Lecture 18: Material and heat balance in roasting of chalcopyrite ore

Problem 1 Material balance

Problem 2 Material balance

Problem 3Material and heat balance

Note: All thermochemical data for lecture 18 and 19 are given at the end of lecture 19.

Problem 1: **Material balance**

Roasting is a unit process in which sulphide is converted to oxide partially or fully. In production of copper from chalcopyrite, partial roasting is carried out.

In one roasting unit, an ore concentrate of the composition $21\%\ Cu_2S, 40\%\ Fe\ S_2, 31\%\ Si\ O_2$ and $8\%\ H_2O$ is roasted using air. The roasting unit is heated by oil of composition 85% C and 15% H, the amount of oil is 5.2% of the weight of the ore. Air for combustion and roasting is 110% in excess of the theoretical requirement.

The gases from combustion and roasting mix together and are carried through a flue. S passes as SO_2. The roasted product consists of CuO, Fe_2O_3 and SiO_2.

__Calculate:__

a) Weight of roasted product
b) Cubic meter of air (i) 1atm and 273 K and (ii) at 1 atm and 973K
c) Amount of H_2O / cubic meter of flue gas.

Solution: Basis 1000 kg ore concentrate

Roasting reactions are (considering roast product given in the problem)

$Cu_2S + 2O_2 = 2CuO + SO_2$ (1)

$2FeS_2 + 5.52O_2 = Fe_2O_3 + 4\ SO_2$ (2)

Weight of roasted product $= CuO + Fe_2O_3 + Si\ O_2,$

$$= 210 + 266.7 + 310$$

$= \mathbf{786.7\ kg}$ **Ans (a)**

110% excess air is used in the process for roasting and combustion.

Combustion reactions are (assuming complete combustion)

$C + O_2 = CO_2$, (3)

$H_2 + 0.5\ O_2 = H_2O$ (4)

From reactions 1, 2,3 and 4 one can calculate mols of oxygen theoretically (or stoichiometrically) required for roasting and combustion. According to problem all sulphure passes to SO_2

Total moles of O_2 required (theoretically) =17.42 moles.

Theoretic air: 1mole of oxygen is equivalent to 4.76 moles of air and 1kg mol of any gas occupies$22.4\ m^3\ (1atm., 273k)$.

Theoretical air $= \mathbf{1858\ m^3\ (1atm., 273k)}$.

Actual amount of air $= \mathbf{3907 m^3\ (1atm., 973k)}$ **Ans b**

The flue gas. Consists CO_2, N_2, O_2, H_2O and SO_2

Amount of flue gas $3969\ m^3$

Amount of water 150.84 kg.

Water/m^3 flue gas $= 0.038$ kg

Note the following:

- Roasting produces roast product which is approximately 78.6% of the ore concentrate
- Roasting always employs excess amount of air since the roasting reactions are carried out in the solid state at high temperature. Excess air is necessary.
- Material balance shows that flue gas contains $77.9\%\ N_2$, which amounts to $3091 m^3\ /1000$ kg concentrate. Flue gas exist at temperature at least equal to roasting temperature. This means large amount of heat is carried out by N_2 of flue gas.
- Use of excess air brings O_2 in flue gas and so O_2 also carries heat.
- Excess air optimization would make roasting energy efficient

Problem 2: Material balance

The flue gas in one particular roaster analyses (volume%)$CO_2\ 2\%, SO_2\ 7.4\%, H_2O\ 0.6\%, N_2 80\%$ and $O_2 10\%$. The ore concentrate analyzes 10% Cu, 34% Fe, $15\%\ SiO_2$ and 41% S. During roasting 80% S is removed. The fuel is coal containing 75%C.The ore and flue are separate, but the resulting gases mix

Calculate:

a) Amount of roasted product assuming it to contain Cu_2S, FeS, Fe_2O_3 and SiO_2.

b) The cubic meter of flue gases
c) Amount of fuel used.
d) %excess air used for combustion and roasting.
e) Theoretical ratio of air required for roasting to combustion

Solution :

This problem gives elemental analysis in terms ofCu, Fe and S of ore concentrate

All SiO_2 of ore concentrate will enter into roast product

Sulphur balance gives amount of S reacting with Cu and Fe

Similarly Fe balance givesFe to Fes and Fe to Fe_2O_3

Amount of roast product =775kg (a)Answer

To calculate cum of flue gas one has to do sulphur balance.

Let x kg moles is flue gas

S in feed = S in flue gases + S in roast product.

X = 3102.7m^3 (1atm, 273k)(b) Ans.

Amount of fuel can be determined by CO_2 and is 44.32 kg (c) Ans.

Excess air in $\% = \frac{\text{Actual amount of air} - \text{theoretical air}}{\text{Theoretical air}}$

N_2balance determines actual air = 140.28 kg moles.

Theoretical air (for combustion and roasting) = 79.27 kg mols.

Excess air =77% (d) Ans.

$\frac{\textbf{theoretical air for roasting}}{\textbf{theoretical air combustions}} = \mathbf{4.23}$ **(e)Ans.**

Problem 3: Material and heat balance

In a multiple hearth roaster, copper, concentrate of composition $Cu\ FeS_2$ 33% Cu_2S 7%, $Fe\ S_2$ 34%, SiO_2 19% and moisture 7% is roasted. All iron is oxidized to Fe_2O_3, and 50% of Cu oxidizes to CuO and rest to Cu_2S. The furnace gases analyze 12%$O_2$and leaving the furnace at 900 K. The roast product is also discharged at 900K. reactants enter at 298 K. No fuel is used. Assume heat loss to be 10% of the heat input. Calculate

a) Weight of roasted product per ton of concentrate
b) % S in the roast product and express it as % of original S,
c) Volume of air and excess air.
d) Composition of the gases, and
e) Heat balance of the process

Solution: Basis 1000 kg copper concentrate.

Weight of roasted product can be determined easily, it is **773.6 kg (a) Ans.**

Sulphurin roast product $(\%) = \mathbf{6.7}\%$**(b)Ans.**

Flue gas analysis is not known. Problem states that flue gas contains $12\%\ O_2$ which suggests that excess air is used.

From the problem S oxidized =9.04 kg mols

One can calculate theoretical amount of oxygen by considering that S is oxidized to SO_2, Cu is oxidized to CuO and Fe to Fe_2O_3. Amount of CuO and Fe_2O_3 have already been determined.

$$S + O_2 = SO_2$$

$$Cu + 0.5\ O_2 = CuO$$

$$2Fe + 1.5\ O_2 = Fe_2O_3$$

Theoretical oxygen = 49.632 kg mole

Let Z kg mole is flue gas; Amount of O_2 in flue gas $= 0.12\ Z$.

This excess oxygen coming from air will also contain 0.451ZexcessN_2.

Now the flue gas contains SO_2, H_2O,excess O_2 + theroctical N_2 +excess oxygen = Z

$$\mathbf{Z = 145.83\ kg\ mols = 3266.59\ m^3}$$

Excess air $= \mathbf{132.57}\ \%$ **(c) Ans.**

Composition of flue gas $SO_2 = 6.3\%, H_2O = 2.7\%, N_2 = 79\%$ and $O_2 = 12\%$.

Heat balance: heat input = Heat output

Basis of calculation: 298K.

Heat input is due to oxidation reaction like $Cu - CuO$, Fe to Fe_2O_3, Cu to Cu_2S and S to SO_2.

Heat input =1164446 kcal

Decomposition of $Cu\ Fe\ S_2$ absorbs 71675 kcal heat.

Heat output by flue gases =706623 kcal.

Sensible heat in roast product =92243 kcal.

Heat input	kcal	Heat output	kcal
Heat due to oxidation	1164446	Roasted product	706623
Cu Fe S_2 decomposition	-71675	Fluegases.	92243
Heat input	1092771	Heat losses	109277
		Total	908143.

Surplus heat =184628 kcal

Heat balance is an important exercise.