Moles and Solutions

A **solution** is formed when a **solute** is dissolved in a **solvent**. For example, when sodium chloride, NaCl(s), dissolves in water, sodium chloride solution, NaCl(aq), is formed.

The **concentration** of a solution describes the amount of solute in a certain volume of solvent and can be calculated using the equation:

$$\textbf{concentration (mol dm}^{-3}\textbf{)} = \frac{\textbf{amount of solute (mol)}}{\textbf{volume of solvent (dm}^3\textbf{)}}$$

For example:

1. **Calculate the concentration of a solution that contains 0.5 moles of potassium iodide dissolved in 1.0 dm^3 of water.**

   $$\text{concentration} = \frac{0.5}{1.0} = 0.5 \text{ mol dm}^{-3}$$

2. **Calculate the concentration of a solution containing 1.0 mole of sodium hydroxide dissolved in 10 dm^3 of ethanol.**

   $$\text{concentration} = \frac{1}{10} = 0.1 \text{ mol dm}^{-3}$$

The above equation can be rearranged to calculate the number of moles of a solute in a solution of known volume and concentration as follows:

$$\textbf{number of moles (mol) = volume (dm}^3\textbf{)} \times \textbf{concentration (mol dm}^{-3}\textbf{)}$$

For example:

1. **Calculate the number of moles of copper chloride in 1.0 dm^3 of a 0.25 mol dm^{-3} copper chloride solution.**

   number of moles = 1.0 × 0.25 = 0.25 mol

2. **Calculate the number of moles of hydrochloric acid in 0.5 dm^3 of a 1.5 mol dm^{-3} hydrochloric acid solution.**

   number of moles = 0.5 × 1.5 = 0.75 mol

It is important to read information relating to solutions carefully. In practical situations, the volumes of liquids are often recorded in cubic centimetres (cm^3) rather than cubic decimetres (dm^3) and amounts of solutes are often recorded in grams (g) rather than moles (mol). Therefore, it is often necessary to convert the units of given volumes, amounts or concentrations before using them in your calculations.

$$\text{number of moles (mol)} = \frac{\text{mass of substance (g)}}{A_r \text{ or } M_r \text{ of substance (g mol}^{-1})}$$

Examples

1. **Calculate the concentration, in mol dm^{-3}, of a solution that contains 37.3 g of potassium chloride (KCl) in 500 cm^3 of water.**

   M_r of KCl = (39.1 × 1) + (35.5 × 1) = 74.6

   moles of KCl = $\frac{37.3}{74.6}$ = 0.5

   volume = $\frac{500 \text{ cm}^3}{1000}$ = 0.5 dm^3

   concentration = $\frac{0.5}{0.5}$ = 1 mol dm^{-3}

1 dm^3 = 1000 cm^3 = 1 litre

2. **Calculate the mass, in grams, of iron(II) sulfate ($FeSO_4$) in 50 cm^3 of 0.25 mol dm^{-3} iron(II) sulfate solution.**

   volume = $\frac{50 \text{ cm}^3}{1000}$ = 0.05 dm^3

   number of moles of $FeSO_4$ in solution = 0.05 × 0.25 = 0.0125

   M_r of $FeSO_4$ = (55.8 × 1) + (32.1 × 1) + (16.0 × 4) = 151.9

   mass = 0.0125 × 151.9 = 1.89875

   mass = 1.9 g (2 s.f.)

3. **Calculate the concentration of a 20 g L^{-1} (grams per litre) solution of hydrogen peroxide (H_2O_2) in mol dm^{-3}.**

   M_r of H_2O_2 = (1.0 × 2) + (16.0 × 2) = 34.0

   moles of H_2O_2 = $\frac{20}{34.0}$ = 0.588235...

   1 L = 1 dm^3

   concentration = $\frac{0.588235...}{1}$ = 0.588235...

   concentration = 0.59 mol dm^{-3} (2 s.f.)

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