

## Lecture 5

### Exercises on stoichiometry

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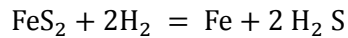
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#### Exercise- i

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

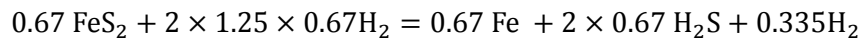


The ore contains 15% inert solid (gangue). Twenty five percent excess hydrogen is used, and the cinder (solid residue) remaining contains 5%  $\text{FeS}_2$  by weight.

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

100 kg ore 85 kg  $\text{FeS}_2$  + 15 kg gangue

$\text{FeS}_2$  reacted = 85 – 4.25 = 80.76kg = 0.67 kg moles



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

= 1.675 kg moles

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

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

#### Exercise ii Do yourself

A limestone is analysed as (weight% )  $\text{CaCO}_3 = 93.1$ ,  $\text{MgCO}_3 = 5.38$  and insoluble matter 1.5wt%

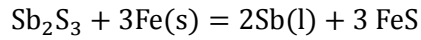
(a) How many kg of CaO could be obtained from 5000 kg of limestone?

(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:



Calculate the following for a process in which 800 g of  $\text{Sb}_2\text{S}_3$  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  $\text{Sb}_2\text{S}_3$  would require  $\frac{168}{340} \times 800 = 395\text{g}$  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  $\text{Sb}_2\text{S}_3$

The available moles of  $\text{Sb}_2\text{S}_3 = 2.35$  moles.

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

- 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 ©

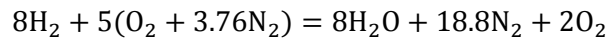
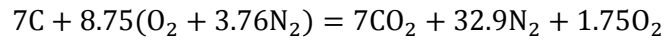
- d) Yield of Sb =  $\frac{\text{antimony produced}}{\text{antimony supplied}} \times 100$   
$$= \frac{250}{574} \times 100 = 43.54\%$$

### Exercise IV

An annealing furnace uses a fuel oil containing 16% 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:



Flue gas analysis

	Kg moles	%
CO <sub>2</sub>	7	9.9
H <sub>2</sub> O	8	11.4
N <sub>2</sub>	51.7	73.4
O <sub>2</sub>	37.5	5.3
Total	70.45	100%

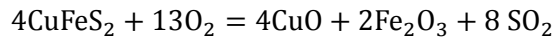
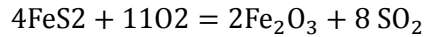
Flue gas when 5% of total carbon is burnt to CO.

	Kg moles	%
CO <sub>2</sub>	6.65	9.4
CO	0.35	0.5
N <sub>2</sub>	51.70	73.2
O <sub>2</sub>	3.93	5.6
H <sub>2</sub> O	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  $\text{Cu FeS}_2$  and S is also present as iron pyrite ( $\text{FeS}_2$ ). 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:



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  $\text{Fe}_2\text{O}_3$  and vol of  $\text{SO}_2$

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

$$\text{S in Cu FeS}_2 = \frac{64}{184} \times 201.25 = 70\text{kg}$$

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

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

$$\text{Amount of FeS}_2 = \frac{120}{64} \times 290 = 543.75\text{kg} = 4.53\text{kg moles}$$

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

a) Amount of mineral : 201.25kg  $\text{Cu FeS}_2$  and 543.75kg  $\text{FeS}_2$

b) Amount of gangue : 255.00kg

c) Moles  $\text{O}_2$  theoretical =  $\left[ \frac{11}{4} \times 4.53 + \frac{13}{4} \times \frac{201.25}{184} \right] = 16.012$ ; volume =  $358.66\text{m}^3$  (atm 273K)

$$\text{Actual volume of O}_2 = 896.65\text{m}^3 (1\text{atm, } 0^\circ\text{C})$$

d) Volume of air =  $4270\text{m}^3$

e) Wt of  $\text{Fe}_2\text{O}_3$  450.4kg, and vol. Of  $\text{SO}_2$  =  $252\text{m}^3$  ans

### Exercise vi

Aluminium is produced by electrolytic decomposition of  $\text{Al}_2\text{O}_3$ . The oxygen released combines of carbon at anode. Assume that 85% of the oxygen from CO, and 15%  $\text{CO}_2$ . The daily output is 300 kg of aluminium

Calculate:

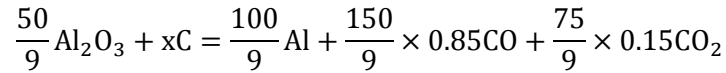
i. The chemical reaction, balanced with minimum whole numbers.

ii. Kg of  $\text{Al}_2\text{O}_3$  consumed

iii. Cubic meter of CO and  $\text{CO}_2$  liberated

**Solution:**

Moles of Al produced =  $\frac{100}{9}$  from  $\frac{50}{9}$  moles of  $\text{Al}_2\text{O}_3$ . The reaction is



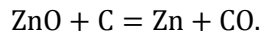
The value of  $x = \frac{138.75}{9}$ .

Balanced chemical equation with minimum whole number is

- i.  $40\text{Al}_2\text{O}_3 + 111\text{C} = 80\text{Al} + 102\text{CO} + 9\text{CO}_2$
- ii. 566.7kg.
- iii. Volume of CO =  $317.3\text{m}^3$  and volume of  $\text{CO}_2 = 28\text{m}^3$  (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



One-fifth of the ZnO remains unreduced. The zinc vapor and CO pass into a condenser, from which the CO escapes and burns to  $\text{CO}_2$  as it emerges from the mouth of the condenser. The CO enters the condenser at  $300^\circ\text{C}$  and 750 mm Hg pressure.

Required:

1. The volume of CO in  $\text{m}^3$  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  $\text{CO}_2$  formed, at ( $750^\circ\text{C}$ , 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 =  $13.89\text{m}^3$  at 273K and 1 atm pressure =  $29.54\text{m}^3$  at 573 and 750 mm Hg
- ii. Weight of CO = 17.36kg
- iii. Volume of  $\text{CO}_2$  on combustion  

$$\text{CO} + \frac{1}{2}\text{O}_2 = \text{CO}_2$$

Volume of  $\text{CO}_2 = 51.37 \text{ m}^3$  (770mmHg and 1023K)

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