Amount of Substance III

OCR A Chemistry A H432 | Specification-led student notes

SPEC → CRACK IT → WORKED EXAMPLE → TEST IT → DONE

SPECIFICATION COVERAGE

OCR A REF	THIS PACK TEACHES	SECTIONS
2.1.3(e)(iii), (g)	Concentration, dilution and solution calculations	1–2, 8–10
2.1.4(a)–(c)	OCR acids companion: acids, alkalis, neutralisation and salts	4–5
2.1.3(i); 2.1.4(d), (e)	Standard solutions, titrations and measurement skills	3, 6–10
2.1.3(a)(v), (e)(ii), (f), (g), (i)	Molar gas volume, pV = nRT and gas measurements	11–13
2.1.3(h), (j)	Percentage yield, atom economy and sustainability	14–15
Combined application	Original mixed practice and complete worked answers	Tests 16–17; answers

YOUR AIM Turn measured masses and volumes into amounts, apply the reaction ratio and calculate a justified result with correct units.

LESSON BOUNDARY Builds on Parts I and II. Includes the OCR acids companion and PAG1/PAG2 skills. Quantitative pH, K_a and buffers belong to later study.

Mapped to OCR A Chemistry A H432, specification version 3.1 (May 2026)

Keep these distinctions clear

M is molar mass in g mol^{-1}. M_r is a relative mass and has no unit. Use n = m/M for mass calculations. For solutions, V is in dm^3 when using c in mol dm^{-3}. For pV = nRT, V must be in m^3.

Attempt each TEST IT before checking the answers. Show the equation, substitutions, units and final result. Retain calculator digits until the final answer.

1. Concentration links amount and volume

SPEC 2.1.3(e)(iii), (g) Use solution volume and concentration in mol dm^{-3} and g dm^{-3}.

CRACK IT Concentration tells you how much solute is present per unit volume of solution. Always identify whether "how much" means moles or grams.

$$c = n/V \qquad n = cV \qquad V = n/c$$

Here c is in mol dm^{-3}, n is in mol and V is the final solution volume in dm^3. Convert cm^3 to dm^3 by dividing by 1000: 25.0 cm^3 = 0.0250 dm^3.

$$\text{mass concentration} = m/V = cM \qquad (\text{g dm}^{-3})$$

WORKED EXAMPLE

5.30 g of Na_2CO_3 is dissolved and made up to 250.0 cm^3 of solution. $M(Na_2CO_3)$ = 106.0 g mol^{-1}. Find both concentrations.

$$n = m/M = 5.30/106.0 = 0.0500 \text{ mol}$$

$$V = 250.0/1000 = 0.2500 \text{ dm}^3$$

$$c = n/V = 0.0500/0.2500 = 0.200 \text{ mol dm}^{-3}$$

$$\text{Mass concentration} = 5.30/0.2500 = 21.2 \text{ g dm}^{-3}$$

EXAM CHECK "Made up to 250 cm^3" means a final solution volume of 250 cm^3. It does not mean adding 250 cm^3 of water. A concentration in g dm^{-3} cannot be substituted directly into n = cV.

TEST IT 1 4.68 g of NaCl is dissolved and made up to 400.0 cm^3 of solution. M(NaCl) = 58.5 g mol^{-1}. Calculate its concentration in mol dm^{-3} and in g dm^{-3}.

[3 marks]

✓ DONE WHEN You can choose m/V or n/V from the required unit and convert solution volume before calculating.

2. Dilution changes concentration

SPEC 2.1.3(e)(iii), (g) Calculate concentrations and volumes when a solution is diluted.

CRACK IT Adding solvent changes the volume and concentration. It does not change the amount of dissolved solute in the transferred sample.

$$n \text{ before dilution} = n \text{ after dilution} \qquad c_1V_1 = c_2V_2$$

Use $c_1V_1 = c_2V_2$ only when the same solute is being diluted without reacting. The two volumes may both be in cm^3 because the conversion factor cancels; use dm^3 if you separately calculate $n = cV$.

WORKED EXAMPLE

25.0 cm^3 of 0.800 mol dm^{-3} NaCl is diluted to 200.0 cm^3.

$$n = 0.800 \times (25.0/1000) = 0.0200 \text{ mol}$$

$$c \text{ after dilution} = 0.0200/0.2000 = 0.100 \text{ mol } dm^{-3}$$

The final volume is eight times larger, so the concentration is eight times smaller.

Planning the volume to transfer

Rearrange before entering numbers: $V_1 = c_2V_2/c_1$. Use a volumetric pipette or another suitable accurate delivery device to transfer the calculated stock volume, then dilute to the required final volume.

EXAM CHECK Do not use the volume of water added as V_2. The dilution equation compares the initial sample volume with the final solution volume.

TEST IT 2 (a) 20.0 cm^3 of 0.750 mol dm^{-3} solution is diluted to 250.0 cm^3. Calculate the new concentration. [2] (b) Calculate the volume of 0.400 mol dm^{-3} stock solution needed to prepare 500.0 cm^3 of 0.0200 mol dm^{-3} solution. [2]

[4 marks]

✓ DONE WHEN You can track the same amount of solute through a dilution and check that dilution lowers concentration.

3. Prepare a standard solution

SPEC 2.1.4(d); 2.1.3(i) Prepare a solution of known concentration accurately. PAG2.

CRACK IT A standard solution has an accurately known concentration. Accurate mass, complete transfer and the correct final volume all matter.

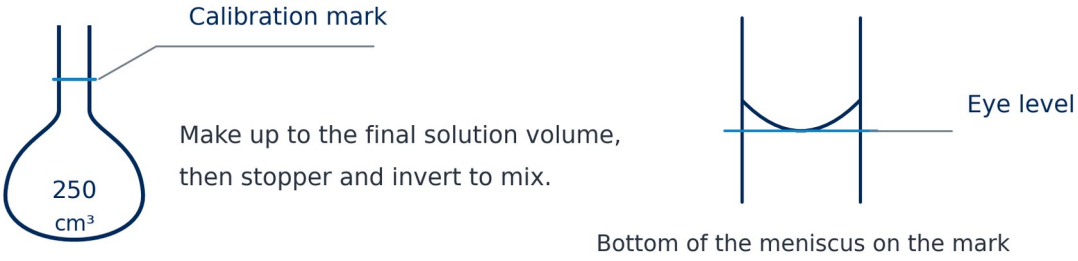
WORKED EXAMPLE

Prepare 250.0 cm^3 of 0.0500 mol dm^{-3} Na_2CO_3. M = 106.0 g mol^{-1}.

$$n = cV = 0.0500 \times 0.2500 = 0.01250 \text{ mol}$$

m = nM = 0.01250 × 106.0 = 1.325 g. Record the mass actually weighed and use it to obtain the actual concentration.

1 Weigh the solid accurately, for example by difference. Dissolve it fully in deionised water in a beaker.
2 Transfer through a funnel into a volumetric flask. Rinse the beaker, glass rod and funnel into the flask.
3 If warm, allow the solution to cool to room temperature. Add water to near the mark, then add the last drops carefully.
4 Set the bottom of the meniscus on the mark at eye level. Stopper and invert repeatedly to mix.



EXAM CHECK Rinsing transfers solute that would otherwise be left behind. If you overshoot the mark, removing some mixed solution will not restore the required concentration; prepare the solution again.

TEST IT 3 Calculate the mass of KNO_3 needed to prepare 250.0 cm^3 of 0.100 mol dm^{-3} solution (M = 101.1 g mol^{-1}). [2]
Describe how to prepare this solution accurately from the weighed solid. [4]

[6 marks]

✓ **DONE WHEN** You can explain how each preparation step protects the calculated amount or final volume.

4. OCR acids and alkalis

SPEC 2.1.4(a), (b) Know common formulae and explain strong and weak acids qualitatively.

CRACK IT Strong and weak describe the extent of dissociation. Concentrated and dilute describe the amount of solute per volume. These are different ideas.

COMMON ACIDS	COMMON ALKALIS
Hydrochloric acid: HCl Sulfuric acid: H_2SO_4 Nitric acid: HNO_3 Ethanoic acid: CH_3COOH	Sodium hydroxide: NaOH Potassium hydroxide: KOH Ammonia: NH_3

Acids release H^+ ions in aqueous solution. Alkalis are water-soluble bases that produce OH^- ions in aqueous solution. NH_3 produces OH^- by reacting with water: $NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$.

A strong acid dissociates essentially completely in aqueous solution. A weak acid dissociates only partially. HCl and HNO_3 are strong acids; H_2SO_4 is also classified as a strong acid. CH_3COOH is weak.

$$HCl(aq) \rightarrow H^+(aq) + Cl^-(aq)$$

$$CH_3COOH(aq) \rightleftharpoons H^+(aq) + CH_3COO^-(aq)$$

WORKED EXAMPLE

Equal concentrations of HCl and CH_3COOH do not give equal concentrations of H^+ ions. HCl dissociates much more fully, so its solution has the greater H^+ concentration.

TEST IT 4 (a) Give the formulae of sulfuric acid and ammonia. [2]
(b) Explain the difference between a weak acid and a dilute acid. [2]
(c) Equal volumes of equal-concentration HCl and CH_3COOH are completely neutralised by NaOH. Compare the amounts of NaOH needed and explain your answer. [2]

[6 marks]

✓ DONE WHEN You can distinguish acid strength from concentration and avoid treating a weak acid as “less acid”.

5. Neutralisation and salts

SPEC 2.1.4(c) Write full equations for acids reacting with alkalis, metal oxides and carbonates.

CRACK IT The acid supplies H^+. The reacting base removes H^+. The remaining ions determine the salt.

$$H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$$

Acid + metal hydroxide → salt + water. Acid + metal oxide → salt + water. Acid + carbonate → salt + water + carbon dioxide.

ACID	SALT TYPE
HCl	chloride
H_2SO_4	sulfate
HNO_3	nitrate
CH_3COOH	ethanoate

WORKED EXAMPLES

$$2HCl(aq) + MgO(s) \rightarrow MgCl_2(aq) + H_2O(l)$$

$$H_2SO_4(aq) + 2NaOH(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(l)$$

$$2HNO_3(aq) + CaCO_3(s) \rightarrow Ca(NO_3)_2(aq) + H_2O(l) + CO_2(g)$$

Ammonia accepts H^+ to form NH_4^+. For example, $NH_3(aq) + HCl(aq) \rightarrow NH_4Cl(aq)$. This forms an ammonium salt; the equation does not need water as a product.

EXAM CHECK Work out the salt formula from ion charges first. For example, Cu^{2+} needs two NO_3^- ions, giving $Cu(NO_3)_2$. Then balance the equation.

TEST IT 5 Write balanced equations for:
(a) copper(II) oxide reacting with nitric acid; [2]
(b) potassium carbonate reacting with hydrochloric acid; [2]
(c) the ionic reaction between H^+ and OH^- ions. [1]
State symbols are not required.

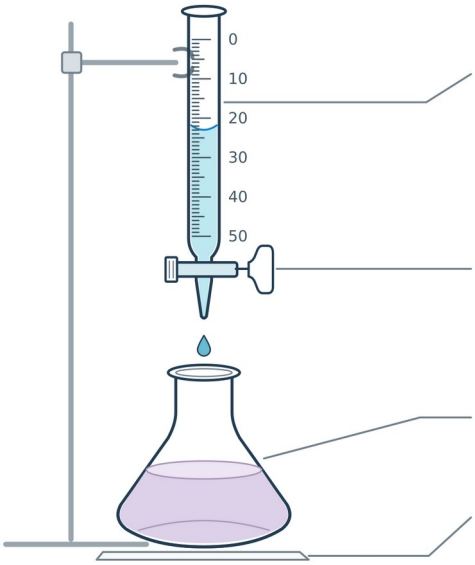
[5 marks]

✓ **DONE WHEN** You can construct the salt formula and include CO_2 when a carbonate reacts with an acid.

6. Carry out an accurate titration

SPEC 2.1.4(d); 2.1.3(i) Use a pipette, burette and suitable indicator. PAG2.

CRACK IT A pipette fixes the sample volume. The burette measures how much of the other solution is needed to reach the end point.



Burette
Titrant of known concentration.
Read the volume delivered.

Tap and delivery tip
Add dropwise near the end point.
Keep the tip filled, with no air bubble.

Conical flask
Pipetted sample of known volume
and a few drops of indicator.

White tile
Makes the colour change easier to see.

Rinse the burette and pipette with deionised water, then with the solutions they will contain. Use a pipette filler. Rinse the conical flask with deionised water only. Fill the burette tip, remove air bubbles and remove the filling funnel.

Pipette the sample into the flask and add a few drops of a suitable indicator. Record the initial burette reading. Do a rough titration, then repeat with fresh samples, swirling and adding dropwise near the end point. Stop at the first permanent colour change.

Read the bottom of a colourless meniscus at eye level. Record readings to the precision specified, commonly to the nearest 0.05 cm^3 (two decimal places). Repeat until concordant titres are obtained.

Typical indicator choices: phenolphthalein for weak acid + strong alkali; methyl orange for strong acid + weak alkali. Either can be suitable for strong acid + strong alkali. Follow the stated method.

WORKED EXAMPLE

A pipette contains residual water before the sample is measured. The sample is diluted, so the aliquot contains fewer moles of solute. Less titrant is needed than for a correctly rinsed pipette.

TEST IT 6 (a) Explain why deionised water left in the conical flask does not change the titre. [2]
(b) An air bubble in the burette tip is expelled during the titration. Explain its effect on the measured titre. [2]
(c) State how overshooting the end point affects the titre. [1]

[5 marks]

✓ DONE WHEN You can link a practical error to the amount reacting or to the volume recorded.

7. Select titres and calculate uncertainty

SPEC 2.1.4(e); 1.1.3(c), 1.1.4(c) Process titration results and evaluate measurement uncertainty.

CRACK IT Titre = final reading − initial reading. Use concordant accurate titres, not the rough result, to calculate a mean.

Concordant titres are within 0.10 cm³ of each other. Repeat until you obtain a consistent set. Do not include an outlying result just because it is available.

RUN	INITIAL / cm³	FINAL / cm³	TITRE / cm³
Rough	0.00	24.85	24.85
1	0.10	24.20	24.10
2	0.20	24.40	24.20
3	0.00	24.60	24.60

WORKED EXAMPLE

Use runs 1 and 2: mean = (24.10 + 24.20)/2 = 24.15 cm³.

If each burette reading has uncertainty ±0.05 cm³, a titre uses two readings: absolute uncertainty = ±0.10 cm³.

Percentage uncertainty = (0.10/24.15) × 100 = 0.41%.

EXAM CHECK Use the stated apparatus uncertainty. Two decimal places describe the reading precision; they do not automatically mean an uncertainty of ±0.01 cm³. Larger titres reduce percentage uncertainty for the same absolute uncertainty.

TEST IT 7 For the accurate titrations below, calculate (a) all three titres [1], (b) the appropriate mean titre, stating which results you used [2], and (c) its percentage uncertainty if each reading has uncertainty ±0.05 cm³. [2]

RUN	INITIAL / cm³	FINAL / cm³
1	0.10	19.90
2	19.90	39.80
3	0.05	20.35

[5 marks]

✓ **DONE WHEN** You can select the correct mean and account for both readings in a titre.

8. Use the titration mole ratio

SPEC 2.1.3(e)(iii), (g); 2.1.4(e) Calculate an unknown concentration from a titration.

CRACK IT Known concentration and volume give moles. The equation links those moles to the other substance. Divide by that substance's own volume.

WORKED EXAMPLE

25.00 cm³ of 0.0500 mol dm⁻³ Na_2CO_3 reacts with 23.60 cm³ of HCl. Find c(HCl).

$$Na_2CO_3 + 2HCl \rightarrow 2NaCl + H_2O + CO_2$$

QUANTITY	Na_2CO_3	HCl
V / dm³	0.02500	0.02360
c / mol dm⁻³	0.0500	0.105932…
n / mol	**0.001250**	**0.002500**

1 n = cV → 2 multiply n by 2 → 3 c = n/V

1 $n(Na_2CO_3) = 0.0500 \times 0.02500 = 0.001250$ mol.
2 $n(HCl) = 2 \times 0.001250 = 0.002500$ mol.
3 $c(HCl) = 0.002500/0.02360 = 0.106$ mol dm⁻³ (3 s.f.).

EXAM CHECK $c_1V_1 = c_2V_2$ only works directly for a 1:1 reaction. Use the balanced equation when coefficients differ. Do not use the combined volume of both solutions.

TEST IT 8 25.00 cm³ of sulfuric acid reacts with 22.40 cm³ of 0.150 mol dm⁻³ NaOH.
$H_2SO_4 + 2NaOH \rightarrow Na_2SO_4 + 2H_2O$
Calculate $c(H_2SO_4)$ in mol dm⁻³ [3] and its mass concentration in g dm⁻³ [1]. $M(H_2SO_4) = 98.1$ g mol⁻¹.

[4 marks]

✓ DONE WHEN You can use a non-1:1 ratio and keep the acid and alkali volumes attached to the correct substances.

9. Scale from a sample to the whole solution

SPEC 2.1.3(e)(iii), (g); 2.1.4(e) Handle dilutions, aliquots and unfamiliar acids.

CRACK IT A titration tells you the amount in the sample you titrated. Scale up only when you need the amount in the full flask.

An aliquot is a measured portion of a solution. If 25.00 cm^3 is taken from 250.0 cm^3 of well-mixed solution, it contains one tenth of the total amount of solute.

WORKED EXAMPLE

10.00 cm^3 of ethanoic acid solution is diluted to 250.0 cm^3. A 25.00 cm^3 aliquot requires 20.00 cm^3 of 0.1000 mol dm^{-3} NaOH. Find the original acid concentration.

$$CH_3COOH + NaOH \rightarrow CH_3COONa + H_2O$$

STAGE	AMOUNT OF ACID / mol
In titrated 25.00 cm^3	0.1000 × 0.02000 = 0.002000
In full 250.0 cm^3	0.002000 × (250.0/25.00) = 0.02000
In original 10.00 cm^3	0.02000 (dilution did not change n)

$$c(\text{original}) = 0.02000/0.01000 = 2.000 \text{ mol } dm^{-3}$$

EXAM CHECK “Multiply by ten” is not a universal step. Calculate full volume ÷ aliquot volume. For an unfamiliar acid, use the supplied equation to determine how many moles of base react per mole of acid.

TEST IT 9 1.920 g of a pure acid H_3A is dissolved and made up to 200.0 cm^3. A 20.00 cm^3 aliquot reacts with 24.00 cm^3 of 0.1000 mol dm^{-3} NaOH.

$H_3A + 3NaOH \rightarrow Na_3A + 3H_2O$

Determine the molar mass of H_3A. Give your answer to 4 significant figures.

[5 marks]

✓ **DONE WHEN** You can distinguish amount in the aliquot, amount in the flask and the original concentration.

10. Use a titration to measure what remains

SPEC 2.1.3(g); 2.1.4(e) Apply mole ratios to an unfamiliar titration procedure.

CRACK IT If a sample reacts with excess acid, a later titration measures the acid left over. Subtract remaining acid from the amount initially added.

This is called a back titration. The arithmetic uses the same equations as a direct titration, but you must identify which reaction each measured amount belongs to.

WORKED EXAMPLE

A 0.250 g limestone sample reacts with 25.00 cm^3 of 0.200 mol dm^{-3} HCl. The remaining acid needs 10.00 cm^3 of 0.100 mol dm^{-3} NaOH. Only $CaCO_3$ in the sample reacts. Find its percentage purity.

$$CaCO_3 + 2HCl \rightarrow CaCl_2 + H_2O + CO_2$$

$$HCl + NaOH \rightarrow NaCl + H_2O$$

ACID ACCOUNT	n(HCl) / mol
Initially added	0.200 × 0.02500 = 0.005000
Remaining	0.100 × 0.01000 = 0.001000
Used by $CaCO_3$	**0.005000 − 0.001000 = 0.004000**

$n(CaCO_3)$ = 0.004000/2 = 0.002000 mol.
$m(CaCO_3)$ = 0.002000 × 100.1 = 0.2002 g. Purity = (0.2002/0.250) × 100 = 80.1%.

EXAM CHECK Subtract amounts in mol, then apply the reaction ratio. The titre does not directly measure the amount that reacted with the solid.

TEST IT 10 A 0.200 g sample containing MgO reacts with 50.00 cm^3 of 0.200 mol dm^{-3} HCl. The remaining acid requires 20.00 cm^3 of 0.100 mol dm^{-3} NaOH. Only MgO reacts with the acid.
$MgO + 2HCl \rightarrow MgCl_2 + H_2O$; $HCl + NaOH \rightarrow NaCl + H_2O$
Calculate the percentage by mass of MgO. M(MgO) = 40.3 g mol^{-1}.

[5 marks]

✓ DONE WHEN You can separate acid added, acid remaining and acid consumed before using the solid's mole ratio.

11. Gas volumes at RTP

SPEC 2.1.3(a)(v), (e)(ii), (g) Use molar gas volume and gas stoichiometry.

CRACK IT Molar gas volume is gas volume per mole. At room temperature and pressure, OCR uses 24.0 dm^3 mol^{-1}.

$$n = V/24.0 \quad (V \text{ in } dm^3) \qquad n = V/24\,000 \quad (V \text{ in } cm^3)$$

For gases at the same temperature and pressure, volume ratios equal mole ratios. You can therefore use equation coefficients directly for gas-to-gas volume calculations. Count only substances that are gases under the stated conditions.

WORKED EXAMPLE

0.486 g of Mg reacts completely with excess HCl. Find the volume of H_2 at RTP. M(Mg) = 24.3 g mol^{-1}.

$$Mg + 2HCl \rightarrow MgCl_2 + H_2$$

QUANTITY	Mg	H_2
m / g	0.486	not needed
M / g mol^{-1}	24.3	not needed
n / mol	0.486/24.3 = 0.0200	0.0200 (1:1 ratio)
V at RTP	**not applicable**	**0.0200 × 24.0 = 0.480 dm^3**

1 n = m/M → 2 equation ratio → 3 V = n × 24.0

0.480 dm^3 = 480 cm^3. The same result follows from 0.0200 × 24 000.

EXAM CHECK The value 24.0 applies at RTP. If pressure and temperature are given at other conditions, use pV = nRT.

TEST IT 11 (a) 0.327 g of Zn reacts completely with excess HCl. Calculate the volume of H_2 at RTP in cm^3. M(Zn) = 65.4 g mol^{-1}. [3]

$Zn + 2HCl \rightarrow ZnCl_2 + H_2$

(b) $N_2 + 3H_2 \rightarrow 2NH_3$. Assuming complete reaction, calculate the volume of NH_3 formed from 12.0 dm^3 of H_2 with excess N_2, all at the same temperature and pressure. [2]

[5 marks]

✓ **DONE WHEN** You can use 24.0 or 24 000 with the matching volume unit and apply a gas-volume ratio.

12. Use the ideal gas equation

SPEC 2.1.3(f) Use pV = nRT with quantities in SI units.

CRACK IT Convert the data before substitution. The most common difficulty is the units, not the rearrangement.

$$pV = nRT \qquad n = pV/(RT) \qquad V = nRT/p$$

SYMBOL	REQUIRED UNIT	CONVERSION
p	Pa	kPa × 1000
V	m^3	$dm^3 \div 1000$; $cm^3 \div 1\,000\,000$
n	mol	use n = m/M if mass is given
T	K	temperature in °C + 273
R	J mol^{-1} K^{-1}	8.314 (OCR data sheet)

WORKED EXAMPLE

Find the amount of gas in 100 cm^3 at 101 kPa and 27 °C.

p = 101 000 Pa; V = 1.00×10^{-4} m^3; T = 300 K.

$$n = (101\,000 \times 1.00 \times 10^{-4})/(8.314 \times 300)$$

$$n = 4.05 \times 10^{-3} \text{ mol (3 s.f.).}$$

The precise Celsius-to-kelvin offset is 273.15. Using 273 is the usual A-level approximation; use any conversion specified in the question. In this pack, calculations use +273.

EXAM CHECK A dm^3 is 10^{-3} m^3; a cm^3 is 10^{-6} m^3. Never substitute °C into the ideal gas equation. Keep the full numerator and denominator together on the calculator.

TEST IT 12 A gas occupies 1.50 dm^3 at 95.0 kPa and 35 °C. Calculate its amount in mol. Use R = 8.314 J mol^{-1} K^{-1} and give the answer to 3 significant figures.

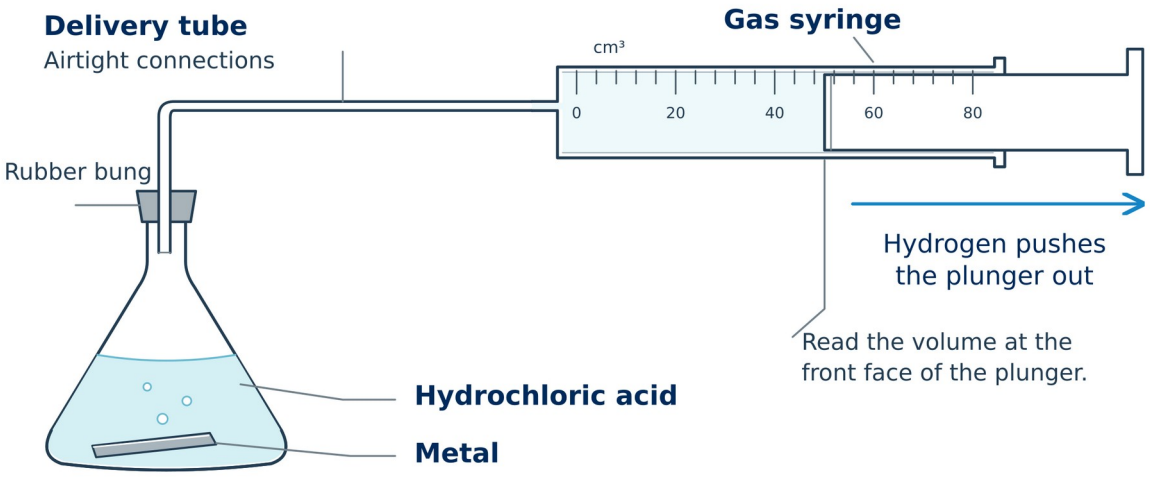
[4 marks]

✓ DONE WHEN You can convert every given quantity and rearrange the ideal gas equation for the unknown.

13. Gas measurements and molar mass

SPEC 2.1.3(e), (f), (i) Measure gas volume and combine gas data with mass. PAG1.

CRACK IT A measured gas volume gives an amount. Combine that amount with the sample mass to find M = m/n.



Check for leaks and allow the syringe piston to move freely. Arrange the reaction so that gas is not lost before collection begins. Record the final volume once the reaction is complete and the gas is at the temperature used in your calculation.

Collection over water can be used for gases that are sufficiently insoluble. A gas that dissolves in water can give a volume that is too low; a gas syringe avoids that source of loss.

WORKED EXAMPLE

A 0.184 g gas sample occupies 100 cm³ at 100 kPa and 27 °C. Calculate its molar mass.

$$n = (100\,000 \times 1.00 \times 10^{-4})/(8.314 \times 300) = 0.00400946\ldots \text{ mol}$$

$$M = 0.184/0.00400946\ldots = 45.9 \text{ g mol}^{-1} \text{ (3 s.f.)}.$$

The corresponding relative molecular mass, M_r, is 45.9, with no unit.

EXAM CHECK For a fixed measured sample mass, losing some of the gas lowers the measured volume and calculated n. Dividing the mass by this smaller n makes the calculated M too high.

TEST IT 13 A 0.320 g gas sample occupies 250 cm³ at 99.0 kPa and 27 °C.
(a) Calculate its molar mass using R = 8.314 J mol^{-1} K^{-1}. [4]
(b) Explain how gas escaping before its volume is measured would affect the calculated molar mass. [2]

[6 marks]

✓ DONE WHEN You can calculate M from gas data and trace the direction of an experimental error.

14. Percentage yield compares actual with theoretical

SPEC 2.1.3(h)(i) Calculate percentage yield and related quantities.

CRACK IT First calculate the theoretical amount from the limiting reactant. Then compare the actual amount of the same product with that maximum.

percentage yield = (actual yield / theoretical yield) × 100

WORKED EXAMPLE

10.0 g of $CaCO_3$ is heated. 4.48 g of CaO is collected. $M(CaCO_3) = 100.1$ and $M(CaO) = 56.1$ g mol^{-1}. Calculate the percentage yield.

$$CaCO_3 \rightarrow CaO + CO_2$$

QUANTITY	$CaCO_3$	CaO theoretical
m / g	10.0	5.60439…
M / g mol^{-1}	100.1	56.1
n / mol	10.0/100.1 = 0.099900…	0.099900… (1:1)

n = m/M → 1:1 ratio → m = nM → compare yields

percentage yield = (4.48/5.60439…) × 100 = 79.9%

Yield may be reduced by incomplete reaction, competing reactions or loss during transfer and purification. A wet or impure product can give an apparent yield above 100%. To work backwards: theoretical yield = actual yield ÷ (percentage yield/100).

EXAM CHECK Actual product mass ÷ starting reactant mass is usually not percentage yield. The denominator must be the theoretical mass of that same product.

TEST IT 14 $MgCO_3 \rightarrow MgO + CO_2$. $M(MgCO_3) = 84.3$ and $M(CO_2) = 44.0$ g mol^{-1}.
(a) 8.43 g of $MgCO_3$ produces 3.08 g of collected CO_2. Calculate the percentage yield. [4]
(b) At this same yield, calculate the mass of $MgCO_3$ required to collect 4.62 g of CO_2. [3]

[7 marks]

✓ DONE WHEN You can find theoretical yield with the equation ratio and reverse the calculation when a target yield is given.

15. Atom economy and sustainability

SPEC 2.1.3(h)(ii), (j) Calculate atom economy and explain the benefit of using atoms efficiently.

CRACK IT Atom economy asks what fraction of the reactant mass could become the desired product, according to the balanced equation.

$$\text{atom economy} = \frac{\text{coefficient} \times M_r \text{ of desired product}}{\Sigma(\text{coefficient} \times M_r \text{ of each reactant})} \times 100$$

Use the balanced coefficients. By conservation of mass, the denominator can also be the sum of coefficient × M_r for all products. Do not substitute experimentally collected masses.

WORKED EXAMPLE

$2CuO + C \rightarrow 2Cu + CO_2$. The desired product is Cu. Use $M_r(CuO) = 79.5$, $A_r(C) = 12.0$ and $A_r(Cu) = 63.5$.

Desired mass contribution = 2 × 63.5 = 127.0

Total reactant mass contribution = (2 × 79.5) + 12.0 = 171.0

Atom economy = (127.0/171.0) × 100 = 74.3%.

A high atom economy means less reactant material becomes unwanted by-products. This can reduce waste, raw-material demand and separation costs. Sustainability also depends on factors such as energy use, toxicity and feedstock source.

PERCENTAGE YIELD	ATOM ECONOMY
Compares actual and theoretical product.	Calculated from the balanced equation.
Affected by incomplete reaction and losses.	Unchanged by collecting more of the same product.

TEST IT 15 $TiCl_4 + 4Na \rightarrow Ti + 4NaCl$. Titanium is the desired product. Use $M_r(TiCl_4) = 189.9$, $A_r(Na) = 23.0$ and $A_r(Ti) = 47.9$.

(a) Calculate the atom economy. [3]

(b) State one sustainability benefit of a higher atom economy. [1]

(c) Explain how a reaction can have 100% yield but a low atom economy. [2]

[6 marks]

✓ DONE WHEN You can include every coefficient and distinguish product recovery from atoms used in the desired product.

Mixed exam-style practice

Use R = 8.314 J mol^{-1} K^{-1} and a molar gas volume of 24.0 dm^3 mol^{-1} at RTP where needed. Give calculated answers to 3 significant figures unless stated otherwise.

TEST IT 16 A 0.300 g sample contains $CaCO_3$ and an impurity that does not react with HCl. Excess HCl produces 60.0 cm^3 of CO_2 at RTP. M($CaCO_3$) = 100.1 g mol^{-1}.

$CaCO_3 + 2HCl \rightarrow CaCl_2 + H_2O + CO_2$

(a) Calculate the percentage by mass of $CaCO_3$ in the sample. [4]

(b) Calculate the minimum volume of 0.200 mol dm^{-3} HCl needed to react with the $CaCO_3$ in this sample. Give your answer in cm^3. [2]

[6 marks]

TEST IT 17 0.701 g of a pure Group 1 metal hydroxide, MOH, is dissolved and made up to 250.0 cm^3. A 25.00 cm^3 aliquot reacts with 12.50 cm^3 of 0.1000 mol dm^{-3} HCl.

$MOH + HCl \rightarrow MCl + H_2O$

Determine the molar mass of MOH and identify the metal M.

A_r: H = 1.0; O = 16.0; Li = 6.9; Na = 23.0; K = 39.1; Rb = 85.5.

[6 marks]

Worked answers 1 to 4

These are original CrackingChem practice questions. Mark allocations below are indicative, not official OCR mark schemes.

TEST IT 1 Concentration [3 marks]

n(NaCl) = 4.68/58.5 = 0.0800 mol [1].

c = 0.0800/0.4000 = 0.200 mol dm^{-3} [1].

Mass concentration = 4.68/0.4000 = 11.7 g dm^{-3} [1].

TEST IT 2 Dilution [4 marks]

(a) n = 0.750 × 0.0200 = 0.0150 mol [1]. c_2 = 0.0150/0.2500 = 0.0600 mol dm^{-3} [1].

(b) Required n = 0.0200 × 0.5000 = 0.0100 mol [1]. Stock volume = 0.0100/0.400 = 0.0250 dm^3 = 25.0 cm^3 [1].

TEST IT 3 Standard solution [6 marks]

n = 0.100 × 0.2500 = 0.0250 mol [1]. m = 0.0250 × 101.1 = 2.53 g (3 s.f.) [1].

Dissolve the weighed solid fully in deionised water in a beaker [1].

Transfer to a 250 cm^3 volumetric flask and rinse the beaker, rod and funnel into it [1].

Make the final solution up to the mark with deionised water, adding dropwise near the end and reading the bottom of the meniscus at eye level [1].

Stopper and invert repeatedly to make the concentration uniform [1]. Record the mass actually weighed if an exact concentration is needed.

TEST IT 4 Acids and alkalis [6 marks]

(a) H_2SO_4 [1] and NH_3 [1].

(b) A weak acid only partially dissociates in aqueous solution [1]. A dilute acid has a low amount of acid per unit volume [1]; this does not state its degree of dissociation.

(c) Equal amounts of NaOH are needed [1]. The samples contain equal amounts of monoprotic acid and each reacts with NaOH in a 1:1 ratio on complete neutralisation [1]. Further weak-acid molecules dissociate as H^+ is removed.

EXAM CHECK Concentration calculations use the final solution volume. Neutralisation uses the total amount of acid able to react, not just the H^+ present before the reaction starts.

Worked answers 5 to 8

TEST IT 5 Neutralisation equations [5 marks]

(a) $CuO + 2HNO_3 \rightarrow Cu(NO_3)_2 + H_2O$. Correct salt/products [1]; balanced [1].

(b) $K_2CO_3 + 2HCl \rightarrow 2KCl + H_2O + CO_2$. Correct products [1]; balanced [1].

(c) $H^+ + OH^- \rightarrow H_2O$ [1].

TEST IT 6 Titration technique [5 marks]

(a) Added water changes the concentration and total volume in the flask, but not the moles of solute in the pipetted sample [1]. The same amount, and hence volume, of titrant is needed [1].

(b) Some liquid leaving the burette fills the tip instead of reaching the flask [1]. The measured titre is too high [1].

(c) The titre is too high [1].

TEST IT 7 Titres and uncertainty [5 marks]

(a) Titres: 19.80, 19.90 and 20.30 cm^3 [1].

(b) Use runs 1 and 2, which differ by 0.10 cm^3 [1]. Mean = (19.80 + 19.90)/2 = 19.85 cm^3 [1].

(c) Absolute uncertainty = 0.05 + 0.05 = 0.10 cm^3 [1]. Percentage uncertainty = (0.10/19.85) × 100 = 0.50% [1].

TEST IT 8 Sulfuric acid concentration [4 marks]

$n(NaOH) = 0.150 \times 0.02240 = 0.003360$ mol [1].

$n(H_2SO_4) = 0.003360/2 = 0.001680$ mol [1].

$c(H_2SO_4) = 0.001680/0.02500 = 0.0672$ mol dm^{-3} [1].

Mass concentration = $0.0672 \times 98.1 = 6.59$ g dm^{-3} [1].

EXAM CHECK The two burette readings both contribute uncertainty. The 2:1 ratio in sulfuric acid neutralisation comes from the equation, not from the measured volumes.

Worked answers 9 to 11

TEST IT 9 Molar mass from a titration [5 marks]

n(NaOH) = 0.1000 × 0.02400 = 0.002400 mol [1].

n(H_3A) in 20.00 cm^3 = 0.002400/3 = 0.0008000 mol [1].

n(H_3A) in 200.0 cm^3 = 0.0008000 × (200.0/20.00) = 0.008000 mol [1].

M = 1.920/0.008000 = 240.0 g mol^{-1}. Correct calculation [1]; unit and 4 s.f. [1].

TEST IT 10 Back titration [5 marks]

Initial n(HCl) = 0.200 × 0.05000 = 0.01000 mol [1].

Remaining n(HCl) = n(NaOH) = 0.100 × 0.02000 = 0.002000 mol [1].

HCl consumed by MgO = 0.01000 − 0.002000 = 0.008000 mol [1].

n(MgO) = 0.008000/2 = 0.004000 mol [1].

m(MgO) = 0.004000 × 40.3 = 0.1612 g; percentage = (0.1612/0.200) × 100 = 80.6% [1].

TEST IT 11 Gas volumes [5 marks]

QUANTITY	Zn	H_2
m / g	0.327	not needed
M / g mol^{-1}	65.4	not needed
n / mol	0.327/65.4 = 0.00500 [1]	0.00500 (1:1) [1]
V at RTP / cm^3	not applicable	0.00500 × 24 000 = 120 [1]

(b) V(NH_3) = (2/3) × V(H_2) [1] = (2/3) × 12.0 = 8.00 dm^3 [1]. The gas volumes are compared at the same temperature and pressure.

EXAM CHECK For Test 9, the factor of ten scales the aliquot to the flask. For Test 10, subtraction finds the acid consumed. These are different operations serving different purposes.

Worked answers 12 to 15

TEST IT 12 Ideal gas equation [4 marks]

p = 95 000 Pa and V = 1.50 × 10^{-3} m^3 [1]. T = 35 + 273 = 308 K [1].

n = pV/(RT) = (95 000 × 1.50 × 10^{-3})/(8.314 × 308) [1] = 0.0556 mol [1].

TEST IT 13 Molar mass and gas loss [6 marks]

(a) p = 99 000 Pa, V = 2.50 × 10^{-4} m^3, T = 300 K [1].

n = pV/(RT) [1] = (99 000 × 2.50 × 10^{-4})/(8.314 × 300) = 0.009923… mol [1].

M = 0.320/0.009923… = 32.2 g mol^{-1} [1].

(b) The measured volume and calculated n would be too low [1]. With the same mass divided by a smaller n, the calculated M would be too high [1].

TEST IT 14 Percentage yield [7 marks]

QUANTITY	$MgCO_3$	CO_2 theoretical
m / g	8.43	4.40 [1]
M / g mol^{-1}	84.3	44.0
n / mol	8.43/84.3 = 0.100 [1]	0.100 (1:1) [1]

(a) Percentage yield = (3.08/4.40) × 100 = 70.0% [1].
(b) Required theoretical m(CO_2) = 4.62/0.700 = 6.60 g [1]. n(CO_2) = 6.60/44.0 = 0.150 mol [1]. The 1:1 ratio requires 0.150 mol $MgCO_3$, so m = 0.150 × 84.3 = 12.6 g [1].

TEST IT 15 Atom economy [6 marks]

(a) Desired contribution = 47.9 [1]. Total reactant contribution = 189.9 + (4 × 23.0) = 281.9 [1]. Atom economy = (47.9/281.9) × 100 = 17.0% [1].

(b) For example, less material becomes waste / lower raw-material demand per amount of desired product [1].

(c) 100% yield means all the theoretical desired product is obtained [1]. A low atom economy means much of the reactant mass still forms other products [1].

Worked answers 16 to 17 and final check

TEST IT 16 Gas collection and purity [6 marks]

QUANTITY	CO_2	$CaCO_3$
V at RTP / cm^3	60.0	not applicable
n / mol	60.0/24 000 = 0.00250 [1]	0.00250 (1:1) [1]
m / g	not needed	0.00250 × 100.1 = 0.25025 [1]

(a) Percentage by mass = (0.25025/0.300) × 100 = 83.4% [1].
(b) n(HCl) = 2 × 0.00250 = 0.00500 mol [1]. V = n/c = 0.00500/0.200 = 0.0250 dm^3 = 25.0 cm^3 [1].

TEST IT 17 Identifying the hydroxide [6 marks]

n(HCl) = 0.1000 × 0.01250 = 0.001250 mol [1].

The 1:1 ratio gives 0.001250 mol MOH in the 25.00 cm^3 aliquot [1].

Total n(MOH) = 0.001250 × (250.0/25.00) = 0.01250 mol [1].

M(MOH) = 0.701/0.01250 = 56.1 g mol^{-1} (3 s.f.) [1].

A_r(M) = 56.08 − 16.0 − 1.0 = 39.08 ≈ 39.1 [1], so M is potassium, K [1].

YOUR TOTAL _____ / 88 TOPIC TO REVISIT _____

Before you call this topic secure

☐ I choose the right equation and units. ☐ I use the balanced mole ratio.
☐ I distinguish an aliquot from the whole flask. ☐ I select concordant titres.
☐ I can explain preparation and measurement errors. ☐ I distinguish yield from atom economy.

Specification and source check

Mapped to OCR A H432 v3.1 (May 2026): 2.1.3(a)(v), (e)–(j), 2.1.4(a)–(e), and relevant Module 1 analysis/evaluation skills. Parts I and II provide the assumed mass–mole and equation-ratio foundations. All questions and worked numbers here are original.

OCR specification: ocr.org.uk/Images/171720-specification-accredited-a-level-gce-chemistry-a-h432.pdf
OCR practical guidance: ocr.org.uk/Images/598371-practical-activities-support-guide.pdf
OCR practical context checked against H032/01 June 2024 Q22 and H432/03 Autumn 2020 Q4.