

STOICHIOMETRY.

(1)

3) Calculation Based on Mass-Volume Relationship.

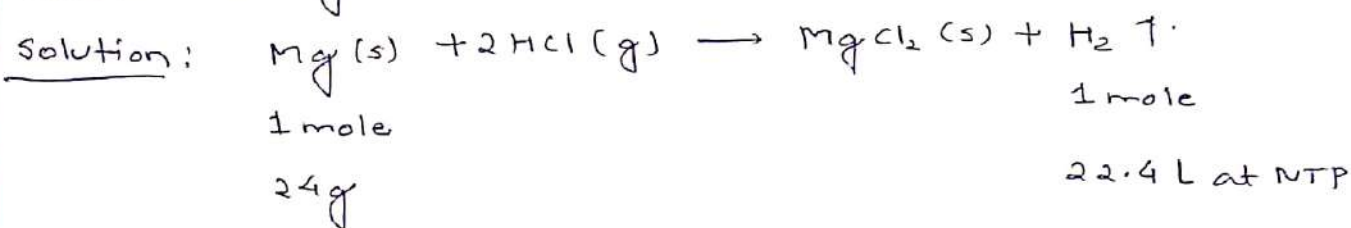
In such calculations, masses of reactant are given & volume of the product is required & vice versa.

1 mole of gas occupies 22.4 litre volume at STP, mass of gas can be related to volume according to the following gas

Equation: $PV = nRT$

$$PV = \frac{W}{M} RT.$$

Example: Calculate the volume of hydrogen liberated at 27°C and 760 mm pressure by treating 1.2g of magnesium with excess of Hydrochloric Acid.



\therefore 24g of Mg liberate hydrogen = 22.4 Litre

1.2g of Mg will liberate hydrogen = $\frac{22.4}{24} \times 1.2 = 1.12$ Litre.

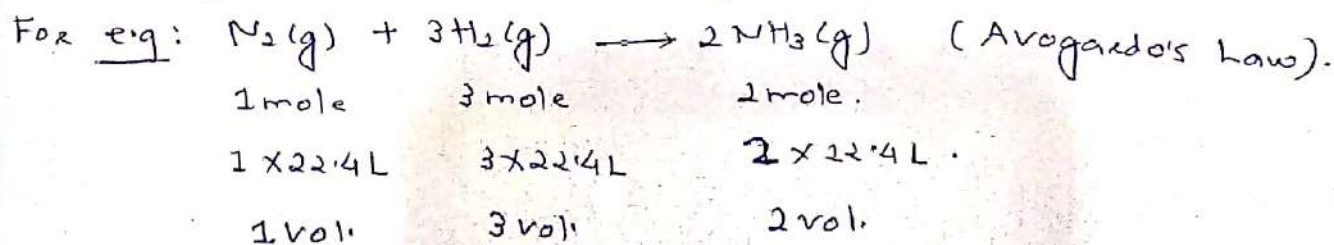
Volume of hydrogen under given condition can be calculated by

applying: $\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$ | $V_2 = \frac{760 \times 1.12}{273} \times \frac{300}{760} = 1.23$ Litre.

4) Calculation Based on Volume-Volume Relationship.

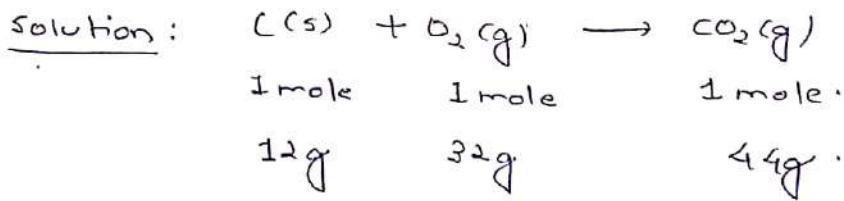
These calculation are based on two laws:

(i) Avogadro's Law (ii) Gay-Lussac's Law.



(2)

Example: What volume of air containing 21% oxygen by volume is required to completely burn 1kg of carbon containing 100% combustible substances?



\therefore 12g of carbon requires 1 mole of O_2 for complete combustion.

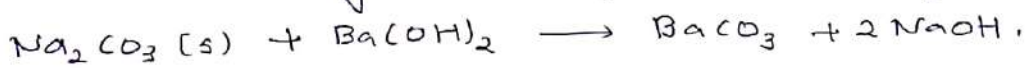
\therefore 1000g of carbon will require $\frac{1}{12} \times 1000$ mole $\text{O}_2 = 83.33$ mole

\therefore Volume of O_2 at NTP = 83.34×22.4 Litre = 1866.592 litre

\therefore 21 litre of O_2 is present in 100 litre air,

\therefore 1866.592 litre of O_2 will be present in $\left(\frac{100}{21} \times 1866.592 \text{ litre}\right)$
 $= 8888.5$ litre.

Example: A mixture of NaHCO_3 & Na_2CO_3 weighed 1.0235g. The dissolved mixture was reacted with excess of Ba(OH)_2 to form 2.1028 g BaCO_3 , by the following reactions:



What was the percentage of NaHCO_3 in the original mixture?

Solution: let x g of NaHCO_3 be present in the mixture

• mass of Na_2CO_3 in the mixture = $(1.0235 - x)$ g.

Number of moles of $\text{NaHCO}_3 = \left(\frac{x}{84}\right)$

Number of moles of $\text{Na}_2\text{CO}_3 = \left(\frac{1.0235 - x}{106}\right)$

Number of moles of $\text{BaCO}_3 = \left(\text{No. of moles of } \text{Na}_2\text{CO}_3\right) + \left(\text{No. of moles of } \text{NaHCO}_3\right)$

$$\left(\frac{2.1028}{197}\right) = \left(\frac{x}{84}\right) + \left(\frac{1.0235 - x}{106}\right)$$

$x = 0.4122g$

Amount of $NaHCO_3 = 0.4122g$

Percentage of $NaHCO_3 = \frac{0.4122g}{1.0235} \times 100 = 40.27\%$

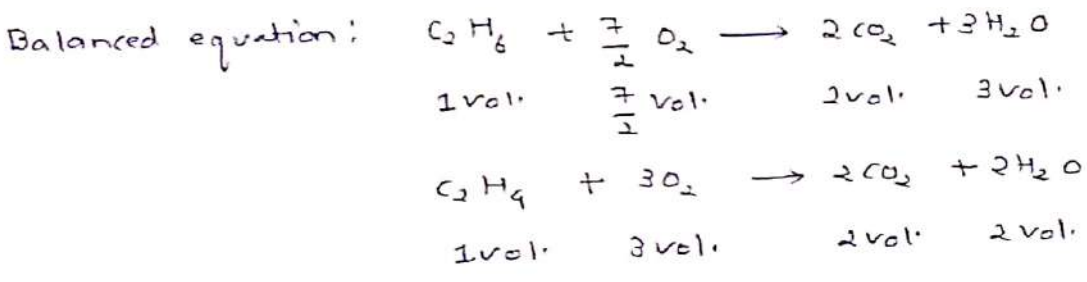
Example: A mixture of ethane & ethene occupies 40 litres at 1atm and at 400K. The mixture react completely with 130g of O_2 to produce CO_2 & H_2O . Assuming ideal gas behaviour, calculate the mole fraction of C_2H_6 & C_2H_4 in the mixture?

Solution: Volume of mixture at NTP: $\frac{V_1}{T_1} = \frac{V_2}{T_2}$

$V_2 = \frac{40 \times 273}{400} = 27.3 \text{ litres}$

let the volume of ethane = x litre.

volume of ethene = (27.3-x) litre.



Total volume of oxygen required for complete combustion of the mixture is; $\left[\frac{7}{2}x + (27.3-x) \times 3 \right]$ litre

Mass of oxygen = $\left[\frac{7x + (27.3-x) \times 6}{2} \right] \times \frac{32}{22.4}$

$130 = (x + 163.8) \times \frac{16}{22.4}$

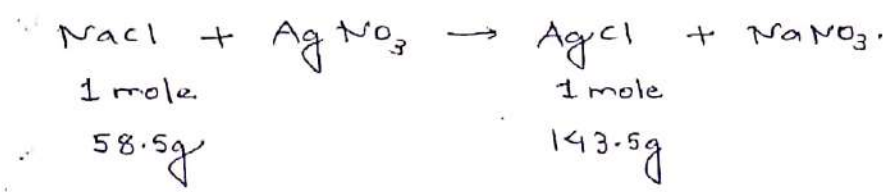
$x = 18.2$

Hence, Mole fraction of ethane = $\frac{18.2}{27.3} \times 100 = 66.66$

Mole fraction of ethene = 33.34.

Example: 3.6g of sodium chloride & potassium chloride is dissolved in water. The solution is treated with excess of silver nitrate solution. 7.74g of silver chloride is obtained. Find out the percentage of NaCl & KCl in the mixture.

Solution: The balanced equation b/w NaCl & AgNO₃ is.

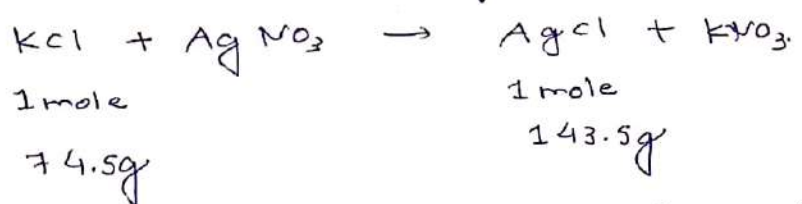


Let xg of NaCl be present in the mixture,

58.5g NaCl produce = 143.5g AgCl.

xg of NaCl will produce = $\frac{143.5}{58.5} \times x$ g AgCl.

The balanced chemical equation between KCl & AgNO₃ is:



KCl present in the mixture = (3.6 - x) g.

74.5g of KCl produce = 143.5g of AgCl.

(3.6 - x) g of KCl will produce = $\frac{143.5}{74.5} \times (3.6 - x)$ g of AgCl.

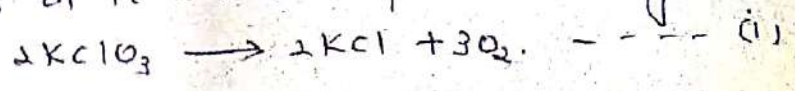
Thus, $\frac{143.5}{58.5} x + \frac{143.5}{74.5} (3.6 - x) = 7.74$

x = 1.54

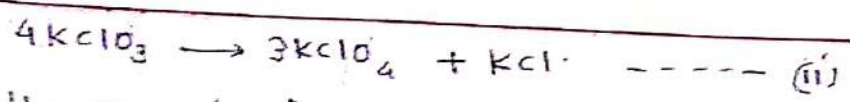
% of NaCl = $\frac{1.54}{3.6} \times 100 = 42.7\%$

% of KCl = $\left(\frac{3.6 - 1.54}{3.6} \right) \times 100 = 57.3\%$

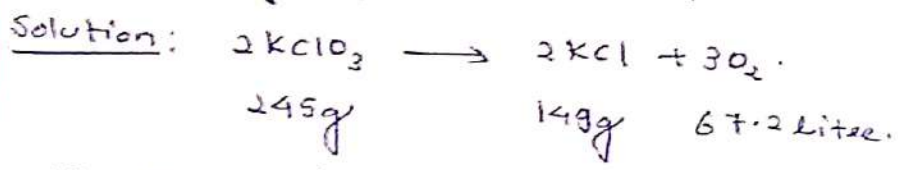
Example: A 1g sample of KClO₃ was heated under such condition that a part of it was decomposed according to the equation:



and the remaining underwent change according to the equation,



If the amount of oxygen evolved was 146.8 mL at STP, calculate the percentage by mass of $KClO_4$ in the residue.



67.2 Litre of oxygen evolved from 245g of $KClO_3$.

$$0.1468 \text{ Litre of oxygen will be evolved} = \left(\frac{245}{67.2} \times 0.1468 \right) = 0.535 \text{ g of } KClO_3$$

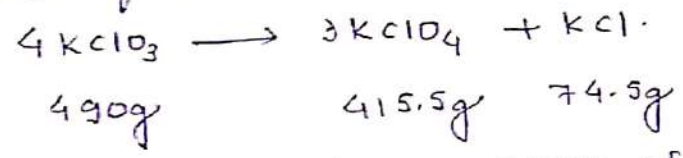
Hence, $KClO_3$ left for the equation (ii) reaction,

$$(1 - 0.535) \text{ g} = 0.464 \text{ g}$$

245g of $KClO_3$ will yield $KCl = 149 \text{ g}$.

$$0.535 \text{ g of } KClO_3 \text{ will yield } KCl = \left(\frac{149}{245} \times 0.535 \text{ g} \right) = 0.325 \text{ g}$$

consider eq (i)



490g of $KClO_3$ yield = 415.5g of $KClO_4$.

$$0.4648 \text{ g of } KClO_3 \text{ will yield} = \left(\frac{415.5 \text{ g}}{490 \text{ g}} \times 0.4648 \right) = 0.3941 \text{ g of } KClO_4$$

490g of $KClO_3$ yield = 74.5g of KCl

$$0.4648 \text{ g of } KClO_3 \text{ will yield} = \left(\frac{74.5}{490} \times 0.4648 \right) = 0.0707 \text{ g of } KCl$$

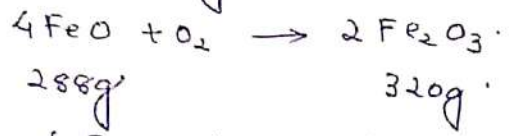
$$\text{Total mass of the residue} = (0.3254 + 0.3941 + 0.0707) = 0.7902 \text{ g}$$

$$\% KClO_4 = \left(\frac{0.3941}{0.7902} \times 100 \right) = 49.8$$

Example: A mixture of FeO & Fe_3O_4 when heated in air to a constant weight gains 5% in its mass. Find the composition of the initial mixture.

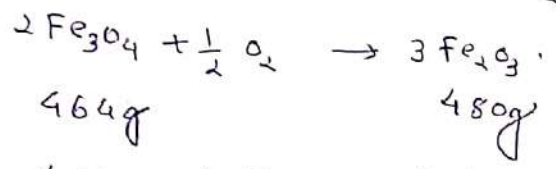
Solution: Let the % FeO in the mixture = $x\%$
 % Fe₃O₄ in the mixture = $(100-x)$

FeO on heating is converted in Fe₂O₃.



288g of FeO yield = 320g of Fe₂O₃.

x g of FeO will yield = $\frac{320}{288} x$ g of Fe₂O₃.



464g of Fe₃O₄ yield = 480g of Fe₂O₃.

$(100-x)$ g of Fe₃O₄ will yield = $\frac{480}{464} (100-x)$ of Fe₂O₃.

Total Fe₂O₃ = $\frac{320}{288} x + \frac{480}{464} (100-x)$

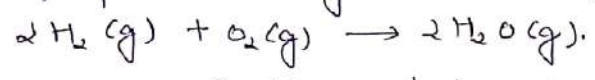
According to the question, 5% of increase in weight;

$$\frac{320}{288} x + \frac{480}{464} (100-x) = 105$$

$x = 20.2$

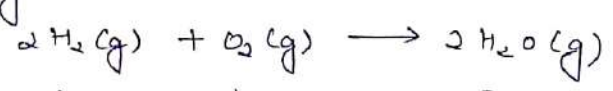
% FeO = 20.2% % Fe₃O₄ = 79.8%

Example: A mixture in which the mole ratio of H₂ & O₂ is 2:1 is used to prepare water by the reaction:



The total pressure of the container is 0.8 atm at 20°C before the reaction. Determine the final pressure at 120°C after the reaction, assuming 80% yield of water.

Solution: The given reaction is:



Initial mole $2n$ n 0

Final mole $(2n-2x)$ $(n-x)$ $2x$

% yield = 80 $\left| \frac{2x}{2n} \times 100 = 80 \right|$ $x = 0.8n$

After the reaction,

$$\text{Number of mole of } H_2 = (2n - 2 \times 0.8n) = 0.4n$$

$$\text{Number of mole of } O_2 = 0.2n$$

$$\text{Number of mole of } H_2O = 1.6n$$

$$\text{Total moles} = (0.4n + 0.2n + 1.6n) = 2.2n$$

Initial state: $PV = nRT$

$$0.8 \times V = 3n \times R \times 293 \quad \text{--- (1)}$$

$$\text{After the reaction, } PV = 2.2n \times R \times 373 \quad \text{--- (2)}$$

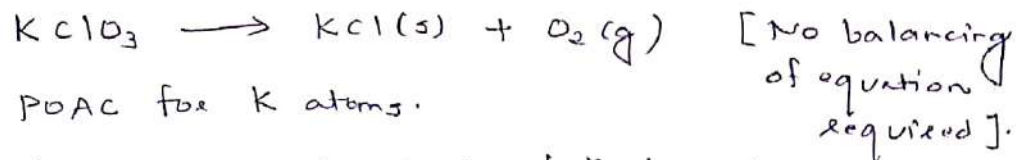
$$\text{From (1) \& (2)} \quad P = 0.787 \text{ atm.}$$

Exercise:

- (1) Calculate the weight of lime (CaO) that can be obtained by heating 200 kg of limestone which is 93% pure. [Ans - 104.16 kg]
- (2) Calculate the volume of air containing 21% by volume of oxygen at NTP required to convert 294 mL of SO_2 into SO_3 under the same condition. [Ans. 700 mL]
- (3) What weight of $AgCl$ will be precipitated when a solution containing 4.77 g of $NaCl$ is added to a solution of 5.77 g of $AgNO_3$. [Ans: 4.87 g]
- (4) Equal weight of Hg & iodine are allowed to react completely to form a mixture of mercurous iodide & mercuric iodide. Calculate the ratio of mass of mercurous iodide & mercuric iodide formed. [Ans. 0.513 : 1]
- (5) A mixture of calcium & magnesium carbonate weighing 1.4 g was strongly heated until no further loss of weight was perceived. The residue weighed 0.76 g. What percentage of $MgCO_3$ was present in the mixture? [Ans: 20.45%]

Principle of Atom Conservation (POAC)

The principle of conservation of mass, expressed in the concept of atomic theory, means the conservation of atoms. And if atoms are conserved, moles of atoms shall also be conserved. This is known as principle of Atom conservation (POAC).



Apply the POAC for K atoms.

Moles of K atom in reactant = Moles of K atoms in products

Mole of K atom in KClO_3 = moles of K atoms in KCl .

Since 1 mole of KClO_3 contains 1 mole of K, similarly 1 mole of KCl contain 1 mole of K.

Moles of K atom in $\text{KClO}_3 = 1 \times \text{moles of } \text{KClO}_3$.

∴ Mole of K atom in $\text{KCl} = 1 \times \text{mole of } \text{KCl}$.

Moles of $\text{KClO}_3 = \text{moles of } \text{KCl}$.

$$\frac{\text{wt. of } \text{KClO}_3 \text{ in (g)}}{\text{mol. wt. of } \text{KClO}_3} = \frac{\text{wt. of } \text{KCl}}{\text{Molecular wt. of } \text{KCl}}$$

Similarly, applying the principle of atom conservation for O atoms,

Moles of O in $\text{KClO}_3 = \text{Mole of O in } \text{O}_2$.

Moles of O in $\text{KClO}_3 = 3 \text{ moles of } \text{KClO}_3$.

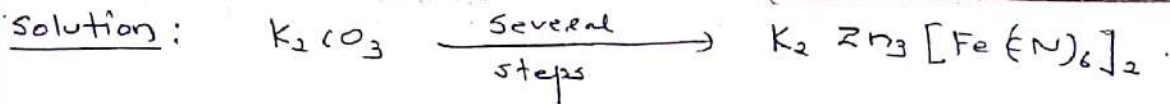
Moles of O in $\text{O}_2 = 2 \text{ moles of } \text{O}_2$.

$3 \times \text{moles of } \text{KClO}_3 = 2 \times \text{moles of } \text{O}_2$.

$$3 \times \frac{\text{wt. of } \text{KClO}_3}{\text{mol. wt. of } \text{KClO}_3} = 2 \times \frac{\text{Vol. of } \text{O}_2 \text{ at NTP}}{\text{standard molar volume}}$$

Example: 27.6 g of K_2CO_3 was treated by a series of reagent so as to convert all its carbon to $\text{K}_2\text{Zn}_3[\text{Fe}(\text{CN})_6]_2$.

Calculate the weight of the product.



Since Carbon atoms are conserved, applying POAC for Carbon.

$$\text{Moles of C atom in } K_2CO_3 = \text{Moles of carbon atom in } K_2Zn_3[Fe(CM)_6]_2$$

$$1 \text{ mole of } K_2CO_3 = 12 \text{ moles of } K_2Zn_3[Fe(CM)_6]_2$$

$$\frac{\text{wt. of } K_2CO_3}{\text{mol. wt. of } K_2CO_3} = \frac{12 \times \text{wt. of } K_2Zn_3[Fe(CM)_6]_2}{\text{mol. wt. of } K_2Zn_3[Fe(CM)_6]_2}$$

$$\frac{27.6 \text{ g}}{138 \text{ g}} = \frac{12 \times \text{wt. of } K_2Zn_3[Fe(CM)_6]_2}{698}$$

$$\text{wt. of } K_2Zn_3[Fe(CM)_6]_2 = \frac{27.6}{138} \times \frac{698}{12} = 11.6 \text{ g}$$

Example: 10cc of H_2O_2 solution when reacted with KI solution produced 0.5g of iodine. Calculate the percentage purity of H_2O_2 .



POAC for H atom,

$$\text{moles of H in } H_2O_2 = \text{mole of H in KOH}$$

$$2 \times \text{moles of } H_2O_2 = 1 \text{ moles of KOH} \quad \text{--- (1)}$$

POAC for K atom,

$$\text{Mole of K in KI} = \text{mole of K in KOH}$$

$$1 \text{ mole of KI} = 1 \text{ moles of KOH} \quad \text{--- (2)}$$

$$= 2 \times \text{moles of } H_2O_2 \quad \text{--- (3)}$$

POAC for Iodine atoms

$$\text{moles of I atom in KI} = \text{moles of I}_2 \text{ atom in } I_2$$

$$1 \times \text{moles of KI} = 2 \times \text{moles of } I_2$$

$$\text{moles of } I_2 = \frac{1}{2} \times \text{moles of KI}$$

$$= \frac{1}{2} \times (2 \text{ moles of } H_2O_2)$$

$$\frac{\text{Wt. of } I_2}{\text{mol. wt. of } I_2} = \frac{\text{wt. of } H_2O_2}{\text{mol. wt. of } H_2O_2}$$

$$\frac{0.5}{254} = \frac{x}{34}$$

$$x = \frac{34 \times 0.5}{254} = 0.0669 \text{ g.}$$

$$\% H_2O_2 = \frac{0.0669}{10} \times 100 = 0.669\%$$

Example: 1g mixture of cuprous oxide & cupric oxide was quantitatively reduced to 0.839g of metallic copper. What was the weight of cupric oxide in the original sample.

Solution: Let the weight of CuO be xg. The weight of Cu₂O will be (1-x)g.

POAC for Cu atom.

moles of Cu in CuO + moles of Cu in Cu₂O = moles of Cu in the product.

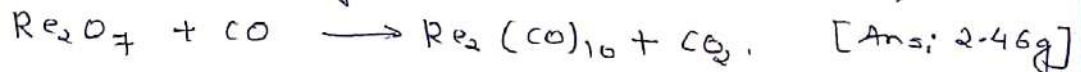
$$1 \times \text{moles of CuO} + 2 \times \text{moles of Cu}_2\text{O} = \text{moles of Cu.}$$

$$\frac{x}{79.5} + 2 \times \frac{(1-x)}{143} = \frac{0.839}{63.5}$$

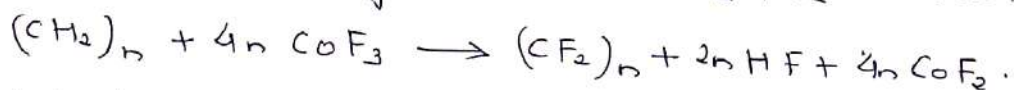
$$x = 0.55 \text{ g.}$$

Exercise:

1) What weight of CO is required to form Re₂(CO)₁₀ from 2.5g of Re₂O₇ according to the unbalanced reaction:



2) From the following reaction: $2CoF_2 + F_2 \rightarrow 2CoF_3$



Calculate how much F₂ will be consumed to produce 1kg of (CF₂)_n.
[Ans: 1.52 kg]

3) 25.4g of iodine & 14.2g of chlorine are made to react completely to yield a mixture of ICl & ICl₃. Calculate the number of moles of ICl & ICl₃ formed.
Ans: (0.1 mole, 0.1 mole)