

Lecture30: Heat balance in iron making

Contents

Exercise-I

Exercise-II

Exercise- I

Mention all the generated and heat output terms in the blast furnace ironmaking.

Solution:

Heat is generated by combustion of carbon. Sensible heat in blast also adds heat input. Small amount of heat may be generated by mixing of silicon in iron, reduction of FeO by CO and silicate formation.

Some heat output terms are: heat carried by slag, hot metal and gases. Heat losses by convection and radiation may be included.

Exercise-II

An iron blast furnace produces pig iron of composition C 3.5%, Si 1.5%, Mn 0.8% and rest is iron. The burden of blast furnace consists of the following materials:

Iron ore : Fe_2O_3 76%, SiO_2 14%, Al_2O_3 9%, MnO 1%

Coke: C 88% and SiO_2 12% .Amount 1100Kg per ton of pig iron.

Limestone: pure CaCO_3

The exit gas analyzes 26% CO, 13% CO_2 and 61% N_2 . Assume no loss of iron in slag.

Required:

- Weight of iron ore/ton of pig iron.
- Wt. of limestone/ton of pig iron, required to produce slag containing 36% CaO.
- Volume of gases
- Volume of blast based on O_2 and N_2 balance.
- Heat of decomposition of CaCO_3 at 298K
- Heat content of pig iron and slag at 1700K
- Sensible heat in gases: exit temp is 600K
- Heat of combustion
- Heat absorbed by Boudward reaction
- Heat produced by reduction reactions.

Thermo chemical data

a) Sensible heat in products $H_T - H_{298}$

Product	Temperature (K)	Sensible heat kcal/kg. mole
Fe	1700	13090
C	1700	6610
Mn	1700	17840
Si	1700	20756
SiO ₂	1700	22860
Al ₂ O ₃	1700	40090
MnO	1700	1749
CaO	1700	14333
CO	600	2137
CO ₂	600	2088
N ₂	600	2126.

b) Heat of formation of compounds in $\frac{\text{Kcal}}{\text{kg.mole}}$

$$\text{CO} = -26.4 \times 10^3$$

$$\text{CaO} = -151 \times 10^3$$

$$\text{CO}_2 = -94.45 \times 10^3$$

$$\text{CaCO}_3 = -289.5 \times 10^3$$

$$2\text{CaO} \cdot \text{SiO}_2 = -26.4 \times 10^3$$

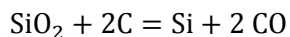
c) Heat of mixing in kcal/kg mole.

$$(\text{C})_s = (\text{C})_{\text{liquid, 1wt.\%}} = 5.4 \times 10^3$$

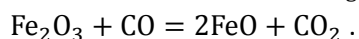
$$(\text{Si})_s = (\text{Si})_{\text{l, 1wt.\%}} = -28 \times 10^3$$

d) Heat of combustion of CO = $26.4 \times 10^3 \frac{\text{kcal}}{\text{kg.mole.}}$

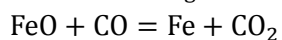
e) Heat evolved/absorbed in reduction reaction



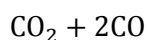
$$\text{Heat absorbed} = 148200 \frac{\text{kcal}}{\text{kg mole}}$$



$$\Delta H_R^\circ = 2000 \frac{\text{kcal}}{\text{kg mole.}}$$



$$\Delta H_R^\circ = -4400 \frac{\text{kcal}}{\text{kg mole.}}$$



$$\Delta H_R^\circ = +41.6 \times 10^3 \frac{\text{kcal}}{\text{kg mole.}} \text{ (endothermic)}$$

Solution:

The reader should attempt to make materials balance. Here materials balance results are given:

a) Amount of iron ore = 1770 kg.

b) Amount of CaCO_3 = 518 kg.

Amount of slag = 804 kg.

c) Volume of exit gas = 4762m^3 .

d) Volume of air from N_2 balance = 3677m^3 .

e) Heat of decomposition of CaCO_3 from the data = 228179 kcal (highly endothermic). The reader should note that decomposition of CaCO_3 absorbs large amount of heat.

f) Heat content of pig iron and slag at 1700K.

From the thermo chemical data, heat content in pig iron = 254134 kcal. This heat content of slag can be calculated from the thermo chemical data and materials balance.

Heat content in slag = 244978.8 kcal

g) Sensible heat in gases

From the data: sensible heat in gases = 479.18×10^3 kcal

h) Heat of combustion. At the tuyere all the carbon is burnt into CO

Heat generated = -2081.2×10^3 kcal Exothermic

i) Heat evolved or absorbed in reduction reactions.

SiO_2 reduction to Si absorbs heat.

Heat absorbed = 79.392 kcal.

Reduction of Fe_2O_3 to FeO

Heat absorbed = 16820 kcal

Reduction of FeO to Fe.

$\text{FeO} + \text{CO} = \text{Fe} + \text{CO}_2$

Heat produced = -74014 kcal

j) Heat absorbed by Boudward reaction

Boudward reaction

$\text{CO}_2 + \text{C} = 2\text{CO}$

is one of the most important reactions in metal extraction in general and blast furnace in iron making particular.

$$\text{Heat of reaction} = 41.6 \times 10^3 \frac{\text{kcal}}{\text{kg mole}}$$

Boudward reaction is highly endothermic.

CO_2 in exit gas = 27.64 kg moles.

Number of CO_2 moles reduced = CO_2 produced by reduction of Fe_2O_3 and FeO by
 $\text{CO} - \text{CO}_2$ in exit gas + CO_2 in CaCO_3

From the material balance one can obtain CO_2 produced by reduction of Fe_2O_3 and FeO by $\text{CO} = 25.23$ kg moles.

CO_2 in $\text{CaCO}_3 = 5.18$ kg moles.

Moles of CO_2 reduced by $\text{C} = 2.77$.

Heat absorbed = 115232 kcal.