ON BLAST FURNACE SLAGS AND THE FUSIBILITY OF SILICATES.

BY AUGUSTÉ J. ROSSI.

(*Concluded.*)

An examination of a few specimens of natural silicates occurring as ordinary minerals and of which the composition is very often reproduced artificially in blast furnaces, will corroborate the preceding statement that, in a slag, in a multiple silicate, the silicates of the bases RO and R_2O_3 are of the same type. The following examples are taken from a table of silicates by Prof. Eggleston, of Columbia College, in which the old formula for silica, SiO_3, is used :

*Orthoclase.**—O Ratio, $\overset{R_2O}{1} : \overset{R_2O_3}{3} : \overset{SiO_3}{12}$ or $RO, SiO_3+Al_2O_3, 3SiO_3$ (Trisilicate of Percy), or, written with SiO_2, $2RO\ 3SiO_2+2R_2O_3\ 9SiO_2$. *Total*—O of SiO_2 : O of bases : : 24 : 8=12 : 4=3 : 1, a *sesqui-acid silicate ;* the O ratio for each silicate is 3 : 1 in both formulæ, as for the mineral itself. It is the tri-silicate of the present time derived from $H_4Si_3O_8=2(H_2O)3SiO_2$. O ratio 6 : 2=3 : 1.

*Sodalite.**—1 : 3 : 4. $3NaO, SiO_3+3(Al_2O_3, SiO_3)$. (Tribasic or monosilicate of Percy). Formula, with SiO_2, $2NaO\ SiO_2+2R_2O_3 3SiO_2$. *Bibasic silicate.* O ratio 1: 1 for each silicate, for the compound 12 : 12=1 : 1; derived from $H_4SiO_4=2(H_2O) SiO_2$, a monosilicate or orthosilicate with O ratio ; 2 : 2=1 : 1.

Anorthite.—1 : 3 : 4. $3CaO, SiO_3+3(Al_2O_3, SiO_3)$ the same as sodalite, O of acid, : O of bases=3 : 3=1 : 1 ; or with SiO_2, $2CaO\ SiO_2+2Al_2O_3\ 3SiO_2$ a *bibasic silicate.* O of acid : O

---

* Found in the United States.

of base=2 : 2=6 : 6=1 : 1 for each silicate and for the compound.

Epidote.—1 : 2 : 3 or $3R_2O\ SiO_3+(R_2O_3\ SiO_3)$; O ratio 1 : 1 the same as sodalite, a *bibasic silicate* $2RO, SiO_2+2R_2O_3, 3SiO_2$; O ratio of compound 1 : 1, of each silicate 1 : 1.

Garnet.—1 : 1 : 2, $3RO\ SiO_3+R_2O_3SiO_3$. Oxygen ratio 1 : 1 for each silicate and for the compound; now a *bibasic silicate*, $2RO\ SiO_2+2R_2O_3\ 3SiO_2$ O ratio 1 : 1. Pyrope $3(CaO, MgO) SiO_3+(Al_2O_3Fe_2O_3)SiO_3$.

Prehnetoid.—1 : 2 : 6, $3RO\ 2SiO_3+2(Al_2O_3\ 2SiO_3)$ (sesquibasic or bisilicate of Percy), O ratio 6 : 3 for each silicate=2 : 1: for the compound 18 : 9=2 : 1; or with SiO_2 : $RO, SiO_2+R_2O_33SiO_2$ a *neutral silicate;* O ratio of each silicate 2 : 1; of the compound 2 : 1. It is monosilicate of modern nomenclature derived from $H_2SiO_4=H_2O\ SiO_2$; O ratio 2 : 1.

Petalite.—1 : 4 : 20, $3RO\ 4SiO_3+(Al_2O_3, 4SiO_3)_4$ O ratio for the compound and for each silicate 60 : 15=12 : 3=12 : 3=4 : 1, an *acid silicate*, or with SiO_2 : $RO\ 2SiO_2+R_2O_3\ 6SiO_2$: O ratio for the compound and for each silicate 16 : 4=12 : 3=4 : 1; the disilicate of modern nomenclature derived from $H_2Si_2O_5=H_2O\ 2SiO_2$; O ratio 4 : 1.

Chloritoid.—1 : 2 : 2 : 1 Aq., $3RO\ SiO_3\ \frac{2}{3}+2\ (R_2O_3\ SiO_3\ \frac{2}{3})+3HO$; multiplying by 3 we have $9RO\ 2SiO_3+2\,(3R_2O_3\ 2SiO_3)+9HO$. O ratio compound=18 : 27=2 : 3. For each silicate 6 : 9=6 : 9=2 : 3; or with SiO_2 : $3\ RO\ SiO_2+R_2O_3SiO_2$, a *tribasic silicate;* O ratio for the compound and each silicate=2 : 3 derived from $H_6SiO_5=3(H_2O)SiO_2$; a parasilicic monosilicate; O ratio 2 : 3.

(*a.*) Assume that we have a slag having a composition corresponding to $RO\ 2SiO_2+R_2O_36SiO_2$ an acid silicate of the same type in $RO+R_2O_3$; O ratio for each 4 : 1; for compound 4 : 1; it corresponds to the following proportions:

1°. $SiO_2=75.120$	We find, *transforming all the bases into lime,*
$(CaO)RO=8.763$	SiO_2 68.19
$Al_2O_3=16.117$	CaO 31.81
100.000	100.00 an acid silicate as

we can see from the Table V., O ratio=4 : 1. The transformation into lime has *at once* furnished us the type of the silicate without using any formula or symbol.

2°. Let us calculate the formula of this slag by the determination of the oxygen of the constituents : We have

$$\begin{array}{lcr} & \text{Oxygen.} & \\ SiO_2 = 75.120 \ldots\ldots\ldots\ldots\ldots\ldots & & 40.08 \\ \left.\begin{array}{l} CaO = 8.763 \ldots\ldots 2.507 \\ Al_2O_3 = 16.117 \ldots\ 7.521 \end{array}\right\} & \ldots\ldots & 10.028 \end{array}$$

O of acid = 40.08 = O of bases 10.02 × 4 ; the type is *acid*. Proportioning the O of silica to that of the bases we find :

$$\frac{2 \times 507 \times 40.06}{10.028} = 10.028$$ O of silica in RO, or 5.014 SiO_2 with RO ; we have 2.507 O in RO, the formula is 2.507 RO, 5.014 SiO_2.

O of silica in $R_2O_3 = 40.08 - 10.028 = 30.05$, or 15.025 SiO_2 combined with R_2O_3.

O of $R_2O_3 = 7.521 = 2.507$ R_2O_3. Formula : 2.507 R_2O_3 15.025 SiO_2 or

2.507 (RO $2SiO_2$) + 2.507 (R_2O_3 $6SiO_2$) a perfect acid silicate of bases in RO and in R_2O_3. O ratio 4 : 1, the same result as obtained by transformation into lime.

3°. Let us calculate the empirical formula from the equivalents :

$$\left.\begin{array}{l} SiO_2 = 75.120 = 2.50 \text{ Eq., or } 8. \\ CaO = 8.763 = 0.313 \text{ Eq., or } 1. \\ Al_2O_3 = 16.117 = 0.313 \text{ Eq., or } 1. \end{array}\right\}$$

Hence, the *empirical formula* is (RO R_2O_3)$8SiO_2$, and O of silica : O of bases : : 16 : 4 = 4 : 1 as before. The type is an acid silicate as found at once by transformation into lime. But as may be seen, the empirical formula does not furnish any indication as to the grouping of the elements. If we *are to be guided by the oxygen ratio* of the compound, then the only *rational formula* is : RO $2SiO_2$ + R_2O_3 $6SiO_2$ and fatty silicate in RO and R_2O_3 are of the same type.

(*b.*) Let us assume now that we have a substance of the following composition :

R_2O_3 $3SiO_2$ (Neutral) + $2RO$ SiO_2 (Bibasic). Such a compound may certainly exist, but, if run in a blast furnace, since R_2O_3 $3SiO_2$ as well as $2RO$ SiO_2 are both refractory or very little fusible, (see fusibility of silicates), let RO be MgO or CaO, and let R_2O_3 be Al_2O_3 ; there must certainly be such a combination of the two types, such an exchange of the bases as will no longer correspond to a saturation of $1R_2O_3$ for $3SiO_2$ and of $2RO$, for $1SiO_2$, but will furnish a different one corresponding to a unique type or the multiple silicate, and one which must be the same for the bases in R_2O_3 and those in RO.

This formula leads to the following composition :

$$\left.\begin{array}{l} SiO_2 = 52.747 \\ CaO = 24.615 \\ Al_2O_3 = 22.637 \end{array}\right\}$$

In the table of fusibility, we see that 58 silica, 16 alumina and 26 lime give a *very fusible* silicate. A silicate of the annexed composition would therefore fuse readily in the blast furnace, but if we proportion the silica according to the above formula $R_2O_3, 3SiO_2 + 2RO, SiO_2$, we come to

$$\left.\begin{array}{l} 21.10\ SiO_2 \\ 24.61\ CaO \end{array}\right\}$$

or about $46CaO$ to $56SiO_2$, the "simple silicate" begins to be barely "fusible," and at SiO_2 31.67, Al_2O_3 22.63, or about 58 SiO_2 to 42 Al_2O_3, the simple silicate is absolutely refractory, it must certainly be then by different saturation of silica to form a unique type that these proportions of silica, lime and alumina furnish a fusible compound.

Transforming *all* into lime, we obtain the following percentage :

$$\left\{\begin{array}{l} SiO_2 = 46.164. \\ CaO = 53.836. \end{array}\right.$$

(O of acid = 1.6 O of bases) which, falling between a sesquibasic and a neutral silicate (Table V.) represents a sufficiently fusible slag. This transformation gives us at once an approximation of basicity of the slag and the type of the silicate.

3°. If we calculate the formula from the oxygen of the compounds, we find :

$$\left.\begin{array}{ll} \text{O of Silica} \ldots\ldots\ldots\ldots\ldots\ldots & 28.131 \\ \left.\begin{array}{l} \text{O of RO} \ldots\ldots\ldots\ 7.033 \\ \text{O of } R_2O_3 \ldots\ldots 10.562 \end{array}\right\} & 15.95 \end{array}\right\}$$

O of acid : O of bases : : 28.131 : 15.95 = 1.6 : 1 as before. If we proportion the O of silica to that of the bases in RO and R_2O_3, we find for the formula :

5.61 SiO_2 7.033 RO + 8.45 SiO_2 3.52 R_2O_3, or 3.52 (R_2O_3 2.4 SiO_2), O ratio 4.8 : 3 = 1.6 : 1 + 5.61 ($1\frac{1}{4}$ RO, SiO_2) O ratio 2 : $1\frac{1}{4} = \frac{8}{4} : \frac{5}{4}$ = 8 : 5 = 1.6 : 1 the silicates in RO $2R_2O_3$ are of the same type and of the same type as the compound itself.

R_2O_3, 2.4 SiO_2 is less neutral or *more basic* than R_2O_3, $3SiO_2$ a neutral silicate, but *less basic* than R_2O_3, $2SiO_2$, a sesquibasic silicate; the same for the silicates in RO, the slag as given by the formula falls between a neutral and a sesquibasic slag; just what the trnsformation into lime had given us.

4°. If we calculate the equivalents, we have:

$$\begin{array}{lcc} SiO_2 = 52.747 = 1.758 \text{ Eq. of } SiO_2 & & 4 \\ CaO = 24.615 = 0.879 \text{ Eq. of } CaO & \text{or} & 2 \\ R_2O_3 = 22.637 = 0.439 \text{ Eq. } Al_2O_3 & & 1 \end{array}$$

The empirical formula is $(2RO, R_2O_3)4SiO_2$. O ratio is 8 : 5 = 1.6 : 1, just what has been furnished to us by the transformation in lime. But the empirical formula does not afford any means of grouping the elements.

Two types satisfy the condition $(2RO\ R_2O_3)4SiO_2$; they are:

$2RO, SiO_2$ (Bibasic) and $R_2O_33SiO_2$ (Neutral), or $2RO\ 3SiO_2$ (Sesquiacid) + $R_2O_3SiO_2$ (Tribasic).

The first corresponds to the formula which has given us the preceding composition, but the second does not, and we have no way to choose *a priori*. If we take as a guide the O ratio, which has been found to be 1.6 to 1 *for the compound*, we reach the preceding formulæ, R_2O_3, $2.4SiO_2 + 1.25RO\ SiO_2$ or $5R_2O_3\ 12SiO_2 + 5RO\ 4SiO_3$. O ratio = 24 : 15 = 8 : 5 = 1.6 : 1 for R_2O_3, and the same for the silicate in RO, 8 : 5 = 1.6 : 1.

(*c*.) Suppose now that we have a slag of the same type in RO and R_2O_3 (Neutral), we are at perfect liberty to admit a composition as follows:

$2(R_2O_3\ 3SiO_2) + 4(RO\ SiO_2)$, as indeed the O ratio: 8 + 12 = 20 oxygen of acid : 4 + 6 = 10 oxygen of bases : : 2 : 1 (type neutral), is not changed. It corresponds to:

$$\begin{array}{llr} 1°. & SiO_2 = & 58.25 \\ & CaO = & 21.74 \\ & Al_2O_3 = & 20.00 \\ \hline & & 99.99 \end{array}$$

Calculating the formula we have O of $SiO_2 = 31.06$; O of RO = 6.21; $OR_2O_3 = 9.33$; 6.21 (RO, SiO_2) + 3.11 $(R_2O_3\ 3SiO_2)$ a perfectly neutral silicate in RO and R_2O_3. O of silica for each : O of base : : 2 : 1 : : 6 : 3.

And 6.21 of neutral silicate in RO : 3.11, of neutral silicate in R_2O_3 : : 4, of neutral silicate in the compound : 2, of neutral silicate in the compound $= 2 : 1$.

The relative proportion of each is maintained.

2°. Transforming *all into lime* we would have found *at once*, without symbols or formulæ :

$$\begin{array}{lll}
SiO_2 = 58.25 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots & & 58.25 \\
CaO = \ldots\ldots\ldots\ldots\ldots & 21.74\ CaO & \\
Al_2O_3 = 20 \times 1.631 = & 32.625\ CaO & \\
\cline{2-2}
 & 54.365 \ldots\ldots & 54.36 \\
\cline{3-3}
 & & 112.61
\end{array}$$

Or reducing to percentage :

$$\begin{array}{l}
SiO_2 = 51.72 \\
CaO = 48.28
\end{array}$$

a typical neutral silicate, Table V.

3°. If we calculate the equivalents, we have :

$$\begin{array}{llcl}
SiO_2 & = 1.941 & & 5 \\
CaO & = 0.776 & \text{or} & 2 \\
R_2O_3 & = 0.388 & & 1
\end{array}$$

And the empirical formula is $(R_2O_3\ 2RO)5SiO_2$, O of silica 10 : O of bases 5 : : 2 : 1 ; the type is neutral.

But if we do not take this as a guide, we can group the bases and the silica in the following manner :

$$1°.\ \underbrace{2(RO\ 2SiO_2)}_{\text{Acid silicate}} + \underbrace{R_2O_3SiO_2}_{\text{Tribasic}}\ ;\ \text{or}$$

$$2°.\ \underbrace{2RO\ 3SiO_2}_{\text{Sesquiacid}} + \underbrace{R_2O_3\ 2SiO_2}_{\text{Sesquibasic}}\ ;\ \text{or}$$

4°. $2RO\ SiO_2$ (Bibasic) $+ R_2O_3$, $4SiO_2$ (?), and we have no way to choose which is the rational formula. If we adopt the O ratio furnished by the compound, then the *only rational formula* is: $2(RO\ SiO_2) + R_2O_3\ 3SiO_2$, and the silicates in R_2O_3 and in RO are again of the same type; furthermore this gives 2 of silicates in RO for 1 of silicate in R_2O_3, the same proportions as in the original compound. The transformation into lime has furnished us at once the character of the slag.

We will complete these illustrations by a few examples of slags actually run in blast furnaces, and of which the composition is given in standard books on metallurgy (Percy and others).

Percy gives as the composition of a slag, run in a coke furnace, with hot blast, iron gray :

SiO_2 38.00..........O 20.26. O of acid=very nearly O of bases, *type bibasic.*

Al_2O_3	14.00	6.53		20.09
CaO	33.50	9.57	13.56	
MgO	6.50	2.60		
MnO	2.50	0.55		
FeO	2.00	0.44		
K_2O	2.00	0.40		

O of SiO_2 in R_2O_3=6.53 or 3.26 SiO_2 (exactly : 3.29) O of SiO_2 in RO=13.56 or 6.78 SiO_2 (exactly : 6.84). The formula is 2RO, SiO_2 (bibasic)+$2R_2O_3$, $3SiO_2$ (bibasic) O of acid : O of bases : 1 : 1.

Established from the O ratio or transformed from the formula in SiO_2, the formula in SiO_3 is (R_2O_3 SiO_3) 2.18+4.52 (3RO SiO_3): O of acid for each silicate: O of base : : 1 : 1; total oxygen of bases=$(3\times4.52+2.18\times3)=20.10$; O of acid=$(2.18\times3+3\times4.52)=20.10$=O of bases.

Percy gives as an approximate formula : "(R_2O_3 SiO_3+3RO SiO_3)" which is the type formerly called tribasic or monosilicate, now called *bibasic* in SiO_2 : as $3SiO_2=2SiO_2$.

This is the mineral called "Mellilite" : 2(3CaO, MgO, NaO) SiO_3+($Al_2O_3Fe_2O_3$)SiO_3. If we had transformed the slag at once into lime we should have found without any formula or symbol :

SiO_2=38.00	38.00	SiO_2
$Al_2O_3=14.00\times1.631$	22.83	CaO
CaO=33.50	33.50	"
$MgO=6.50\times1.40=$	9.10	
$MnO=2.50\times0.78=$	1.95	
$FeO=2.00\times0.78=$	1.56	
$K_2O=2.00\times0.59=$	.24	
	69.18	

Or:	SiO_2	38.00, or in %,	SiO_2=35.45	34.88
	CaO	69.18	CaO=64.55	65.12
		107.10	100.00	100.00

type bibasic.
(Table V.)

Percy gives the composition of a slag from blast furnaces of Olsberg on the Rhine :

		OXYGEN.		
SiO_2	53.76	............28.67		O of acid 28.67: O of bases 15.07 =1.90 : 1, or nearly 2 : 1 *type neutral*
Al_2O_3	4.76	....2.22.....	2.22	
CaO	29.48	....8.42	... 12.85	O of Silica in R_2O_3=4.35=1.45 SiO_2
MnO	1.30	....0.30		
FeO	1.48	....0.33		O of Silica in RO=24.32=8.11 SiO_2
MgO	9.50	....3.80	15.07	

Formula : 0.74 R_2O_3, 1.45 SiO_3, or, 0.74 (R_2O_3, $2SiO_3$)
12.85 RO, 8.11 SiO_3, or, (3RO 1.90 SiO_3) 4.28.

Percy says : Very nearly "(R_2O_3 $2SiO_3$+3RO $2SiO_3$)" or, in SiO_2, RO SiO_2+$R_2O_3$$3SiO_2$, a neutral silicate in RO and R_2O_3. It is the mineral called *Augite,* containing aluminium silicate, aluminiferous Augite or Pyroxene 3(CaO MgO) $2SiO_3$.

Transformed into lime we find at once :

SiO_2=53.76
Al_2O_3=4.76×1.631 = 7.76 CaO
CaO= .... =29.48
MnO=1.30×.78=.... 1.01
FeO=1.48×.78=..... 1.15
MgO=9.50×1.40=...13.30
52.70

Or, SiO_2	53.76	reducing to	SiO_2 =50.50....	SiO_2=	51.71
CaO	52.70	percentage	CaO = 49.50....	CaO =	48.28
	106.46		100.00		100.00

Very nearly a neutral slag as found before.
O ratio : 2 : 1

We see, from the preceding examination, that in slags corresponding in composition to certain minerals, slags actually run in blast furnaces or in slags made up *a priori* from a given formula, as well as in natural minerals themselves, as quoted from table of such silicates, the individual silicates in RO and R_2O_3, have been found to be of the same type, which is the type of the compound itself characterized by a certain *ratio of the total oxygen of SiO_2 to that of the bases.* Whatever may be the relation of the oxygen of the bases in RO, to the oxygen of the bases in R_2O_3, if it is rational to say that the amounts of silica combined with each class of oxide must bear a certain relation to the quantities of oxygen contained in each, we are then justified in dividing the oxygen of the silica proportionally to these numbers. By so doing we must find constantly as the quota of oxygen of the silica combined with the bases RO and R_2O_3, figures which will give for the silicates of RO and R_2O_3 a ratio of O of acid to O of the base precisely the same as that of the compound itself, since in each case the calculation is established as follows : Total O of silica $= m$, O of RO $= a$, O of $R_2O_3 = b$, and total O of bases $= a + b$. Ratio of the total O of SiO_2 to total O of bases in the compound $= \frac{M.}{a+b}$

O of silica combined with $R_2O_3 = \frac{M \times b}{a + b}$

O of silica combined with

$$RO = M - \frac{Mb}{a+b} = \frac{Ma + Mb - Mb}{a + b} = \frac{Ma}{a+b}$$

and $\frac{Ma}{a+b}$ O of silica as silicate of RO : a O of RO $= \frac{M}{a+b}$

$\frac{Mb}{a+b}$ O of silica as silicate of R_2O_3 : b O of $R_2O_3 = \frac{M}{a+b}$

the O ratio of the compound itself.

The rational formula of a silicate cannot be established otherwise than by taking as a guide the O ratio, the only clear and indisputable character furnished directly by the analysis. The use of the equivalents or atomic weights, as we have seen, gives an *empirical* *formula* which allows of the grouping of the constituents in different manners ; some of them not corresponding at all with the formula of the compound taken as basis of composition *a priori*.

For example : A slag run with white iron calculated in equivalents gave

$$(\text{Silica as } SiO_3),\ (3RO\ R_2O_3),\ 4SiO_3.$$

It can be grouped as follows :

O ratio 12 : 6 or 6 : 3 = 2 : 1 *Neutral*

$$(a.)\quad \underbrace{3(RO\ SiO_3)}_{\text{Trisilicate of Percy.}} + \underbrace{R_2O_3\ SiO_3}_{\text{Monosilicate of Percy.}} \quad (b.)\ \underbrace{3RO\ SiO_3}_{\text{Monosilicate of Percy.}} + \underbrace{R_2O_3\ 3SiO_3}_{\text{Trisilicate of Percy.}}$$

and, lastly, if the oxygen ratio is taken as a guide

$$(c.)\quad \underbrace{3RO\ \ 2SiO_3}_{\text{Bisilicate of Percy.}} + \underbrace{R_2O_3\ \ 2SiO_3}_{\text{Bisilicate of Percy.}},\ \text{or}\ RO\ SiO_2 + R_2O_3\ 3SiO_2$$

a neutral silicate in RO and R_2O_3.

In all cases, whether the *empirical* or the *rational* formula be adopted, we can obtain immediately, without the use of any symbol, by a simple multiplication and reduction to a percentage, all the elements necessary to judge of the "basicity" of a slag, of its approximation to certain types, and consequently of its fusibility as well as all the data for comparison with any other of different composition. All that is necessary is to transform all the bases into their equivalent in lime, as has been explained.

By such transformation we do not alter in any manner the type of the silicate, its oxygen ratio.

The characteristic feature of a silicate being afforded by the proportion of the oxygen of the acid to that of the base, if, in such a compound, a neutral silicate for instance,

$$SiO_2 = 51.72$$
$$RO = CaO = 48.28$$
$$\text{O ratio } 2 : 1$$

the quantity of R^1O (magnesia for example) which replaces a certain quantity of lime bears a direct proportion to their saturation for SiO_2, which, for this class of oxide MO, is as to that of their equivalent R^1O and RO, it is evident that the silicate *will pre-*

serve its type, the oxygen ratio of the silica remaining the same and being still double that of the base.

This can be established in an absolutely general manner as follows :

1°. Let

$$SiO_2 = a$$
$$CaO = RO = b$$

be a regular type of silicate of any kind for which *we know* that O of silica = k, O of base. O of $SiO_2 = \frac{8}{15} a$. O of $CaO = \frac{2}{7} b$,

and we have, as characteristic of the compound,

$$\frac{8}{15} a = \frac{2b}{7} \times k.$$

Let us first replace any part b' of the weight b of lime by a weight b'' of MgO, saturating the same quantity of silica as b' of lime, thus b'' magnesia : b' lime : : 20 equiv. of MgO or 40 atomic weight of MgO : 28 eq. of lime or 56 atomic weight of lime

$$= 5 : 7 \qquad \frac{b''}{b'} = \frac{5}{7} ; \; b'' = \frac{5}{7} b',$$

the composition of the silicate may be written then :

$$SiO_2 = a$$
$$CaO = b - b'$$
$$MgO = b'' = \frac{5}{7} b'$$

the O of the silica in the new compound

$$= \frac{8}{15} a = \frac{2b}{7} \times K$$

as above. O of bases $= \frac{2}{7} (b - b')$ O of lime $+ \underbrace{\frac{2}{5} \times \frac{5b'}{7}}$ O of MgO

$$\text{O of bases} : = \frac{2b}{7} - \frac{2b'}{7} + \frac{2b'}{7} = \frac{2b}{7}$$

O of acid $= \frac{2b}{7} \times k =$ O of bases $\frac{2b}{7} \times k$ as before. The silicate *has maintained its type,* whatever it may have been originally, and whatever may have been the quantities a, b, k, b', b''.

2°. But if we replace the total weight b of lime by any weight b' of CaO and b'' of MgO, such that $b' + b'' = b$, the composition of the silicate becomes

$$\begin{aligned} SiO_2 &= a \\ CaO &= b' \\ MgO &= b'' = b - b' \end{aligned}$$

the O of silica is always

$$\frac{8}{15}a = k\frac{2b}{7}$$

The oxygen of the bases $= \frac{2}{7}b' + \frac{2}{5}(b-b') = \frac{2b'}{7} + \frac{2b}{5} - \frac{2b'}{5} = \frac{10b' + 14b - 14b'}{35} = \frac{14b-4b'}{35}$

Let b' be any part whatsoever of $b = \frac{mb}{n}$ we have then :

$$\text{O of bases} = \frac{14b-4b'}{35} = \frac{14b - 4 \times \frac{m}{n}b}{35} = \frac{14bn-4mb}{35n} = \frac{2b}{7} \times \frac{7n-2m}{5n}$$

and, O of acid :

$\frac{2b}{7} \times k$ is no longer equal to O of bases $\frac{2b}{7} \times k$: *the type is changed,*

but, if $\frac{7n-2m}{5n} = 1$ we return to the original silicate, this will happen if $n = m$.

$\frac{m}{n} = 1$ then $\frac{7n-2m}{5n} = \frac{7m-2m}{5m} = 1$: $b = b'$ and the composition becomes

$$\left.\begin{aligned} SiO_2 &= a \\ CaO &= b \\ MgO &= b - b' = b'' = 0 \end{aligned}\right\} \text{O of acid } \frac{2b}{7} \times k = \text{O of bases } \frac{2b}{7} \times k \text{ as}$$

it should be.

3°. In the same manner if in the silicate $\left\{\begin{array}{l} SiO_2 = a \\ CaO = b \end{array}\right.$ we replace *b'* of lime by a weight b'' of alumina equivalent as saturation for silica (see Table III. *a*) $= \frac{b'}{1.631}$

We have for the new composition $\left\{\begin{array}{l} SiO_2 = a \\ CaO = b-b' \\ Al_2O_3 = \frac{b' = b''}{1.631} \end{array}\right.$

This number 1.631 has been obtained by the consideration that for saturation of silica, for the same type (neutral) $1RO = 28$ saturates $1SiO_2 = 30$ or $3RO = 84$ saturate $3SiO_2 = 90$, while $1Al_2O_3 = 51.50$ saturates $3SiO_2 = 90$. Hence: 84 lime are equivalent to 51.50 Al_2O_3, since they saturate the same quantity 90 of SiO_2.

Hence: $1 \text{ lime} = \frac{51.50}{84} Al_2O_3$ or $1Al_2O_3 = \frac{84}{51.50} = 1.631\ CaO.$

$$1.631 = \frac{84}{51.50}$$

and we have: $b'' = \frac{b'}{\left(\frac{84}{51.50}\right)} = \frac{b' \times 51.50}{84}$. The composition of the silicate can then be written:

$$\left.\begin{array}{l} SiO_2 = a \\ CaO = b-b' \\ Al_2O_3 = b' \times \frac{51.50}{84} \end{array}\right\}$$

$$\text{O of bases} = \underbrace{\frac{2}{7}(b-b')}_{CaO} + \underbrace{\left\{ b' \times \frac{51.50}{84} \right\} \times \frac{24}{51.50}}_{\text{O of } Al_2O_3 = \frac{2b'}{7}} =$$

$$\left\{\frac{2b}{7}-\frac{2b'}{7}\right\}+\frac{24b'}{84}=\frac{2b}{7}-\frac{2b'}{7}+\frac{2b'}{7}$$

$$\text{O of acid} = \frac{8}{15}a = \frac{2b}{7} \times k$$

$$\text{Total O of bases} = \frac{2b}{7}-\frac{2b'}{7}+\frac{2b'}{7}=\frac{2b}{7} \text{ and}$$

O of acid = O of bases $\frac{2b}{7} \times$ k as before, the type has not been changed.

Let us calculate the formula of the compound in this case.

$$\text{O of RO} = \frac{2b-2b'}{7};\ \text{O of } R_2O_3 = \frac{2b'}{7}$$

$$\text{Total O of acid} = \frac{8}{15}a = \frac{26}{7} \times k.$$

$$\text{Total O of bases} = \frac{26}{7} = \begin{cases} O,\ \text{O of RO} = \dfrac{2b-2b'}{7} \\ +\ O_3,\ \text{O of } R_2O_3 = \dfrac{2b'}{7} \end{cases}$$

$$\text{O of acid } \frac{2b}{7} \times k = \text{O of bases } \frac{2b}{7} \times k.$$

Proportioning the O of SiO_2:

$$\text{O of silica combined with RO} = \frac{\left\{\frac{2b}{7} \times k\right\}(2b-2b')}{\frac{2b}{7}} = k\left\{\frac{2b-2b'}{7}\right\}$$

$$\text{O of silica combined with } R_2O_3 = \frac{2b}{7}k - k\left\{\frac{2b-2b'}{7}\right\} = k \times \frac{2b'}{7}$$

and formula is :

$$\left\{\frac{2b-2b'}{7}\right\} R,\ k\left\{\frac{2b-2b'}{7}\right\} Si\ ;\ \text{O of acid } k\left\{\frac{2b-2b'}{7}\right\} =$$

$$\text{O of bases} \left\{\frac{2b-2b'}{7}\right\} \times k \left\{\frac{2b'}{7}\right\} R_2,\ k \left\{\frac{2b'}{7}\right\} Si;$$

$$\text{O of acid } k \left\{\frac{2b'}{7}\right\} = \text{O of base} \left\{\frac{2b'}{7}\right\} \times k$$

The silicates in RO and R_2O_3 are of the same type as k×O of base and of the same type as the compound itself.

We could prove in the same manner that if the weight b″ of Al_2O_3 were not equivalent for saturation of silica to that of the lime it replaces in the compound, the type of the silicate, the oxygen ratio, is changed, but remains the same for the silicates in RO and R_2O_3 as the new ratio of the compound itself.

Hence: Let a slag be expressed with SiO_2 or SiO_3, as the symbol for silica; let the equivalents or the atomic weights be used, the empirical or rational formulæ, the nomenclature neutral, e. g., sesquiacid, sesquibasic......slag, or the more modern names derived from hypothetical radicals be employed: in all cases the oxygen ratio remains the same, as it should be. This ratio constitutes, so to speak, the individual feature of a silicate, it decides as to its greater or lesser fusibility, its possible coexistence with certain grades of iron, and, since the transformation of all the bases into their equivalent of lime does not modify it in any manner, as we have just seen, we possess, then, in this method an absolutely exact and easy mode of comparison of two slags. No notation or symbol of any kind is required; we have to deal only with *figures* representing the composition of the substance as given by the analysis itself; the relative character of two silicates can be judged at once, the tables of references furnishing all the other data pertaining to each case.

CALCULATION OF SLAG.—This method of transformation of all the constituents into lime will be found very advantageous in calculating a slag. It simplifies the work considerably, and from the beginning to the end the operations can be performed by a non-technical person without using any symbol or formula.

Assume that we have a mixture of ores, of which the average composition is :

ORE.		LIMESTONE.			ASHES OF COAL.		
SiO_2	20.00	We use a limestone of composition :	SiO_2	6.00	And anthracite coal with 6.28% ash, of which ash the composition in per ct. of *coal* is	SiO_2	3.35
Al_2O_3	3.20		Al_2O_3	1.15		Al_2O_3	2.73
CaO	3.10		CaO	30.00		CaO	0.10
MgO	2.60		MgO	19.00		MgO	0.10
O of iron	70.00		CO_2	44.20			
Mn_3O_4	0.20						
P_2O_5	1.05						
S	0.10						
	100.25	Metallic iron, 50%		100.35			6.28%

We have decided to obtain a slag of such a character that the fusibility will be about that of a *sesquibasic slag*, that is, if preferred, of one in which O ratio is 4:3. Looking at the table we see that, for such a type, 1 of lime saturates 0.714 of silica, or 1 of silica takes up 1.400 of lime. Assuming any proper amount of coal per ton of ore smelted and, in most cases, 0.75 ton is all that is required, we have all the data necessary for our calculations. Transform *all the analyses into lime :*

ORE.

$$\begin{array}{ll} SiO_2 = 20.00\% \ldots\ldots\ldots\ldots & 20.00 \\ \left.\begin{array}{ll} Al_2O_3 = 3.20 \times 1.631 & = 5.22\% \\ CaO = 3.10 & = 3.10 \\ MgO = 2.60 \times 1.40 & = 3.64 \\ Mn_3O_4 = 0.20 & = .15 \end{array}\right\} & \begin{array}{c} = 12.11\% \\ CaO \end{array} \end{array}$$

The *ore* is equivalent per ton to $\left\{\begin{array}{l} SiO_2 = 20.00\% \\ CaO = 12.11\% \end{array}\right.$

STONE.

$$\begin{array}{ll} SiO_2 = \ldots\ldots\ldots\ldots\ldots & 6.00 \\ \left.\begin{array}{l} Al_2O_3 = 1.15 \times 1.631 = 1.87 \\ CaO = 30 \ldots\ldots\ldots = 30.00 \\ MgO = 19 \times 1.40 \ldots = 26.60 \end{array}\right\} & \begin{array}{c} 58.47\% \\ \text{Lime.} \end{array} \end{array}$$

The *stone* is equivalent per ton to $\left\{\begin{array}{ll} SiO_2 & 6.00\% \\ CaO & 58.47\% \end{array}\right.$

COAL.

$$\begin{array}{ll} SiO_2 = \ldots\ldots\ldots\ldots\ldots 3.35\% & \\ \left.\begin{array}{l} Al_2O_3 = 2.73 \times 1.631 = 4.45 \\ CaO \ldots\ldots\ldots\ldots\ldots = 0.10 \\ MgO \ldots\ldots\ldots\ldots\ldots = 0.14 \end{array}\right\} & CaO \end{array}$$

The *coal* is equivalent per ton to $\left\{\begin{array}{ll} SiO_2 & 3.35\% \\ CaO & 4.69\% \end{array}\right.$

Hence, as we use only ¾ ton of coal per ton of ore, the coal used is equivalent to ¾ of the above analysis, or:

$$\begin{array}{l} SiO_2 \ldots\ldots 2.52 \\ CaO \ldots\ldots 3.52 \\ \hline SiO_2 = 20 + 2.52 = SiO_2 \ \ldots 22.52 \end{array}$$

per ton of ore; the coal and ores are equivalent to $CaO = 12.11 + 3.52 = CaO \ldots 15.63$. Since, to make the proper silicate, 1 of lime takes up 0.714 of silica, the 15.63 of lime in coal and ores will take up: 0.714 × 15.63 = 11.16% of silica, leaving as *free silica* in the ore and coal 22.52 — 11.16 = 11.36 SiO_2 to saturate with limestone. The 6% of *silica of the stone* will require, at the rate of 1.400 lbs. lime per lb. of SiO_2, 6 × 1.40 = 8.40 lime, leaving of *free lime* or the equivalent in the limestone, 58.47 — 8.40 or 50.07 *free lime.* We have to saturate in coal and ores, 11.36 free silica. At the rate of saturation adopted, it will take: 11.36 × 1.40 lime = 15.91 lime; we have 50.07 free lime in 1 ton of limestone, we require only 15.91 of lime to *saturate the* SiO_2 in coal and ores, hence, we need only *per ton of ore and ¾ ton coal,*

$$\frac{15.91}{50.07} = 0.317$$

ton of stone. *The charges* are thus: 1 ton of ore, 0.75 ton of coal, 0.317 ton of limestone and, as the ore contains *50% of iron, we require :*

$$\left.\begin{array}{l}\text{2 tons ore}\\ \text{1.50 tons coal}\\ \text{0.634 ton stone}\end{array}\right\}\textit{per ton of pig made.}$$

The composition of the slag is :

Silica in ore and coal per ton of ore and per ¾ ton of coal	22.520
In stone 6×0.317 ton	1.908
Total SiO_2	24.428
Lime in ¾ ton coal and 1 ton ore (per ton ore)	15.63
In stone 0.318 ton × 58.47% =	18.59
Total lime	34.22

and composition of slag is :

SiO_2 = 24.428	or reducing to a	SiO_2 = 41.66	
CaO = 34.220	percentage :	CaO = 58.34	
58.648		100.00	

exactly a sesquibasic silicate. See Table V.

Using the preceding charges of ores, stone and coal we should have every reason to expect a slag of the above composition or of one very close to it.

We have adopted 1½ ton coal per ton of pig. If it were found that this could be reduced it should be done and the slag would hardly be modified in general character by this charge. If greater accuracy were necessary the preceding calculations could be made over again with the *new charges* in coal; but, practically, it is absolutely useless, the ash of coal entering, as it may be seen, as a small percentage into the general composition. With inferior cokes or anthracite it becomes an important factor *not to be neglected* but *too often ignored*. Cokes with 15% of ash are not uncommon in certain localities.

As an example of the close coincidence between slags actually run from known calculated charges and the slag determined *a priori* we quote the following slag run in a furnace 60 feet high, 16 feet bosh, running on hot blast 850 to 900° F. Pressure of blast 7½ lbs., American furnace, anthracite coal. The analyses of materials were as follows :

	Ores.	Stone.	Coal.
SiO_2	23.31	9.90	3.00
Al_2O_3	4.51	3.88	2.30
CaO	1.61	28.00	0.10
MgO	3.41	16.00	0.08
Alkalies	2.67	----	----
Mn_3O_4	traces	----	----
P_2O_5	0.31	----	----
S	0.08	----	----

Making the calculations proportionally to the quantity of the different materials charged, we find that the slag contained :

	Metallic iron 46.46%.	New Jersey Dolomite.	Lehigh Summit.
Charges :	8cwt. 1q 0lb.	3cwt. 1q 14lbs.	5—1—0
	924 lbs.	378 lbs.	588 lbs.

	Ores.	Stone.	Coal.	Total.
Silica	215.38	37.42	17.64	270.44 lbs.
Alumina	41.67	14.66	13.52	69.85 "
Lime	14.90	105.84	0.59	121.33 "
Magnesia	31.50	60.48	0.47	92.45 "
Alkalies	24.67	----	----	24.67 "
Mang. oxide	Traces	----	----	---- "
Total weight of slag				578.74 lbs.

924 lbs. of ore gave in iron 425 lbs., the ores having 46.60% Fe. With such slag, of which the character was sesquibasic, a light grade of iron was to be expected, such pig as contains in an average 1.50% silicon or 3.20% silica corresponding, in 425 lbs. of pig iron, to 13.60 lbs. of silica, which, subtracted from the total silica which went to form slag and pig, leaves a balance of 256.84 lbs. SiO_2 to be expected in slag. The composition of the slag was then :

	Calculated.		Per Cent.		The analysis gave:
SiO_2	256.84	SiO_2	45.44	SiO_2	44.27
Al_2O_3	69.85	Al_2O_3	12.36	Al_2O_3	12.91
Lime	121.33	CaO	21.40	CaO	20.00
MgO	92.45	MgO	16.36	MgO	16.50
Alkalies	24.67	Alk	4.40	Alkalies	3.98
				Ox. of iron	2.47
	565.14		99.96	MnO	Traces
				S	0.56
					100.69

This quantity of iron, 2.47% is not abnormal, but occurs in many slags. If we take it into consideration in calculating the slag we have 99.96 + 2.40 = 102.36. Reducing to a percentage we find :

	Calculated Slag (iron added).	*Actual Analysis.*
SiO_2	44.34	44.27
Al_2O_3	12.06	12.91
CaO	20.88	19.81
MgO	16.00	16.50
Alkalies	4.22	3.98
Ox. iron	2.47	2.47

The iron was found to be No. 3 light gray, containing 1.53 silicon. Transformed into lime, this slag corresponds to :

SiO_2	40.66
CaO	59.34
	100.00

A typical sesquibasic slag has for its composition :

SiO_2	41.66	Table V.
CaO	58.34	
	100.00	

But, if *we neglect* the 2.47% of iron *not taken into consideration in the first calculations* we find when transformed into lime:

$$\left.\begin{array}{ll} SiO_2 & 41.65 \\ CaO & 58.36 \end{array}\right\}$$ for the composition of the "calculated slag."

Having explained how to obtain the formulæ of slags with the symbols SiO_2 or SiO_3 for silica and how to transform the old formula into the new one or inversely, and possessing now, for all cases, an easy and rapid method of comparison of two slags, by transforming all the bases into lime, without using any chemical symbols, or making any hypotheses as to their composition, we shall proceed to the critical examination of a number of slags for which we know, at least and with certainty the grade of iron accompanying them, to see if the general statement that as the slag is more basic the tendency of the iron is to be of a darker grade, finds itself corroborated by blast furnace practice.

We give first the full analyses of the slags, as they were given by the different writers, or as they were obtained by us, many of them having been made by ourselves, completing them by a succinct description of the furnace from which they were run, and of the circumstances of their production as nearly as we have been able to ascertain them. For many slags we have also the analyses of the ores, stone and coals, and the charges, but they do not figure in this paper. In the transformation of the slags into lime, we have often stopped the operations at the first decimal; it is a sufficient approximation for a study of such compounds.

TABLE VI.—ANALYSES OF SLAGS.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
SiO_2	46.37	45.23	38.48	43.40	70 23	53.79	49.57	48 39	41.11	37.84	45.64	41.11	39.95	40.20
Al_2O_3	4.30	14.30	15.13	12.20	6.37	13.04	9.00	6 66	13.45	13.20	10.84	9.46	17.41	16.45
CaO	38.64	32.09	32.82	18.13	20.41	25.67	.....	.....	29.82	20.68	35.01	37 90	29.64	30.00
MgO	7.40	3.78	7.44	4.50	.....	0.57	15.15	10.22	4.75	2.93	3.16	2.11	6.47	7.29
MnO	1.86	1.02	1.62	5.80	2.70	2.20	25.84	33.96	0.66	0.80	traces.	1.61	0.91	0.84
FeO	0.95	3.03	0.76	10.99	0.15	2.44	0.04	0.06	6.44	20.83	0.71	0.38	0.24	0.57
K_2O	0.30	1.55	1.92	.....	.....	.....	.....	.....	Alk.	Alk.	Alk.	Alk.	Alk.	
Na_2O	0.14	.....	.....	.....	.....	.....	.....	.....	1.84	1.08	0.82	0.71	1.46	1.30
S	0.03	CaS_2 1.87	Sulp Ca 2.22	CaS_2 3.97	.....	.....	.....	.....	S. Calc. 1.34	S. Cal. 1.77	S. Calc. 3.30	S. Calc. 6.41	S. Cal. 3.60	2.71
PO_5	traces	.....	0.15	.....	.....	.....	.....	.....	.....	traces.	traces.	traces.	traces.	traces.
Character of Iron	Gray No. 3.	White.	Foundry Gray.	Gray.	Gray.	Mottled.	Gray.	White.	White.	White.	Gray.	Gray No. 2.	Gray No. 2.	Gray No. 2.
Bl. Furnaces	Edsken Sweden	Dowlais England.	Dowlais England.	Westphalia.	Sweden	Sweden	Sweden	Spiegeleisen.	English	English	English Dowlais	English Dowlais	English Aberdare.	English Aberdare.

TABLE VI.—(*Continued.*)

	15	16	17	18	19	20	21	22	23	24	25	26	27	28
SiO_2	41.64	42.94	36.80	48.42	29.25	37.80	40.10	40.50	37.99	38.26	39.30	39.71	49.57	47.39
Al_2O_3	13.20	16.29	13.80	7.56	19.25	13.70	10.40	9.90	14.33	9.28	11.28	18.96	9.00	6.66
CaO	35.91	31.10	46.00	27.89	38.25	48.50	49.30	49.50	47.66	39.50	43.84	35.26	.....	.....
MgO	4.21	4.16	2.54	6.48	0.60	.....	.....	.....	.....	.....	.....	0.66	15.15	10.22
MnO	0.74	0.51	.....	6.37	8.76	.....	.....	.....	.....	.....	.....	0.62	25.84	33.96
FeO	0.11	0.34	.....	4.39	1.04	.....	.....	.....	.....	.....	.....	0.887	0.04	0.06
K_2O	Alk.	Alk.	Alk.	.....	.....	.....	.....	.....	.....	.....	.....	Alk. 0.98	.....	.....
Na_2O	0.70	1.87	0.86	.....	.....	.....	.....	.....	.....	.....	.....	Cu.0.083	.....	.....
S	Ca. S. 2.19	Ca. S. 2.16	.....	.....	2.16	.....	.....	.....	.....	.....	.....	Ca. S. 2.35	0.80	.....
P_2O_5	traces.	traces.	.....	0.02	SiO_2 0.75	.....	.....	.....	.....	.....	.....	traces.	.....	.....
	Gray No. 2.	Gray No. 2.	Gray.	Gray, Light and Mottled	Gray, 1, 2 to 3.	Gray.	Gray.	Gray & Mottled	Gray.	Gray.	Gray & Mottled	Gray.	Gray.	White.
	Aberdare, English	Aberdare, English	Tonlaw English	Sweden	Cleveland, England.	Bessèges, Belgium.	Bessèges, Belgium.	Bessèges, Belgium.	Bessèges. Belgium.	Prussian, Westphalia.	Prussian. Westphalia.	Aninan Austrian.	Hamm.	Hamm.

TABLE VI.—(*Continued.*)

	29	30	31	32	33	34	35	36	37	38	39	40	41	42
SiO_2	52.80	57.00	45.40	37.80	36.60	32.65	35.00	35.40	39.00	41.85	39.07	44.87	39.48	36.59
Al_2O_3	3.40	10.60	4.60	2.10	18.40	23.00	19.70	15.00	14.10	14.73	9.32	9.14	8.35	8.22
CaO	5.60	5.60	4.20	.....	35.80	31.00	29.90	48.00	44.00	30.99	45.59	23.37	29.81	39.68
MgO	9.00	13.80	8.60	8.60	4.80	0	.....	0.50	1.00	4.76	3.17	14.13	13.31	9.25
MnO	26.20	5.40	33.40	29.20	.....	4.20	8.20	.....	1.00	1.24	0.80	0.99	1.94	2.04
FeO	1.40	6.80	1.80	21.50	2.00	2.00	1.00	.....	1.40	2.63	0.80	3.42	3.01	2.12
K_2O	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	Alk 0.23	Alk	Alk	Alk
Na_2O	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	BaO 0.40	3.50	3.37	1.62
S	.....	.....	.....	0.02	1.00	.....	.....	1.80	1.20	Sul Calc 2.07	SiO_2 *	0.58	0.73	.....
P_2O_5	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....		.....	.....	.....
	White. Müsen.	Mottled White. Müsen.	White. Müsen.	Hamm. White.	Gray. Terrenoire, France.	Scotch Gray No. 1.	Scotch Gray Nos. 2 to 4.	Bessèges. Gray Graphitic. Belgium.	Bessèges. 20% P. Cinders Gray.	Mottled and White. Dowlais England.	Gray No. 1& 2 Colorado, ¼ Puddled Cinders containing 10% SiO_2.	White. N. J. American.	White. N. J. American.	Gray. N. J. American.

TABLE VI.—(*Continued.*)

	43	44	45	46	47	48	49	50	51	52	53	54	55	56
SiO_2	40.17	43.22	50.10	35.48	44.28	47.16	45.98	47.89	43.07	48.16	43.55	45.71	48.50	48.35
Al_2O_3	6.59	9.11	8.26	10.26	8.02	10 41	10.17	9.24	8.80	9.14	10.84	13.19	12.05	12.74
CaO	36.10	36.08	27.04	35.79	37.58	23.30	25.15	22.52	28.30	27.17	28.20	30.26	25.41	24.83
MgO	8.60	7.92	9.40	9.80	9.01	15.79	15.99	15.63	13.22	9.51	12.70	6.96	10.70	10.71
MnO	3.47	0.82	0.02	2.54	0.92	1.85	1.85	2.10	2.27	1.22	1.05	0.39	0.52	0.63
FeO	3.06	1.02	4.88	3.73	2.16	0.28	traces	traces	2.65	3.80	1.68	2.31	1.74	1.58
K_2O	Alk	Alk	Alk	Alk	.....	Alk	Alk	Alk	Alk	Alk	Alk	Alk	Alk	Alk
Na_2O	1.62	1.79	.....	1.94	.....	0.93	0.64	1.57	1.05	0.60	2.00	1.38	0.25	0.33
S	0.39	0.59	.....	0.46	0.45	0.45	0.28	0.12	0.64	0.41	.....	.....	0.82	0.82
P_2O_5	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	Gray.	White and Mottled	White.	White Chromium.	Mottled	White.	White.	White.	Gray No. 2.	White and Mottled	Gray.	Light Gray No. 3.	White.	White and Mottled

*All American furnaces.

TABLE VI.—(*Concluded.*)

	57	58	59	60	61	62	63	64	65	66	67	68	69	70
SiO_2	42.80	39.15	42.64	40.97	43.19	46.80	43.36	40.45	42.77	46.04	46.11	44.27	42.77	35.48
Al_2O_3	9.76	10.32	13.48	11.31	16.33	13.69	16.92	8.90	11.90	12.05	11.89	12.91	11.93	10.26
CaO	28.52	32.76	27.75	30.30	24.73	21.38	23.67	28.89	23.26	21.88	21.66	19.81	23.26	35.79
MgO	14.55	14.27	12.89	13.77	12.85	14.75	13.91	15.65	16.78	16.28	14.80	16.50	16.78	9.80
MnO	1.05	0.35	0.20	0.10	traces.	traces.	traces.	3.01	traces.	0.30	traces.	traces.	traces	2.54
FeO	1.99	1.61	2.12	1.88	1.55	1.18	0.99	0.99	0.80	1.28	1.75	2.47	1.39	3.73
K_2O	Alk.	Alk.	Alk.	Alk.	Alk.	Alk.	Alk.	Alk.	Alk.	Alk.	Alk.	Alk.	Alk.	Alk.
Na_2O	0.60	0.79	0.12	0.79	0.69	1.69	0.50	1.13	3.44	1.68	2.91	3.48	3.44	1.94
S	0.73	0.75	0.90	0.88	0.66	0.51	0.68	0.98	0.64	0.54	0.55	0.56	0.57	0.46
P_2O_5	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	Gray No. 1.
	Mottled	Gray No. 2x.	Gray.	Gray No. 1.	Gray No. 2.	Gray No. 2 and 3.	Gray No. 3.	Gray No. 2.	Gray No. 2 and 3.	No. 3 and Mottled	Mottled	Gray No. 3, Light.	Gray No. 3.	Gray No. 1.

All American furnaces.

(1.) Edsken, Sweden.—Hot blast, 572° Farh.; height of furnace, 44' to 48'; boshes, 7'4"; blast, $0^{k}.07$ to $0^{k}.105$; average, 0.0875 ky. per □ centimetre = 1.20 lbs. per square inch; very fluid slag.

(2.) Dowlais furnace.—Ores, mixture of argillaceous carbonates and hematites; iron run; generally gray No. 2 and No. 3.

(3.) Dowlais furnace. (4.) Westphalia slag, leek green, the quantity of FeO, 10.99%, is remarkably high; vitreous and conchoidal fracture. (5.) Argillaceous ores, enamel like, bluish white, wood furnace, Sweden. (6.) Swedish furnace, wood as combustible, green and vitreous slag; spathic carbonates and brown hematites; air *very hot.* (7.) Spiegeleisen. (8.) Do. Spiegeleisen Swedish furnace. (9.) Hot blast, Dowlais. (10.) Cold blast, English. (11)-(12.) Argillaceous ores; pisolithic ores and puddle cinders. (13)-(14.) Aberdare B. furnaces, argillaceous ores, cold blast. (15)-(16.) Aberdare furnaces, hot blast 315° C. (17.) Coke furnace, Tonlaw. (18.) Lake and bog ores, cold air 0.07 kilo. per cm_2, Tinspong, Sweden, charcoal furnace. (19.) Manganiferous ores containing 37.19% mang. oxide, Cleveland furnace. (20.) Bességes, Belgium, hot blast 536° Farh.: pressure, $0^{m}.12$ to $0^{m}.14$. (21)-(22)-(23.) Do. (24)-(25.) Berge Borbeck furnace, hematites and argillaceous ores, poor; average, 35% iron; coke furnace, 47 ft. high x 15'6" boshes; crucible, 5'3" diam.; temperature of air, 180° C.; pressure, 0.16m. mercury per square centimetre. (26). Austrian furnace, hematites and magnetites; hot blast; pressure, 0.069m. mercury; coke furnace, height 48'; boshes, 13'6"; hearth, 3'4"; temperature blast, 150°C.; pressure in lbs., 2½ to 3 lbs. (27.) Hamm furnace slag, manganiferous ores; manganese oxide in slag 25.84%. (28.) 33.96% MnO in slag. (29.) Müsen furnace, Spiegeleisen 26.20% MnO in slag. (30.) Müsen slag, 6.80 FeO in slag, 540 MnO. (31.) Do., Spiegeleisen MnO in slag 33.40%. (32.) Cold blast Hamm furnace, slag containing 29.20% MnO and 21.50 FeO. (33.) Terrenoire (France). (34.) Scotch iron. (35.) Do. (36)-(37.) Bességes (Belgium) furnaces, 20% puddle cinders added to charges for slag, No. 37. (38.) English slag, Dowlais furnace; average. (39.) Slag from Colorado furnace; Hot Spring and Calumet ores, mixture of rich magnetites 58% iron ; and rich hematites 45% iron ; Bessemer ores 25%, puddle cinders containing 9.47% titanic acid added regularly to the charges. Iron No. 1 and No. 2 Foundry, very tough ; coke furnace 70 ft. high, 18% ashes.

(40.) Magnetite ores from New Jersey, very rich, general average, 50 to 55%. Iron, with gangue of free silica, hornblende, iron mica, furnace 45 feet high. Anthracite. Pressure of blast 3½ lbs. per square inch; temperature, 750 to 800° F. (41.) Same ores, with a mixture of one-half Staten Island hematite, containing 1.25% chromium, which went into the iron making it white and hard. (42.) Half Staten Island hematite, half New Jersey magnetites, chromium in the pig iron, 1.10%. (43.) All New Jersey magnetites. (44.) Do. (45.) Do. ; ores very silicious at the time, containing as much as 40% hornblende and iron mica, the furnace being only 45 feet high, they did not have time to be reduced, got into the hearth, fused and passed out as slag, which explains the anomaly of such an acid slag in connection with a gray forge iron. (46.) Staten Island hematites added to the charges, making the iron white; chromium in the iron, 1.20%. (47.) Regular N. J. hematites. (48)-(49)-(50.) Do. (51.) Same ores, but furnace 60 feet high ; pressure of blast, 6 to 7 lbs.; temperature, 800 to 900° Fahr. (52) to (70.) Do.

Average charges for Pig,	1.00.	
Ores,	2.00.	New Jersey magnetites generally.
Stone,	1.00.	New Jersey dolomites.
Coal,	1.50.	Lehigh anthracite and Scranton.

To compare these slags we have to transform them all into lime, and, as the approximations of a type to "basicity" is more logically expressed by the quantity of lime, we shall tabulate *only* the quantity of lime (calculated in some cases to only one decimal) to which all of the basic elements of the slags are equivalent. As some of the results fall between two types, the slag of the type to which it comes the nearest will determine the designation. An acid slag containing 31.80% CaO and the next type, the sesquiacid, 38.35% CaO ; (see tables) any slag which contains a quantity of lime greater than the average$=\frac{38.35+31.81}{2}=$*35.08%* of lime will be tabulated as *sesquiacid,* if *less* as an *acid* slag. Any slag containing a quantity of lime greater than *43.31%,* the average of 38.35 (sesquiacid) and 48.28 (neutral), will be tabulated as *neutral,* below this figure as *sesquiacid.* Any slag containing more than *53.31CaO%,* the average of 48.28% (neutral) and 58.34% sesquibasic, will be tabulated as *sesquibasic,* below that figure as neutral. Any slag containing more than *61.73CaO,* the average of 58.34 neutral and 65.12 (bibasic), will be tabulated as *bibasic,* below this *sesquibasic.*

Any slag containing more than *69.42%* CaO average of 65.12 (bibasic) and 73.70 (tribasic) will be tabulated as *tribasic,* below this as bibasic.

We give in a special column the amount of lime contained in each type, the figures being followed by capital letters, the first letters of the denomination of each type. Thus : A stands for acid, SA for sesquiacid, N for neutral, SB for sesquibasic, B for bibasic, T for tribasic.

In the next column we have put down the preceding figures, representing the *limit* of lime at which a slag has been classified under the type next in basicity. This was done in case of a possible approximation to one type, leaving in doubt the character of the slag ; but, as it will be noticed, it was not necessary in any case. Another column contains the character of the slag determined as explained. The next gives the character of the pig iron accompanying each slag, and the last contains such observations as may explain certain anomalies observed in the type in connection with the grade of iron, or such other special data regarding certain slags which make them rather abnormal. For details we refer to notes, pages 69 to 71, and to the Table VI., which gives the composition in full.

TABLE VII.

Nos. of Slags.	Equivalent of Lime in slag.	Lime in nearest type.	Limit of lime deciding type.	Character of Slags.	Character of Pig Iron Run.	OBSERVATIONS.
1	55.30	58.34 S. B.	53.31	Sesquibasic.	Gray, No. 3.	
2.	57.37	58.34 S. B.	"	Sesquibasic.	White.	
3	65.00	65.12 B.	61.73	Bibasic.	Gray, No. 2.	
4	57.50	58.34 S. B.	53.31	Sesquibasic.	Gray.	10.99 FeO and 5.80 MnO in Slag.
5	32.00	31.81 A.	35.08	Acid.	Gray.	
6	48.00	48.28 N.	43.31	Neutral.	Mottled.	
7	53.00	58.34 S. B.	53.31	Sesquibasic.	Gray.	Very hot blast. MnO 25.84.
8	48.30	48.28 N.	43.31	Neutral.	White.	MnO 33.96. Spiegeleisen.
9	60.00	58.34 S. B.	53.31	Sesquibasic.	White.	Cold blast.
10	62.00	" S. B.	"	Sesquibasic.	White.	?
11.	54.00	" S. B.	"	Sesquibasic.	Gray.	Puddle cinders in the charges.
12	59.00	" S. B.	"	Sesquibasic.	Gray.	" " "
13	63.30	65.12 B.	61.73	Bibasic.	Gray, No. 1.	
14	64.00	" B.	"	Bibasic.	Gray, No. 2.	
15	61.80	" B.	"	Bibasic.	Gray, No. 2.	
16	61.00	" B.	"	Bibasic.	Gray, No. 2.	
17	66.30	" B.	"	Bibasic.	Gray.	
18	54.40	58.34 S. B.	53.31	Sesquibasic.	Light gray. Mottled.	MnO=6.37; FeO=4.39. Cold blast.
19	72.50	73.70 T.	69.42	Tribasic.	Gray, No. 1.	MnO; 8.76.
20	65.20	65.12 B.	61.73	Bibasic.	Gray.	
21	62.20	" B.	"	Bibasic.	Gray and mottled.	
22	61.90	" B.	"	Bibasic.	Mottled and gray.	
23	65.10	" B.	"	Bibasic.	Gray.	
24	58.80	58.34 S. B.	53.31	Sesquibasic.	Gray forge. M.	
25	61.30	" S. B.	"	Sesquibasic.	Gray forge.	
26	63.50	65.12 B.	61.73	Bibasic.	Gray.	
27	53.30	58.34 S. B.	53.31	Sesquibasic.	Gray.	MnO 25.84%.
28	53.60	" S. B.	"	Sesquibasic.	White.	MnO 33.96.
29	46.40	48.28 N.	43.31	Neutral.	White.	MnO 26.20.
30	47.70	" N.	"	Neutral.	White.	MnO 5.40%; FeO 6.80.
31	46.50	" N.	"	Neutral.	White.	MnO 33.40.
32	58.37	58.34 S. B.	53.31	Sesquibasic.	White.	MnO 29.20; FeO 21.50.
33	67.00	65.12 B.	61.73	Bibasic.	Gray, No. 1.	
34	69.50	73.72 T. B.	69.42	Tribasic.	Scotch gray, No. 1.	
35	66.50	65.12 B.	61.73	Bibasic.	Scotch gray, No. 2.	
36	66.40	" B.	"	Bibasic.	Gray. No. 1.	Graphitic Iron.
37	66.40	" B.	"	Bibasic.	Gray. No. 1 and No. 2x	
38	60.00	58.34 S. B.	53.31	Sesquibasic.	White and mottled.	
39	63.07	65.12 B.	61.73	Bibasic.	Gray, Nos. 1 and 2.	¼ Puddled cinder containing 9.47 SiO_2.
40	58.80	58.34 S. B.	53.31	Sesquibasic.	White.	
41	63.16	65.12 B.	61.73	Bibasic.	White.	½ Staten Island Hematite. Chromium in iron making it white.
42	65.00	" B.	"	Bibasic.	White.	⅛ Staten Island Hematite. 1.25 Chrom. in iron making it white.
43	62.00	" B.	"	Bibasic.	Gray.	
44	60.00	58.34 S. B.	53.31	Sesquibasic.	White.	
45	53.30	" S. B.	"	Sesquibasic.	Gray forge.	45% Silicates of iron Hornblende and Mica in ore not reduced and increasing unduly SiO_2.
46	65.00	65.12 B.	61.73	Bibasic.	White.	½ Staten Island Hematite. Chromium in iron.
47	59.70	58.34 S. B.	53.31	Sesquibasic.	White.	
48	57.70	" S. B.	"	Sesquibasic.	White.	
49	58.00	" S. B.	"	Sesquibasic.	White.	
50	56.40	" S. B.	"	Sesquibasic.	White.	
51	60.40	" S. B.	"	Sesquibasic.	Gray, No. 2.	
52	56.10	" S. B.	"	Sesquibasic.	White and mottled.	
53	61.80	65.12 B.	61.73	Bibasic.	Gray.	
54	58.70	58.34 S. B.	53.31	Sesquibasic.	Light gray forge.	
55	56.20	" S. B.	"	Sesquibasic.	Mottled and white.	
56	56.20	" S. B.	"	Sesquibasic.	Mottled.	
57	60.20	" S. B.	"	Sesquibasic.	Mottled.	
58	64.60	65.12 B.	61.73	Bibasic.	Gray, No. 2 and No. 3.	
59	63.00	" B.	"	Bibasic.	Gray.	
60	64.10	" B.	"	Bibasic.	Gray, No. 2xx.	
61	62.35	" B.	"	Bibasic.	Gray, No. 2.	
62	57.90	58.34 S. B.	53.31	Sesquibasic.	Gray.	
63	62.30	65.12 B.	61.73	Bibasic.	Gray, No. 3.	
64	63.50	" B.	"	Bibasic.	Gray, No. 2.	
65	61.80	" B.	"	Bibasic.	Gray, No. 3.	
66	59.20	58.34 S. B.	53.31	Sesquibasic.	No. 3 and Mottled.	
67	58.50	" S. B.	"	Sesquibasic.	Mottled.	
68	60.00	" S. B.	"	Sesquibasic.	No. 3, Gray.	
69	61.80	65.12 B.	61.73	Bibasic.	No. 3, Gray dark.	
70	66.50	" B.	"	Bibasic.	Gray. No. 1.	

Referring to the data contained in the preceding table we see that:

When the slags were "*neutral*," which happened five times, the iron was four times white and once mottled.

When they were "*sesquibasic*," which happened 32 times, the iron was twelve times white; three times white and mottled: four times mottled; twice light gray and mottled, and eleven times gray; the shades of gray being mostly light.

When they were "*bibasic*," which happened 30 times, the iron was three times white; twice gray and mottled gray, and 25 times gray, graphitic No. 1, No. 2^{xx}, No. 2^{x} and No. 2, the darker shades corresponding most generally to slags reaching very near the typical bibasic slag or even going beyond it in quantity of lime. *The three cases* when the iron was "white" it was due invariably to the presence of chromium in the pig; chromium making the pig iron white and hard when present in certain quantities; the conditions of the furnace were not normal so far as the study of types of slags is concerned.

When they were "*tribasic*," which happened twice, the iron was No. 1 graphitic iron.

When they were "*acid*," which happened once, the iron was gray.

We are justified in concluding at least from the examples quoted, that, with a neutral slag the iron can be expected to be normally white, exceptionally mottled.

With a slag approaching a sesquibasic slag, according to the conditions of the furnace, height, temperature and pressure of blast, the iron can be expected to affect the lightest grades of gray or to be mottled,being white only in special conditions, and a darker gray if the composition of the slag is decidedly sesquibasic. Irons run with such slags are very advantageous as forge irons. The pig contains a greater percentage of iron and less silicon and carbon than grayer pigs, conditions very favorable in the puddling process, which is intended to eliminate all substances foreign to the iron.

With a bibasic slag, in normal conditions of ores and charges, we can expect invariably a gray pig from the darkest shades to

No. 2. No. 1, No. 2^{xx} and kish cinders, if the composition in lime reaches over the type of bibasic No. 2^{x} and No. 2, if not quite up to the percentage of lime of the latter, as the case may be.

With a tribasic slag the iron will invariably be a No. 1 iron, Scotch gray (judging from the limited number of examples of such slags, which are not very economical).

An acid slag, as could be expected from diminished fusibility when the proportion of silica goes above a certain limit, corresponds to gray iron.

The higher grades of iron contain the most silicas and carbon (total carbon), corresponding therefore to higher temperatures in a furnace, a condition necessary to insure the reduction of the silica and the passage of silica into the pig, as well as the solution of the carbon in the molten iron ; they are accompanied by the more basic slags. Blast furnace practice corroborates then completely the direct experiments on the fusibility of silicates which showed that the more basic they are the less their fusibility, and that, beyond a certain limit of acid, the silicates become again more refractory.

If objections are made to the denomination "Basic," "Bibasic," "Neutral," slags used in this discussion, we can say : Putting aside all considerations as to the molecular constitution of silicates and taking only as a guide *the oxygen ratio, an element of comparison which the analysis furnishes in all cases.*

The silicates in which the ratio of oxygen of SiO_2 to oxygen of the bases is comprised between $\overset{\text{(Sesquibasic.)}}{4 : 3}$ and $\overset{\text{(Bibasic.)}}{4 : 4}$ (1 : 1) accompany most invariably the higher grades of iron ; when this ratio falls between 4 : 2 (neutral 2 : 1) and 4 : 3 (sesquibasic), mottled iron and lighter grades of gray may be expected, darker as the ratio approaches 4 : 3.

At 4 : 2 (2 : 1), white iron and occasionally mottled iron can be depended upon. When this ratio reaches 1 : 4 (acid), the fusibility appears to diminish again, and as a consequence, the darkest grades are obtained.

At 4 : 6 (2 : 3) (tribasic) graphitic iron and kish cinder are the rule. If these deductions are correct, and the more numerous the observations the better their truth could be ascertained, their importance is not to be overlooked. The failure to obtain a certain grade of iron with a given slag within certain limits would then be a warning to an intelligent iron master to look in his ores or other materials charged in the furnace, for a disturbing element or for abnormal conditions of temperature, volume and pressure of blast. It would call for a thorough chemical analysis. The same ores frequently change in composition. When silica is present in a combined state in an iron ore, as hornblende or iron mica, these silicates of iron may melt before being reduced, especially in a low furnace, and pass out in the slag *as such,* and unreduced completely changing *its character* as calculated from a "general analysis," or "expected" from a previous practice with the same ores. Such a circumstance did present itself in one of the slags quoted, No. 45. It showed at the analysis 50.10 silica and 4.88 FeO, corresponding, transformed into lime, to a slag containing 53.20 CaO, just about the limit, 53.31, to be called a sesquibasic slag (58.34); it was tabulated so, but, strictly speaking, it was nearer a neutral slag, 48.28. With such a slag an iron of lighter gray than gray forge iron was to be expected. If a darker one was obtained, it was certainly due to the fact that, omitting the *silicate of iron* melted without reduction in a low furnace, and existing simply as an *inert matter* in the liquid slag, the slag had a different saturation for silica than the apparent one. A more complete and thorough examination of the slags quoted would disclose for several of them other anomalies, more or less important, but it would carry us too far. We have intended to show, only in a general manner, that the relation between the chemical character of a slag and grade of iron is much closer than, we believe, it is generally admitted to be, leaving far more complete and numerous observations to determine the question, not forgetting the wise maxims of Sir Lowthian Bell and his reserve: "If it is proper to give an opinion on a subject which one has not *thoroughly* experimented."

The following Tables VIII. and IX. recapitulate practically the results of this examination. No formulæ or symbols are used in it; the bases being called by the names they are generally known by. It is, so to speak, a practical table allowing any one not familiar with technical chemistry to transform a slag of any composition into lime and also to find the oxygen ratio if desired. Comparing the results with those tabulated, the character of the slag can be ascertained and permit its fusibility and the iron "likely" to be expected in normal conditions of furnace, as well as its relation with another one. The Table IX. of equivalence includes all the bases likely to be met with in slags, some as constant elements, others as occasional ones in certain localities. Table VIII. giving also the saturation of lime for silica, or inversely, for different types of slags of different fusibility these figures can readily be used, as explained previously, for the calculation, *a priori*, of a slag from certain charges in ores, stone and coal of which the analyses may be given:

TABLE VIII.—TYPES OF SLAGS (*Resumé*).

Chem. Denomination: *Acid.* Disilicates.	Chem. Denomination. *Sesquiacid.* Trisilicates.	Chem. Denomination: *Neutral.* Metasilic Monosilicates.	Chem. Denomination: *Sesquibasic.* Disilicates.	Chem. Denomination: *Bibasic.* Orthosilic Monosilicates.	Chem. Denomination: *Tribasic.* Parasilicic Monosilicates.
Oxygen Ratio: O of Silica: O of Bases 4 : 1	Oxygen Ratio: O of Silica: O of bases 3 : 1	Oxygen Ratio: O of Silica: O of bases 2 : 1	Oxygen Ratio: O of Silica: O of bases 4 : 3	Oxygen Ratio: O of Silica: O of bases 1 : 1	Oxygen Ratio: O of Silica: O of bases 2 : 3
Composition: Silica ....68.19 Lime.............31.81	Composition: Silica.............61.65 Lime.............38.35	Composition: Silica.............51.72 Lime.............48.28	Composition: Silica ....41.66 Lime.............58.34	Composition: Silica............34.88 Lime............65.12	Composition: Silica...........26.30 Lime...........73.70
Saturation: 1 Lime satur..2.143 Silica 1 Silica saturates.... 0.466 Lime	Saturation: 1 Lime.....1.607 Silica 1 Silica.....0.622 Lime	Saturation: 1 Lime.....1.071 Silica 1 Silica.....0.932 Lime	Saturation: 1 Lime.....0.714 Silica 1 Silica.....1.400 Lime	Saturation: 1 Lime....0.538 Silica 1 Silica....1.858 Lime	Saturation: 1 Lime....0.357 Silica 1 Silica....2.829 Lime
Fusibility: "Fusible."	Fusibility: "Moderately Fusible."	Fusibility: "Very fusible."	Fusibility: "Very fusible," but less than preceding one.	Fusibility: "Fusible."	Fusibility: "Fusible," but less than preceding one.
Grade of iron likely to accompany such slag: Gray No. 2.	Grade of iron likely to accompany such slag: Gray, lighter.	Grade of iron likely to accompany such slag: White.	Grade of iron likely to accompany such slag: Mottled and Lighter Grays.	Grade of iron likely to accompany such slag: Gray No. 2. No. 2x, No. 2xx, and No. 1 occasionally.	Grade of iron likely to accompany such slag: Gray No. 1. Kish Cinder.

TABLE IX.

Bases likely to be found in slags.

Eqnivalence in Lime.	Oxygen in 1 lb. of Base.
1 lb. Alumina = 1.631 Lime	0.466
1 lb. Magnesia = 1.400 "	0.400
1 lb. Potash = 0.594 "	0.170
1 lb. Soda = 0.903 "	0.258
1 lb. Iron Oxide (FeO) = 0.780 "	0.222
1 lb. Manganese Oxide (MnO) = 0.780	0.225
1 lb. Baryta = 0.365	0.104
1 lb. Copper Oxide (CuO) = 0.704	0.201
1 lb. Lithia = 1.866	0.550
1 lb. Nickel Oxide (NiO) = 0.747	0.213
1 lb. Iron Sesquioxide (Fe_2O_3) = 1.050	0.300
1 lb. Chromium Sesquioxide(Cr_2O_3)= 1.100	0.314
Iron and Chromium Sesquioxide, (Ferric and Chromic oxide,) to be treated as Alumina.	O of Silica: 0.533