Lecture 5

Exercises on stoichiometry

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Exercise- i

A pyritic ore is reduced with hydrogen according to the following reaction:

$\mathrm{FeS_2 + 2H_2 \ = \ Fe + 2\ H_2\ S}$

The ore contains 15% inert solid (gangue). Twenty five percent excess hydrogen is used, and the cinder (solid residue) remaining contains 5% $\mathrm{FeS_2}$ by weight.

Calculate the volume of furnace gases (at 400°C and 1 atm) per 100 kg of ore charged.

$100\ \mathrm{kg\ ore}\ 85\ \mathrm{kg\ FeS_2} + \ 15\ \mathrm{kg\ gangue}$

$\mathrm{FeS_2\ reacted} \ = 85 - 4.25 = 80.76\mathrm{kg} = 0.67\ \mathrm{kg\ moles}$

$0.67\ \mathrm{FeS_2} + 2 \times 1.25 \times 0.67\mathrm{H_2} = 0.67\ \mathrm{Fe}\ + 2 \times 0.67\ \mathrm{H_2S} + 0.335\mathrm{H_2}$

Volume of furnace gases $= 2 \times 0.67 + 0.335$

$= 1.675\ \mathrm{kg\ moles}$

$\mathrm{Volume\ (400°C\ and\ 1\ atm.)} = \ 1.675\ \times 22.4 \times \frac{673}{273} = 92.49\mathrm{m^3}$

$\mathrm{Volume\ (400°C\ and\ 1\ atm.)} = \ 32.65 \times 10^4\mathrm{Cu\ ft.}$

Exercise ii Do yourself

A limestone is analysed as (weight%) $\mathrm{CaCO_3} \ = 93.1, \mathrm{MgCO_3} = 5.38$ and insoluble matter 1.5wt%

(a) How many kg of CaO could be obtained from 5000 kg of limestone?
(b) How many kg of carbon dioxide will be produced?

Ans (a) 2607.4 (b) 2048.6 kg

Exercise iii

Antimony can be produced according to the following reaction:

$Sb_2S_3 + 3Fe(s) = 2Sb(l) + 3\ FeS$

Calculate the following for a process in which 800 g of Sb_2S_3 is mixed with 300g of Fe to form 250g of Sb

a) The limiting reactant, b) percent excess reactant, c) the degree of conversion of Fe to FeS, d) percent conversion, e) the yield of Sb

Solution:

Limiting reactant is the one which controls the completion of reaction.

The stoichiometry of reaction suggests

800g of Sb_2S_3 would require $\frac{168}{340} \times 800 = 395g$ Fe for the completion of reaction. But only 300g of Fe is mixed hence

a) Iron is limiting reactant
b) $\frac{300}{56}$ moles of Fe can reduce 1.79 moles of Sb_2S_3

The available moles of $Sb_2S_3 = 2.35$ moles.

Excess reactant $(\%) = \frac{2.35-1.79}{2.35} \times 100 = 23.8\%$

c) Degree of conversion of Fe to FeS $= \frac{\text{moles of Fe converted to FeS}}{\text{moles of Fe supplied}}$

$$= \frac{3.074 \times 56}{300} = 0.573$$

Or 57.3% Answer ©

d) Yield of Sb $= \frac{\text{antimony produced}}{\text{antimony supplied}} \times 100$

$= \frac{250}{574} \times 100 = 43.54\%$

Exercise IV

An annealing furnace uses a fuel oil containing16%C. Fuel is burnt with 25% excess air. Calculate the flue gas analysis, assuming complete combustion. Repeat the calculation assuming that 5% of the total carbon is burnt to CO only.

Assume 100kg oil, $C = 84kg$ and $H = 16kg$

Combustion equations:

$$7C + 8.75(O_2 + 3.76N_2) = 7CO_2 + 32.9N_2 + 1.75O_2$$

$$8H_2 + 5(O_2 + 3.76N_2) = 8H_2O + 18.8N_2 + 2O_2$$

Flue gas analysis

	Kg moles	%
CO_2	7	9.9
H_2O	8	11.4
N_2	51.7	73.4
O_2	37.5	5.3
Total	70.45	100%

Flue gas when 5% of total carbon is burnt to CO.

	Kg moles	%
CO_2	6.65	9.4
CO	0.35	0.5
N_2	51.70	73.2
O_2	3.93	5.6
H_2O	8.00	11.3
Total	70.63	100.0

Exercise v

The copper ore contains 7% Cu and 36%S. The copper mineral is chalcopyrite Cu FeS_2 and S is also present as iron pyrite (FeS_2). The rest of the ore is gangue containing no Cu, S, or Fe.

The ore is roasted until all the sulphur is removed; the following reactions are taking place:

$$4FeS2 + 11O2 = 2Fe_2O_3 + 8\ SO_2$$

$$4CuFeS_2 + 13O_2 = 4CuO + 2Fe_2O_3 + 8\ SO_2$$

Required: for 100kg of ore a) weight of each mineral and the gangue

b) Oxygen required in cubic meter c) cubic meter of air d) weight of Fe_2O_3 and vol of SO_2

$1000\text{kg ore Cu} = 70\text{kg. whic is equal to Cu FeS}_2 = \frac{184}{64} \times 70 = 201.25\text{kg}$

S in Cu $FeS_2 = \frac{64}{184} \times 201.25 = 70\text{kg}$

S in ore $= 360\text{kg.}$

S combined with Fe $= 360 - 70 = 290\text{kg.}$

Amount of $FeS_2 = \frac{120}{64} \times 290 = 543.75\text{kg} = 4.53\text{kg moles}$

Wt of gangue $= 1000 - (201.25 + 543.75) = 255\text{kg}$

a) Amount of mineral : 201.25kg Cu FeS_2 and 543.75kg FeS_2
b) Amount of gangue : 255.00kg
c) Moles O_2 ftheoretical $= \left[\frac{11}{4} \times 4.53 + \frac{13}{4} \times \frac{201.25}{184}\right] = 16.012; \text{volume} = 358.66\text{m}^3\ (\text{atm } 273\text{K})$

Actual volume of $O_2 = 896.65\text{m}^3(1\text{atm}, 0°\text{C})$

d) Volume of air $= 4270\text{m}^3$
e) Wt of Fe_2O_3 450.4kg, and vol. Of $SO_2 = 252\text{m}^3$ ans

Exercise vi

Aluminium is produced by electrolytic decomposition of Al_2O_3. The oxygen released combines of carbon at anode. Assume that 85% of the oxygen from CO, and 15% CO_2. The daily output is 300 kg of aluminimum

Calculate:

i. The chemical reaction, balanced with minimum whole numbers.
ii. Kg of Al_2O_3 consumed
iii. Cubic meter of CO and CO_2 liberated

Solution:

Moles of Al produced $= \frac{100}{9}$ from $\frac{50}{9}$ moles of $\mathrm{Al_2O_3}$. The reaction is

$$\frac{50}{9}\mathrm{Al_2O_3} + \mathrm{xC} = \frac{100}{9}\mathrm{Al} + \frac{150}{9} \times 0.85\mathrm{CO} + \frac{75}{9} \times 0.15\mathrm{CO_2}$$

The vlalue of $\mathrm{x} = \frac{138.75}{9.}$

Balanced chemical equation with minimum whole number is

i. $40\mathrm{Al_2O_3} + 111\mathrm{C} = 80\mathrm{Al} + 102\mathrm{CO} + 9\mathrm{CO_2}$
ii. 566.7kg.
iii. Volume of CO $= 317.3\mathrm{m^3}$ and volume of $\mathrm{CO_2}$ $= 28\mathrm{m^3}$ (expressed at 1 atm. Pressure and 273K).

Exercise Vii Do yourself

A zinc retort is charged with 100Kg. of roasted zinc concentrates carrying 50% zinc, present as ZnO. Reduction takes place according to the reaction

$\mathrm{ZnO + C = Zn + CO.}$

One- fifth of the ZnO remains unreduced. The zinc vapor and CO pass into a condenser, from which the CO escapes and burns to $\mathrm{CO_2}$ as it emerges from the mouth of the condenser. The CO enters the condenser at $300°\mathrm{C}$ and 750 mm Hg pressure.

Required:

1. The volume of CO in m3 entering the condenser (a) measured at 273K and 760 mm Hg. (b) measure at actual conditions
2. The weight of CO, in kilograms
3. The volume of $\mathrm{CO_2}$ formed, at (750°C, and 770mm Hg. pressure) due to burning of CO
4. The volume (Standard conditions) and weight of air used in burning the CO.

Answer:

i. Moles of CO $= 13.89\mathrm{m^3}$ at 273K and 1 atm $\mathrm{pressure} = 29.54\mathrm{m^3}$ at 573 and 750 mm Hg
ii. Weight of CO $= 17.36\mathrm{kg}$
iii. Volume of $\mathrm{CO_2}$ on combustion
$\mathrm{CO} + \frac{1}{2} = \mathrm{CO_2}$

Volume of CO2 $= 51.37\ \mathrm{m^3}$ (770mmHg and 1023K)

iv. Volume of $\mathrm{air} = 33.06\mathrm{m^3}$ (1 atm. Pressure and 273K)
Weight of $\mathrm{air} = 42.80\mathrm{kg.}$