaO + CO_2$

This represents the burning of limestone to produce quicklime. If we want 100 lbs. quick-lime (CaO) what weight must we take of the limestone? *Ans.* 178.6 lbs.

(y) $Fe_2O_3 + 3C = 3CO + Fe_2$

Hematite (Fe_2O_3) is reduced in the blast furnace in about this ratio to the carbon introduced (theoretically).

Suppose the coke to contain ninety per cent. of carbon, how many pounds of it will reduce 432 lbs. of hematite to metallic iron? *Ans.* 108 lbs.

(z) $(NH_4)_2 PtCl_6$. This salt (chloroplatinate of ammonium) is decomposed on heating, leaving behind only its platinum. Wishing to obtain 100 grams of the metal, what weight of the salt must we take? *Ans.* 227.8 grams.

Many examples involving this principle will be found under other headings. They are not placed here, because the above cases introduce no considerations but weight, while the slightly more complex problems under other captions include gas volumes, thermometer and barometer and atomic weight determinations.

DEDUCTION OF ANALYSIS FROM FORMULA.

Problem III.—(a) Given the formula of a chemical compound, to deduce its analysis, or composition expressed in percentages.

Before illustrating the working of this very simple problem, we call attention to the various possible subdivisions we may make in a compound.

Take $PbSO_4$. It may be divided into its three elements, in which case we should get its percentages of lead, sulphur and oxygen, respectively, which must sum to 100. It might be divided into the metal lead and the anion SO_4, which is merely a negative radical with no independent existence as a compound. It might be more rationally divided into PbO and SO_3, and it was in fact so written in the days of the long prevalent "dualistic" nomenclature and symbolism: PbO, SO_3. The character of the subdivision will depend upon the purpose or point of view to be subserved, but whatever division be called for, the method of solution is not altered in the least.

The molecular weight (using nearest units of atomic weights) is 303, *i.e.*,

Pb = 207
S = 32
O_4 = 64 Total 303

The number 303 must be used in any case. If we are to get the percentage of lead we compare it with 207. If per cent. of PbO is required we compare it with 223 (Pb, 207 + O,16) and so on for any combination.

The student should realize that the subdivisions of compounds as expressed by formulæ and as set forth in analyses sometimes differ considerably. Binaries with only one atom of each element in the formula admit of only one subdivision; many other substances (compounds) have to be divided according to the demands of special requirements.

In the case of the hydroxides they may usually be divided into the oxide and water. Example:

$$Fe_2(OH)_6 = Fe_2O_3 + 3H_2O$$

Another familiar instance is found in the carbonates which are always subdivided into the oxide and CO_2, *e.g.*,

$$CaCO_3 = CaO + CO_2$$

The same is true of all the amphid salts. They must often be separated, in an analytical statement, into oxide and anhydride.

The beginner in analytical chemistry should be made aware that although the "dualistic" nomenclature is about dead, it survives after a fashion in the summations of many analyses.

Thus, in the now obsolete method, we once wrote $3CaO,P_2O_5$. We now write $Ca_3(PO_4)_2$. But in summing an analysis which showed lime and phosphates, we should have to write CaO and P_2O_5 as constituents for summation.

We mentioned in the introduction that a difficulty sometimes arose by forgetting to double a symbol in making a formulistic transposition. We have here a cognate case, though not of exactly the same description.

Suppose an alum is to be analysed, general formula AlK $(SO_4)_2 + 12H_2O$. On attempting to "adjudicate" such an expression, or to write its "analysis" by percentages, we find we cannot do so rationally, without doubling first, and then separating into the well-known proximate constituents, thus:

$$Al_2(SO_4)_3 + K_2SO_4 + 24H_2O$$

This serves to show the separate relations of the metals to the sulphuric acid anion, but for analytical statement we would have to go further, summing the oxides and of necessity the anhydrides.

$$Al_2O_3, 3SO_3 + K_2O, SO_3 + 24H_2O$$

This is the full "dualistic" form, and for *analytical* statement the two portions of anhydride (SO_3) would have to be put under the same heading constituting one of the "percentages" of the complete analysis.

In metallurgical formulæ the student may often have occasion to transform a silicate from modern into ancient form of statement, for the latter survives in the consideration of slag silicates.

Example.—$Al_4Si_3O_{12}$. It is not easy to recognize the class (metallurgically) to which this silicate belongs, without taking out the silica first. Since there are three atoms of silicon we "take out" $3SiO_2$, which leaves Al_4O_6, quickly recognized as $2Al_2O_3$. ("Singulo silicate.")

The fact that the old system is obsolete might seem a sufficient reason for excluding all mention of it from this work. But although extinct in form, "the fact remains" that there are numerous cases in which separation into the old proximates is necessary.*

The student must then understand that in the computation of percentages something more is often required than the mere estimation, element by element. These cautions, already somewhat extended, will receive illustration in a number of examples.

We now turn to the statement of Problem III (*a*) as in the heading.

We have only to remember that each symbol represents a weight proportional to the atomic weight. Then:

"The molecular weight of the compound is to the atomic (or molecular) weight of a given constituent, as 100 is to the percentage of the constituent in question."

Examples.—(*a*) Find percentage composition of pyrite, FeS_2.

Atomic weight of iron..............................	56
Molecular weight of two sulphurs....................	64
Molecular weight of FeS_2...........................	120

*The subject is expanded for the benefit of beginners. Those who think too much space has been given to an extremely simple sub-topic are not far mistaken. They are recommended, however, to take a course *as instructor* in the subject. The author has had trouble enough for three lectures in the above elementary exposition.

Now apply the rule, putting the "theoretical" weights in the first member of your proportion. As a rule, let the "unknown" come in as fourth term.

For iron.......120 : 56 = 100 : x. x = 46.66 = per cent. iron.
For sulphur...120 : 64 = 100 : y. y = 53.33 = per cent. sulphur.

Proof : Total.......................99.99 per cent.

(*b*) Find composition of calcite, $CaCO_3$, expressed in percentages of lime (CaO) and carbon dioxide (CO_2).

$$CaO = 40 + 16 = 56. \quad CO_2 = 12 + 32 = 44. \quad \text{Total} = 100.$$

It happens that the molecular weight of the compound is just 100. It is evident then that the figures for the partial molecular weights are the same as "percentages."

Ans. CaO, 56 per cent., and CO_2, 44 per cent.

(*c*) Find percentage composition of magnesium pyrophosphate $Mg_2P_2O_7$, expressed as MgO and P_2O_5. Also find percentage of phosphorus.

Remember here that the MgO is *formulistically* Mg_2O_2, or rather, 2MgO. Also, that the phosphorus must be figured as P_2 as in the formula, not as "P."

Ans. 2MgO = 36.24 per cent. P_2O_5 = 63.76 per cent. P_2 = 27.84 per cent.

(*d*) Find composition of the silicate $Ca_2SiO_4 + Fe_2SiO_4$, expressed in terms of CaO, FeO and SiO_2.

Evidently there are two molecules of CaO and two of FeO. After subtracting these, we find remaining Si_2O_4, that is, $2SiO_2$.

We now tabulate the various molecular weights and sum up. It is hardly necessary to "spread" all of these in the form of the complete proportion. The student will rapidly learn to dispense with that form in many cases. *He will use it in fact,* but will hardly trouble himself to write the proportional equation out in full.

$$2SiO_2 = 120 \qquad \frac{120 \times 100}{376} = 31.91 = \text{per cent. of } SiO_2$$

$$2CaO = 112 \qquad \frac{112 \times 100}{376} = 29.78 = \text{per cent. of CaO}$$

$$2FeO = 144 \qquad \frac{144 \times 100}{376} = 38.30 = \text{per cent. of FeO}$$

Total.....376 99.99 = Total per cent. (Proof.)

(*e*) Bone ash has the average composition, formulistically, $CaCO_3, 3Ca_3(PO_4)_2$.

Find the percentage composition:

(1) By elements.

(2) As oxides and anhydrides.

(3) As salts (*i.e.*, carbonates and phosphates).

Method (operations not given in detail).—The phosphate symbols are to be extended, *i.e.*, multiplied out, which gives us $Ca_9P_6O_{24}$. Take out all the CaO, *i.e.*, since there are 9 times Ca subtract 9 oxygens also. This leaves P_6O_{15}, that is, $3P_2O_5$. Treat the $CaCO_3$ in the same way. Thus we easily get molecular weights of the whole and of each part, in all the three ways.

Answers:

AS ELEMENTS.		AS OXIDES, ETC.	
Carbon.........	1.16 per cent.	CaO....	54.37 per cent.
Calcium........	38.84 per cent.	CO_2....	4.27 per cent.
Phosphorus.....	18.06 per cent.	P_2O_5...	41.36 per cent.
Oxygen.........	41.94 per cent.		
	100.00 per cent.		100.00 per cent.

AS SALTS.	
$CaCO_3$........	9.71 per cent.
$Ca_3(PO_4)_2$.....	90.29 per cent.
	100.00 per cent.

This problem being very simple, examples are not extended. However, the table of per cent. composition (III) and the table of chemical factors (II), especially the first, contain as many "problems" in this line as there are substances given. The same may be said of the table of compositions in relation to the next problem, viz: the derivation of formula from analysis.

Before dropping the problem, we may repeat what has been said elsewhere as to the difference between strictly formulistic and analytical subdivision of proximates.* Generally we may say that a statement of composition would hardly be recognized as "analytical" which contained as a percentage constituent a radical or "ion" not susceptible of actual separation. It is just as easy to "figure out" such a percentage as any other, but that is no justification for doing so.

*If water be present, state its percentage as such, not separating it into oxygen and hydrogen.

For example, the very familiar anion SO_4 has no real existence as a *substance*, however real it is as existing in a compound. Neither has the excessively frequent "OH"—hydroxyl.

Problem III.—(*b*) To construct a table of chemical factors. (Table II.)

The "factors" used in the calculation of chemical analyses are useful both for acceleration of the work and for the avoidance of error.

Suppose we are making a series of determinations of tin in tin alloys. The substance *weighed* will always be tin binoxide (SnO_2). This we know contains: Sn = 119 and O_2 = 32 as to atomic weights. Thus we have the proportion, calling the known weight "*a*" and the weight of tin (sought) "*x*:"

$$SnO_2 : Sn = SnO_2 \text{ found} : Sn \text{ sought.}$$
$$151 : 119 = a : x$$
$$x = \frac{a \times 119}{151}$$

Evidently the fraction $\frac{119}{151}$ will always enter this particular computation, and be reduced to a factor in decimals. Performing the indicated division we find this factor to be 0.7881. That is, *any given weight of tin binoxide multiplied by this factor gives the weight of the tin which it contains.* If we have taken one gram for analysis the result will be the figures expressing percentage as well as actual weight.

Example.—We take one gram for analysis, and find 0.1325 SnO_2. This, multiplied by factor 0.7881, gives 0.1044, which is the weight of the tin in decimals of a gram. But the figures of course express the percentage also. *We have only to multiply by* 100, *writing them* 10.44, to get the ordinary expression for percentage, with 100 instead of unity as the total.

The "factors" are in short simply the percentages of the required element in the given compound, divided by 100.

In case a multiple or sub-multiple of a gram has been taken—or, as was once the regular practice, a wholly irregular and chance-selected weight, the operation of ascertaining the percentage is lengthened. Irregular weights are now rarely taken, and indeed only as a matter of necessity. It sometimes happens that a very hard metal is brought to the chemist in coarse pieces instead of filings. It is usually much easier to weigh out an "irregular" quantity and perform the necessary extra calculations than to try to reduce the metal to a powder fine enough for taking a weight of it to the exact gram.

As we always want an expression in percentage, we must somewhere in our calculations divide weight found, *times* 100, by total weight. This may be accomplished without going through this operation literally, but the operation must be there in some shape.

When any quantity other than a gram has been taken for analysis, the easiest way to calculate is simply to divide the weight found by the weight taken. The quotient is the weight that would have been found *had one gram been taken originally.*

Example.—We take one gram of an ore for analysis and find for magnesium the precipitate $Mg_2P_2O_7$ weighing 0.2246. Required, percentage of MgO. We multiply by 0.3622 (see Table II) and find 0.0814 or 8.14 per cent.

Suppose we had taken 1.5 gram instead of 1 gram. Then the $Mg_2P_2O_7$ would have weighed 1.5 times more, or 0.3369 gram. Dividing by 1.5 we reduce to the figure 0.2246, *i.e.*, the figure obtained when we take 1 gram.

Similarly, had we taken 0.5 gram we would have found 0.1123 as weight of $Mg_2P_2O_7$. Divide by 0.5 and we again get the figure 0.2246.

Exercises on the use of the table of factors, both for one gram and for irregular weights, are given below.

The student should observe that, as a rule, the smaller the proportion of an element "sought" in the compound weighed, the more accurate the determination so far as concerns the sources of error derived from ordinary loss or gain.

Assume two cases. In the first we are to determine bismuth from the weight of Bi_2O_3. In the second we are to determine sulphur from the weight of $BaSO_4$. Let us suppose that the weight of each (derived from original portion taken of one gram in each case) comes out the same (0.0700 gram). If from each analysis we have lost the same weight of precipitate, say five milligrams (*i.e.*, alike of Bi_2O_3 and $BaSO_4$), a very simple calculation will show that the error in bismuth will be .0045 or 0.45 per cent., while that of the sulphur will be only 0.0007 or 0.07 per cent.

Deduction of weight *sought* from weight of another substance *found* being the commonest of all laboratory calculations, this problem has been frequently introduced as part of the necessary calculation in other problems, such as computation of atomic weights, excess and deficiency, etc.

The logarithms of these factors are often used, and are as usual annexed to them in the table. In working a series of the same determinations it is convenient to have the log. of the factor which is being so constantly used ready on the computation paper, so that it remains only to take out the log. of the weight which is to be multiplied. Some persons, however, find it easier to multiply four digits by four others than to "take out" from the logarithmic table. With practice, the latter becomes the quicker.

EXERCISES IN THE USE OF CHEMICAL FACTORS (TABLE II).
WEIGHT TAKEN ONE GRAM.

Substance Weighed.	Weight Found.	Substance Sought.	Percentage.
$PbSO_4$	0.2350	Pb	16.05
Fe_2O_3	0.9120	Fe	63.78
ZnO	0.5480	Zn	44.07
$Mn_2P_2O_7$	0.0260	MnO	1.30
Cu_2S	0.5252	Cu	41.94
$AgCl$	0.1234	Ag	9.29
$BaSO_4$	0.5000	SO_3	17.15
Bi_2O_3	0.1111	Bi	9.96
N	0.1326	NH_3	16.12
$Mg_2P_2O_7$	0.2732	MgO	9.90
ZnS	0.8432	Zn	56.66
Pt [$(NH_4)_2PtCl_6$]	0.1214	N	1.74
$BaSO_4$	0.4321	S	5.93
SiO_2	0.1233	Si	5.79
PbS	0.2324	Pb	20.12
$BaSO_4$	0.3734	BaO	24.53
CO_2	0.0770	C	2.10
$Mg_2P_2O_7$	0.0821	P_2O_5	5.24
Ag (from Ag_3AsO_4)	1.0000	As	23.17
Sb_2S_3	0.3642	Sb	26.01
SnO_2	0.6140	Sn	48.39
KCl	0.0378	K_2O	2.39
NiO	0.0414	Ni	3.31
Cr_2O_3	0.0762	Cr	5.22
$NaCl$	0.3611	Na_2O	19.15
$CaSO_4$	0.5406	CaO	22.27

EXERCISES IN THE USE OF CHEMICAL FACTORS (TABLE II).
IRREGULAR WEIGHTS.

Weight Taken.	Found.	Weight Found.	Sought.	Percentage.
(*a*) 0.435	KCl	0.102	K_2O	14.81
(*b*) 1.234	$CaSO_4$	0.064	CaO	2.14
(*c*) 0.800	CaO	0.328	$CaCO_3$	73.16
(*d*) 0.412	Pt	0.414	N	14.44
(*e*) 2.500	Pt	0.284	NH_3	1.99
(*f*) 0.886	$BaSO_4$	0.441	BaO	32.70
(*g*) 0.765	$BaSO_4$	0.202	S	3.63
(*h*) 1.500	$BaSO_4$	0.606	SO_3	13.85
(*i*) 0.750	Fe_2O_3	0.302	Fe	28.16
(*j*) 0.250	Fe_2O_3	0.072	FeS_2	43.28
(*k*) 1.200	ZnO	0.840	Zn	56.29
(*l*) 0.500	ZnS	0.225	Zn	30.24
(*m*) 3.000	SnO_2	0.488	Sn	12.82
(*n*) 2.750	Sb_2S_3	1.668	Sb	43.32
(*o*) 0.400	$Mg_2P_2O_7$	0.186	P	12.95
(*p*) 5.000	$Mg_2P_2O_7$	0.026	P_2O_5	0.332
(*q*) 1.275	$Mn_2P_2O_7$	0.456	MnO	17.88
(*r*) 1.400	Cu_2S	0.233	Cu	13.29
(*s*) 3.500	CuO	0.998	Cu	22.78
(*t*) 0.428	$AgCl$	0.187	Ag	32.88
(*u*) 0.924	$AgCl$	0.296	Cl	7.92
(*v*) 0.756	SiO_2	0.700	Si	43.45
(*w*) 0.280	$PbSO_4$	0.300	Pb	73.19
(*x*) 0.350	Bi_2O_3	0.062	Bi	15.88
(*y*) 0.275	$NaCl$	0.106	Na_2O	20.44
(*z*) 0.892	$Mg_2P_2O_7$	0.099	MgO	4.02

Problem III.—(*c*) To reduce any summation to the basis of percentage, it is only necessary to proceed exactly as in obtaining an analysis from a formula.

Example.—Calculation of a slag shows us that we may expect total weight from a given charge, of 450 lbs. of slag, distributed as follows:

Silica	180 lbs.
Alumina	90 lbs.
Lime	160 lbs.
Magnesia	20 lbs.
Total weight	450 lbs.