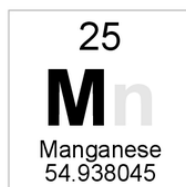
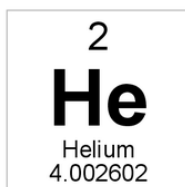
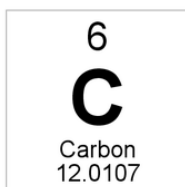
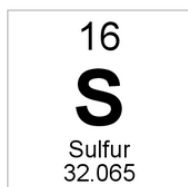
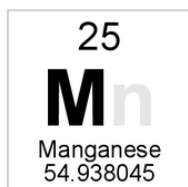


Stoichiometric Relationships

Part three

(answers)

IB CHEMISTRY SL/HL



Syllabus objectives:

Understandings

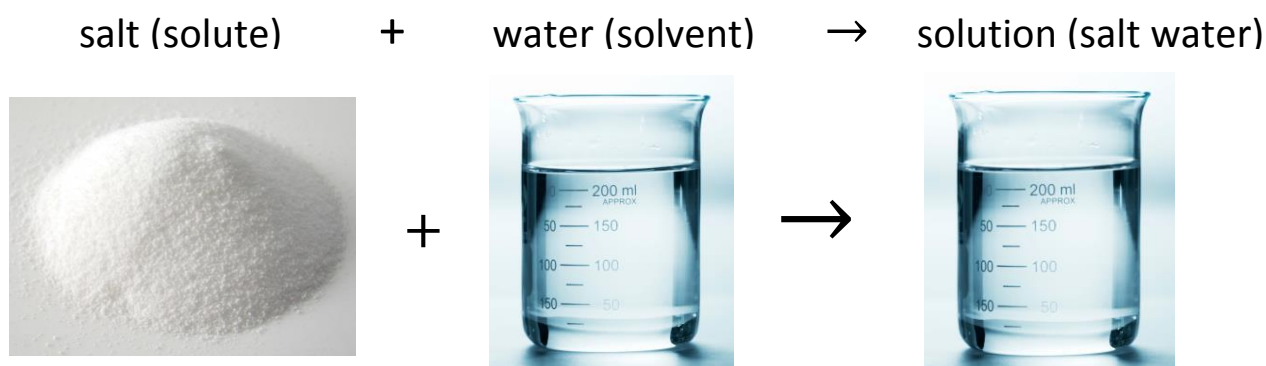
- The molar concentration of a solution is determined by the amount of solute and the volume of solution.
- A standard solution is one of known concentration.

Applications and skills:

- Solution of problems involving molar concentration, amount of solute and volume of solution.
- Use of the experimental method of titration to calculate the concentration of a solution by reference to a standard solution (this is covered in the lab part of the course).

Solutions

- Solutions are homogeneous mixtures.
- A solution is composed of a solute (usually a solid) dissolved in a solvent (usually water).



- Solutions can be dilute (less solute, more solvent) or concentrated (more solute, less solvent).

Standard solutions (covered in the lab part of the course)

- A standard solution is a solution that has a concentration that is known accurately.
- A primary standard solution is prepared using a substance of high purity which is dissolved in a known volume of solvent.
- A secondary standard solution refers to a solution that has its concentration determined by titration with a primary standard solution.
- When making up a standard solution it is important that the correct mass of substance is accurately measured. In addition, it is important that all the solute is transferred to the volumetric flask used to make up the solution.

Calculating the concentration of a solution

- The concentration of a solution can be expressed in mol dm⁻³ or g dm⁻³
- The equation for calculating concentration in mol dm⁻³ is shown below.
- In this equation, **volume must be in dm³** (to convert from cm³ to dm³, divide by 1000).

$$c \text{ (mol dm}^{-3}\text{)} = \frac{\text{amount of solute (mol)}}{\text{volume of solution (dm}^3\text{)}}$$

$$C = \frac{n}{V} \quad \begin{array}{l} C = \text{concentration in mol dm}^{-3} \\ n = \text{amount in mol} \\ V = \text{volume in dm}^3 \end{array}$$

$$n = CV \quad V = \frac{n}{C}$$

- The equations for calculating concentration in g dm⁻³ and ppm are shown below.

$$c \text{ (g dm}^{-3}\text{)} = \frac{\text{mass of solute (g)}}{\text{volume of solution (dm}^3\text{)}}$$

$$c \text{ (ppm)} = \frac{\text{mass of solute (g)}}{\text{mass of solution (g)}} \times 10^6$$

Example:

50.0 g of NaCl are dissolved in 100 cm³ of water which is then made up to 500.0 cm³ in a volumetric flask. Calculate the concentration of the solution in mol dm⁻³ and g dm⁻³.

In g dm⁻³

C = mass of solute ÷ volume of solution

$$C = 50.0 \div (500.0 \div 1000)$$

$$C = 100.0 \text{ g dm}^{-3}$$

In mol dm⁻³

Convert from mass to amount in mol

$$n = m \div M$$

$$n = 50.0 \div 58.44 = 0.856 \text{ mol NaCl}$$

$$C = n \div V$$

$$C = 0.856 \div (500 \div 1000)$$

$$C = 1.71 \text{ mol dm}^{-3}$$

Exercises:

1. Calculate the concentration (in mol dm⁻³ and g dm⁻³) of these solutions:

a) 10.6 g of sodium carbonate (Na₂CO₃) in 1.00 dm³ of solution.

$$n = m \div M$$

$$n = 10.6 \div 105.99 = 0.100 \text{ mol Na}_2\text{CO}_3$$

$$C = n \div V$$

$$C = 0.100 \div (1.00)$$

$$C = 0.100 \text{ mol dm}^{-3}$$

$$C = 10.6 \div (1.00)$$

$$C = 10.6 \text{ g dm}^{-3}$$

b) 117 g of sodium chloride (NaCl) in 5.00 dm³ of solution.

$$n = m \div M$$

$$n = 117 \div 58.44 = 2.00 \text{ mol NaCl}$$

$$C = n \div V$$

$$C = 2.00 \div 5.00$$

$$C = 0.400 \text{ mol dm}^{-3}$$

$$C = 117 \div 5.00$$

$$C = 23.4 \text{ g dm}^{-3}$$

c) 0.830 g of potassium iodide (KI) in 25.0 cm³ of solution.

$$n = m \div M$$

$$n = 0.830 \div 166.00 = 5.00 \times 10^{-3} \text{ mol KI}$$

$$C = n \div V$$

$$C = 5.00 \times 10^{-3} \div (25.0 \div 1000)$$

$$C = 0.200 \text{ mol dm}^{-3}$$

$$C = 0.830 \div (25.0 \div 1000)$$

$$C = 33.2 \text{ g dm}^{-3}$$

2. Calculate the amount (in mol) of solute in each of the following solutions:

a) 0.250 dm³ of 0.400 mol dm⁻³ ammonium chloride solution.

$$n = CV$$

$$n = 0.400 \times 0.250$$

$$n = 0.100 \text{ mol}$$

b) 200.0 cm³ of 0.800 mol dm⁻³ sodium carbonate solution.

$$n = CV$$

$$n = 0.800 \times (200.0 \div 1000)$$

$$n = 0.160 \text{ mol}$$

c) 300.0 cm³ of 4.00 mol dm⁻³ sodium hydroxide solution.

$$n = CV$$

$$n = 4.00 \times (300.0 \div 1000)$$

$$n = 1.20 \text{ mol}$$

3. Calculate the mass of solute in the following solutions:

a) 2.00 dm³ of 0.200 mol dm⁻³ potassium hydroxide (KOH) solution.

$$n = CV$$

$$n = 0.200 \times 2.00$$

$$n = 0.400 \text{ mol}$$

$$m = nM$$

$$m = 0.400 \times 56.11$$

$$m = 22.6 \text{ g KOH}$$

b) 200.0 cm³ of 0.100 mol dm⁻³ sodium carbonate (Na₂CO₃) solution.

$$n = CV$$

$$n = 0.100 \times (200.0 \div 1000)$$

$$n = 0.0200 \text{ mol}$$

$$m = nM$$

$$m = 0.0200 \times 105.99$$

$$m = 2.12 \text{ g Na}_2\text{CO}_3$$

c) 25.0 cm³ of 0.0500 mol dm⁻³ copper(II) sulphate (CuSO₄•5H₂O) solution.

$$n = CV$$

$$n = 0.0500 \times (25.0 \div 1000)$$

$$n = 1.25 \times 10^{-3} \text{ mol}$$

$$m = nM$$

$$m = 1.25 \times 10^{-3} \times 249.72$$

$$m = 0.312 \text{ g CuSO}_4 \cdot 5\text{H}_2\text{O}$$

Parts per million (ppm) exercises

1. 25.0 grams of a chemical is dissolved in 75.0 grams of water. Calculate the concentration of the solution in ppm.

$$\begin{aligned} \text{ppm} &= (25.0 \div 100.0) \times 10^6 \\ &= 250000 \text{ ppm} \end{aligned}$$

2. 17.0 grams of sucrose is dissolved in 183 grams of water. Calculate the concentration of the solution in ppm.

$$\begin{aligned} \text{ppm} &= (17.0 \div 200) \times 10^6 \\ &= 85000 \text{ ppm} \end{aligned}$$

3. 35.0 grams of ethanol is dissolved in 115 grams of water. Calculate the concentration of the solution in ppm.

$$\begin{aligned} \text{ppm} &= (35.0 \div 140) \times 10^6 \\ &= 233333 \text{ ppm} \end{aligned}$$

4. The solubility of NaCl is 284 grams per 100.0 grams of water. Calculate the concentration of the solution in ppm.

$$\begin{aligned} \text{ppm} &= (284 \div 384) \times 10^6 \\ &= 740000 \text{ ppm} \end{aligned}$$

5. The solubility of AgCl is 0.008 grams per 100.0 grams of water. Calculate the concentration of the solution in ppm.

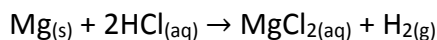
$$\begin{aligned} \text{ppm} &= (0.008 \div 100.008) \times 10^6 \\ &= 80 \text{ ppm} \end{aligned}$$

6. A certain pesticide has a toxic solubility of 5.00 grams per kg (1000g). Calculate the concentration of the solution in ppm.

$$\begin{aligned} \text{ppm} &= (5.00 \div 1005) \times 10^6 \\ &= 4980 \text{ ppm} \end{aligned}$$

More practice examples

1. What volume of 2.00 mol dm^{-3} HCl reacts completely with 5.00 g of magnesium? What volume of hydrogen gas will be produced at STP?



$$n \text{ Mg} = 5.00 \div 24.31 = 0.206 \text{ mol}$$

Ratio of Mg to HCl is 1:2

$$0.206 \text{ mol of Mg reacts with } 2 \times 0.206 = 0.412 \text{ mol of HCl}$$

$$V = n \div C$$

$$V = 0.412 \div 2.00$$

$$V = 0.206 \text{ dm}^3 (206 \text{ cm}^3) \text{ HCl}$$

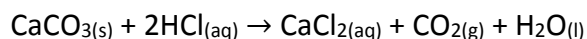
Ratio of Mg to H_2 is 1:1

$$0.206 \text{ mol of Mg produces } 0.206 \text{ mol of H}_2$$

$$1 \text{ mol of gas at STP} = 22.7 \text{ dm}^3$$

$$0.206 \times 22.7 = 4.68 \text{ dm}^3 \text{ H}_2$$

2. What volume of 1.00 mol dm^{-3} HCl reacts completely with 10.00 g of calcium carbonate (CaCO_3)? What volume of carbon dioxide gas will be produced at STP?



$$n \text{ CaCO}_3 = 10.00 \div 100.09 = 0.100 \text{ mol}$$

Ratio of CaCO_3 to HCl is 1:2

$$0.100 \text{ mol of CaCO}_3 \text{ reacts with } 2 \times 0.100 = 0.200 \text{ mol of HCl}$$

$$V = n \div C$$

$$V = 0.200 \div 1.00$$

$$V = 0.200 \text{ dm}^3 (200 \text{ cm}^3) \text{ HCl}$$

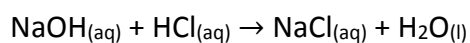
Ratio of CaCO_3 to CO_2 is 1:1

$$0.100 \text{ mol of CaCO}_3 \text{ produces } 0.100 \text{ mol of CO}_2$$

$$1 \text{ mol of gas at STP} = 22.7 \text{ dm}^3$$

$$0.100 \times 22.7 = 2.27 \text{ dm}^3 \text{ CO}_2$$

3. Sodium hydroxide (NaOH) reacts with hydrochloric acid (HCl) according to the following equation:



What volume of $0.500 \text{ mol dm}^{-3}$ HCl reacts with 25.0 cm^3 of 2.00 mol dm^{-3} NaOH solution?

$$n \text{ NaOH} = 2.00 \times (25.0 \div 1000) = 0.0500 \text{ mol}$$

Ratio of NaOH to HCl is 1:1

0.0500 mol of NaOH reacts with 0.0500 mol of HCl

$$V = n \div C$$

$$V = 0.0500 \div 0.500$$

$$V = 0.100 \text{ dm}^3 (100 \text{ cm}^3) \text{ HCl}$$