KNOWLEDGE — Chemistry Topic 4 Chemical calculations — ORGANISER

Section 1: Chemical calculations Key Terms

Law of conservation of mass	**No atoms** are **destroyed** or **created** during a **chemical reaction.** The total mass of the products is the same as the total mass of the reactants. Some reactions **appear to give a change in mass**, but this is because a **gas may have escaped** from the reaction container.
Relative atomic mass (A_r)	The **average mass** of an **atom of an element** compared to Carbon-12.
Relative formula mass (M_r)	The **sum** of **all the atomic masses** of the atoms in a **formula** of a substance (e.g. CO_2).
Uncertainty	The **interval** within which the **true value** can be **expected to lie.** E.g. 25°C $\pm$ 2°C – the true value lies between 23°C and 27°C.
Mole (HT)	A measurement for the amount of a chemical. It is the amount of substance in the relative atomic or formula mass of a substance in grams. The **mass** (in grams) of **6.02×10^{23}** (the Avogadro constant) **atoms of an element.** Symbol: mol.
Balanced equation (HT)	Balanced symbol equations show **the number of moles that react.** e.g. $Ca + 2HCl \rightarrow CaCl_2 + H_2$ Shows one mole of Calcium reacting with two moles of hydrochloric acid to form one mole of Calcium chloride and one mole of hydrogen.
Limiting reactant (HT)	The **reactant** that **gets used up first** in a chemical reaction. It **limits the amount of product** formed.
Excess reactant (HT)	The reactant that is **not completely used up** in a chemical reaction. There is some reactant left at the end.
Concentration	A measure of the **number of particles** of a chemical in a **volume.** Can be measured in **g/dm^3**.
Decimetre^3 (dm^3)	A **measurement of volume.** Contains 1**000cm^3**.

Section 2: Calculating relative formula mass (M_r)

Add up all the atomic masses in a formula.	e.g. CO_2 Mass of C = 12. Mass of oxygen = 16. 12 + (2x16) = 44

Section 3: Calculating moles and masses (HT)

Number of moles = $\frac{\text{mass (g)}}{M_r}$	1) How many moles are there in 9.8g of sulfuric acid H_2SO_4? **Number of moles = $\frac{9.8}{98}$ = 0.1 moles** 2) What is the mass of 2.5 moles of Carbon dioxide? **Mass = 2.5 x 44 = 88g**

Section 4: Equations and calculations (HT)

Number of moles = $\frac{\text{mass (g)}}{M_r}$	1) What masses of reactants and products are involved in the balanced symbol equation $H_2 + Cl_2 \rightarrow 2HCl$ **Reactants: (2x1) + (2x35.5) = 73** **Products: 2 x 36.5 = 73** 2) What mass of oxygen will react with 72.0g of magnesium? $2Mg + O_2 \rightarrow 2MgO$ **Moles Mg = 72/12 = 3 moles** **Molar ratio Mg:O_2 is 2:1** **Moles O_2 = 3/2 = 1.5 moles** **Mass O_2 = 1.5 x 32 = 48g**

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Section 5: From masses to balanced equations (HT)

Number of moles = $\frac{\text{mass (g)}}{M_r}$	1) 8.08g of Potassium nitrate KNO_3 was decomposed on heating to form 6.8g of potassium nitrite KNO_2 and 1.28g of oxygen. a) Calculate the number of moles of KNO_3, KNO_2 and O_2 and hence **Moles KNO_3 = 8.08/101 = 0.08** **Moles KNO_2 = 6.8/85 = 0.08** **Moles O_2 = 1.28/32 = 0.04** b) Use your answers to a) to work out the simplest whole number ratio of these values and use this to write a balanced equation for the reaction. **Moles KNO_3: KNO_2 : O_2** **0.08 : 0.08 : 0.04** **2 : 2 : 1** **Hence equation is** **$2KNO_3 \rightarrow 2KNO_2 + O_2$**

Section 7: Expressing concentrations (in g/dm³)

If you are working in decimetres cubed (dm^3)

Concentration (g/dm^3) = $\frac{\text{mass of solute (g)}}{\text{volume } (dm^3)}$

If you are working in centimetres cubed (cm^3)

Concentration (g/dm^3) = $\frac{\text{mass of solute (g)} \times 1000}{\text{volume } (cm^3)}$

1) Calculate the concentration in g/dm^3 of 6g of magnesium chloride dissolved in 1.5 dm^3 of solution
   Concentration = 6/1.5 = 4 g/dm^3

2) Calculate the concentration in g/dm^3 of 40g of sodium hydroxide dissolved in 500 cm^3 of solution
   Concentration = 40/500 x 1000 = 80 g/dm^3

Section 6: Limiting reactants (HT)

Number of moles = $\frac{\text{mass (g)}}{M_r}$

Remember:

A **limiting reactant** is the **reactant** that **gets used up first** in a chemical reaction. It **limits the amount of product** formed.

Excess reactant is the **reactant** that is **not completely used up** in a chemical reaction. There is some reactant left at the end.

1) If you have 7.2g of magnesium reacting with 10.95g of dilute hydrochloric acid, which reactant is in excess?

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

Moles Mg = 7.2/24 = 0.3 mol
Moles HCl = 10.95/36.5 = 0.3 mol
From the balanced equation you see that 1 mole of Mg reacts with 2 moles of HCl.
Hence 0.3 mol of Mg requires 0.6 mol of HCl to react completely. We only have 0.3 mol of HCl so dilute hydrochloric acid is the limiting reactant.

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Section 8: Chemical calculations Key Terms (Triple)

Yield of a chemical reaction	Describes how much product is made
Percentage yield	Tells you how much product is made compared with the maximum amount that could be made.
Atom Economy	A measure of the amount of starting materials that end up as useful products
Titration	Used to measure accurately what volumes of acid and alkali react together completely.
Standard solution	A solution of known concentration.

Section 9: The yield of a chemical reaction (Triple)

Number of moles = $\frac{\text{mass (g)}}{M_r}$

Percentage yield = $\frac{\text{actual yield of product produced}}{\text{theoretical yield of product}} \times 100$

1) A gas fired kiln produced 100g of calcium oxide (CaO) from 200g of Limestone ($CaCO_3$). What is the percentage yield of calcium oxide produced? $CaCO_3 \rightarrow CaO + CO_2$

Moles of $CaCO_3$ = 200/100 = 2 mol
For every 1 mol of $CaCO_3$ we make 1 mol of CaO
Hence theoretical yield of CaO = 2 x 56g = 112g
Actual yield of CaO = 100g
Percentage yield = 100/112 x 100 = 89.3%

Factors affecting percentage yield
- Reaction may be reversible
- Some unwanted products may be formed
- Some of the desired product lost in handling/left on apparatus
- Reactants may be impure

Section 10: Atom economy (Triple)

Percentage atom economy = $\frac{\text{relative formula mass of desired product x 100}}{\text{sum of the relative formula masses of the reactants}}$

1) Calculate the atom economy for the production of dichloromethane CH_2Cl_2.
$CH_4 + 2Cl_2 \longrightarrow CH_2Cl_2 + 2HCl$

Relative formula mass desired product CH_2Cl_2 = 12 + 2 + (2x35.5) = 85
Sum of relative formula mass of all reactants = 12 + 4 + (2 x 71) = 158
Percentage atom economy = 85/158 x 100 = 53.8%

Section 11: Titrations (Triple)

A **Volumetric pipette** is used to measure out a fixed volume of solution
A **burette** is used to measure the volume of the solution added

Steps for carrying out a titration
- Wash a **volumetric pipette** with distilled water followed by some of the **alkali**
- Measure a known volume of alkali into a **conical flask** using the pipette
- Add a few drops of **indicator** to the solution in the conical flask and **swirl**
- Place a **white tile** under the flask
- Rinse a burette with distilled water followed by some of the acid, allowing some of the acid to pass through the tap (filling the jet)
- Fill the burette up to the mark using the acid
- Record initial reading on the burette
- Open tap to **slowly** release acid into the conical flask whilst **swirling**
- Keep on repeating this until the **indicator changes colour** (end point)
- Record final **volume reading** on the burette by reading the **bottom of the meniscus.**
- Work out the volume of acid (**titre**) that was run into the flask
- Repeat the whole process at least three times until you get **concordant titres**
- Calculate the **mean** titre
- Use results to calculate concentration of the alkali in mol/dm^3

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Chemical calculations (Triple)

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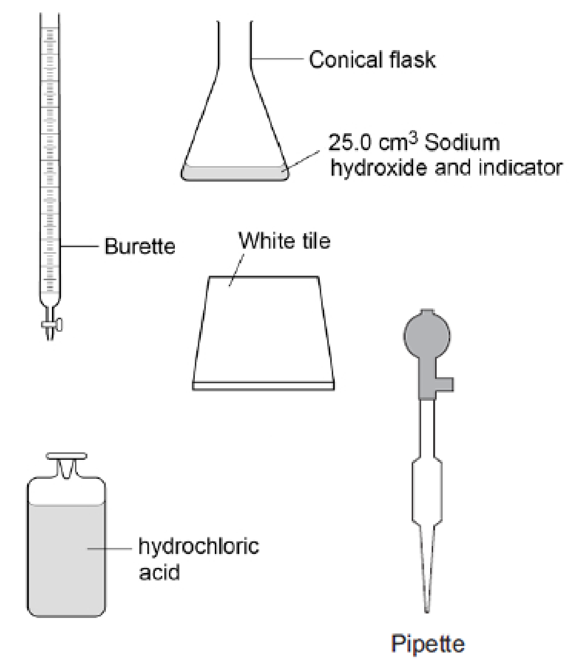
Section 12: Titration apparatus (Triple)



Section 13 (cont): Titration calculations (Triple & HT)

A student titrated hydrochloric acid with 0.10 mol/dm^3 sodium hydroxide solution. The method used is shown below:

- Pipette 25.0 cm^3 of sodium hydroxide solution into a conical flask.
- Add a few drops of Phenolphthalein indicator to the sodium hydroxide solution.
- Add hydrochloric acid solution from a burette until the end-point is reached.

The table below shows the students results:

	Titre 1	Titre 2	Titre 3	Titre 4	Titre 5
Volume HCl cm^3	13.60	12.10	11.10	12.15	12.15

The equation for the titration is: $HCl_{(aq)} + NaOH_{(aq)} \rightarrow NaCl_{(aq)} + H_2O_{(l)}$

1) Use concordant results in the table to calculate:
   a) The mean titre   b) Concentration of the hydrochloric acid solution

a) Concordant results are those within 0.10 cm^3 of each other.
Mean titre = $\frac{12.10 + 12.15 + 12.15}{3}$ = 12.13

b) Moles NaOH = 0.1 x 25/1000 = 0.0025
Moles HCl = Moles NaOH = 0.0025
Concentration HCl = 0.0025 x 1000/12.13 = 0.206 mol/dm^3

Section 13: Titration calculations (Triple & HT)

Concentration (mol/dm^3) = $\frac{\text{number of moles x 1000}}{\text{volume (cm}^3\text{)}}$

1) In a titration, 20cm^3 of 0.2 mol/dm^3 HCl reacted with 50cm^3 of NaOH. Calculate the concentration of the sodium hydroxide.

$NaOH + HCl \longrightarrow NaCl + H_2O$

Moles = Conc x vol/1000
hence moles HCl = 0.2 x 20/1000 = 0.004 mol
Ratio of HCl: NaOH 1:1 hence moles of NaOH is 0.004 mol
Concentration NaOH = 0.004 x 1000/50 = 0.08 mol/dm^3

Section 14: Volume of gases (Triple & HT)

Number of moles of gas = $\frac{\text{volume of gas (dm}^3\text{)}}{24 \text{ dm}^3}$ or $\frac{\text{volume of gas (cm}^3\text{)}}{24000 \text{ cm}^3}$

2) How many moles of gas are present in 48 dm^3 of $CO_{2(g)}$

Moles = 48/24 = 2 moles

2) Calculate the volume of gas (in cm^3) in 1.5 moles of N_2O_4

Volume = 1.5 x 24000 = 36000cm^3