

Lecture 29: Exercises in materials Balance in iron making

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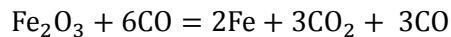
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Exercises -1

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



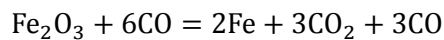
Coke of composition 94% C is used to produce CO by combustion with air at the bottom of the furnace. Of the coke charged, 3.5% is absorbed by iron and 90.5% burns to CO only. No CO₂ is produced by combustion of coke.

Calculate

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

Solution

From the reaction

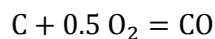


$$\text{Moles of CO} = \frac{6}{2} \times \frac{1000}{56} = 53.6 \text{ kg moles}$$

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

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

Volume of air



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

$$= 2858.7\text{m}^3 \quad (\text{c})$$

Gases formed (kg mole) % (d)

$$\text{CO} = 53.6 \quad 34.7$$

$$\text{N}_2 = 100.8 \quad 65.3$$

$$154.4 \quad 100\% \quad (\text{d})$$

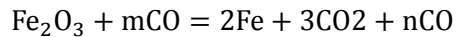
Gases formed during combustion and reduction comprise of CO, CO₂ and N₂. The amount in kemoles and percent are given below

Gas	Amount (Kgmole)	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% Fe₂O₃ is reduced in blast furnace using coke of 85% C.

The reduction equation is:



It is required to produce exit gas of composition CO: CO₂ = 7: 4 .The pig iron analyzes 94% and 4% C and ignore rest.

Determine:

- Reduction equation, balanced with whole numbers
- Amount of coke/ton of pig iron
- Amount of air required/ton of pig iron to burn C of coke to produce CO
- % 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 Fe 94%, Si 2%, Mn 0.5% and C 3.5% by reduction smelting of iron ore, coke and limestone. The analysis is as follows:

Iron ore : Fe₂O₃ 78%, SiO₂ 8%, Al₂O₃ 5%, MnO 2% H₂O 7%

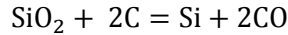
Coke : 86% C and 10% S and 4% Al₂O₃; Amount is 600 Kg per ton of pig iron

Limestone : pure CaCO₃ to produce a slag of 45% CaO

Calculate:

- Amount of ore/ton of pig iron
- % of total Si O₂ and of MnO reduced in the furnace
- Amount of slag/ton of pig iron and its % composition.

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



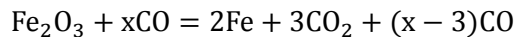
$$\begin{aligned} \text{SiO}_2 \text{ reduced in \%} &= \frac{\text{SiO}_2 \text{ equivalent to Si in pig iron}}{\text{Total SiO}_2} \times 100 \\ &= 31\% \end{aligned}$$

MnO reduced in % = 18.75%

Exercise IV

In blast furnace, pure hematite (Fe₂O₃) 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



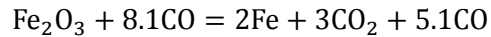
Ratio of CO: CO₂ in the exit gas mixture is 1.7:1 by volume; the furnace produces 2000 tons of iron per day.

Calculate:

- Value of x in the equation.
- Volume of CO and CO₂ produced daily.
- Consumption of coke per day when C of coke is 88%.
- Blast of air for combustion of carbon in coke per day.
- Revised ratio of CO/ CO₂ in the exit gas when pure CaCO₃ charged is 25% of the Fe₂O₃ reduced. Assume that CaCO₃ decomposes to CaO and CO₂.

Solution:

$$x = 8.1 \text{ kg moles (a)}$$



$$\left. \begin{array}{l} \text{volume of CO}_2 = 1200 \times 10^3 \text{ m}^3 \\ \text{volume of CO} = 2040 \times 10^3 \text{ m}^3 \end{array} \right\} \text{(b)}$$

$$\text{Coke required} = 1972 \text{ tone. (c)}$$

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

$$\text{Moles of Fe}_2\text{O}_3 \text{ reduced} = 17857 \text{ kg moles}$$

$$\text{Limestone charged} = 2500 \text{ kg moles.}$$

$$\frac{\text{CO}}{\text{CO}_2} = 1.6424 \quad \text{(e)}$$

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: C 88%, SiO_2 10%, Al_2O_3 1%, Fe 1%

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 (2400m³/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:

- Amount of coke/ton of pig iron.
- Composition of slag/ton of pig iron.
- 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 .

SiO₂ in slag can be calculated from Si balance Al₂O₃ in slag can be obtained from Al₂O₃ 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 ₂ O ₃	7.5
MnO	1.8
CaS	1.1
CaO	36.0
MgO	0.5
FeO	13.12

Amount of top gas = 4368 m³/ton pig iron

Amount of air (from N₂ balance) = 3470 m³ (c)

Oxygen balance:

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

O₂ in top gas = 50.71 kg moles.

O₂ in top gas is from air and oxygen released from various oxides.

O₂ from air = 50.71 - O₂ released from oxides

During BF iron making: Fe₂O₃, SiO₂ and MnO are reduced and release oxygen. Decomposition of Ca CO₃ and Mg CO₃ also releases oxygen.

Oxygen released = 18.057 kg moles.

O₂ from air = 32.653 kg moles

Blast volume = 3483 m³

This volume compares very well with that determined from N₂ balance.