Lecture 29: Exercises in materials Balance in iron making

Contents

Exercises -1

In a furnace, iron ore is reduced according to the following reaction:

$$\mathrm{Fe_2O_3 + 6CO = 2Fe + 3CO_2 + \ 3CO}$$

Coke of composition 94% C is used to produce CO by combustion with air at the bottom of the furnace. Of the coke charged, 3.5% is absorbed by iron and 90.5% burns to CO only. No CO_2 is produced by combustion of coke.

<u>Calculate</u>

a) Volume of CO to produce 1000Kg iron.
b) Weight of coke required to produce 1000Kg iron.
c) Volume of air to burn the coke amount determined in b)
d) Volume and % composition of gases formed in combustion.
e) Volume and % composition of gases resulting in combustion and reduction

Solution

From the reaction

$$\mathrm{Fe_2O_3 + 6CO = 2Fe + 3CO_2 + 3CO}$$

Moles of CO $= \frac{6}{2} \times \frac{1000}{56} = 53.6$ kg moles

Volume of CO $= \mathbf{1200m^3}$ (a)

Coke required $= \frac{\mathbf{53.6 \times 12}}{\mathbf{0.905}} = \mathbf{710}$ **kg (b)**

Volume of air

$$\mathrm{C + 0.5\ O_2 = CO}$$

Volume of air $= \frac{710 \times 0.905}{24 \times 0.21} \times 22.4$

$= 2858.7m^3$ (c)

Gases formed (kg mole) % (d)

$CO = 53.6$ 34.7

$N_2 = 100.8$ 65.3

154.4 100% (d)

Gases formed during combustion and reduction comprise of CO, CO_2 and N_2. The amount in kemoles and percent are given below

Gas	Amount (Kgmoles)	Percent
CO	26.8	17.35
CO_2	26.8	17.35
N_2	100.8	65.30
Total	154.4	100

Exercise –II Do Yourself

Hematite ore of 80% Fe_2O_3 is reduced in blast furnace using coke of 85% C.

The reduction equation is:

$$Fe_2O_3 + mCO = 2Fe + 3CO2 + nCO$$

It is required to produce exit gas of composition $CO : CO_2 = 7 : 4$ .The pig iron analyzes 94% and 4% C and ignore rest.

Determine:

a) Reduction equation, balanced with whole numbers
b) Amount of coke/ton of pig iron
c) Amount of air required/ton of pig iron to burn C of coke to produce CO
d) % composition of gas resulting due to combustion and reduction

The readers should test themselves, how far have they understood. Purposely answers are not given.

Solution and answer can be found in video lecture number 31 on materials and heat balance in metallurgical processes.

Exercise -III

Blast furnace produces pig iron of composition $\mathrm{Fe}\ 94\%, \mathrm{Si}2\%, \mathrm{Mn}\ 0.5\%$ and $\mathrm{C}\ 3.5\%$ by reduction smelting of iron ore, coke and limestone. The analysis is as follows:

Iron ore : $\mathrm{Fe_2O_3}\ 78\%, \mathrm{SiO_2}\ 8\%, \mathrm{Al_2O_3}\ 5\%, \mathrm{MnO}\ 2\%\ \mathrm{H_2O}\ 7\%$

Coke : 86% C and 10% S and 4% $\mathrm{Al_2O_3}$; Amount is 600 Kg per ton of pig iron

Limestone : pure $\mathrm{CaCO_3}$ to produce a slag of 45% CaO

<u>Calculate</u>:

a) Amount of ore/ton of pig iron
b) % of total Si $\mathrm{O_2}$ and of MnO reduced in the furnace
c) Amount of slag/ton of pig iron and its % composition.

Fe balance gives amount of ore = 1721.6 kg. (a)

$$\mathrm{SiO_2} + 2\mathrm{C} = \mathrm{Si} + 2\mathrm{CO}$$

$$\mathrm{SiO_2}\text{ reduced in }\% = \frac{\mathrm{SiO_2}\text{equivalent to Si in pig iron}}{\text{Total } \mathrm{SiO_2}} \times 100$$

=31%

MnO reduced in % = 18.75%

Exercise IV

In blast furnace, pure hematite ($\mathrm{Fe_2O_3}$) is reduced by CO. To ensure complete reduction, an excess CO is used. CO is obtained by combustion of carbon with air.

The following chemical reaction occurs

$$\mathrm{Fe_2O_3} + x\mathrm{CO} = 2\mathrm{Fe} + 3\mathrm{CO_2} + (x-3)\mathrm{CO}$$

Ratio of CO: $\mathrm{CO_2}$ in the exit gas mixture is 1.7:1 by volume; the furnace produces 2000 tons of iron per day.

Calculate:

a) Value of x in the equation.
b) Volume of CO and $\mathrm{CO_2}$ produced daily.
c) Consumption of coke per day when C of coke is 88%.
d) Blast of air for combustion of carbon in coke per day.
e) Revised ratio of CO/ $\mathrm{CO_2}$ in the exit gas when pure $\mathrm{CaCO_3}$ charged is 25% of the$\mathrm{Fe_2O_3}$ reduced. Assume that $\mathrm{CaCO_3}$ decomposes to CaO and $\mathrm{CO_2}$.

Solution:

$x = 8.1$ kg moles (a)

$Fe_2O_3 + 8.1CO = 2Fe + 3CO_2 + 5.1CO$

$$\left.\begin{array}{ll} \text{volume of } CO_2 & = 1200 \times 10^3\ m^3 \\ \text{volume of } CO & = 2040\ \times 10^3\ m^3 \end{array}\right\} \text{(b)}$$

Coke required $= 1972$ tone. (c)

Air for combustion of $C = \frac{868 \times 22.4}{12 \times 2 \times 0.21} = 3856m^3$ | mole Fe (d

Moles of Fe_2O_3 reduced $= 17857$kg moles

Limestone charged $= 2500$kg moles.

$\frac{CO}{CO_2} = 1.6424$ (e)

Exercise V

The input and output of a blast furnace are:

Iron ore: Fe_2O_3 79%, SiO_2 12%, Al_2O_3 3%, MnO 1.6%, H_2O 4.4%

Coke: C88%, SiO_2 10%, Al_2O_3 1%, FeS1%

Limestone (500Kg): $CaCO_3$97.5%$MgCO_3$1.5% $SiO_2$1%

Pig Iron: Fe 93.7%, C 3.9%, Mn 1.2%, Si 1.2%

Top Gas ($2400m^3$/ton of iron ore): CO 25%, $CO_2$13.5%, H_2O 4%, $N_2$57.5%

Assume some iron is lost as FeO in slag. Per ton of pig iron there is 1.82 tons of ore is used

Determine:

a) Amount of coke/ton of pig iron.
b) Composition of slag/ton of pig iron.
c) Perform oxygen balance and comment.

Solution:

Carbon balance:

Carbon from coke + carbon from $CaCO_3$ and $MgCO_3$ = carbon in pig iron + carbon in gases

Substituting values give coke =1000.37 kg (a)

Composition of slag: It consists of SiO_2, Al_2O_3, MnO, CaS, CaO, MgO and FeO.

SiO_2 in slag can be calculated from Si balance Al_2O_3 in slag can be obtained from Al_2O_3 balance. Similarly, Mn, Ca, Mg and Fe balance can be done to obtain respective oxides.

Amount of slag = 742.78 kg (b)

	Percent
SiO_2	40
Al_2O_3	7.5
MnO	1.8
CaS	1.1
CaO	36.0
MgO	0.5
FeO	13.12

Amount of top gas $= 4368\ m^3/\text{ton pig iron}$

Amount of air (from N_2 balance) $= 3470\ m^3$ (c)

Oxygen balance:

Oxygen balance can be made air to compare answer in c.

O_2 in top gas = 50.71 kg moles.

O_2 in top gas is from air and oxygen released from various oxides.

O_2 from air = 50.71 -O_2 released from oxides

During BF iron making: Fe_2O_3, SiO_2 and MnO are reduced and relesase oxygen. Decomposition of $Ca\ CO_3$ and $Mg\ CO_3$ also releases oxygen.

Oxygen released = 18.057 kg moles.

O_2 from air = 32.653 kg moles

Blast volume = 3483 m3

This volume compases very well with that determined form N_2 balance.