

SIMPLIFICATION OF DATA PREVIOUS TO CALCULATION.

In ores of lead, copper and the precious metals we frequently have a large number of elements, some of which will be reckoned as completely reduced to metal (*e.g.*, lead and its accompanying gold and silver), some brought into the form of matte with sulphur or of speiss with arsenic, others leave the furnace as slag (silicates), while finally an uncertain proportion will be dissipated in fumes, either permanently lost or partly regained as "flue dust."

Usually the latter losses are uncalculated, but when stock and all other conditions are fairly constant, it becomes possible in the light of experience to make close allowances for these "subtractive" elements of computation.

If for example in smelting an ore high in zinc, analysis of products shows one-fifth of same unaccounted for, such a loss would become part of the data.

- Such allowances consist merely in omission of the presumed losses from the weights or percentages as shown by the analysis.

As it may be a matter of complexity to make separate figures for each and every base, it is a common practice to substitute one for another, *e.g.*, when lime and magnesia are both present, calculate all as lime. This is sometimes done "weight for weight," more usually according to the chemical relations of the bases, that is, in stoichiometric ratio.*

Manganese and iron are so close in atomic weight that it is usual to add manganese to the iron weight in calculation, without change.

At best, there is much that is conventional in this substitution. It is sometimes inevitable. Naturally the metallurgist will try to group together bases which may be presumed to act similarly toward silica or toward the other bases in the slag. For the assumption underlying the substitution of one element

* When the totals of the bases thus treated are small, we may disregard chemical ratios, and lump them "weight for weight," under one head.

for another must be that the displacing element will act in a manner similar to the one displaced.*

No one supposes anything of the kind, the whole simplification by this artifice being a convention for the reduction of slags to certain "type" forms. All that can be done is to see to it that too great violence is not done to the facts as demonstrated by long experience.

"As nearly as I can make it out," remarked a metallurgist of very great practice to the writer, "the rule is to call manganese, iron; and everything else, lime." This, while a humorous exaggeration, is fairly close to the actual practice in a large class of working problems.

Take a single example. We have zinc to treat as slagging material, and we place it in the lime group by multiplying by 0.7. The result will be that in computing for the addition of limestone as flux, we shall use less of it, as we have already a "conventional" lime in the shape of the calculated zinc. Here is a case where we make this substitution on the principle "by contraries." The more lime in a slag the worse is its carrying power for zinc oxide; in fact, there comes a point where the slag, getting too high in lime, refuses to accept zinc at all, throwing it into crusts and fumes to the damage of good running. Thus, the figuring of zinc into the lime column is far from indicating that these two act similarly, but it serves a purpose, nevertheless, by diminishing the *actual* lime. (CaO = 56. ZnO = 81. These are very nearly as 7 to 10.) Other substitutions, however, are in accord with chemical similarity.

Take a simple illustration of this substitution. We have a limestone whose analysis shows CaO 39 per cent., MgO 9 per cent. Now, since

$$\text{MgO} : \text{CaO} = 40 : 56 = 1 : 1.4$$

we can, if we have occasion to reduce the number of our bases for computation, figure thus: $\text{MgO} \times 1.4$, that is, 9×1.4 , is equivalent to 12.6 CaO. Then we add this to the actual lime: $39 + 12.6 = 51.6$.

The excess figured from analysis will not be affected by this sub-

* For example, we combine *actual* lime and *actual* magnesia into one weight, which we calculate thenceforth as lime. These two are the "displacing" and "displaced" bases, *in the computation*.

stitution. An example will make this clear. Take the above limestone; suppose it to contain, in addition to the bases as given, 10 per cent. silica.

We are figuring on the basis of a "singulo" silicate, and want to know the basic excess of the limestone. First take it as it stands, *i.e.*, without the transformation of the MgO.

$$\begin{aligned} 2\text{MgO} : \text{SiO}_2 &= 80 : 60 = 4 : 3 = 9 : 6.75 \text{ SiO}_2 \text{ required for MgO} \\ \text{Total SiO}_2 &= 10. \quad 10 - 6.75 = 3.25 = \text{SiO}_2 \text{ remaining for lime} \\ \text{SiO}_2 : 2\text{CaO} &= 60 : 112 = 3.25 : 6.07 \text{ CaO} \end{aligned}$$

$$\text{Total lime, less that required by SiO}_2 = 39 - 6.07 = 32.93$$

Now make the change of MgO into CaO by using factor as above, we get total lime = 51.6. Figure CaO excess in regular way:

$$\begin{aligned} \text{SiO}_2 : \text{CaO} &= 60 : 112 = 10 : 18.67 = \text{CaO required by SiO}_2 \\ 51.60 - 18.67 &= 32.93 \end{aligned}$$

or exactly the former figure.

This is *a priori* evident to anyone to whom the stoichiometric relation has become familiar. We again remind the practitioner that we are here, as in many other places, writing for the student.

An example in "simplification" will now be given.

A carbonate ore analyzes as follows:

SiO ₂	36.3 per cent.
FeO.....	16.0 per cent.
MnO.....	5.9 per cent.
CaO.....	5.6 per cent.
MgO.....	4.0 per cent.
S.....	5.1 per cent.
As.....	0.6 per cent.
Pb.....	18.0 per cent.
Cu.....	4.4 per cent.
CO ₂ and O.....	4.1 per cent.
Total.....	100.0 per cent.

(1) Adjust matte and speiss.

$$\text{Cu}_2 : \text{S} = 4 : 1 = 4.4 : 1.1 = \text{S for Cu}_2\text{S in matte.}$$

(2) S remaining is 5.1 - 1.1 or 4 per cent. Take out FeS to the extent that this S permits.

$$\text{S} : \text{FeO} = 32 : 72 = 4 : 9$$

= per cent. of FeO to be subtracted. This leaves (16 - 9) 7 per cent. FeO.

(3) Take out As and Fe, as Fe₃As.

$$\text{As} : 5\text{FeO} = 75 : 360 (= 5 : 24) = 0.6 : 2.88$$

FeO finally remaining for slag is 7 - 2.88 = 4.12.

NOTE.—It is quite useless, if the analysis states the iron as FeO, to reduce this to Fe (metallic iron) in calculating out S and As. Take the equivalent amounts (molecular weights) of the compounds given by the analysis. As this may not be at once evident to the student, we here step aside to "take out" the As in the ordinary way, *viz.* (look at "3" above):

$$\text{As} : \text{Fe}_3 = 75 : 280 = 0.6 : 2.24$$

That is, metallic iron required is 2.24 per cent. But now we would have to convert this into FeO, in order to subtract, thus:

$$\text{Fe} : \text{FeO} = 56 : 72 = 2.24 : 2.88$$

precisely the figure obtained before by one proportion instead of two.

This is very elementary; but it is by no means uncommon to see just this "round the corner" way of calculating, through lack of familiarity with the language of symbols.

To resume the calculation:

(4) Reduce the bases to two groups. Let us suppose that the required slag is to have a certain ratio of FeO to CaO. As we have four slagging bases we reduce MnO to FeO, and MgO to CaO.

As the molecular weights of FeO and MnO are as 72 : 71 it is the universal practice to combine them by simple addition. So we merely add residual iron to all of the manganese oxide, 4.12 + 5.9, and call this the total available FeO = 10.02, which might as well be entered as 10 per cent. for all the practical difference it would make.

Also, MgO × 1.4 = 5.6 nominal lime, CaO.

Total CaO will figure as 5.6 + 5.6 or 11.2 per cent.

Thus we have prepared the ore for calculation, so to speak. Whatever fluxes are to be used can now be computed.

The copper, sulphur and arsenic are disposed of.

The iron has been accounted for to the extent rendered necessary by the residual sulphur and the arsenic. The lead is out of the calculation, under the supposition of its complete reduction.

The silica and the fluxing bases are arranged, albeit in part conventionally, for adjudication with one another and with their proper weights of other flux.

Remains then, for calculation:

Silica.....	36.3
Iron oxide.....	10.0
Lime (CaO).....	11.2
Total.....	57.5 lbs.

for actual slag reckoning.

But these are not actual pounds, that is, not altogether, as the 4 of magnesia have become 5.6 of nominal lime. These and the pounds of FeO are the *chemical equivalents of pounds* in the special relation into which they are now to be brought with fluxing material.

Let us assume that we have a hematite for iron flux, containing SiO₂, 4 per cent., and FeO, 86 per cent. (The analysis would, of course, show Fe₂O₃, but this is reduced by the ratio 10 : 9 to FeO.)

We may figure the whole charge on the basis of percentage alone as we have so far. That is, assuming 100 lbs. as ore charge, pounds and "per cents." become the same expression in numbers.

Find what weight of this flux must be used to produce a bisilicate slag with the ore. It is hardly necessary to go into the details of this calculation, as it has been twice made in previous examples. We outline it, and the student should verify the results. (Bisilicate form, CaO, SiO₂.)

SiO ₂ taken from the ore by its CaO.....	12.00 per cent.
SiO ₂ taken from the ore by its FeO.....	8.33 per cent.
	20.33 per cent.

SiO₂ left for bases in the iron flux = 15.97 per cent. of the ore.

In the iron flux: FeO required by its own SiO₂ = 4.8 per cent. This leaves 81.2 excess of FeO for "available." The final adjudication gives:

$$\text{SiO}_2 : \text{FeO} = 5 : 6 = 15.97 : 19.16 = \text{FeO required by SiO}_2 \text{ of the ore.}$$

$$81.2 : 100 = 19.16 : 23.6 = \text{weight required in lbs. of the iron flux.}$$

The slag (leaving out of account the difference in weight caused by substitution of 5.6 nominal CaO for 4 lbs. actual MgO), figures out as follows:

SiO ₂ from ore.....	36.30
SiO ₂ from iron flux.....	0.94.....
	37.24 lbs.
FeO from ore.....	10.00
FeO from iron flux.....	20.30.....
	30.30 lbs.
CaO from ore.....	11.20 lbs.
	78.74 lbs.

Analysis of slag:

SiO ₂	47.3 per cent.
FeO.....	38.5 per cent.
CaO.....	14.2 per cent.
	100.00 per cent.

The student may verify by simple calculations.

In strictly formulistic slag calculations, it is not often necessary to transform one base into another, after the fashion shown above, where it was used merely as an exercise.

In most cases of computation for given percentages, however, these transformations are made, since calculations for percentage, rather than chemical ratios, have become the rule. Certain proportions are considered as "types," *e.g.*:

SiO ₂	40.00 per cent.
FeO(MnO).....	34.00 per cent.
Ca(Mg, Ba,)O.....	26.00 per cent.
	100.00 per cent.

This being assumed, the various bases are transformed by their proper factors into one or the other of the "groups" and the calculation proceeds.

CONVERSION FACTORS FOR BASES.

Iron and Manganese.—These metals have for atomic weights 56 and 55, respectively, and for protoxides 72 and 71. Hence it is hardly worth while to adopt any factor. The percentage of manganese oxide is added to that of iron oxide, and the whole is treated as iron oxide.

Alumina.—This is supposed to act as an “acid” and to form “aluminates” with strong bases, just as silica forms silicates. In slags high in silica, alumina certainly acts as a base, and is so calculated. In iron smelting it is highly probably that in slags low in silica and containing considerable amounts of both alumina and magnesia, a compound of these is formed of a highly infusible nature, possibly something like spinel, whose formula is MgO, Al_2O_3 . Alumina 71.8 per cent. and magnesia 28.2 per cent.

Opinions differ as to how to “group” alumina, and some metallurgists are inclined to dodge the question, when its proportion is not great, by setting it apart with an apportionment, it may be, of silica, to take care of it, but letting it be a thing aside from the nominal “formula” or “type” of the slag.

Taking any of the ordinary relations, say bisilicate, and compare alumina with lime silicate by equalizing the silica, we have: $Al_2O_3, 3SiO_2$ and $(CaO)_3, 3SiO_2$. That is, in relation to saturating power for silica, since $Al_2O_3 = 102$ and $3CaO = 168$, we should have 1.65 as factor for converting alumina to lime.

Magnesia.—Multiply MgO by 1.4 as already shown, for CaO .

Baryta.— $BaO : CaO = 153 : 56$. This gives 0.366, but the factor used is 0.4. The matter is so far conventional that it is not worth while to split hairs or second decimals over it.

Zinc.—Zinc oxide = 81; $CaO = 56$. $81 \times .7$ is close enough to .56 for us to safely adopt 0.7 as factor for conversion of zinc oxide into CaO .

Zinc oxide and baryta are “undesirable citizens” in any slag, as both are somewhat uncertain in their actions. Some of the features of zinc have already been noted. Baryta divides largely according to the heat and reducing action of the furnace, some of it often goes into barium sulphide, and this in turn joins itself to matte rather than slag.

Iron confers fluidity on almost any mixture. Since in the matting furnace the two essentials for good separation of slag and matte are (1) fluidity, and (2) sufficient difference in specific gravity, it becomes a difficult question at times, whether the additional specific gravity given to a slag by heavy percentage of iron is counterbalanced by the extra fluidity obtained.

Lime per contra may be taken as almost the opposite in these considerations, since it certainly diminishes the specific gravity,

as compared with a slag of greater iron per cent., but high lime slags are objectionable as a rule, and the iron would be preferred. In fact we see very few analyses of slags higher in lime than in iron oxide, and the conditions under which they become inevitable are rare.

These remarks have no bearing on iron metallurgy. At the great majority of iron furnaces slags high in lime are the rule, and lime, magnesia and alumina are the only bases, except by accident, or in the case of manganiferous ores. But the temperatures in an iron “stack” take it out of the range of the heat and reduction power of the lead or copper-matting furnace.

Notwithstanding the utility of these “conversions” it is no uncommon practice to omit them entirely. When to do so is a question of detail belonging rather to the requirements of special cases than to a general treatise.

Example.—A slag problem is often put into something like the following form.

Required.—A slag whose composition shall be:

Silica.....	35.00 per cent.
Iron oxide.....	45.00 per cent.
“Earthy bases”.....	20.00 per cent.
	100.00 per cent.

It will shortly be seen that our “representative” method, which deals directly only with cases in which percentages are the requirement, is simplified, not complicated, by such a wholesale bunching of bases.

It is obvious that if we have merely to add together the percentages (or weights, as the case may be) of the “earthy bases,” without regard to any chemical consideration, we have simplified the calculation. Whether we have simplified the running of the furnace is quite another question.

Although we shall give a case or two involving the lumping of all bases except iron oxide, in an “arithmetical” sense, *i.e.*, taking no account of the differences in their saturating power for silica, it forms no real addition to any “method” to illustrate this procedure. The difference is one of omission. Instead of “adjudicating” according to chemical “weights” we adjust nothing, but add together all the bases specified.

Problem of mixing ores.—It is sometimes necessary to mix ores or other material, so that the mixture shall contain a certain percentage of a given substance. The problem is indeterminate unless there are but *two* lots to be mixed.

The problem is readily formulated. It can then be “translated” into the following rule, viz.:

Take weights of the ores in inverse ratio to the differences between their assays and the (required) assay of the mixture.

Example.—(a) Mix two ores containing respectively 40 per cent. and 8 per cent. of a certain constituent, so that the mixture shall contain 16 per cent.

No. 1. The larger per cent. less the required per cent. is $40 - 16 = 24$.

No. 2. The required less the smaller per cent. is $16 - 8 = 8$.

Now take weights of the two ores *inversely* as these figures, *i.e.*, take 8 parts of No. 1, and 24 parts of No. 2 (or, in this case, reducing to simple ratio, 1 part of No. 1 and 3 parts of No. 2).

<i>Proof.</i>	100 lbs. of No. 1 contain.....	40 lbs. metal
	300 lbs. of No. 2 contain (3 × 8).....	24 lbs. metal
	400 lbs. of mix contains.....	64 lbs. metal
	$\frac{6400}{400}$	= 16 per cent., as required.

If we have three lots there is no definite solution. The intermediate or required figure falls either between No. 1 and No. 2 or between No. 2 and No. 3, so that in any case we have a definite solution for only two ores, those, namely, between whose percentages the required percentage falls.

We may, however, by limiting the weights of one lot to a certain figure or by stipulating a certain proportion *as between certain classes of ore*, reduce the problem to a determinate one.

Although cases of this kind are exceptional, it is well to have a ready method of figuring on them.

(b) We have three ores, whose assay is 39, 24 and 8 respectively. (N. B.—It makes no difference whether the figures indicate percentages or ounces to the ton.) We want 16 per cent. in mixture. This may obviously be obtained from 1 and 3 or from 2 and 3. But we are compelled to use *both* 1 and 2 and the latter in twice the quantity of the first. What proportions of the three ores in the mixture?

100 lbs. of 1 contain.....	39 lbs. of substance
200 lbs. of 2 contain.....	48 lbs. of substance
300 lbs. of mix contain.....	87 lbs. of substance

The “mix” then contains

$$\frac{87 \times 100}{300} = 29 \text{ per cent.}$$

Now proceed as in (a), calculating on the mix as an ore to be used in getting second mix.

$$29 - 16 = 13, \text{ and } 16 - 8 = 8$$

Take, then, 8 units of the mix and 13 units of the No. 3 ore.

Suppose we also have to make up an “even” weight of the total mixture. We divide the required weight into 21 parts (8 + 13) and take 8 and 13 of these parts respectively. Or we may go back to original ore parts. In the present case in 1000 lbs. mix we would have 127, 254 and 619 lbs. of 1, 2 and 3 respectively. Prove this as in former example:

$$\left. \begin{array}{l} 127 \times .39 = 49.53 \\ 254 \times .24 = 60.96 \\ 619 \times .08 = 49.52 \end{array} \right\} \text{Sum} = 160 = 16 \text{ per cent. of } 1000$$

Concentration.—Ordinarily the furnace treating concentrates buys them from the mining or milling company, and has little or nothing to do with the question of concentration. A check on operations of this nature is appended. It has to do with the simplest case only, *i.e.*, the one where the only products are concentrates for treatment, and “tailings.”

The formula may be extended to meet any case, one for example in which there are two distinct “products,” and tailings.

The data by which to check are: (1) assay of the crude ore; (2) assay of concentrates; (3) assay of tailings, and (4) ratio of concentrates to total.

If this ratio be called “*R*” and the assays of ore, concentrate and tailings be respectively *a*, *b* and *c*, then designating the weight of ore by unity, we evidently have: $bR + c(1 - R) = a$; that is, metal in concentrates plus metal in tailings equals metal in original total ore.

This gives by solving with respect to R :

$$R = \frac{a - c}{b - c}$$

We may solve with respect to any other letter.

$$a = R(b - c) + c \quad b = \frac{Rc + a - c}{R} \quad c = \frac{Rb - a}{R - 1}$$

Examples:

1. $R = 0.25$	$a = 15$	$b = 40$	$c = 6.66$
2. $R = 0.15$	$a = 22$	$b = 80$	$c = 11.76$
3. $R = 0.05$	$a = 10$	$b = 195$	$c = 0.26$
4. $R = 0.2$	$a = 12$	$b = 48$	$c = 3.0$
5. $R = 0.1$	$a = 16$	$b = 151$	$c = 1.0$
6. $R = 0.2$	$a = 15$	$b = 67$	$c = 2.0$
7. $R = 0.01$	$a = 20$	$b = 1950.5$	$c = 0.5$
8. $R = 0.166$	$a = 22$	$b = 120$	$c = 2.4$
9. $R = 0.15$	$a = 6.95$	$b = 35$	$c = 2.0$

Three of these being known the fourth may be calculated. Very few custom mills check up their work carefully enough to know exactly what they are doing. The application of this little proof, simple as it is, would perhaps surprise some of those who are so positive in their claims of "ninety per cent. saving."

To determine the percentage recovered in concentration, without assay of the tailings:

"Divide assay of concentrates by the ratio of concentration, multiply the product by 100, and divide by assay of original ore." In this rule the "ratio" is the "number of tons into one."

Example.—Take Example 1 above. It shows "four into one" as ratio.

$$\frac{40}{4} = 10, \quad 10 \times 100 = 1000$$

$$\frac{1000}{15} = 66.67 \text{ or } \frac{2}{3} \text{ recovery}$$

This is easily verified, for assay of original ore being 15 oz., four tons yield 60 oz., two-thirds of which = 40.

Take No. 3: $R = 0.05$ indicates 20 into 1. Then:

$$\frac{195}{20} = 9.75$$

$$9.75 \times 100 = 975, \quad \frac{975}{10} = 97.5$$

Recovery = 97.5 per cent.

The method is too simple to be worth further exemplification.

A few tables are appended, which explain themselves. The first one, showing the proportions of silica and base in various silicates, is mainly taken from Balling. Analyses of most of these are added, which is the same thing in another form. For applicative utility the first is better suited. To the Balling table, Hofman (Metallurgy of Lead) adds BaO and PbO.

PROPORTIONAL TABLE FOR SILICATES.

For Singulo-Silicates:		For Singulo-Silicates:	
1 part by weight of silica requires:	Parts by weight of bases.	1 part by weight of bases requires:	Parts by weight of silica.
Lime (CaO).....	1.86	Lime.....	0.535
Baryta (BaO).....	5.10	Baryta.....	0.196
Magnesia (MgO).....	1.33	Magnesia.....	0.750
Alumina (Al ₂ O ₃).....	1.14	Alumina.....	0.873
Ferrous oxide (FeO).....	2.40	Ferrous oxide.....	0.416
Manganous oxide (MnO).....	2.36	Manganous oxide.....	0.422
Lead oxide (PbO).....	7.43	Lead oxide.....	0.134
For Bi-Silicates:		For Bi-Silicates:	
Lime.....	0.93	Lime.....	1.070
Baryta.....	2.55	Baryta.....	0.392
Magnesia.....	0.66	Magnesia.....	1.500
Alumina.....	0.57	Alumina.....	1.747
Ferrous oxide.....	1.20	Ferrous oxide.....	0.833
Manganous oxide.....	1.18	Manganous oxide.....	0.845
Lead oxide.....	3.71	Lead oxide.....	0.269
For Sesqui-Silicates:		For Sesqui-Silicates:	
Lime.....	1.24	Lime.....	0.803
Baryta.....	3.40	Baryta.....	0.294
Magnesia.....	0.88	Magnesia.....	1.125
Alumina.....	0.76	Alumina.....	1.310
Ferrous oxide.....	1.60	Ferrous oxide.....	0.625
Manganous oxide.....	1.57	Manganous oxide.....	0.633
Lead oxide.....	4.95	Lead oxide.....	0.202

PERCENTAGE TABLES, SINGULO AND BI-SILICATES.

SINGULO SILICATES:		
	p. c.	p. c.
2K ₂ O, SiO ₂	Potassium oxide.....	75.73
2Na ₂ O, SiO ₂	Sodium oxide.....	67.25
2CaO, SiO ₂	Calcium oxide.....	64.97
2MgO, SiO ₂	Magnesium oxide.....	57.16
2BaO, SiO ₂	Barium oxide.....	83.61
2Al ₂ O ₃ , 3SiO ₂	Alumina.....	52.96
2FeO, SiO ₂	Ferrous oxide.....	70.45
2MnO, SiO ₂	Manganous oxide.....	70.16
2PbO, SiO ₂	Lead oxide.....	88.14
	Silica	24.27
	Silica	32.75
	Silica	35.03
	Silica	42.84
	Silica	16.39
	Silica	47.04
	Silica	29.55
	Silica	29.84
	Silica	11.86

BI-SILICATES.			
		p. c.	p. c.
K ₂ O, SiO ₂	Potassium oxide.....	60.93	Silica 39.07
Na ₂ O, SiO ₂	Sodium oxide.....	50.65	Silica 49.35
CaO, SiO ₂	Calcium oxide.....	48.11	Silica 51.89
MgO, SiO ₂	Magnesium oxide.....	40.00	Silica 60.00
BaO, SiO ₂	Barium oxide.....	71.83	Silica 28.17
Al ₂ O ₃ , 3SiO ₂	Alumina.....	36.02	Silica 63.98
FeO, SiO ₂	Ferrous oxide.....	54.38	Silica 45.62
MnO, SiO ₂	Manganous oxide.....	54.03	Silica 45.97
PbO, SiO ₂	Lead oxide.....	78.80	Silica 21.20

FORMULISTIC AND "PERCENTAGE" SLAGS.

Although the application of the "excess" is often inevitable, and, in fact, can never be dispensed with in the calculated elimination of mattes, yet there are many cases in which the simplest method for adjustment is to use one or more equations of the first degree. We shall call these "representative" equations, as they are strict representations of the analyses of material.

It will often be a matter of judgment with the computer whether to proceed altogether by the "excess" figures on the plan already indicated, or to "equate" his data. Certain persons imagine that any calculation "with an 'x' in it" is harder than a "merely arithmetical" problem. Before we are through with the subject we shall present examples well fitted to disabuse the mind of such a prejudice. Our "x" problems are indeed the easiest ones we give.

In the adjustment of several materials, all of which enter into the charge, the excess method becomes more and more troublesome, and there are situations in which it is inapplicable, except under modifications themselves complicated. It will not be necessary to consider such examples, since the equation method will easily solve them.

Slags to be calculated by the method of equations may be formulistic or numerical. That is, the requirement may be that a fixed chemical formula shall be maintained, or it may be merely that certain elements must be present in certain proportions or percentages. Frequently the latter requirement has been originally based upon a formula.

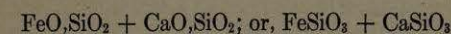
As has been shown, any formula may be easily thrown into an analytical form, *i.e.*, expressed as a summation to 100. This

may not be necessary for calculation, but it is usually done, if only to enable the operator to see at a glance how the analysis compares with well-known types.

As for formulated slags, observe that the mere fact that a slag analyses as a "singulo" or a "bisilicate" does not make it a full chemical "formula." It would, indeed, *were but there one base present*.

Suppose we have a slag carrying iron oxide and lime as its only bases. Let the silica also be so adjusted that its ratio to the iron is FeO, SiO₂, and to the lime CaO, SiO₂. That is a "bisilicate," but the whole is not a chemical formula unless the iron and the lime stand in some simple ratio to each other.

If we write this slag as:



we enforce upon it the chemical condition implied by the laws of chemical symbolization. The SiO₂ combined with the iron is equal in weight to the SiO₂ combined with the CaO. The FeO weight is to the CaO weight as 72 to 56, or as 9 to 7. This, then, is a truly "formulistic" slag, so called because it can be read and "translated" into exact numerical equivalents without further explanation. It is, in short, a true chemical compound.

The chemical relation of iron oxide to lime here (FeO to CaO) is 1 to 1, *i.e.*, one molecule of each. Their arithmetical relation is whatever is imposed by the relative weights of these particular molecules. We are writing for those whose chemistry has become very rusty. Those who never had any chemical instruction should stop reading here, and book up in the first elements.

Let us now take a singulo silicate *not* a chemical formula, to make the difference clear to the beginner.

Suppose that we have a singulo silicate, the weights of whose iron oxide and lime stand to each other as 17 to 19. We cannot well express that fact in any chemical formula. The expression 17FeO, SiO₂ + 19CaO, SiO₂ is very far off, being erroneous both as to bases and silica. In fact, when we try to mix chemical formulæ and ordinary weight relations, we had better drop the attempt at once and write out in descriptive phrase what the proportions are by weight, for fear of misapprehension. Many technical articles of recent date "mix things" shamefully in this respect, leaving the reader in final

doubt as to whether their formulæ are to be read in the only possible correct way, *i.e.*, chemically, or whether they mean little or nothing in that sense, and are used merely as attempted abbreviations.

Slags which are properly adjusted as to relation between oxygen in SiO_2 and in bases, may, to coin a term, be called "semi-formulistic."

It is only when a definite and chemical relation exists *between bases* as well as between silica and bases, that we can speak of a slag as a chemical formula. Only in such are we entitled to attach the full chemical significance to each and every symbol.

When we have such a requirement, and wish to compute it, we may properly translate the formula at once into its numerical equivalent. Example:

$\text{Fe}_2\text{SiO}_4 + \text{Ca}_2\text{SiO}_4$ becomes, when put into numerical expression:

$$\begin{array}{l} \text{SiO}_2 = 120 \} \\ 2\text{FeO} = 144 \} \\ 2\text{CaO} = 112 \} \end{array} \left. \begin{array}{l} \text{SiO}_2 = 15 \} \\ \text{or, } 2\text{FeO} = 18 \} \\ 2\text{CaO} = 14 \} \end{array} \right\} \begin{array}{l} \text{SiO}_2 = 31.91 \text{ per cent.} \\ \text{FeO} = 38.30 \text{ per cent.} \\ \text{CaO} = 29.79 \text{ per cent.} \\ \hline 100.00 \text{ per cent.} \end{array} \quad \left. \begin{array}{l} \text{SiO}_2 = 31.91 \text{ per cent.} \\ \text{FeO} = 38.30 \text{ per cent.} \\ \text{CaO} = 29.79 \text{ per cent.} \\ \hline 100.00 \text{ per cent.} \end{array} \right\} \text{(or, in per cents.)}$$

It is not always necessary to reduce the formula to the form of an analysis.

This will probably be done sooner or later, to enable the computer to get the comparative idea which long habit has based upon percentage. But so far as "laying out" the statistics for computation is concerned, the above example is a sufficient exposition of the fact that much simpler figures than the "per cents." of an analysis will serve to introduce the same ratios.

Frequently it happens that the ratios are *very close* to simple ones, although given by rather complex figures in the preparation of the data for calculation. A case in point occurs among the examples to follow. It may little affect the practical outcome of the problem, and greatly facilitate the computation, to change the ratio over to the simple one at once. Judgment comes in here, and some perception of the extent to which the outcome will be affected. These are mental data hardly reducible to "rules."

METHOD OF REPRESENTATIVE EQUATIONS.

In our so-called "representative" equations it will be found useful to adopt as a fixed rule 100 pounds of ore as the basis of calculation.

The *analysis* of the ore is always stated as totalling one hundred per cent. Analyses of all the other constituents of the charge will be similarly stated.

The "representative" feature of the equations is found in the adoption of the *percentages of constituents*, as the *coefficients of the unknown quantities*.

Before detailing the method, we make some general remarks on the "preparation" of the data for calculation. The item of reducing the number of bases by substitution of one for another by "conversion factors" has already been given. Another point is the fuel ratio, most important in iron, not always to be neglected in other metals. *If the fuel charge be a fixity in relation to the ore*, its ash, if it has been analysed both as to weight and composition, may be added directly to the ore analysis, so as to diminish the work of computation.

Example.—Suppose the case to be one in iron. Analysis of ore shows 8 per cent. silica. Analysis of coke shows 6 per cent. silica. Coke is to be seventy per cent. of weight of ore. Then for 100 lbs. of ore we have 70 lbs. of coke. The 100 lbs. of ore contain 8 lbs. silica; the 70 lbs. coke contain 4.2 lbs. silica (6 per cent. of 70). Add, and compute for 12.2 per cent. SiO_2 in the ore.

The same can be done for any other constituent. In this way the subsequent statement is simplified.

Coke ash is not usually allowed for in lead and matte smelting, though in cases where high fuel ratio combines with high ash in the fuel it might well be made an element of calculation.

In "pyritic" smelting, *i.e.*, theoretical pyritic work, where there is no coke at all, it vanishes. The case, however, is a trifle too ideal for discussion.

There are cases in iron smelting where the coke furnishes more silica than the ore. We shall sometimes include and sometimes neglect the coke ash in our examples. Its addition