

3.2.1 Quantitative measurements and uncertainty

Name: _____ Class: _____ Date: _____

Total: 24 marks

KEY WORDS molar volume

- limiting reagent
- percentage uncertainty

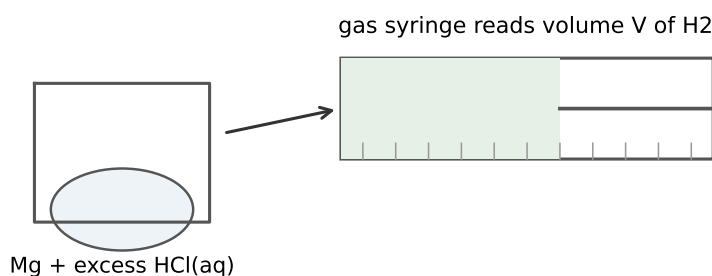
Objective

Handle the quantitative side of practical chemistry: molar volume from a gas syringe, proving which reagent is in excess, maximum product mass, and measurement uncertainty from apparatus resolution. Original practice for WCH13's calculation demands (Summer 2025 Q4e, Q5a pattern; CP1 context).

1 Key knowledge and worked examples

■ Molar volume by gas syringe

A weighed mass of magnesium reacts with excess acid; the syringe reads the hydrogen volume.



$n(H_2)$ from the mass of magnesium; $V_m = V / n$ (room conditions)

Worked check. 0.120 g Mg (A_r 24.3) gives 118 cm³ H₂ at room conditions: $n = 0.120/24.3 = 4.94 \times 10^{-3}$ mol; $V_m = V/n = 118/4.94 \times 10^{-3} = 23\,900$ cm³ mol⁻¹ ≈ 23.9 dm³ mol⁻¹.

■ Excess and maximum mass

Compare amounts, not masses. **Worked check.** 50.0 cm^3 of $1.00 \text{ mol dm}^{-3} \text{ ZnSO}_4$ holds $n = 0.0500 \times 1.00 = 0.0500 \text{ mol}$; 2.20 g Mg is $2.20/24.3 = 0.0905 \text{ mol}$ – magnesium is in excess, so the zinc ions limit the reaction and any enthalpy-per-mole uses 0.0500 mol .

From 2.00 g Fe (A_r 55.8), with $M_r(\text{FeCl}_3) = 55.8 + 3 \times 35.5 = 162.3$: $n = 2.00/55.8 = 0.0358 \text{ mol}$; maximum mass = $0.0358 \times 162.3 = 5.82 \text{ g}$. 5.80 is rejected – under-claiming the supported figures.

■ Uncertainty from the instrument

Each reading carries $\pm$ half a division (a 50 cm^3 burette: $\pm 0.05 \text{ cm}^3$); a **difference of two readings** carries $\pm 0.10 \text{ cm}^3$. Percentage uncertainty = (uncertainty $\div$ measured value) $\times 100$. Reduce it by a bigger measured value (larger titre) or a finer instrument – never by pretending.

2 Practice

2.1 0.240 g of magnesium gives 236 cm^3 of hydrogen. Calculate the molar volume in $\text{dm}^3 \text{ mol}^{-1}$ ($A_r \text{ Mg} = 24.3$). [3]

2.2 Show, by calculation, whether 25.0 cm^3 of $0.500 \text{ mol dm}^{-3}$ acid or 0.30 g of magnesium is in excess. [3]

2.3 A titre is read as 21.40 cm^3 from initial 0.60 cm^3 . State the absolute uncertainty of the delivered volume and its percentage uncertainty. [3]

2.4 Calculate the maximum mass of iron(III) chloride from 5.00 g of iron (A_r 55.8; A_r Cl 35.5). [3]

3 Exam-style questions

3.1 In a molar-volume experiment, the syringe reads 96 cm³ after 0.0970 g of magnesium fully reacts with excess dilute hydrochloric acid. Calculate the molar volume, and give two reasons why the experimental value may be below 24 dm³ mol⁻¹. [5]

3.2 1.50 g of anhydrous sodium carbonate (M_r 106) is dissolved and made up to 250 cm³. Calculate the concentration, and the maximum mass of carbon dioxide ($M = 44.0$) it could release with excess acid. [4]

3.3 A student claims a gas syringe ($\pm 0.5 \text{ cm}^3$ on a 100 cm^3 reading) is “more precise than a burette ($\pm 0.10 \text{ cm}^3$ on a 25.00 cm^3 titre)”. Evaluate the claim with percentage uncertainties. [3]

Solutions

Original-task marking: M1 method, A1 accuracy, B1 reasoning.

2.1 $n = 0.240/24.3 = 9.88 \times 10^{-3} \text{ mol}$; $V_m = 236/9.88 \times 10^{-3} = 23\,900 \text{ cm}^3 \text{ mol}^{-1}$; $= 23.9 \text{ dm}^3 \text{ mol}^{-1}$.

2.2 Acid: $0.0250 \times 0.500 = 0.0125 \text{ mol}$; Mg: $0.30/24.3 = 0.0123 \text{ mol}$; Mg is (slightly) in excess – acid limits.

2.3 Delivered $= 21.40 - 0.60 = 20.80 \text{ cm}^3$ with $\pm 0.10 \text{ cm}^3$ (two readings); $0.10/20.80 \times 100 = 0.48\%$.

2.4 $n = 5.00/55.8 = 0.0896 \text{ mol}$; $M_r = 162.3$; mass $= 0.0896 \times 162.3 = 14.5 \text{ g}$.

3.1 $n = 0.0970/24.3 = 3.99 \times 10^{-3} \text{ mol}$; $V_m = 96/3.99 \times 10^{-3} = 24\,060 \approx 24.1 \text{ dm}^3 \text{ mol}^{-1}$ – in fact slightly above 24. Reasons a value could read low: gas leaked from the syringe or connections; some hydrogen dissolved in the solution before the reading; magnesium partly oxidised so less gas per recorded mass; reading taken before the reaction finished.

3.2 $n = 1.50/106 = 0.0142 \text{ mol}$ in 0.250 dm^3 ; $c = 0.0142/0.250 = 0.0566 \text{ mol dm}^{-3}$. $\text{Na}_2\text{CO}_3 + 2\text{HCl} \rightarrow 2\text{NaCl} + \text{H}_2\text{O} + \text{CO}_2$: 1 mol carbonate $\rightarrow$ 1 mol CO_2 ; mass $= 0.0142 \times 44.0 = 0.623 \text{ g}$.

3.3 Syringe: $0.5/100 \times 100 = 0.5\%$. Burette: $0.10/25.00 \times 100 = 0.40\%$. The burette's percentage uncertainty is lower, so the claim is wrong in percentage terms – though the syringe reads a larger volume, which hides its coarser resolution.