CHEMISTRY

Mass and Stoichiometry

Stoichiometry

- The word 'stoichiometry' is derived from two Greek words—stoicheion (meaning element) and metron (meaning measure).

> Stoichiometry is the amount of reactants required or the products produced in a chemical reaction.

- It deals with the calculation of masses and volumes of the reactants and products involved in a chemical reaction.

Example:

In a given reaction,

$$CH_{4(g)} + \mathbf{2}O_{2(g)} \rightarrow CO_{2(g)} + \mathbf{2}H_2O_{(g)}$$

- The coefficient 2 for O_2 and H_2O is called stoichiometric coefficient. Similarly, the coefficient for CH_4 and CO_2 is one in each case.
- They represent the number of molecules and moles taking part in the reaction or formed in the reaction.

Thus, according to the above chemical reaction,

- One mole of $CH_{4(g)}$ reacts with two moles of $O_{2(g)}$ to give one mole of $CO_{2(g)}$ and two moles of $H_2O_{(g)}$.
- One molecule of $CH_{4(g)}$ reacts with 2 molecules of $O_{2(g)}$ to give one molecule of $CO_{2(g)}$ and 2 molecules of $H_2O_{(g)}$
- 22.7 L of $CH_{4(g)}$ reacts with 45.4 L of $O_{2\ (g)}$ to give 22.7 L of $CO_{2\ (g)}$ and 45.4 L of $H_2O_{(g)}$.
- 16 g of $CH_{4\ (g)}$ reacts with 2 × 32 g of $O_{2\ (g)}$ to give 44 g of $CO_{2\ (g)}$ and 2 × 18 g of $H_2O_{\ (g)}$.

From these relationships, the given data can be interconverted as follows:

$$\text{Mass} \rightleftharpoons \text{Moles} \rightleftharpoons \text{Number of molecules}$$

Limiting Reagent

- Quite often, one of the reactants is present in a larger amount than the other as required according to the balanced equation.
  In such situations, one reactant is in excess over the other. The reactant which is present in the lesser amount gets consumed after sometime, and thereafter, no further reaction takes place whatever be the amount of the other reactant present.
- Hence, the reactant which gets consumed completely limits the amount of product formed and is therefore called the limiting reagent.
- The reactant which is not consumed completely in the reaction is called excess reactant which is left unreacted.
- While performing stoichiometric calculations, this aspect is also to be kept in mind.

Reactions in Solutions

- Most reactions are carried out in solutions in the laboratories. Therefore, it is important to understand how the amount of substance is expressed when it is present in the form of a solution.
- The concentration of a solution or the amount of substance present in its given volume can be expressed in any of the following ways:

1. Mass percent or weight percent (w/w %)
2. Mole fraction
3. Molarity
4. Molality

Mass Percent

It is obtained by using the relation

$$\text{Mass percent} = \frac{\text{Mass of solute}}{\text{Atomic of solution}} \times 100$$

Mole Fraction

It is the ratio of the number of moles of a particular component to the total number of moles of the solution. If a substance ‘A’ dissolves in substance ‘B’ and their number of moles is n_A and $n_{B,}$ respectively; then the mole fractions of A and B are

$$\text{Mole fraction of A} = \frac{\text{No. of moles of A}}{\text{No. of moles of solution}} = \frac{n_A}{n_A + n_B}$$

$$\text{Mole fraction of B} = \frac{\text{No. of moles of B}}{\text{No. of moles of solution}} = \frac{n_B}{n_A + n_B}$$

Molarity

It is the most widely used unit and is denoted by M. It is the number of moles of the solute in 1 litre of the solution.

$$\text{Molarity (M)} = \frac{\text{No. of moles of solute}}{\text{Volume of solution in litres}}$$

Example:

We have 1 M solution of NaOH, and we want to prepare a 0.2 M solution from it.

1 M NaOH means 1 mol of NaOH present in 1 litre of the solution. So, for a 0.2 M solution, we require 0.2 moles of NaOH in a 1 litre solution. Hence, we have to take 0.2 moles of NaOH and make the solution 1 litre.

Now how much volume of concentrated 1 M NaOH solution will be taken which contains 0.2 moles of NaOH?

For such calculations, a general formula, $M_1 \times V_1 = M_2 \times V_2$ is used.

where M = Molarity

V = Volume

In this case, $M_1 = 0.2$, $V_1 = 1000$ ml and $M_2 = 1.0$; V_2 is to be calculated.

Substituting the values in the formula,

$M_1 \times V_1 = M_2 \times V_2$

$0.2 \text{ M} \times 1000 \text{ ml} = 1.0 \text{ M} \times V_2$

$$\therefore V_2 = \frac{0.2\text{ M} \times 1000\text{ ml}}{1.0\text{ ml}} = 200\text{ ml}$$

Molality

It is the number of moles of solute present in 1 kg of solvent. It is denoted by m.

$$\text{Molality (m)} = \frac{\text{No. of moles of solute}}{\text{Mass of solvent in kg}}$$