

Quantitative Analysis – GCSE Chemistry

CONTENTS:

1. Introduction
2. What is Concentration?
3. What is Titration?
4. Calculations from Titration Results
5. What is molar volume?
6. What is Avogadro's law?
7. What is percentage yield?
8. What is atom economy?

1. Introduction

- Quantitative analysis in chemistry focuses on determining and calculating the quantities of substances involved in chemical reactions.
- It enables chemists to identify the strength of solutions, estimate the amount of products formed, and evaluate how effective a reaction is.
- Through the use of experiments and mathematical calculations, it ensures reactions are performed precisely, minimizes unnecessary waste, and enhances safety in laboratory and industrial processes.

Applications of Quantitative Analysis:

- **Medicine** – calculating accurate drug dosages for safe treatments.
- **Food industry** – testing sugar, salt, or nutrient levels in foods.
- **Water treatment** – measuring concentrations of harmful ions or chemicals in drinking water.
- **Industrial chemistry** – ensuring the right amounts of reactants are used to maximise yield.

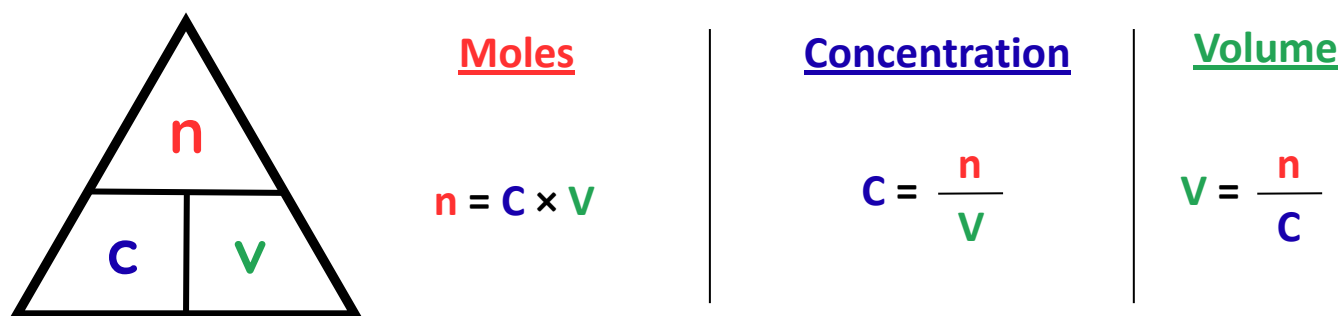
Quantitative Analysis – GCSE Chemistry

2. What is Concentration?

- Concentration tells us the amount of solute (the substance being dissolved) present in a given volume of solution.
- **Example:** When sugar is added to water, the sweetness increases as more sugar dissolves. This shows that the solution becomes more concentrated with each spoon of sugar added.



- Concentration is usually measured in **mol/dm³** (moles per cubic decimetre).
- In chemistry, moles are represented by *n*, concentration by *C*, and volume by *V*.
- Concentration can be calculated using the triangle formula, where moles (*n*) are at the top and concentration (*C*) and volume (*V*) are at the bottom.



Note: How do we convert between **g/dm³** and **mol/dm³**?

- To change from **g/dm³** to **mol/dm³**, divide by the molar mass of the solute.
- To change from **mol/dm³** to **g/dm³**, multiply by the molar mass.

Quantitative Analysis – GCSE Chemistry

Example: A solution contains 10 g of sodium hydroxide (NaOH) dissolved in 1 dm³ of solution. Calculate its concentration in mol/dm³.

Solution:

- Given:**
- Mass of NaOH = 10 g
 - Volume of solution = 1 dm³
 - Molar mass of NaOH = 40 g/mol

Step#1: Convert mass into moles

$$\text{Moles of NaOH} = \frac{\text{Mass}}{\text{Molar Mass}}$$

$$\text{Moles of NaOH} = \frac{10}{40} = 0.25\text{mol}$$

Step#2: Find concentration

Using formula:

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

$$C = \frac{0.25}{1}$$

$$C = 0.25\text{mol/dm}^3$$

Concentration = 0.25 mol/dm³

Quantitative Analysis – GCSE Chemistry

3. What is Titration?

- The experimental technique used to find the exact concentration of an unknown acid or alkali is called titration.
- It is very important in chemistry because it gives accurate results.

How is titration carried out?

- Place the acid into a burette and note the starting volume.



- Use a pipette to transfer a known volume of alkali into a conical flask.



- Add a few drops of a suitable indicator, such as **phenolphthalein or methyl orange**.
- Slowly release the acid from the burette while gently swirling the flask, until the indicator changes colour. This point is called the end point.
- Record the volume of acid used — this is known as the **titre**.
- Repeat the experiment several times until you obtain results that are very close together, known as concordant results.

Quantitative Analysis – GCSE Chemistry

4. Calculations from Titration Results

- We can find the concentration of an unknown solution or the volume required to neutralise another solution.

How do we calculate it?

Step#1: Use the titre volume and the concentration of the known solution to determine the number of moles.

Step#2: Apply the balanced chemical equation to identify the mole ratio between the acid and the alkali.

Step#3: Using this ratio, calculate the moles of the unknown solution.

Step#4: Calculate the unknown concentration or volume using the formula for concentration.

Example: If 30.0 cm³ of 0.250 mol/dm³ H₂SO₄ completely neutralises 25.0 cm³ of NaOH solution, what is the concentration of the NaOH?

Solution:

Step#1: To calculate moles:

$$\text{Moles of H}_2\text{SO}_4 = \text{concentration} \times \text{volume (in dm}^3\text{)}$$

$$\text{Moles of H}_2\text{SO}_4 = 0.250 \times \left(\frac{30}{1000}\right)$$

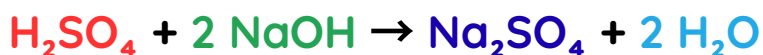
$$\text{Moles of H}_2\text{SO}_4 = 0.250 \times 0.0300$$

$$\text{Moles of H}_2\text{SO}_4 = 0.00750 \text{ mol}$$

Step#2: Apply the balanced chemical equation:

Balanced equation:

Quantitative Analysis – GCSE Chemistry



Ratio H₂SO₄ :

$$\text{NaOH} = 1 : 2$$

Step#3: Using this ratio, calculate the moles of the unknown solution.

Moles of NaOH :

$$= 2 \times 0.00750 = 0.0150 \text{ mol}$$

Step#4: Calculate the unknown concentration or volume using the formula for concentration.

$$\text{Concentration} = \frac{\text{Moles}}{\text{Volume}}$$

- First calculate the volume:

$$\text{Volume} = \frac{25}{1000}$$

$$\text{Volume} = 0.0250$$

Now,

$$\text{Concentration} = \frac{0.0150}{0.0250}$$

$$\text{Concentration} = 0.600 \text{ mol/dm}^3$$

The concentration of the NaOH solution is 0.600 mol/dm³.

Quantitative Analysis – GCSE Chemistry

5. What is molar volume?

- At room temperature and pressure (RTP, 20°C, 1 atm), 1 mole of any gas occupies 24 dm³. This is called the molar volume of a gas.
- At room temperature and pressure (RTP), one mole of any gas occupies about 24 dm³ (24,000 cm³).
- At standard temperature and pressure (STP), one mole of any gas occupies about 22.4 dm³.
- Formulas:
 - **Volume (dm³) = moles × 24**
 - **Volume (cm³) = moles × 24,000**

Example: Calculate the volume of carbon dioxide gas produced at RTP when 10 g of calcium carbonate (CaCO₃) reacts with hydrochloric acid.

Solution:

Step#1: Write the balanced equation



Step#2: Calculate moles of Calcium Carbonate

Molar mass of Calcium Carbonate(CaCO₃) = 100 g/mol

$$\text{Moles of CaCO}_3 = \frac{10}{100}$$

$$\text{Moles of CaCO}_3 = 0.1\text{mol}$$

Step#3: Calculate moles of Calcium Carbonate

From the balanced equation:

- 1 mole of CaCO₃ produces 1 mole of CO₂.
- Therefore, 0.1 mole of CaCO₃ will produce 0.1 mole of CO₂.

Quantitative Analysis – GCSE Chemistry

Step#4: Convert moles of CO₂ to volume

$$\text{Volume of CO}_2 = 0.1 \times 24 = 2.4\text{dm}^3$$

So, 2.4 dm³ of CO₂ gas is produced at RTP.

6. What is Avogadro's law?

- Avogadro's law states that 1 mole of any substance contains 6.02×10^{23} particles, such as atoms, ions, or molecules.

It is useful because:

- Connects moles to the number of particles.
- Equal moles of gases have the same volume in the same conditions.
- Makes it easy to compare and calculate gas volumes.

Example: How many molecules are present in 2 moles of hydrogen gas (H₂)?
(Take Avogadro's number = 6.02×10^{23} .)

Solution:

$$\text{Number of molecules} = \text{moles} \times \text{Avogadro's number}$$

$$\text{Number of molecules} = 2 \times 6.02 \times 10^{23}$$

$$\text{Number of molecules} = 1.204 \times 10^{24} \text{ molecules}$$

2 moles of H₂ contain 1.204×10^{24} molecules.

Quantitative Analysis – GCSE Chemistry

7. What is percentage yield?

- **Percentage yield** tells us the portion of product we actually get compared to the amount we would get if the reaction worked perfectly.
- It is a measure of efficiency.
- Formula:

$$\text{Percentage yield} = \frac{\text{Actual yield}}{\text{Theoretical yield}} \times 100$$

Example: In a chemical reaction, the theoretical yield of a product is 50 g, but only 40 g is actually obtained. Calculate the percentage yield.

Solution:

- Given:**
- Theoretical yield of a product = 50 g
 - Actual yield of a product = 40 g

Now using formula:

$$\text{Percentage yield} = \frac{40}{50} \times 100$$

$$\text{Percentage yield} = 0.8 \times 100$$

$$\text{Percentage yield} = 80\%$$

The percentage yield is 80%.

Quantitative Analysis – GCSE Chemistry

8. What is atom economy?

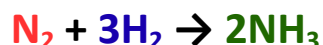
- Atom economy tells us what fraction of the reactants is actually turned into the product we want.
- It tells us how efficient a process is.
- It is calculated by using formula:

$$\text{Atom economy} = \frac{\text{Mass of desired product}}{\text{Total mass of all reactants}} \times 100$$

Importance of atom economy:

- High atom economy → produces less waste and is more sustainable.
- Helps protect the environment.
- Saves money in industrial processes.

Example1: Calculate the atom economy for the reaction:



(Molar masses: $\text{N}_2 = 28 \text{ g/mol}$, $\text{H}_2 = 2 \text{ g/mol}$, $\text{NH}_3 = 17 \text{ g/mol}$)

Solution:

Step#1: Find the total mass of desired product:

2 moles of NH_3 : $2 \times 17 = 34 \text{ g}$

Step#2: Find the total mass of reactants:

- $\text{N}_2 + 3 \text{H}_2$:

$$= 28 + (3 \times 2) = 28 + 6 = 34 \text{ g}$$

Step#3: Calculate atom economy:

Using formula:

Quantitative Analysis – GCSE Chemistry

$$\text{Atom economy} = \frac{\text{Mass of desired product}}{\text{Total mass of all reactants}} \times 100$$

Now plug the values into formula,

$$\text{Atom economy} = \frac{34}{34} \times 100$$

$$\text{Atom economy} = 100\%$$

Example2: Calculate the atom economy for the reaction:



(Molar masses: $\text{CH}_4 = 16 \text{ g/mol}$, $\text{Cl}_2 = 71 \text{ g/mol}$, $\text{CH}_2\text{Cl}_2 = 85 \text{ g/mol}$, $\text{HCl} = 36.5 \text{ g/mol}$)

Solution:

Step#1: Identify the desired product

- The desired product is CH_2Cl_2 (dichloromethane).
- The by-product is HCl .

Step#2: Calculate total mass of products

$$\begin{aligned} \text{Total Mass of all reactants} &= (1 \times 85) + (2 \times 36.5) \\ &= 85 + 73 = 158 \end{aligned}$$

Step#3: Calculate atom economy

$$\text{Atom economy} = \frac{\text{Mass of desired product}}{\text{Total mass of all reactants}} \times 100$$

Quantitative Analysis – GCSE Chemistry

Now plug the values into formula,

$$\text{Atom economy} = \frac{85}{158} \times 100$$

$$\text{Atom economy} = 53.8\%$$