# Solutions and Concentrations Revision Notes | CIE | A-Level Chemistry

## Defining Concentration

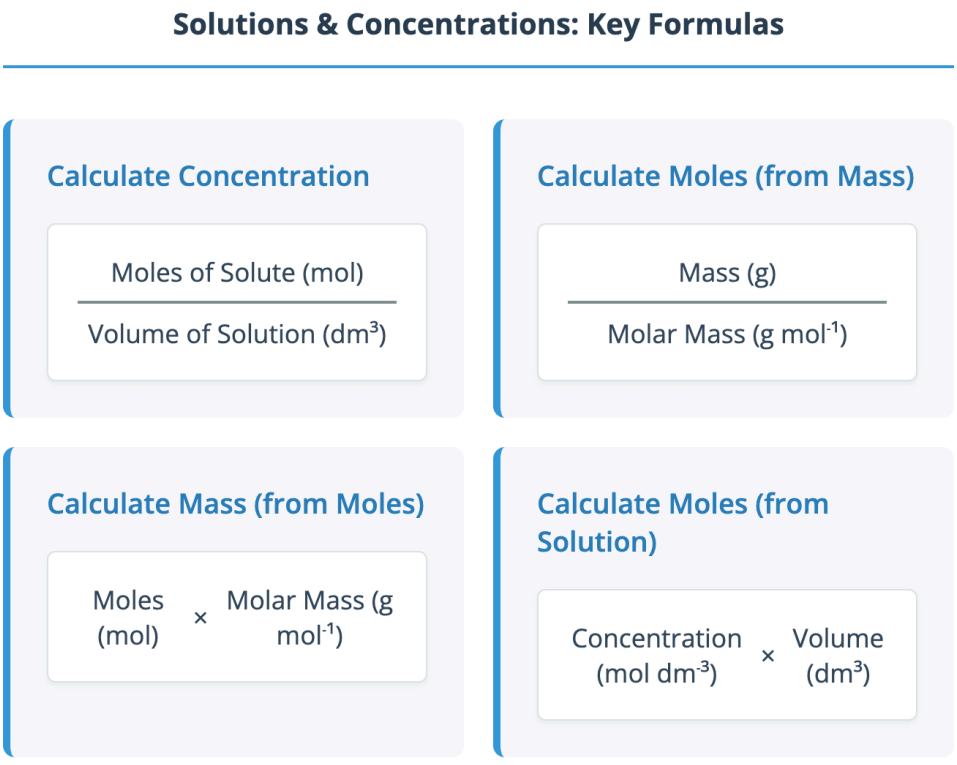
The concentration of a solution is a measure of the amount of solute dissolved in a specific volume of solvent, which is typically water in A-Level Chemistry. The standard unit for concentration is moles per cubic decimetre (mol $dm^{-3}$).

It is important to remember the conversion between cubic centimetres ($cm^3$) and cubic decimetres ($dm^3$):

- 1 $dm^3$ = 1000 $cm^3$

A solution with a high amount of solute is described as concentrated, while one with a low amount of solute is described as dilute. The relationship between concentration, moles, and volume is given by the formula:

Concentration (mol $dm^{-3}$) = Moles of solute (mol) / Volume of solution ($dm^3$)



# Calculating Concentration from Mass

To find the concentration of a solution when you know the mass of the solute and the total volume of the solution, a two-step calculation is required.

1. Calculate the moles of the solute by dividing its mass in grams by its molar mass (Mr).
   Moles = Mass (g) / Molar Mass (g $mol^{-1}$)
2. Convert the volume of the solution from $cm^3$ to $dm^3$ by dividing by 1000.
3. Use the concentration formula to determine the concentration in mol $dm^{-3}$.

**Example Calculation:**

Calculate the concentration of a solution containing 4.0 g of sodium hydroxide (NaOH) in 250 $cm^3$ of solution. (Mr of NaOH = 40.0 g $mol^{-1}$)

Step 1: Calculate moles of NaOH.
Moles = 4.0 g / 40.0 g $mol^{-1}$ = 0.10 mol

Step 2: Convert volume to $dm^3$.
Volume = 250 $cm^3$ / 1000 = 0.250 $dm^3$

Step 3: Calculate concentration.
Concentration = 0.10 mol / 0.250 $dm^3$ = 0.40 mol $dm^{-3}$

# Calculating Mass from Concentration

It is often necessary to calculate the mass of a solute present in a solution of a known concentration and volume. This involves rearranging the concentration formula.

1. Calculate the moles of solute by multiplying the concentration by the volume in $dm^3$.
   Moles = Concentration (mol $dm^{-3}$) × Volume ($dm^3$)
2. Calculate the mass of the solute by multiplying the moles by the molar mass.
   Mass (g) = Moles (mol) × Molar Mass (g $mol^{-1}$)

**Example Calculation**

Calculate the mass of anhydrous copper(II) sulfate ($CuSO_4$) in 50 $cm^3$ of a 0.20 mol $dm^{-3}$ solution. (Mr of $CuSO_4$ = 159.6 g $mol^{-1}$)

Step 1: Calculate moles of $CuSO_4$.
Volume = 50 $cm^3$ / 1000 = 0.050 $dm^3$
Moles = 0.20 mol $dm^{-3}$ × 0.050 $dm^3$ = 0.010 mol

Step 2: Calculate mass of $CuSO_4$.
Mass = 0.010 mol × 159.6 g $mol^{-1}$ = 1.6 g (to 2 significant figures)

# Titration Calculations

Titration is a practical technique used to determine the unknown concentration of a solution by reacting it with a solution of known concentration. Calculations based on titration data follow a clear, logical sequence.

1. Calculate the moles of the reactant with the known concentration and volume (the standard solution).
   Moles = Concentration × Volume (in $dm^3$)
2. Use the mole ratio (stoichiometry) from the balanced chemical equation to determine the number of moles of the other reactant.
3. Calculate the unknown concentration using the moles determined in step 2 and the volume of the solution used in the titration.
   Concentration = Moles / Volume (in $dm^3$)

**Example Calculation**
In a titration, 25.0 $cm^3$ of sodium hydroxide solution is exactly neutralised by 15.00 $cm^3$ of 0.200 mol $dm^{-3}$ sulfuric acid ($H_2SO_4$). Calculate the concentration of the sodium hydroxide solution.
The balanced equation is: $2NaOH + H_2SO_4 \rightarrow Na_2SO_4 + 2H_2O$

Step 1: Calculate moles of $H_2SO_4$.
Volume of $H_2SO_4$ = 15.00 $cm^3$ / 1000 = 0.01500 $dm^3$
Moles of $H_2SO_4$ = 0.200 mol $dm^{-3}$ × 0.01500 $dm^3$ = 0.00300 mol

Step 2: Use the mole ratio to find moles of NaOH.
From the equation, the ratio of NaOH to $H_2SO_4$ is 2:1.
Moles of NaOH = 0.00300 mol × 2 = 0.00600 mol

Step 3: Calculate the concentration of NaOH.
Volume of NaOH = 25.0 $cm^3$ / 1000 = 0.0250 $dm^3$
Concentration of NaOH = 0.00600 mol / 0.0250 $dm^3$ = 0.240 mol $dm^{-3}$