

Lecture 19: Roasting of zinc and lead concentrates

Content

Problem 1: Material balance in roasting of zinc concentrate

Problem 2: Material balance in roasting of lead concentrate

Problem 3: Material and heat balance

Analysis

Problem 4: Material balance in roasting of galena concentrate

Thermochemical data

Problem 1: Material balance in roasting of zinc concentrate

Zinc concentrates of a location are composed of 60% zinc, present as ZnS , iron present as FeS and 7% SiO_2 . On roasting Zn oxidizes to ZnO , iron to Fe_2O_3 and S to SO_2 , 3% of ZnS however, remains unchanged. Coal equal to 20% of raw one is used: the ashes from the coal do not mix with the ore, but the products of combustion pass through the furnace and into the flue mixed with the gases from the roasting. The coal is 72% C, 6% H, 8% O, 2% S and 12% ash.

The flue gases carry 12% oxygen.

Calculate:

- The weight of roasted ore, and the % as sulphur in the roasted ore.
- The theoretical vol. of air used in roasting and for combustion of coal.
- The % composition of the flue gases and the % excess air used above the theoretical requirement for roasting and combustion

Solution:

Proximate analysis of concentrate is

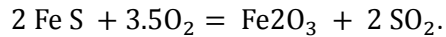
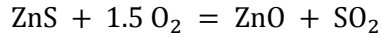
$$Zn S = 89.5\%$$

$$Fe S = 3.5\%$$

$$Si O_2 = 7.0\%$$

Basis: 1000 kg of zinc concentrate

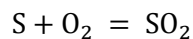
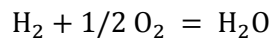
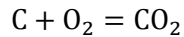
Roasting reactions ore



Weight of roasted ore = 853.8 kg and

%S in roasted ore = 1.04% (a) Answer.

Combustion of coal



Theoretical volume of air for combustion + roasting as determined by the roasting and combustion equations is 3067 m³ Ans. (b)

Flue gas consists of CO₂, H₂O, SO₂, N₂, and O₂

Amount of CO₂, H₂O and SO₂ can be determined from the roasting and combustion equations.

Let x in kg moles of flue gas

O₂ in flue gas = 0.12 x

Excess N₂ in flue gas = 0.45 x

N₂ in flue gas is theoretical N₂ + excess N₂ theoretical air is determined in b. From theoretical air, theoretical N₂ can be determined

$$12 + 6 + 9.475 + 108.11 + 0.12 Z + 0.45 Z = Z$$

Z = 315.3 kgmols Ans. (c)

Composition of flue gas

C O₂ 3.8 %

H₂O 1.9 %

S O₂ 3.0 %

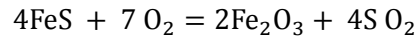
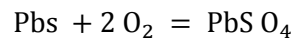
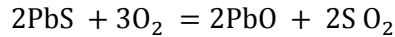
N₂ 79.3 %

O₂ 12.0 %

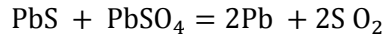
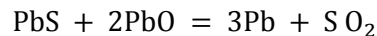
Excess air = 131.6% Ans. (c)

Problem 2: Material balance in roasting of lead concentrate

The lead concentrate of a particular plant analyzes PbS 83.1%, FeS 7.9%, SiO₂ 3% and remaining CaCO₃. The concentrate is treated by roast-reaction method to produce Pb. The reactions during roasting stage are:



At the end roasting stage all FeS is oxidized, but some PbS remains. The formation of PbS O₄ and PbO is in the ratio 1:3 by weight. During the reaction stage following reactions occur:



Both of the above reaction continues till all PbS, PbS O₄ has been consumed.

Find:

- Weight of the end of roasting stage and its proximate analysis/ 1000 kg concentrate.
- % S eliminated at the end of roasting stage.
- Gases formed during (i) roasting stage (ii) reaction stage in M³ at 1atm and 273K

Solution:

Proximate analysis of ore refers to mineral analysis.

Roasted ore contains Pbs, PbO, SiO₂, CaO, Fe₂O₃, PbsO₄. We can easily calculate amounts of SiO₂, CaO, and Fe₂O₃

Let x kg PbSO₄ ∴ 3x kg PbO forms in roasting stage

Let y kg PbS left at the end of roasting stage

Perform material balance of lead in roasting stage and reaction stage

$$x = 130 \text{ kg}(\text{PbSO}_4), \text{ and } y = 311\text{kg PbS left and } \text{PbO} = 3 \times 130 = 390 \text{ kg}$$

Weight of ore = 965.8 kg; Fe₂O₃ = 7.4%, CaO = 3.4%,

Si O₂, = 3.1%, PbSO₄ = 13.5%, PbO = 40.4% and PbS = 32.2%

% S eliminated = 60.5%

Gases formed = 72.8 m³ roasting stage and 38.8 m³ in reaction stage

Problem 3: Material and heat balance

A zinc concentrate of composition ZnS 76%PbS 7% Fe S₂ 7% and rest inert is roasted continuously with dry air. Assume ZnS converts to ZnO, PbS to PbO and Fe S₂ to Fe₃O₄ and all S to SO₂ and SO₃, the gases leaving the system analyses 7% SO₂and 2.5% SO₃ (volume basis)

Calculate:

- a) Rate of blowing of air (m³/min) when 100 ton concentrate is roasted in24 hrs
- b) Excess air
- c) Analysis of flue gases.
- d) Perform heat balance of the roasting/ton of concentrate. The reactants enter at 298K and the products leave at 1100K. Roasting is carried out at 1100K.You may assure heat loss is 10% of total heat input.(All the thermo chemical data are given at the end of lecture 19.)

Solution:

Basis 1000kg concentrate

Several problems on material balance are illustrated.

To perform heat balance, material balance is a pre-requisite

Material balance results are given

Rate of blowing of air/100 Ton concentrate = 2.68 $\frac{m^3}{s}$

Excess air = 45.2 %

Flue gas SO₂ = 7%, SO₃ = 2.5%,

N₂ = 83.6% and O₂ = 6.9%

Complete material balance in terms if input and output of material is required for heat balance reference temperature 298 K

Sources of heat input	Heat output
Heat of reaction	Roast product
Sensible heat of reactants	Flue gases

This problem is solved in video lecture 19 in materials and heat balance in metallurgical processes

To complete the solution of the problem: From heat of formation values, heat of reaction can be calculated. From the sensible heat of gases, heat taken by the gas can be calculated.

Heat input	kcal	Heat output	kcal
Heat of reaction	1436756	Roast product	85424
Sensible heat of reactants	0	Flue gases	624100
		Heat loss	143675

Total heat output = 853199 kcal

Analysis

1. In roasting large amount of heat is generated

In this problem there is 583557 kcal is surplus which is 40.6% of heat input. This heat will raise the temperature within the reactor, if surplus heat is unutilized.

2. Around 33% of heat input is carried by N_2 in flue gas. One may think to utilize this heat. Flue gas contains large amount of dust particles, ash particles. Hence utilization of heat in flue gas is a problem.

Problem 4: Material balance in roasting of galena concentrate

Lead concentrate is composed of PbS, FeS_2 , and SiO_2 . The moist concentrate contains 8% H_2O , 28% SiO_2 and 11% S. They are roasted down to 4% S, the roasted ore being composed of FeS , PbS , PbO and SiO_2 , the last two combined as silicate.

The furnace is fired with coal containing 72% C, 4% H, 8% O, 3% H_2O and 13% ash.

The furnace gas analyses (volume % dry) are SO_2 3%, CO_2 3.5%, O_2 10.5%. Neglect moisture in air, calculate per ton of moist concentrate (a) the weight of roasted ore and (b) the volume of furnace gases, including moisture, (c) weight of coal.

Solution:

Here analysis of lead concentrate is not known. Consider 1000 kg moist concentrate

Let x kg S forms PbS ; amount of $PbS = \frac{239}{32}x$ kg

(110-x)kg S forms FeS_2 and hence amount of $\text{FeS}_2 = \frac{(110-x)}{64} \times 120 \text{kg}$

From the balance we can get.

PbS = 580 kg, Fe S₂ = 60 kg, SiO₂ = 280 kg and moisture =80kg

Weight of roasted ore can be determined from S content of roasted ore and performing Pb balance

Pb in concentrate – Pb in roasted ore = Pb as Pb in roasted ore

Weight of roasted ore= 874 kg (a) Ans.

Sulphur balance gives volume of dry gas. Addition of amount of water will give wet gas.

Amount of wet gas = 1906 m³ Ans (b)

Weight of coal as found from CO₂ = 47kg Ans (c)

Thermochemical data:

Zn + 0.5 O ₂ = ZnO	$\Delta H_f^\circ = -83500$	Kcal/kg.mol
Pb + 0.5 O ₂ = PbO	$\Delta H_f^\circ = -52500$	Kcal/kg.mol
3Fe + 2 O ₂ = Fe ₃ O ₄	$\Delta H_f^\circ = -266000$	Kcal/kg.mol
S + O ₂ = SO ₂	$\Delta H_f^\circ = -70940$	Kcal/kg.mol
S + 1.5 O ₂ = SO ₃	$\Delta H_f^\circ = -93900$	Kcal/kg.mol
Cu + 0.5 O ₂ = CuO	$\Delta H_f^\circ = -38500$	Kcal/kg.mol
2Fe + 1.5 O ₂ = Fe ₂ O ₃	$\Delta H_f^\circ = -198500$	Kcal/kg.mol
2Cu + S = Cu ₂ S	$\Delta H_f^\circ = -18950$	Kcal/kg.mol

H ₁₁₀₀ - H ₂₉₈ ZnO	=9500	Kcal/kg.mol
H ₁₁₀₀ - H ₂₉₈ PbO	=10800	Kcal/kg.mol
H ₁₁₀₀ - H ₂₉₈ Fe ₃ O ₄	=40350	Kcal/kg.mol
H ₁₁₀₀ - H ₂₉₈ SO ₂	=9397	Kcal/kg.mol
H ₁₁₀₀ - H ₂₉₈ SO ₃	=13860	Kcal/kg.mol
H ₁₁₀₀ - H ₂₉₈ Zn	=7400	Kcal/kg.mol
H ₁₁₀₀ - H ₂₉₈ Pb	=6640	Kcal/kg.mol
H ₁₁₀₀ - H ₂₉₈ Fe	=7160	Kcal/kg.mol
H ₁₁₀₀ - H ₂₉₈ S	=6860	Kcal/kg.mol
H ₁₁₀₀ - H ₂₉₈ O ₂	=6208	Kcal/kg.mol
H ₁₁₀₀ - H ₂₉₈ N ₂	=5916	Kcal/kg.mol
H ₉₀₀ - H ₂₉₈ N ₂	=4358	Kcal/kg.mol
H ₉₀₀ - H ₂₉₈ O ₂	=4602	Kcal/kg.mol
H ₉₀₀ - H ₂₉₈ H ₂ O(1)	=15762	Kcal/kg.mol
H ₉₀₀ - H ₂₉₈ SO ₂	=6843	Kcal/kg.mol
H ₉₀₀ - H ₂₉₈ SiO ₂	=8950	Kcal/kg.mol
H ₉₀₀ - H ₂₉₈ CuO	=7320	Kcal/kg.mol
H ₉₀₀ - H ₂₉₈ Fe ₂ O ₃	=20020	Kcal/kg.mol
H ₉₀₀ - H ₂₉₈ Cu ₂ S	=11730	Kcal/kg.mol
H ₉₀₀ - H ₂₉₈ Cu	=7170	Kcal/kg.mol
H ₉₀₀ - H ₂₉₈ Fe	=4680	Kcal/kg.mol
H ₉₀₀ - H ₂₉₈ S	=5102	Kcal/kg.mole