

from the requirement of the formula, *although it will be a perfect "singulo."*

Suppose again that instead of adjusting CaO to the excess silica of the ore we took just enough limestone to yield CaO in the exact required proportion *to the iron*. Of course this could be very easily done, but the result would be that we should *no longer have a singulo silicate*. The *excess of silica* would now be a very material one over that requirement. In practice the metallurgist must now decide whether he will adhere to the "singulo" idea, or accept a more siliceous slag for the sake of the desired ratio between his bases. In all likelihood a compromise figure would be adopted, but discussions of this nature are endless, and we have assumed at the outset that they shall not be gone into to any extent.

This is a good point at which to call attention to the relation of the two oxides of iron. Slags are invariably figured as containing only the FeO form. Per contra, iron (other than sulphide) is introduced into the furnace as Fe<sub>2</sub>O<sub>3</sub>. To compare these, remember that we must first equalize the iron, comparing Fe<sub>2</sub>O<sub>3</sub> with 2FeO:

Molecular weight of Fe <sub>2</sub> O <sub>3</sub> = .....	160
Molecular weight of 2FeO = .....	144

160 : 144 = 10 : 9, so that to reduce the higher to the lower oxide (*i.e.*, in passing from analyses to slag calculations) it is only necessary to multiply the percentage of ferric oxide by 0.9 to obtain the percentage of ferrous oxide. This explanation of the reason for the factor 0.9 would hardly have found a place here but for the fact that we recently saw, in actual practice, the curious error of *forgetting the equalization* of the iron in comparing the two oxides arithmetically. The operator had forgotten the factor, and tried to regain it as above, with amazing result. A similar error in other cases of stoichiometrical calculations is by no means uncommon.

## INTRODUCTORY PROBLEMS.

(a) Ore has: Silica, 40 per cent.; alumina, 20 per cent. We are to calculate on a "singulo" basis, having a limestone analyzing: Silica, 10 per cent.; calcium carbonate, 90 per cent.

It is required to find what weight of limestone must be added to 100 lbs. of the ore, to form a lime-alumina silicate on above basis.

*Solution.*—We must first find silica excess in the ore itself on the "singulo" basis. Singulo silicate of alumina is 2Al<sub>2</sub>O<sub>3</sub> + 3SiO<sub>2</sub>.

Refer here to the problems in excess and deficiency. The silica excess of the ore will be found to be *22.36 per cent.*

We must next find the CaO excess in the limestone. Enough of the CaO must be taken out of the limestone *to satisfy its own silica*, before we can compute for the ore. In other words, we must get the *CaO excess* of the limestone, and compare it with the *SiO<sub>2</sub> excess* of the ore. Under the condition, this calculation of excess must be for the singulo form. (The method is illustrated for the lime here; it is of course the same as for the alumina above, where answer was given without operation.)

$$\begin{array}{l} \text{SiO}_2 : 2\text{CaO} = \text{lbs. SiO}_2 : \text{lbs. CaO} \\ 60 : 112 = 10 : 18.66 \end{array}$$

But the total lime in the limestone is fifty-six per cent. of ninety per cent., that is,  $90 \times .56 = 50.4$  per cent. CaO.

Lime required by silica in the limestone being 18.66 per cent., we have:  $50.4 - 18.66 = 31.74 =$  excess of CaO or "available" lime.

The problem is now reduced to this: An ore with 22.36 per cent. silica is to be "adjudicated" as to lime silicate with a limestone with 31.74 per cent. lime.

For the *alumina of the ore* is now out of the computation, having been set aside with its proper amount of silica in the first operation.

Also, the *silica of the limestone* is "out" of this final computation, having been set aside with its proper per cent. of lime.



These quantities, being already in the proper singulo ratios, do not in the least disturb the calculation of the remaining portions of the ingredients, nor do they affect the correctness of the outcome, since that must be in "singulo" form.

Thus we have now to do only with *excess silica* on the one side and *excess lime* on the other. These are often called, as above, "available" quantities.

We adjust silica and lime as follows (remember that lime is 2CaO):

$$\begin{array}{l} \text{Silica : lime} = \text{excess silica : required lime} \\ 60 : 112 = 22.36 : 41.74 \end{array}$$

But we know that there is 31.74 available CaO in the limestone, and since the limestone is "100 per cent. of itself," we have:

$$31.74 : 100 = 41.74 : 131.5$$

It will, then, require *131.5 lbs. of the limestone* to satisfy 100 lbs. of the ore.

This, as a sort of "type" excess problem, has been detailed at great length. In future we shall take certain operations for granted.

(b) Suppose the ore of Problem (a) and the limestone to be fused together, the constituents mentioned being the only ones going to the formation of slag, what will be the analysis of the slag?

	Silica.	Alumina.	Lime.
From 100 lbs ore.....	40.00	20.00	.....
From 131.5 lbs. limestone.....	13.15	.....	66.27
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	53.15	20.00	66.27

Sum of these weights = 139.42. We then have Problem III (c):

$$\begin{array}{l} \frac{5315}{139.42} = 38.12 \text{ per cent. silica} \\ \frac{2000}{139.42} = 14.34 \text{ per cent. alumina} \\ \frac{6627}{139.42} = 47.53 \text{ per cent. lime} \\ \hline \text{Sum} = 99.99 \text{ per cent.—proof.} \end{array}$$

The omitted operations are obvious. Similar proofs should always be made for safety.

This is really a problem and its solution, in slag calculation, albeit a very simple one.

In "taking out" matte constituents, preparatory to computing for slag, the method is the same.

"Taking out" a matte, *i.e.*, calculating it in advance, means simply the estimation of matte composition on what is supposed to be the most probable chemical scheme of formation. The adjudication of elements having been made, the compounds thus (theoretically) formed are subtracted from the totals as given by analysis. The slag is computed from the remainder, with the aid of such other material as may be added.

That is, in the actual operation of smelting, the ingredients thus "taken out" do actually separate in the form of matte, so that they must be computed and subtracted before we can proceed to figure on the slag formation.

(c) A roasted ore contains:

Copper.....	4.5 per cent.
Iron.....	18.0 per cent.
Sulphur.....	6.0 per cent.

Assuming that the matte will consist of Cu<sub>2</sub>S and FeS, also that there will be *no loss of sulphur*, how much iron will be left for slag formation?

It is always assumed that copper will take precedence of iron in matte formation, owing to its greater affinity for sulphur. Thus the proceeding will be to *first* calculate all of the copper into Cu<sub>2</sub>S. *Second*, if any sulphur is left over, calculate it all into FeS. *Third*, having subtracted the iron required from total iron, we shall now have remaining the constituents of the original roasted ore, minus all the copper, and all the sulphur, and minus *so much of the iron as was found necessary to form matte*.

All of this is simply a case under Problems II (c) and V.

*Solution.*—In most cases a glance at the figures will show whether there is excess of a given constituent, unless the excess or deficiency is small. Here for example it is evident that there is more than enough sulphur for the copper, and more iron than will satisfy the remaining sulphur. This determines the order of our proportions.

$$\begin{array}{l} \text{Cu}_2\text{S} : \text{S} = \text{copper present} : \text{sulphur required for copper} \\ 4 : 1 = 4.5 : 1.1 \end{array}$$



As there is 6 per cent. of sulphur in the ore we subtract the 1.1 required by the copper, leaving 4.9 per cent. of "residual" sulphur to be combined with iron. In the proportion now to be figured for FeS, make this sulphur the third term:

$$\begin{array}{l} \text{S : Fe} = \text{residual sulphur : iron in matte} \\ 32 : 56 = 4.9 : 8.5 \end{array}$$

There was originally 18 per cent. iron in the ore. Subtract now the iron required for matte formation;  $18 - 8.5 = 9.5$ .

This is, 9.5 per cent. of the iron is left for slag formation.

(d) A mineral analyzes as below:

Silica.....	68.80 per cent.
Iron.....	5.60 per cent.
Zinc.....	6.50 per cent.
Copper.....	6.30 per cent.
Sulphur.....	12.80 per cent.
Total.....	100.00 per cent.

Assuming that the elements are present as CuS, FeS<sub>2</sub> and ZnS, respectively, write the analysis by compounds instead of elements.

Fe : S <sub>2</sub> = 56 : 64 = 5.6 : 6.4	FeS <sub>2</sub> = 12.00 per cent.
Zn : S = 65 : 32 = 6.5 : 3.2	ZnS = 9.70 per cent.
Cu : S = 63 : 32 = 6.3 : 3.2	CuS = 9.50 per cent.
	SiO <sub>2</sub> = 68.80 per cent.

Total, by compounds.....100.00 per cent.

This is a mere "set up" case, with all the elements exactly satisfied, but the method serves in matte computation, when we must allow for sulphides before figuring our silicates. In this example the summation is complete, but such is very rarely the case in practice. In most raw, and in all roasted sulphide ores there will be an analytical deficit when only the metals, sulphur and silica are accounted for. This deficit stands chiefly for oxygen combined with the metals. A trial on the principle of the above will serve to "adjudicate" the metals to the oxygen deficit, and a summation fairly complete may thus be usually obtained.

(e) A zinc ore contains 62 per cent. of zinc, which is present as sulphide, ZnS.

1. What is percentage of ZnS in the ore?
2. What will the ore weigh after roasting, if all the ZnS becomes ZnO?

3. What will be the assay in zinc, of the product?

*Solution.*

(1) ZnS contains 67.01 per cent. Zn, and 32.99 per cent. S, so that:  
 $67.01 : 100 = 62 : 92.52 = \text{per cent. ZnS in the ore.}$

(2)  $\text{ZnS} : \text{ZnO} = \text{ZnS} : \text{ZnO}$   
 $97 : 81 = 92.52 : 77.26$

Then  $\text{ZnS} - \text{ZnO} = 92.52 - 77.26 = 15.26 \text{ lbs.} = \text{loss of weight.}$

As we are supposed to figure always from the unit figure of 100 lbs., our 100 lbs. will now weigh  $100 - 15.26 = 84.74 \text{ lbs.}$

(3)  $\frac{6200}{84.74} = 73.16 = \text{percentage of zinc in the roasted ore.}$

(f) This is similar to (e) but is, so to speak, "inverted."

A lot of zinc ore is roasted, all the ZnS being converted into ZnO. All the zinc having been present originally, as ZnS, we now find the weight of the roasted lot is 100 lbs., and its assay 70 per cent. of zinc.

It is required to find:

1. From what weight of raw ore was this 100 lbs. of roasted ore produced?
  2. What was the zinc assay of the raw ore?
  3. What was percentage of zinc oxide in the roasted product?
- Solution.*—(1) 70 per cent. zinc makes 87.23 zinc oxide, hence there are 12.77 per cent. of impurities (*i.e.*, 12.77 lbs. in the 100 lbs. considered.)

$$\text{ZnO} : \text{ZnS} = 81 : 97 = 87.23 : 104.46$$

This weight 104.46 is that of the original ZnS alone. Add 12.77 we have as original weight of the raw ore 117.23 lbs.

2. Zinc assay of original ore,

$$\frac{70 \times 100}{117.23} = 59.7 \text{ per cent. zinc.}$$

3. This has already been obtained in (1), *i.e.*, 87.23 per cent.

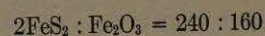
(g) A pyritiferous hematite is roasted, having originally contained only SiO<sub>2</sub>, Fe<sub>2</sub>O<sub>3</sub>, and FeS<sub>2</sub>. When all of the FeS<sub>2</sub> has become Fe<sub>2</sub>O<sub>3</sub>, it is found to have lost 4 per cent. of its weight, and assays 64.166 iron.

1. What were original percentages of FeS<sub>2</sub>, Fe<sub>2</sub>O<sub>3</sub>, and SiO<sub>2</sub>? Also, give separate original percentages of iron and sulphur.



2. What are present percentages of  $\text{Fe}_2\text{O}_3$  and  $\text{SiO}_2$ ?

*Solution:*



That is, the loss in weight equals one-third of the weight of the  $\text{FeS}_2$ . As this loss was four pounds the ore originally contained  $3 \times 4$  or 12 lbs. of pyrites (in 100 lbs.).

It contributed 5.6 to per cent. of iron in original, and  $\frac{5.60}{0.96} = 5.833$  to iron in roasted ore, leaving 58.33 as iron in the unchanged  $\text{Fe}_2\text{O}_3$ .

Hence  $\text{Fe}_2\text{O}_3$  in roasted ore is 91.66 per cent., and  $\text{SiO}_2$  is 8.33 per cent.

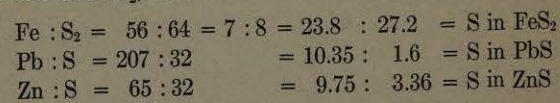
Analysis of the original ore is as follows:

$\text{FeS}_2$ .....	12.00 per cent.
$\text{Fe}_2\text{O}_3 = \frac{58.33}{0.7} \times 0.96 =$ .....	80.00 per cent.
$\text{SiO}_2 = 8.33 \times 0.96 =$ .....	8.00 per cent.
Total.....	100.00 per cent.

(h) An ore is reported as containing:

$\text{SiO}_2$ .....	23.94 per cent.
Fe.....	23.80 per cent.
Pb.....	10.35 per cent.
Zn.....	9.75 per cent.
S.....	32.16 per cent.
Total.....	100.00 per cent.

Recalculate as  $\text{FeS}_2$ ,  $\text{PbS}$  and  $\text{ZnS}$ , showing summation for proof.



Proof for sulphur.....32.16 = total S.

The revised analysis is as follows:

Fe, 23.80 + $\text{S}_2$ , 27.2 = $\text{FeS}_2 =$ .....	51.00 per cent.
Pb, 10.35 + S, 1.6 = $\text{PbS} =$ .....	11.95 per cent.
Zn, 9.75 + S, 3.36 = $\text{ZnS} =$ .....	13.11 per cent.
$\text{SiO}_2$ .....	23.94 per cent.

Total summation by compounds.....100.00 per cent.

These checks, or similar ones, should never be omitted. The following is a problem hardly "practical" but involving useful methods of computation.

(i) An ore has the following analysis:

$\text{SiO}_2$ ....	31.48 per cent.		
$\text{FeS}_2$ ....	30.00 per cent.	Fe....14.00	$\text{S}_2$ ....16.00 per cent.
$\text{PbS}$ ....	19.12 per cent.	Pb....16.56	S.... 2.56 per cent.
$\text{ZnS}$ ....	19.40 per cent.	Zn....13.00	S.... 6.40 per cent.
	100.00 per cent.	Total sulphur.....	24.96 per cent.

This ore is roasted until it contains no more *sulphides*, losing 10 per cent. of its lead and 20 per cent. of its zinc in fumes.

All of the iron has now become  $\text{Fe}_2\text{O}_3$ .

$\frac{1}{2}$  of the remaining lead goes to  $\text{PbO}$  and  $\frac{1}{2}$  to  $\text{PbSO}_4$ .  $\frac{1}{3}$  of the remaining zinc goes to  $\text{ZnO}$  and  $\frac{2}{3}$  to  $\text{ZnSO}_4$ .

1. What is weight of the roasted product?

2. What is summation analysis of same?

This may be done in several ways, all involving the same method in point of fact. As easy a way as any is to open a debit and credit account, setting losses against gains according to the specified conditions. Gains are all in oxygen.

We here tabulate the whole, distinguishing between O in oxides and in sulphates:

Losses.	Lbs.	Gains.	Lbs.
$\text{FeS}_2$ loses $\text{S}_2$ .....	16.000	O.....	6.00
$\text{PbS}$ loses 1/10 of Pb.....	1.656	O (in $\text{PbO}$ ).....	.576
$\text{PbS}$ loses 1/10 of S.....	.256	$\text{O}_4$ (in $\text{PbSO}_4$ ).....	2.304
$\text{PbS}$ loses 1/2 of 9/10 S... ..	1.152		
$\text{ZnS}$ loses 2/10 of Zn.....	2.600	O (in $\text{ZnO}$ ).....	.853
$\text{ZnS}$ loses 2/10 of S.....	1.280	$\text{O}_4$ (in $\text{ZnSO}_4$ ).....	6.826
$\text{ZnS}$ loses 1/3 of 8/10 S... ..	1.706		
Total loss.....	24.650	Total gain.....	16.559
Subtract.....	16.559		
Net loss.....	8.091		

Composition by weights of roasted product.	Lbs.	Summation analysis of same.
$\text{SiO}_2$ .....	31.480	$\text{SiO}_2$ ..... 34.251 per cent.
Fe.....	14.00	Fe..... 15.232 per cent.
O (in $\text{Fe}_2\text{O}_3$ ).....	6.00	Pb..... 16.216 per cent.
Pb.....	14.904	Zn..... 11.316 per cent.
O + $\text{O}_4$ (with Pb).....	2.880	S..... 4.968 per cent.
S in $\text{SO}_4$ .....	1.152	O..... 18.016 per cent.
Zn.....	10.400	
O + $\text{O}_4$ (with Zn).....	7.679	
S in $\text{SO}_4$ .....	3.414	
	91.909	



Original weight 100 lbs., present weight  $100 - 8.091 = 91.909$  lbs.

Summation analysis by compounds:

SiO <sub>2</sub> .....	34.251 per cent.
Fe <sub>2</sub> O <sub>3</sub> .....	21.760 per cent.
PbO.....	8.735 per cent.
PbSO <sub>4</sub> .....	11.868 per cent.
ZnO.....	4.701 per cent.
ZnSO <sub>4</sub> .....	18.670 per cent.
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	99.985 per cent.

The procedure in such computations having been sufficiently indicated, the actual proportions and computations are omitted. They are somewhat tedious, but absolutely simple in principle.

In reducing any product or mixture, whose various constituents are known by weight, to the form of a summation analysis (100.00 per cent.), we may either, as already shown, divide each weight multiplied by 100 by total weight, or else may find a factor by which to multiply each separate weight. Having adopted one of these methods, adhere to it.

(j) A calculated matte should contain:

FeS.....	65 lbs.
Cu <sub>2</sub> S.....	10 lbs.
PbS.....	7 lbs.
ZnS.....	5 lbs.
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	87 lbs.

We may write,  $\frac{6500}{87} = 74.71$  and so on for the other constituents, or else divide 100 by 87, getting quotient of 1.149 and using this as multiplier on each substance, get substantially the same result, *e.g.*:

$$65 \times 1.149 = 74.69 \text{ per cent. FeS}$$

and similarly for all others.

Details so trivial as this appear at first sight to be superfluous. But nothing is superfluous which tends to minimize chances of error on the part of a tired computer, and uniformity of method is one of the best guarantees of average correctness.

(k) An iron ore has 88 per cent. Fe<sub>2</sub>O<sub>3</sub>, and 0.8 phosphoric anhydride (P<sub>2</sub>O<sub>5</sub>). In smelting it produces, with its fluxing material:

1. Pig metal whose analysis shows:

Carbon.....	3.0 per cent.
Silicon.....	2.8 per cent.

It also contains *all of the phosphorus*, reduced from the P<sub>2</sub>O<sub>5</sub> of the ore.

2. Slag, whose weight is one-fifth of the weight of the ore charge, and which contains 3 per cent. of iron oxide (FeO) derived from the ore.

What weight of the ore produces 100 lbs. of the pig metal?

What is the completed analysis of the pig metal?

No operations are given nor even indicated; the student should be able to select methods for solution.

*Answer.* Weight of ore which produces 100 lbs. pig = 153.2 lbs.

Analysis of the pig metal:

Iron.....	93.66 per cent.
Carbon.....	3.00 per cent.
Silicon.....	2.80 per cent.
Phosphorus.....	0.54 per cent.
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Total.....	100.00 per cent.

Examples enough have been given to enable the student to easily follow the cases now to be introduced of actual furnace calculation.

As an example of calculation by "excess," we take a case from the actual record of an iron blast furnace.

Very rarely is any flux employed in the iron furnace except limestone, though this may be either a limestone proper or a magnesian lime. There is some prejudice against magnesia, as it has been supposed to "stiffen" the slag. This hardly applies to the iron furnace, as excellent and free flowing slags have been often produced with a considerable percentage of magnesia in their composition.

It is, however, not possible to run an iron furnace on silicate of lime. No lime silicate is fusible enough to act as a slag. The almost universal presence of alumina in iron ores makes it possible to produce slags of sufficient fusibility to run freely and separate from the pig metal.

It occasionally happens that the charge is too exclusively silica and lime, in which case the furnace produces a slag with



iron in it. This is a serious matter, as iron in a slag should always be under 1 per cent. Chemical laws come in, in spite of the reducing action. The "demand," so to speak, of the silica for a fusible slag produces a double iron-lime silicate.

The charging of too little limestone produces the same effect. This was a common happening in old-fashioned practice, the fallacy that "the less you put into the furnace the less work she has to do" led to lime charges that were too small for the silica, the consequence being that iron was drawn into the slag.

The general fact seems to be that di-basic or poly-basic slags are more tractable than slags with a single base. Thus if a silicate of alumina be prepared by mixture of ingredients, also a silicate of lime, and the fusion be separately attempted, the results will be mere "frits" at any reasonable temperatures. But if these very mixtures be now joined, the resulting double lime-alumina silicate proves to be fairly fusible. Numerous experiments have proved the general law of the greater fusibility of polybasic silicates.

As for magnesia, in the iron furnace, the writer knows a case where the limestone was so magnesian that it might have been called a dolomite, yet the slag was excellent. Some alumina was always present, however, and evidence as to action of a purely lime-magnesia base is lacking.

The slag given is about the average of a number of months, and was, except when the furnace was "in trouble," very nearly white, clean and free flowing. As here calculated it is of course theoretical, but is very close indeed to the actual record of the furnace.

Materials.	Iron ore.	Limestone.	Coke.
Silica.....	8.00	6.00	8.00 per cent.
Fe <sub>2</sub> O <sub>3</sub> .....	87.00	....	.... per cent.
Al <sub>2</sub> O <sub>3</sub> .....	5.00	....	.... per cent.
MgO.....	....	6.00	.... per cent.
CaO.....	....	46.00	.... per cent.

Assume 100 pounds of ore as basis for calculation. Find weight of limestone necessary to form a "singulo" silicate.

In computing charges for the iron furnace it is important to figure on the mineral constituents of the coke, owing to the large ratio of fuel employed.

To simplify the present calculation the ash of the coke is

stated as composed of silica only, though in reality it contained a small percentage of bases.

A certain amount of silica always enters the metal as silicon, and some allowance should be made for this fact. This is arbitrary, as the amount varies with fuel ratio and running of the furnace. The subtraction of *three per cent.* from the silica of the ore is a fair allowance, although it would often be too low. However, this subtraction will always make for better, *i.e.*, closer figures on slag than its neglect.

Hence we figure in the present instance on *5 per cent. of silica instead of 8 per cent.* This affects only the silica of the ore, leaving the silica of the limestone and of the coke as in the analysis.

The "singulo" formulæ are: 2Al<sub>2</sub>O<sub>3</sub>, 3SiO<sub>2</sub>; 2CaO, SiO<sub>2</sub>; and 2MgO, SiO<sub>2</sub>.

Under the conditions, and the selection of material, no set ratio *between bases* is possible. As we have taken 100 lbs. of ore the figures will indicate either "pounds" or "percentages."

*Fuel (coke), seventy per cent. of the weight of the ore.*

This being a first case we figure it out in great detail, dividing the statement into four headings.

(1) Take out alumina silicate from the ore. That is, ascertain what per cent. of silica is demanded by the 5 per cent. alumina. Use the formulæ in all of these proportions, and *nearest whole numbers* from table of atomic weights. Baling's tables could also be used.

$$2\text{Al}_2\text{O}_3 : 3\text{SiO}_2 = 204 : 180 (= 17 : 15) = 5 : 4.412$$

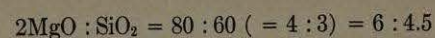
Pounds silica required by alumina, 4.412. Sum up all the silica of ore and coke and subtract this requirement from the total.

Silica in ore (8 - 3).....	5	pounds (or five per cent.)
Silica in coke.....	5.6	pounds ( <i>i.e.</i> , 8 p.c. of 70)
Silica total, ore + coke.....	10.600	
Less required by alumina.....	4.412	
SiO <sub>2</sub> available for limestone...	6.188	(6.188 pounds per 100.)

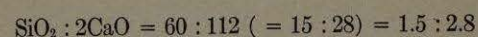
(2) The limestone has now to be "prepared" (by calculation) for adjustment to the ore, etc. That is, the silica must be adjusted to its proper ratio of bases in the limestone itself. It is only the excess of lime *above* this silica requirement which can



be called "available" for the silica of ore and coke. We have 6 per cent. magnesia in the limestone, formula as above:



Six is actual magnesia, 4.5 is its *required* silica, in terms (percentage) of limestone. However, as there is 6 per cent. silica in the limestone, we now subtract this 4.5 and there remains 1.5 per cent. which must be taken care of by lime. (In order to bring lime into last term, put  $\text{SiO}_2$  first.)



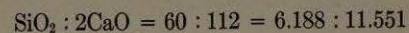
A little later we shall show how lime and magnesia might have been figured at one operation by means of a "conversion factor."

(Let the student note that if it had happened that there was *not enough* silica in the limestone to satisfy the magnesia, then the magnesia would have taken the "unknown" term, and when the per cent. of magnesia had been found which satisfied all of the silica, the remainder ("residual") magnesia would have gone in with the available lime.)

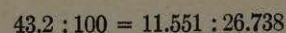
We have found 2.8 lime is required by the last 1.5 of the silica in the limestone. Subtract this, therefore, from the total lime.

$46 - 2.8 = 43.2$ . That is, in our limestone we have 43.2 per cent. of "available" lime (CaO) for combination with "outside" silica.

(3) Now we bring together the ore and the limestone, with their respective excesses, viz:  $\text{SiO}_2$  excess in the ore and CaO excess in the limestone. The question is: "What amount of lime is called for by the silica excess of the ore?" Since we are figuring on 100 lbs. of ore and seeking the required lbs. of limestone, we naturally put the silica excess first in our proportion.



The lime called for (CaO) by 100 lbs. of ore is therefore 11.551 lbs. But this must be "available," *i.e.*, free lime, and we have just found that our limestone yields 43.2 per cent. of this. Hence the evident proportion:



Therefore 100 lbs. ore require 26.738 lbs. limestone.

We have carried the decimals beyond any practical necessity.

It remains only to "assemble" our figures and check up. The analysis of the slag may then be figured.

(4) Take 100 lbs. of the ore, 70 of coke and 26.738 of limestone, and figure out *actual lbs.* of each and every constituent. This will give total weight of the slag, and enable us to figure analysis of the latter in percentages.

	$\text{SiO}_2$ .	$\text{Al}_2\text{O}_3$ .	CaO.	MgO.
In ore.....	*5.00	*5.00	.....	.....
In limestone.....	†1.604	.....	‡12.30	†1.604
In coke.....	§5.60	.....	.....	.....
Totals.....	12.204	5.00	12.30	1.604

Weight of the slag per 100 lbs. of ore charged = 31.108 lbs.

Analysis as below, by rule III (c):

Silica.....	39.23 per cent.
Alumina.....	16.07 per cent.
Lime (CaO).....	39.54 per cent.
Magnesia (MgO).....	5.15 per cent.
Total.....	99.99 per cent.

This is a fairly proportioned slag for the iron furnace, with silica rather higher than in average modern practice. As lime is beneficial in keeping sulphur out of the metal, it is probable that if the ore were sulphurous the "lime burden" would be increased a little.

Owing to the high temperatures of the iron furnace, it is not necessary to obtain slags fusible at comparatively low figures. Hence a wide margin in silica percentage is permissible.

* 5 per cent. of 100 lbs.	† 6 per cent. of 26.738 lbs.
‡ 46 per cent. of 26.738 lbs.	§ 8 per cent. of 70 lbs.