Lecture 19: Roasting of zinc and lead concentrates

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Problem 1: Material balance in roasting of zinc concentrate

Zinc concentrates of a location are composed of 60% zinc, present asZnS, 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:

a) The weight of roasted ore, and the % as sulphur in the roasted ore.
b) The theoretical vol. of air used in roasting and for combustion of coal.
c) 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

$$ZnS + 1.5\,O_2 = ZnO + SO_2$$

$2\,Fe\,S + 3.5O_2 = Fe2O_3 + 2\,SO_2.$

Weight of roasted ore =853.8 kg and

%Sin roasted ore =1.04% (a) Answer.

Combustion of coal

$$C + O_2 = CO_2$$

$$H_2 + 1/2\,O_2 = H_2O$$

$$S + O_2 = SO_2$$

Theoretical volume if air for combustion + roasting as determined by the roasting and combustion equations is $\mathbf{3067\ m^3}$Ans. (b)

Flue gas consists of CO_2,H_2O,SO_2N_2, and O_2

Amount of CO_2, H_2O and SO_2 can be determined from the roasting and combustion equations.

Let x in kg moles of flue gas

O_2in flue gas $= 0.12\ x$

Excess N_2in flue gas $= 0.45\ x$

N_2In flue gas is theoretical N_2 + excess N_2 theoretical air is determined in b. From theoretical air, theoretical N_2can be determined

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

$\mathbf{Z = 315.3\ kgmols}$ **Ans. (c)**

Composition of flue gas

$\mathbf{C\,O_2}$	$\mathbf{3.8}\,\%$
$\mathbf{H_2O}$	$\mathbf{1.9}\,\%$
$\mathbf{S\,O_2}$	$\mathbf{3.0}\,\%$
$\mathbf{N_2}$	$\mathbf{79.3}\,\%$
$\mathbf{O_2}$	$\mathbf{12.0}\,\%$

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%, SiO_2 3% and remaining $CaCO_3$. The concentrate is treated by roast-reaction method to produce Pb. The reactions during roasting stage are:

$$2PbS + 3O_2 = 2PbO + 2S\,O_2$$

$$Pbs + 2\,O_2 = PbS\,O_4$$

$$4FeS + 7\,O_2 = 2Fe_2O_3 + 4S\,O_2$$

At the end roasting stage all FeS is oxidized, but some PbS remains. The formation of $PbS\,O_4$and PbO is in the ratio 1:3 by weight. During the reaction stage following reactions occur:

$$PbS + 2PbO = 3Pb + S\,O_2$$

$$PbS + PbSO_4 = 2Pb + 2S\,O_2$$

Both of the above reaction continues till all PbS, $PbS\,O_4$has been consumed.

Find:

a) Weight of the end of roasting stage and its proximate analysis/ 1000 kg concentrate.
b) % S eliminated at the end of roasting stage.
c) Gases formed during (i) roasting stage (ii) reaction stage in M^3 at 1atm and 273K

Solution:

Proximate analysis of ore refers to mineral analysis.

Roasted ore contains Pbs, PbO, SiO_2, CaO, Fe_2O_3, $PbsO_4$.We can easily calculate amounts of SiO_2, CaO, and Fe_2O_3

Let x kg $PbSO_4$ ∴ 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

$$x = 130\ \text{kg}(PbSO_4), \text{and } y = 311\text{kg PbS left and } PbO = 3 \text{ x } 130 = 390 \text{ kg}$$

Weight of ore $= \mathbf{965.8\ kg}$; $\mathbf{Fe_2O_3 = 7.4}\%, \mathbf{CaO = 3.4}\%,$

$Si\,O_2, = 3.1\%, PbSO_4 = 13.5\%, PbO = 40.4\%$and $PbS = 32.2\%$

% S eliminated $= \mathbf{60.5}\%$

Gases formed $= \mathbf{72.8\ m^3}$ roasting stage and $\mathbf{38.8\ m^3}$ in reaction stage

Problem 3: Material and heat balance

A zinc concentrate of composition ZnS 76%PbS 7% $Fe\ S_2$ 7% and rest inert is roasted continuously with dry air. Assume ZnS converts to ZnO, PbS to PbO and $Fe\ S_2$ to Fe_3O_4 and all S to SO_2 and SO_3, the gases leaving the system analyses 7% SO_2 and 2.5% SO_3 (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 $= \mathbf{2.68\,\frac{m3}{s}}$

Excess air $= \mathbf{45.2}\ \%$

Flue gas $\mathbf{SO_2} = \mathbf{7\%}, \mathbf{SO_3} = \mathbf{2.5\%},$

$$\mathbf{N_2 = 83.6\%\ and\ O_2 = 6.9\%}$$

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	Heatoutput	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 heal 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 fluegas is a problem.

Problem 4: Material balance in roasting of galena concentrate

Lead concentrate is composed of $\mathrm{Pbs, Fe\ S_2, and\ Si\ O_2}$. The moist concentrate contains $8\%\ \mathrm{H_2O}, 28\%\ \mathrm{Si\ O_2}\ \mathrm{and} 11\%\mathrm{S}$. They are roasted down to $4\%\mathrm{S}$, the roasted ore being composed of $\mathrm{FeS, PbS, PbO\ and\ SiO_2}$, the last two combined asa silicate.

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

The furnace gas analyses (volume %dry) are $\mathrm{SO_2} 3\%, \mathrm{CO_2}\ 3{,}5\%, \mathrm{O_2} 10{,}5\%$ 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 1000kg moist concentrate

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

(110-x)kg S forms FeS_2 and hence amount of $FeS_2 = \frac{(110-x)}{64}x120kg$

From the balance we can get.

$PbS = 580$ kg, $Fe\ S_2 = 60$ kg, $SiO_2 = 280$ 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 $= 1906\ m^3$ Ans (b)

Weight of coal as found from $CO_2 = 47$kg Ans (c)

Thermochemical data:

$Zn + 0.5\ O_2$ =- ZnO	$\Delta H_f^o = -83500$	Kcal/kg.mol
$Pb + 0.5\ O_2$= PbO	$\Delta H_f^o = -52500$	Kcal/kg.mol
$3Fe + 2\ O_2 = Fe_3\ O_4$	$\Delta H_f^o = -266000$	Kcal/kg.mol
$S + O_2 = SO_2$	$\Delta H_f^o = -70940$	Kcal/kg.mol
$S + 1.5\ O_2 = SO_3$	$\Delta H_f^o = -93900$	Kcal/kg.mol
$Cu + 0.5 = O_2 = CuO$	$\Delta H_f^o = -38500$	Kcal/kg.mol
$2Fe + 1.5\ O_2 = Fe_2\ O_3$	$\Delta H_f^o = -198500$	Kcal/kg.mol
$2Cu + S = Cu_2\ S$	$\Delta H_f^o = -18950$	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_3O_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
$H_{900} - H_{298}$| $H_2O(1)$	=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_2O_3	=20020	Kcal/kg.mol
$H_{900} - H_{298}$| Cu_2S	=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