Stoichiometric Relationships Part three

IB CHEMISTRY SL/HL

25	16		6	2	25
Mn	**S**	**J**	**C**	**He**	**Mn**
Manganese	Sulfur		Carbon	Helium	Manganese
54.938045	32.065		12.0107	4.002602	54.938045

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).

salt (solute) + water (solvent) → solution (salt 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 dm^3** (to convert from cm^3 to dm^3, divide by 1000).

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

$$c = \frac{n}{V}$$

c = concentration in mol dm^{-3}
n = amount in mol
V = volume in dm^3

$$n = cV \qquad V = \frac{n}{c}$$

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

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

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

Example:
50.0 g of NaCl are dissolved in 100 cm^3 of water which is then made up to 500.0 cm^3 in a volumetric flask. Calculate the concentration of the solution in mol dm^{-3} and g 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 (Na_2CO_3) in 1.00 dm^3 of solution.

   b) 117 g of sodium chloride (NaCl) in 5.00 dm^3 of solution.

   c) 0.830 g of potassium iodide (KI) in 25.0 cm^3 of solution.

2. Calculate the amount (in mol) of solute in each of the following solutions:
   a) 0.250 dm^3 of 0.400 mol dm^{-3} ammonium chloride solution.

   b) 200.0 cm^3 of 0.800 mol dm^{-3} sodium carbonate solution.

   c) 300.0 cm^3 of 4.00 mol dm^{-3} sodium hydroxide solution.

3. Calculate the mass of solute in the following solutions:
   a) 2.00 dm^3 of 0.200 mol dm^{-3} potassium hydroxide (KOH) solution.

   b) 200.0 cm^3 of 0.100 mol dm^{-3} sodium carbonate (Na_2CO_3) solution.

   c) 25.0 cm^3 of 0.0500 mol dm^{-3} copper(II) sulphate ($CuSO_4 \bullet 5H_2O$) solution.

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.

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

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

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

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

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

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?

$$Mg_{(s)} + 2HCl_{(aq)} \rightarrow MgCl_{2(aq)} + H_{2(g)}$$

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?

$$CaCO_{3(s)} + 2HCl_{(aq)} \rightarrow CaCl_{2(aq)} + CO_{2(g)} + H_2O_{(l)}$$

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

$$NaOH_{(aq)} + HCl_{(aq)} \rightarrow NaCl_{(aq)} + H_2O_{(l)}$$

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