

AQA GCSE Combined Science: Trilogy — Chemistry

Topic 10

Quantitative chemistry

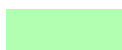
Specification 8464 · AQA

Free edition

Revision notes for one topic, free to download.

These are the summary notes only. The full edition of this booklet also carries the worked examples, the required practicals and the formula sheets, with every topic in one place.

Colour Codes



Definitions



Notes and warnings



Sub-topic headings

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Define Law of conservation of mass

- no atoms are lost or made in a chemical reaction, so the mass of the products equals the mass of the reactants.

Define Relative formula mass (Mr)

- the sum of the relative atomic masses of the atoms in the numbers shown in the formula.

Define Range

- largest value minus smallest value in a set of repeats.

HIGHER TIER

Define HT ONLY Avogadro constant

- the number of atoms, molecules or ions in one mole of a substance, 6.02×10^{23} per mole.

HIGHER TIER

Define HT ONLY Excess reactant

- a reactant added in more than enough quantity so the other reactant is all used up.

Define Solute

- the substance dissolved in the solvent to make the solution.

Define Relative atomic mass (Ar)

- the mass of an atom relative to carbon-12; read from the periodic table.

Define Uncertainty

- how far a measured value could differ from the true value, estimated from the range of repeats.

HIGHER TIER

Define HT ONLY Mole (mol)

- the unit of chemical amount; one mole has a mass in grams numerically equal to the Mr.

HIGHER TIER

Define HT ONLY Limiting reactant

- the reactant completely used up, which therefore limits the amount of product formed.

Define Concentration

- the mass of solute in a given volume of solution, measured in g/dm^3 .

10.1 Chemical measurements, conservation of mass and the quantitative interpretation of chemical equations

10.1.1 Conservation of mass and balanced chemical equations

- The **law of conservation of mass: no atoms are lost or made** during a chemical reaction, so the mass of the products equals the mass of the reactants. Atoms are only rearranged.
- So reactions can be represented by symbol equations balanced in terms of the number of atoms of each element on both sides.
- A multiplier in normal script before a formula ($2\text{H}_2\text{O}$) multiplies everything in that formula — 4 H and 2 O atoms. A **subscript within a formula** (H_2O) applies only to the atom it follows and is part of the substance's identity. When balancing, change only the multipliers in front.

10.1.3 Mass changes when a reactant or product is a gas

- Some reactions **appear** to involve a change in mass. This can usually be explained because a reactant or product is a gas whose mass has not been taken into account — the system is **not enclosed**, so gas can leave or enter.
- **Mass appears to increase** when a gas is a **reactant**: when a metal reacts with oxygen, the mass of the oxide is greater than the mass of the metal, because oxygen atoms from the air have joined the solid.
- **Mass appears to decrease** when a gas is a **product**: in the **thermal decomposition of metal carbonates**, carbon dioxide is produced and **escapes into the atmosphere**, leaving the metal oxide as the only solid product.
- **Particle model**: the gas particles spread out into the surroundings and are no longer on the balance. No atoms are created or destroyed — in a **sealed** container the total mass would not change.

WATCH OUT

Students often "fix" an equation by changing a subscript, writing H_2O_2 for H_2O . **Never change a subscript** — H_2O_2 is hydrogen peroxide, a different substance. Change only the large numbers in front.

10.1.2 Relative formula mass

- The **relative formula mass (M_r)** is the sum of the relative atomic masses of the atoms in the numbers shown in the formula. Ar values are on the **periodic table** given in the exam.
- Brackets multiply everything inside: $\text{Ca}(\text{NO}_3)_2$ contains 1 Ca, 2 N and 6 O.
- Comparing M_r on both sides checks conservation of mass: for $4\text{Al} + 3\text{O}_2 \rightarrow 2\text{Al}_2\text{O}_3$, reactants $(4 \times 27) + (3 \times 32) = 204$ and products $2 \times 102 = 204$.

10.1.4 Chemical measurements

- **Whenever a measurement is made there is always some uncertainty about the result obtained.**
- Repeat the measurement, discard any **anomalous** result, then take the **mean** of the rest.
- The **distribution (spread) of results** shows their precision: closely grouped = low uncertainty; widely spread = high uncertainty.
- Use the range of a set of measurements about the mean as the measure of uncertainty, quoted as **$\pm$ half the range**.

10.2 Use of amount of substance in relation to masses of pure substances

HIGHER TIER

10.2.1 HT ONLY Moles

- **HT ONLY** Chemical amounts are measured in **moles**; the symbol for the unit mole is **mol**.
- **HT ONLY** The mass of one mole of a substance in grams is numerically equal to its relative formula mass — one mole of carbon is 12 g, one mole of water is 18 g.
- **HT ONLY** One mole of a substance contains the same number of the stated particles — atoms, molecules or ions — as one mole of any other substance. That number is the Avogadro constant, 6.02×10^{23} per mole.
- **HT ONLY** Moles apply to atoms, molecules, ions, electrons, formulae and equations: one mole of carbon (C) contains the same number of atoms as there are molecules in one mole of carbon dioxide (CO_2).

ANALOGY

A **mole is the chemist's "dozen"**. A dozen eggs and a dozen bricks both contain 12 things but have very different masses. Likewise one mole of C and one mole of CO_2 both contain 6.02×10^{23} particles but weigh 12 g and 44 g. The mole is just a counting number, chosen so the count in grams matches the M_r .

WATCH OUT

Moles are not mass. A mole is a *count* of particles; a gram is a *mass*. One mole of H_2 weighs 2 g and one mole of I_2 weighs 254 g — same number of molecules, hugely different masses. Always convert mass to moles **before** using the ratio in a balanced equation, and back to mass at the end; never put masses straight into the ratio.

HIGHER TIER

10.2.3 HT ONLY Using moles to balance equations

- **HT ONLY** The balancing numbers can be calculated from the masses of reactants and products by converting the masses in grams to amounts in moles, then converting the numbers of moles to a **simple whole number ratio**.

ANALOGY

Making **cheese sandwiches**, each needing 2 slices of bread and 1 slice of cheese: with 10 slices of bread and 8 of cheese you can make only 5 sandwiches. The bread runs out first, so bread is **limiting** and 3 slices of cheese are left in **excess**. Buying more cheese gets you no extra sandwiches.

HIGHER TIER

10.2.5 Concentration of solutions

- Many reactions take place **in solution**. Concentration is measured as mass of solute per given volume of solution, e.g. **grams per dm^3 (g/dm^3)**.
- $1 \text{ dm}^3 = 1000 \text{ cm}^3 = 1 \text{ litre}$; convert cm^3 to dm^3 by **dividing by 1000**.
- You must be able to calculate the mass of solute in a given volume of solution of known concentration.
- **HT ONLY** Concentration depends on **both** the mass of solute and the volume of solution: it **increases** if more solute is dissolved in the same volume and **decreases** if the same mass is dissolved in a larger volume (diluting).

HIGHER TIER

10.2.2 HT ONLY Amounts of substances in equations

- **HT ONLY** The masses of reactants and products can be calculated from balanced symbol equations.
- **HT ONLY** Equations can be **interpreted in terms of moles**: $\text{Mg} + 2\text{HCl} \rightarrow \text{MgCl}_2 + \text{H}_2$ shows that **one mole** of magnesium reacts with **two moles** of hydrochloric acid to produce one mole of magnesium chloride and one mole of hydrogen gas.
- **HT ONLY** Route for any reacting-mass question: **mass** $\rightarrow$ **moles** ($n = m \div M_r$) $\rightarrow$ **ratio from the balanced equation** $\rightarrow$ **moles** $\rightarrow$ **mass** ($m = n \times M_r$).

HIGHER TIER

10.2.4 HT ONLY Limiting reactants

- **HT ONLY** In a reaction with two reactants it is common to use an **excess** of one to make sure **all** of the other is used up.
- **HT ONLY** The reactant **completely used up** is the **limiting reactant**, because **it limits the amount of product**.
- **HT ONLY** The amount of product is proportional to the amount of limiting reactant; adding more of the excess reactant makes no difference.
- **HT ONLY** To identify it, divide the moles of each reactant by its balancing number — the **smallest** answer is limiting.

NOTE

NOT REQUIRED BY THE SPECIFICATION

Combined Science: Trilogy does **not** include percentage yield, atom economy, concentration in mol/dm^3 , titration calculations, or the volumes of gases (the 24 dm^3 molar gas volume). Concentration is only ever needed in **g/dm^3** , and moles are **Higher tier only**.