



AQA CHEMISTRY 7405

AMOUNT OF SUBSTANCE III

SOLUTIONS • TITRATIONS • GASES • YIELD • ATOM ECONOMY

			
SPEC	CRACK IT	TEST IT	DONE WHEN

Measure amounts and evaluate chemical processes

Build on the mole and equation-ratio methods from Parts I and II. Learn how solution and gas measurements reveal amounts, how titration gives an unknown concentration, and how yield and atom economy describe different aspects of a process.

AQA SECTION	YOUR ROUTE
3.1.2.2	Concentration, solution volumes, mass concentration and dilution.
3.1.2.3	The ideal gas equation in SI units; gas amounts, volumes and molar masses.
3.1.2.5	Solution and gas stoichiometry; percentage yield and atom economy.
Required practical 1	Prepare a volumetric solution; carry out and evaluate an acid–base titration.

BRING FORWARD $n = m/M$; $m = nM$. Balanced coefficients give mole ratios. M is molar mass in g mol^{-1} ; M_r has no unit. The limiting reactant determines the maximum product.

HOW TO USE Follow the worked reasoning, then attempt each fresh TEST IT. Write equations, substitutions and units. Complete answers are at the back.

Use a calculator. Keep unrounded intermediate values. Give final calculated answers to three significant figures unless data or instructions indicate otherwise; retain appropriate burette-reading precision. For gases use $R = 8.31 \text{ J mol}^{-1} \text{ K}^{-1}$ and $T/\text{K} = \text{temperature}/^\circ\text{C} + 273$ unless stated otherwise.

AQA specification checked 7 October 2026. Original questions. This booklet covers the remaining Amount of Substance content and Required Practical 1; detailed acid–base equilibria and redox titrations belong in later topics.

1. Connect concentration, volume and moles



SPEC 3.1.2.2 Calculate concentration, solution volume and amount in moles.



CRACK IT Concentration tells you how much solute is present per unit volume of solution. Convert cm^3 to dm^3 before using $n = cV$.

TERM	MEANING
Solute / solvent	The solute dissolves; the solvent is the liquid in which it dissolves.
Solution	A uniform mixture of a solute and a solvent.
Amount concentration, c	Amount of solute in moles per dm^3 of solution; unit mol dm^{-3} .

$$n = cV \quad | \quad c = n \div V \quad | \quad V = n \div c$$

Use n in mol and V in dm^3 . $1 \text{ dm}^3 = 1000 \text{ cm}^3$; divide a volume in cm^3 by 1000. The volume is the final solution volume, not the volume of water added.

Worked example 1 Find the amount in an aliquot

An aliquot is a measured portion of a solution. A 25.0 cm^3 aliquot of $0.200 \text{ mol dm}^{-3}$ NaCl contains: $V = 25.0/1000 = 0.0250 \text{ dm}^3$; $n = cV = 0.200 \times 0.0250 = 0.00500 \text{ mol}$.

Worked example 2 Find the required volume

For 0.0120 mol KNO_3 from a $0.150 \text{ mol dm}^{-3}$ solution: $V = n/c = 0.0120/0.150 = 0.0800 \text{ dm}^3 = 80.0 \text{ cm}^3$.

EXAM TRAP A concentrated solution has more solute per unit volume. It need not contain more total moles than a larger volume of a dilute solution.



TEST IT 1

a) Calculate the amount of HCl in 35.0 cm^3 of $0.160 \text{ mol dm}^{-3}$ HCl. [2 marks]

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b) Calculate the concentration of a solution containing 0.0180 mol in 150.0 cm^3 . [2 marks]

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c) Calculate the volume, in cm^3 , of $0.250 \text{ mol dm}^{-3}$ NaOH containing 0.0100 mol . [2 marks]

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✓ **DONE WHEN** you select the required rearrangement and use the solution volume in dm^3 .

2. Convert between mass and concentration



SPEC 3.1.2.2 Link mass, molar mass, solution volume and concentration.



CRACK IT Mass concentration uses grams per dm^3 ; amount concentration uses moles per dm^3 . Molar mass connects the two.

QUANTITY	RELATIONSHIP	UNIT
Amount concentration	$c = n/V$	mol dm^{-3}
Mass concentration	$\text{mass} \div \text{solution volume}$	g dm^{-3}
Molar mass, M	$\text{mass} \div \text{amount}$	g mol^{-1}

$$\text{Mass concentration} = c \times M \quad | \quad c = \text{mass concentration} \div M$$

Worked example 1 Dissolve a known mass

5.85 g NaCl is made up to 500.0 cm^3 . $M(\text{NaCl}) = 58.5 \text{ g mol}^{-1}$.

STEP	QUANTITY	VALUE OR CALCULATION
1	Mass / g	5.85
2	Molar mass / g mol^{-1}	58.5
3	Amount / mol	$n = 5.85 \div 58.5 = 0.100$
4	Solution volume / dm^3	$500.0 \div 1000 = 0.5000$
5	Concentration / mol dm^{-3}	$c = 0.100 \div 0.5000 = 0.200$

Mass concentration = $5.85/0.5000 = 11.7 \text{ g dm}^{-3}$. Dividing 11.7 by 58.5 gives the same $0.200 \text{ mol dm}^{-3}$.

Worked example 2 Calculate a mass to weigh

To make 250.0 cm^3 of $0.0800 \text{ mol dm}^{-3}$ KCl, $M = 74.6 \text{ g mol}^{-1}$: $n = cV = 0.0800 \times 0.2500 = 0.0200 \text{ mol}$; $m = nM = 0.0200 \times 74.6 = 1.49 \text{ g}$ (3 significant figures).

PRECISION Keep unrounded numbers through the calculation. Round the final result to the precision supported by the question data. M_r has no unit; molar mass M has unit g mol^{-1} .



TEST IT 2

a) 4.00 g NaOH is made up to 250.0 cm^3 of solution. Calculate its concentration in mol dm^{-3} . $M(\text{NaOH}) = 40.0 \text{ g mol}^{-1}$. [3 marks]

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b) A glucose solution has mass concentration 18.0 g dm^{-3} . Calculate its concentration in mol dm^{-3} . $M(\text{glucose}) = 180.0 \text{ g mol}^{-1}$. [2 marks]

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✓ **DONE WHEN** you distinguish g dm^{-3} from mol dm^{-3} and connect them using molar mass.

3. Calculate a dilution



SPEC 3.1.2.2; 3.1.2.5 Calculate the concentration after dilution and the stock volume required.



CRACK IT Adding solvent changes the volume and concentration, but keeps the amount of solute constant.

A stock solution is a starting solution from which a more dilute solution is prepared. Transfer a measured aliquot of stock solution, then add water until the total solution reaches the required volume.

$$n \text{ before} = n \text{ after} \quad \text{so} \quad c_1V_1 = c_2V_2$$

Use matching volume units on both sides of $c_1V_1 = c_2V_2$. For an individual $n = cV$ calculation, convert volume to dm^3 .

Worked example 1 A fivefold dilution

STAGE	VOLUME	CONCENTRATION	AMOUNT
Stock aliquot	20.0 cm^3	0.500 mol dm^{-3}	$0.500 \times 0.0200 = 0.0100 \text{ mol}$
After making up	100.0 cm^3	$0.0100/0.1000 = 0.100 \text{ mol dm}^{-3}$	Still 0.0100 mol

Volume increases by $100.0/20.0 = 5$, so concentration falls by a factor of 5. The final volume is 100.0 cm^3 , not 120.0 cm^3 .

Worked example 2 Choose the stock aliquot

Prepare 250.0 cm^3 of 0.0400 mol dm^{-3} from 0.200 mol dm^{-3} stock. $V_1 = c_2V_2/c_1 = (0.0400 \times 250.0)/0.200 = 50.0 \text{ cm}^3$. Transfer 50.0 cm^3 and make up to 250.0 cm^3 .

EXAM TRAP Dilution is not a reaction. Do not use $c_1V_1 = c_2V_2$ between different reacting substances unless the balanced equation justifies a 1:1 mole ratio.



TEST IT 3

a) 10.0 cm^3 of 0.600 mol dm^{-3} KNO_3 is diluted to 250.0 cm^3 . Calculate the final concentration. [3 marks]

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b) Calculate the stock volume needed to prepare 100.0 cm^3 of 0.0750 mol dm^{-3} solution from 0.300 mol dm^{-3} stock. [2 marks]

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c) Explain why adding 100.0 cm^3 of water to that stock aliquot is incorrect. [1 mark]

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✓ **DONE WHEN** you conserve solute moles and dilute to the stated final volume.

4. Prepare a standard solution

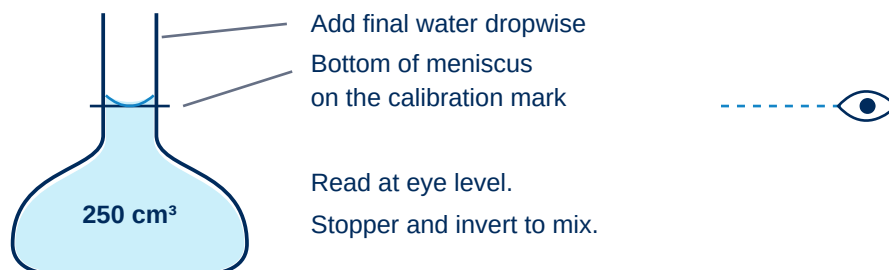


SPEC 3.1.2.5; Required practical 1 Explain how to make a volumetric solution of accurately known concentration.



CRACK IT Calculate the mass, dissolve it fully, transfer all the solute and make up to an accurately defined final volume.

A standard solution has an accurately known concentration. A volumetric flask is calibrated to contain one stated volume at its calibration temperature. Quantitative transfer means transferring all of the measured solute.



Worked example Prepare sodium carbonate solution

For 250.0 cm³ of 0.0500 mol dm⁻³ anhydrous Na₂CO₃, $M = 106.0 \text{ g mol}^{-1}$; $n = 0.0500 \times 0.2500 = 0.0125 \text{ mol}$; $m = 0.0125 \times 106.0 = 1.325 \text{ g}$. Use the actual mass recorded to calculate the precise concentration.

1. Weigh a suitable pure, dry solid accurately, recording the mass transferred (by difference if used). Dissolve it in deionised water in a beaker; stir until no solid remains.
2. Transfer through a funnel into the volumetric flask. Rinse the beaker, rod and funnel with deionised water and add the washings.
3. If the solution is warm, let it reach room temperature. Add water nearly to the mark, then dropwise until the bottom of the meniscus is on the mark at eye level.
4. Stopper and invert repeatedly to mix. Label the solution with its identity and concentration.

EXAM TRAP Do not add 250.0 cm³ of water to the solid. Make the total solution volume 250.0 cm³. An overshoot calibration mark requires a fresh preparation.



TEST IT 4

- a) Calculate the mass of KNO₃ needed to prepare 250.0 cm³ of 0.0400 mol dm⁻³ solution. $M = 101.1 \text{ g mol}^{-1}$. [2 marks]

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- b) Explain why the beaker washings must be added and why the stoppered flask must be inverted. [2 marks]

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✓ **DONE WHEN** you can describe the preparation and explain the purpose of each accuracy step.

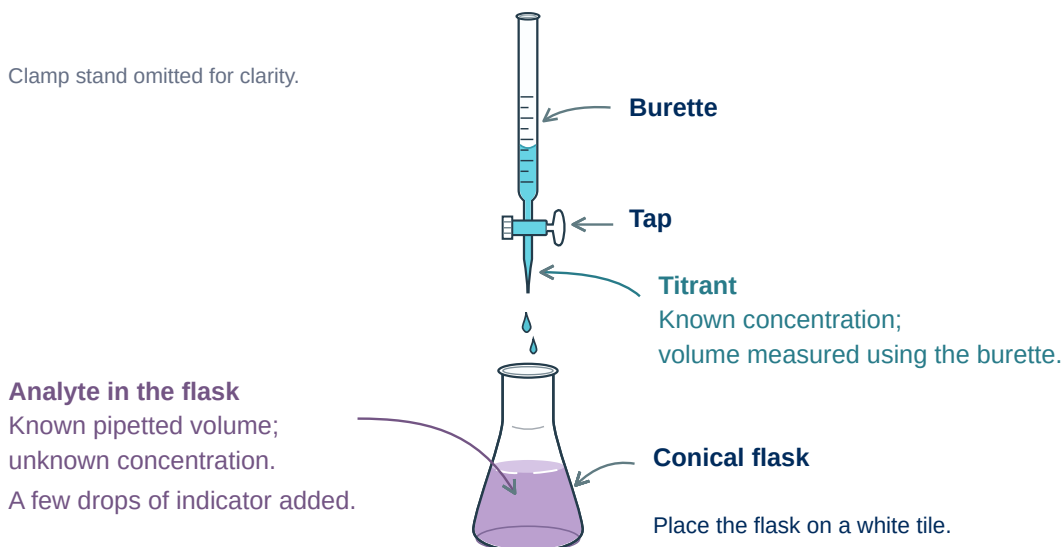
5. Carry out an acid–base titration



SPEC 3.1.2.5; Required practical 1 Explain how a burette and volumetric pipette measure reacting volumes.



CRACK IT A titration measures the volume of one solution needed to react with a fixed aliquot of another solution.



The end point is the observed indicator colour change. The equivalence point is where the reactants have been mixed in the exact stoichiometric ratio. Choose an indicator whose change occurs close to equivalence.

1. Rinse the burette with the solution it will contain. Fill it, run solution through the jet to remove air, and remove the filling funnel. Record the initial meniscus reading at eye level.
2. Rinse the volumetric pipette with the solution it will measure. Use a pipette filler to transfer the fixed aliquot to a conical flask. Let a standard transfer pipette drain; do not blow out its retained drop.
3. Add a few drops of a suitable indicator. Place on a white tile. Add solution while swirling; use a rough titration to locate the end point, then add dropwise near it in accurate repeats.
4. Record the final reading and calculate final minus initial. Repeat with fresh aliquots until concordant titres are obtained; average the concordant accurate titres.

Worked example Choose the indicator

For HCl added to NaOH, phenolphthalein changes from pink to just colourless at the end point. For complete neutralisation of Na_2CO_3 by HCl, use methyl orange: yellow changes to the first persistent orange end point.

PRACTICAL DETAIL Rinse the conical flask with deionised water. Extra water there does not change the moles in the aliquot. Wear eye protection and use a pipette filler; follow the laboratory risk assessment.



TEST IT 5

- a) Explain why the burette is rinsed with its titrant and why its jet must contain no air bubble. [2 marks]

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- b) State the purpose of a rough titration and explain why water may be used to wash splashes down the conical flask walls. [2 marks]

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✓ **DONE WHEN** you can perform the measurement and explain rinsing, dropwise addition and repeat titres.

6. Read a burette and select a mean titre

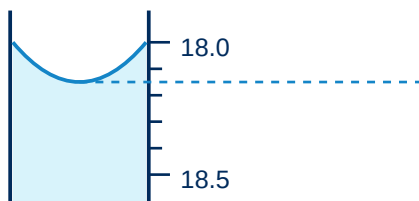


SPEC 3.1.2.5; MS 1.2 Calculate titres, identify concordant results and calculate a justified mean.



CRACK IT Subtract the initial reading from the final reading for each run. Compare titres, not the final burette readings.

The burette scale increases downwards. For a clear solution, read the bottom of the meniscus at eye level. Record readings to two decimal places, normally to the nearest 0.05 cm^3 for a burette graduated every 0.10 cm^3 .



Read the lowest point

Here: 18.15 cm^3

Scale increases downwards.

Concordant titres agree within a specified tolerance. Use 0.10 cm^3 in this pack unless a question gives another value. Exclude the rough titre and non-concordant values from the mean; collect more data if no clear concordant set exists.

Worked example Select the reliable pair

READING / cm^3	ROUGH	1	2	3
Final	25.00	24.45	24.70	24.65
Initial	0.20	0.30	0.20	0.45
Titre	24.80	24.15	24.50	24.20

Titres 1 and 3 differ by 0.05 cm^3 . Mean = $(24.15 + 24.20)/2 = 24.175 \text{ cm}^3$, reported as 24.18 cm^3 . Retain the unrounded mean in later calculations.

TEST IT data

READING / cm^3	ROUGH	1	2	3
Final	19.60	19.10	19.35	19.30
Initial	0.10	0.20	0.40	0.15



TEST IT 6

a) Calculate all four titres from the TEST IT data table. [2 marks]

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b) Select the concordant accurate titres and calculate their mean. Explain both exclusions. [3 marks]

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✓ **DONE WHEN** you calculate a mean using only a justified concordant set.

7. Use a mole ratio in a titration



SPEC 3.1.2.5 Find an unknown concentration from reacting solution volumes.



CRACK IT Go down the known solution column using $n = cV$, across by the equation ratio, then up the unknown column using $c = n/V$.

Worked example 1 A 2:1 acid–carbonate ratio

25.00 cm³ of Na₂CO₃ solution requires 20.00 cm³ of 0.1000 mol dm⁻³ HCl for complete neutralisation. Find $c(\text{Na}_2\text{CO}_3)$.



GRID ROW	HCl		Na ₂ CO ₃
Concentration / mol dm ⁻³	[1] 0.1000 known		[6] $0.001000 \div 0.02500 = 0.04000$
	↓		↑
Volume / dm ³	[2] 0.02000		[5] 0.02500
	↓		↑
Moles / mol	[3] $0.1000 \times 0.02000 = 0.002000$	→	[4] $0.002000 \times 1/2 = 0.001000$

↓ $n = cV$ → × target coefficient / known coefficient ↑ $c = n/V$

The 2:1 equation ratio halves the HCl moles to give carbonate moles. Divide by the carbonate volume, not the acid titre.

Worked example 2 A 1:1 ratio

$\text{HNO}_3 + \text{KOH} \rightarrow \text{KNO}_3 + \text{H}_2\text{O}$. A 25.00 cm³ acid aliquot reacts with 22.40 cm³ of 0.1250 mol dm⁻³ KOH. $n(\text{KOH}) = 0.1250 \times 0.02240 = 0.002800$ mol; acid moles are the same. $c(\text{HNO}_3) = 0.002800/0.02500 = 0.1120$ mol dm⁻³.



TEST IT 7

a) 25.00 cm³ of NaOH reacts with 18.60 cm³ of 0.0500 mol dm⁻³ H₂SO₄. Calculate $c(\text{NaOH})$. $\text{H}_2\text{SO}_4 + 2\text{NaOH} \rightarrow \text{Na}_2\text{SO}_4 + 2\text{H}_2\text{O}$. [4 marks]

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b) Explain why setting acid moles equal to alkali moles would give the wrong result in part (a). [1 mark]

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✓ **DONE WHEN** you use the balanced ratio and divide by the volume of the substance whose concentration is required.

8. Work back through a diluted sample



SPEC 3.1.2.5 Use a titration of an aliquot to find the concentration in the original sample.



CRACK IT Calculate the diluted concentration first. Multiply it by the dilution factor to recover the original concentration.

An aliquot is only part of the prepared solution. Do not treat its moles as the moles in the whole volumetric flask. The scale factor is total flask volume ÷ aliquot volume.

Worked example Vinegar analysis

10.00 cm³ vinegar is diluted to 100.0 cm³. A 25.00 cm³ aliquot of this diluted solution reacts with 20.00 cm³ of 0.1000 mol dm⁻³ NaOH. $M(\text{CH}_3\text{COOH}) = 60.0 \text{ g mol}^{-1}$.



STEP	CALCULATION	RESULT
1 NaOH moles	0.1000×0.02000	0.002000 mol
2 Acid in aliquot	1:1 ratio	0.002000 mol
3 Diluted acid c	$0.002000 \div 0.02500$	0.08000 mol dm ⁻³
4 Original acid c	$0.08000 \times (100.0/10.00)$	0.8000 mol dm ⁻³
5 Mass concentration	0.8000×60.0	48.0 g dm ⁻³

Alternative: the 100.0 cm³ flask contains four aliquots, so 0.008000 mol acid. These moles came from 0.01000 dm³ vinegar: $c = 0.008000/0.01000 = 0.8000 \text{ mol dm}^{-3}$.

TWO DIFFERENT VOLUMES $100.0/25.00 = 4$ scales aliquot moles to the whole flask. $100.0/10.00 = 10$ scales diluted concentration to original concentration. They solve different steps.



TEST IT 8

a) 20.00 cm³ of a monoprotic acid HA is diluted to 250.0 cm³. A 25.00 cm³ aliquot of the diluted solution requires 16.00 cm³ of 0.1000 mol dm⁻³ NaOH. $\text{HA} + \text{NaOH} \rightarrow \text{NaA} + \text{H}_2\text{O}$. Calculate the original acid concentration. [5 marks]

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✓ **DONE WHEN** you identify the aliquot, whole flask and original sample before calculating.

9. Evaluate uncertainty and titration errors



SPEC 3.1.2.5; MS 1.3 Calculate a titre uncertainty and explain the direction of practical errors.



CRACK IT A titre uses two burette readings. Add their absolute uncertainties, then divide by the titre for percentage uncertainty.

$$\text{Percentage uncertainty} = \text{absolute uncertainty} \div \text{measured value} \times 100$$

Worked example Reading uncertainty

Each burette reading has uncertainty $\pm 0.05 \text{ cm}^3$. The titre reading uncertainty is $\pm(0.05 + 0.05) = \pm 0.10 \text{ cm}^3$. For a 20.00 cm^3 titre: $(0.10/20.00) \times 100 = 0.50\%$.

If a question also gives $\pm 0.05 \text{ cm}^3$ for judging the end point, the total becomes $\pm 0.15 \text{ cm}^3$ and 0.75% . Read what uncertainty the question includes. Larger titres reduce percentage uncertainty for the same absolute uncertainty.

DISTINCTION	MEANING
Random variation	Readings scatter. Repeats and a mean help assess and reduce its effect.
Systematic error	Results shift consistently in one direction. Repetition alone does not remove it.
Accuracy / precision	Accuracy is closeness to the true value. Precision is closeness of repeat results to one another.

Worked example Explain the error direction

A known acid is in the burette; an unknown alkali is pipetted into the flask. Residual water in the burette dilutes the acid, so a larger titre is needed. Using the stated, undiluted acid concentration then overestimates the alkali concentration.

WRITE THE CAUSAL CHAIN Name what changes → explain how the titre changes → connect that change to the calculated result. "Human error" does not identify a cause.



TEST IT 9

a) A titre is 24.60 cm^3 . Each reading has uncertainty $\pm 0.05 \text{ cm}^3$. Calculate the percentage uncertainty due to the two readings only. [2 marks]

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b) An unknown alkali is pipetted using a pipette left wet with water. Known acid is added from the burette. Explain the effect on the calculated alkali concentration. [3 marks]

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c) Would concordant titres prove that the calculated concentration is accurate? Explain. [1 mark]

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✓ **DONE WHEN** you distinguish reading uncertainty, end point uncertainty and systematic error.

10. Choose the correct units for gases



SPEC 3.1.2.3 Use SI units with the ideal gas equation.



CRACK IT For $pV = nRT$ use pascals, cubic metres and kelvin. The dm^3 rule for $n = cV$ does not carry over to this equation.

$pV = nRT$ with $R = 8.31 \text{ J mol}^{-1} \text{ K}^{-1}$ in this pack

SYMBOL	QUANTITY	SI UNIT	CONVERSION
p	Pressure	Pa	$\text{kPa} \times 1000$
V	Gas volume	m^3	$\text{dm}^3 \times 10^{-3}$; $\text{cm}^3 \times 10^{-6}$
n	Amount	mol	Use $n = m/M$ if needed
T	Absolute temperature	K	$^{\circ}\text{C} + 273$ (exam approximation)
R	Gas constant	$\text{J mol}^{-1} \text{ K}^{-1}$	Use the value supplied

The ideal gas model assumes negligible particle volume and negligible attractions between particles. Real gases behave most nearly ideally at low pressure and high temperature, away from condensation.

Worked example Convert before substituting

A gas occupies 250 cm^3 at 100 kPa and 27°C . First write $V = 2.50 \times 10^{-4} \text{ m}^3$; $p = 1.00 \times 10^5 \text{ Pa}$; $T = 300 \text{ K}$. Only then insert values into $pV = nRT$.

Worked contrast Solution volume versus gas volume

25.0 cm^3 solution becomes 0.0250 dm^3 in $n = cV$. The same numerical gas volume becomes $2.50 \times 10^{-5} \text{ m}^3$ in $pV = nRT$. Write the unit beside the conversion.

EXAM TRAP Do not substitute a Celsius temperature or pair kPa with m^3 when $R = 8.31 \text{ J mol}^{-1} \text{ K}^{-1}$. A unit error can change the result by factors of 1000 or more.



TEST IT 10

a) Convert 95.0 kPa , 0.750 dm^3 and 32°C into the units required by $pV = nRT$. Use $T/\text{K} = \text{temperature}/^{\circ}\text{C} + 273$. [3 marks]

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b) Convert 48.0 cm^3 to m^3 . State conditions under which real gases approach ideal behaviour. [2 marks]

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✓ **DONE WHEN** you label every converted quantity before using the ideal gas equation.

11. Rearrange the ideal gas equation



SPEC 3.1.2.3 Calculate an unknown amount, volume, pressure or temperature.



CRACK IT Write the equation containing the unknown, rearrange it, convert the known quantities, then substitute.

$$n = pV/RT \quad V = nRT/p \quad p = nRT/V \quad T = pV/nR$$

Worked example 1 Find amount from a gas measurement

A gas occupies 250 cm³ at 100 kPa and 27 °C. $R = 8.31 \text{ J mol}^{-1} \text{ K}^{-1}$.

1. Unknown n : rearrange $pV = nRT$ to $n = pV/RT$.
2. Convert: $p = 100\,000 \text{ Pa}$, $V = 2.50 \times 10^{-4} \text{ m}^3$, $T = 300 \text{ K}$.
3. Substitute: $n = (100\,000 \times 2.50 \times 10^{-4}) / (8.31 \times 300) = 0.0100 \text{ mol}$ (3 significant figures).

Worked example 2 Find the gas volume

Find the volume of 0.0200 mol gas at 298 K and 101 kPa. $V = nRT/p = (0.0200 \times 8.31 \times 298) / 101\,000 = 4.9037 \times 10^{-4} \text{ m}^3 = 490 \text{ cm}^3$ (3 significant figures).

CHECK THE SIZE Near room temperature and atmospheric pressure, 0.0200 mol occupies roughly half a dm³. A result of hundreds of m³ signals a likely unit error. This is a sense check, not a replacement for the calculation.



TEST IT 11

- a) Calculate the amount of gas in 600 cm³ at 98.0 kPa and 310 K. Use $R = 8.31 \text{ J mol}^{-1} \text{ K}^{-1}$. [3 marks]

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- b) Calculate the pressure, in kPa, of 0.0500 mol gas occupying 1.20 dm³ at 300 K. Use $R = 8.31 \text{ J mol}^{-1} \text{ K}^{-1}$. [3 marks]

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- c) Calculate the temperature in K of 0.0300 mol gas at 120 kPa occupying 0.750 dm³. Use $R = 8.31 \text{ J mol}^{-1} \text{ K}^{-1}$. [3 marks]

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✓ **DONE WHEN** you can rearrange for any variable and convert the final unit when requested.

12. Use gas data to find molar mass



SPEC 3.1.2.3 Combine gas measurements with sample mass to determine molar mass and M_r .



CRACK IT Gas data gives n . Sample mass then gives $M = m/n$. Keep m in grams if the required molar mass is in g mol^{-1} .

$$n = pV/RT \quad \text{then} \quad M = m/n \quad \text{so} \quad M = mRT/pV$$

Worked example Find the molar mass of a vapour

A 0.180 g sample vaporises completely to form 100 cm^3 of gas at 100 kPa and 400 K. Assume ideal behaviour.

- Convert: $V = 1.00 \times 10^{-4} \text{ m}^3$ and $p = 1.00 \times 10^5 \text{ Pa}$.
- $n = (1.00 \times 10^5 \times 1.00 \times 10^{-4}) / (8.31 \times 400) = 0.0030084 \text{ mol}$.
- $M = 0.180 / 0.0030084 = 59.832 \rightarrow 59.8 \text{ g mol}^{-1}$. Therefore $M_r = 59.8$, with no unit.

The method assumes all the measured mass is vapour at the recorded temperature and pressure, no vapour is lost, and the measured gas volume belongs to the sample. Trapped air or liquid remaining would invalidate that direct calculation.

Worked contrast Density data

A gas has density 1.20 g dm^{-3} at 100 kPa and 300 K. Take 1.00 dm^3 : mass = 1.20 g; volume = 0.00100 m^3 . $n = 100 / (8.31 \times 300) = 0.040112 \text{ mol}$; $M = 1.20 / 0.040112 = 29.9 \text{ g mol}^{-1}$.

MEASUREMENT CHECK	WHY IT MATTERS
Sample fully vaporised	The weighed sample must match the measured gas amount.
Temperature and pressure recorded	Gas volume alone does not determine moles.

EXAM TRAP Do not switch the sample mass to kg and report the result as g mol^{-1} . A relative molecular mass is numerically equal to the molar mass in g mol^{-1} , but it is dimensionless.



TEST IT 12

a) 0.250 g of a volatile liquid forms 125 cm^3 vapour at 100 kPa and 350 K. Calculate its M_r . Assume ideal behaviour; $R = 8.31 \text{ J mol}^{-1} \text{ K}^{-1}$. [4 marks]

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b) Explain the effect on the calculated M_r if some of the weighed liquid remains unvaporised, with all other measurements correct. [2 marks]

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✓ **DONE WHEN** you link the measured gas amount to the correct sample mass.

13. Use gas volumes and equation ratios



SPEC 3.1.2.5 Use gas volume ratios at matching temperature and pressure.



CRACK IT At the same temperature and pressure, gas volume is proportional to amount. Balanced coefficients therefore give gas volume ratios.

The condition “same temperature and pressure” matters: $V = nRT/p$, so RT/p is common. Apply a volume ratio only to gases. A liquid or solid does not follow this gas-volume rule.

Worked example 1 Gas volumes in a reaction



60.0 cm³ CO requires $60.0 \times 1/2 = 30.0$ cm³ O₂ and forms $60.0 \times 2/2 = 60.0$ cm³ CO₂, all at the same temperature and pressure. If 50.0 cm³ O₂ was supplied, 20.0 cm³ O₂ remains.

Worked contrast A non-unit volume ratio

N₂(g) + 3H₂(g) → 2NH₃(g). If reaction were complete, 90.0 cm³ H₂ with excess N₂ would form $90.0 \times 2/3 = 60.0$ cm³ NH₃ at the same temperature and pressure. Coefficients link gas volumes, not their masses.

Worked example 2 A supplied molar gas volume

Molar gas volume V_m is the volume occupied by one mole of gas at specified conditions. If $V_m = 24.0$ dm³ mol⁻¹ is given, 120 cm³ gas corresponds to $0.120/24.0 = 0.00500$ mol.

$$n = V/V_m \quad \text{and} \quad V = nV_m \quad \text{with matching volume units}$$

AQA HABIT Use $pV = nRT$ when pressure and temperature are supplied. Do not assume 24.0 dm³ mol⁻¹ applies at every temperature and pressure. Use a stated molar volume only for its stated conditions.



TEST IT 13

a) 40.0 cm³ CH₄ burns completely in 100.0 cm³ O₂. CH₄(g) + 2O₂(g) → CO₂(g) + 2H₂O(l). Find the O₂ left and the total gas volume after cooling so all water is liquid. All gas volumes refer to the same temperature and pressure. [3 marks]

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b) At conditions where $V_m = 24.0$ dm³ mol⁻¹, calculate the volume in cm³ of 0.00750 mol N₂. [2 marks]

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✓ **DONE WHEN** you check physical states and matching conditions before using a gas volume ratio.

14. Link solutions, masses and gases



SPEC 3.1.2.2–3.1.2.5 Combine solution and gas data through a balanced equation and identify a limiting reactant.



CRACK IT Use the data available for each substance to calculate moles. The balanced equation connects the mole amounts.

Worked example A solution limits the gas produced

Add 0.300 g Mg to 20.0 cm³ of 1.00 mol dm⁻³ HCl. Find the maximum H₂ volume at 100 kPa and 298 K. M(Mg) = 24.3 g mol⁻¹; R = 8.31 J mol⁻¹ K⁻¹.



GRID ROW	Mg	HCl	H ₂
Given	0.300 g	1.00 mol dm ⁻³ ; 20.0 cm ³	Volume required
Moles available	[1] 0.300/24.3 = 0.01235	[2] 1.00 × 0.0200 = 0.0200	Not yet known
n ÷ coefficient	0.01235/1 = 0.01235	0.0200/2 = 0.0100	[3] Use smaller value
Moles formed	Mg is in excess	HCl is limiting	[4] 0.0100 × 1 = 0.0100

[1–2] Givens ↓ moles → [3] limiting comparison → [4] product moles

[5] $V(\text{H}_2) = nRT/p = (0.0100 \times 8.31 \times 298)/100\,000 = 2.47638 \times 10^{-4} \text{ m}^3 = 248 \text{ cm}^3$. The larger available Mg amount cannot produce extra gas once the acid is used up.

GRID CHECK Only the moles row uses the equation ratio. Masses, concentrations and gas volumes at different conditions cannot be substituted directly for mole ratios.



TEST IT 14

a) 0.270 g Al reacts with 40.0 cm³ of 0.500 mol dm⁻³ HCl. $2\text{Al} + 6\text{HCl} \rightarrow 2\text{AlCl}_3 + 3\text{H}_2$. Determine the limiting reactant and calculate the maximum H₂ volume at 100 kPa and 300 K. M(Al) = 27.0 g mol⁻¹; R = 8.31 J mol⁻¹ K⁻¹. [6 marks]

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✓ **DONE WHEN** you find the limiting reactant before converting product moles into a gas volume.

15. Calculate percentage yield



SPEC 3.1.2.5 Calculate theoretical yield, percentage yield and the mass expected at a given yield.



CRACK IT Calculate the theoretical product from the limiting reactant first. Then compare the actual amount collected with that maximum.

TERM	MEANING
Theoretical yield	Maximum amount of the desired product predicted from the limiting reactant and balanced equation.
Actual yield	Amount of the desired product obtained experimentally.
Percentage yield	Actual yield divided by theoretical yield, multiplied by 100.

$$\text{Percentage yield} = \text{actual yield} / \text{theoretical yield} \times 100$$

Worked example Calculate the theoretical mass first

10.01 g CaCO_3 forms 4.49 g dry CaO . $M(\text{CaCO}_3) = 100.1$; $M(\text{CaO}) = 56.1 \text{ g mol}^{-1}$.



GRID ROW	CaCO_3		CaO
Mass / g	[1] 10.01		[6] theoretical = 5.61
	↓		↑
M / g mol^{-1}	[2] 100.1		[5] 56.1
	↓		↑
Moles / mol	[3] $10.01/100.1 = 0.1000$	→	[4] $0.1000 \times 1/1 = 0.1000$

Yield = $(4.49/5.61) \times 100 = 80.0\%$. Actual mass divided by starting reactant mass would give the wrong percentage.

Worked contrast Work forwards from a stated yield

If the theoretical product mass is 12.0 g and the yield is 75.0%, expected mass = $12.0 \times 75.0/100 = 9.00 \text{ g}$.

WHY LESS THAN 100% Incomplete reaction, competing reactions and losses during separation can reduce yield. An apparent value above 100% suggests wet or impure product, or a measurement/calculation error.



TEST IT 15

a) 5.00 g CuO reacts with excess H_2 : $\text{CuO} + \text{H}_2 \rightarrow \text{Cu} + \text{H}_2\text{O}$. The dry copper mass obtained is 3.60 g. Calculate the percentage yield. $M(\text{CuO}) = 79.5$; $M(\text{Cu}) = 63.5 \text{ g mol}^{-1}$. [4 marks]

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b) Explain why a product that has not been dried can give an apparent yield above 100%. [1 mark]

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✓ **DONE WHEN** you compare actual and theoretical amounts of the same product using matching units.

16. Calculate percentage atom economy



SPEC 3.1.2.5 Calculate atom economy using a balanced equation and the desired product.



CRACK IT Atom economy measures how much of the reactant mass becomes the desired product in the balanced equation.

Atom economy = (coefficient $\times$ M_r of desired product) / Σ (coefficient $\times$ M_r of each reactant) $\times$ 100

Σ means add the terms for all reactants, using their balanced proportions. Do not include catalysts, solvents or deliberately added excess in this theoretical ratio. Conservation of mass also permits the sum of all product masses as the denominator.

Worked example Include every equation coefficient



SPECIES	COEFFICIENT	M_r	COEFFICIENT $\times$ M_r
NaHCO ₃ reactant	2	84.0	168.0
Na ₂ CO ₃ desired product	1	106.0	106.0

If Na₂CO₃ is desired: atom economy = $106.0/168.0 \times 100 = 63.1\%$. The coefficient 2 belongs in the denominator.

Worked contrast The desired product matters



If CaCl₂ is desired: $111.1/(100.1 + 2 \times 36.5) \times 100 = 64.2\%$. If CO₂ is desired instead: $44.0/173.1 \times 100 = 25.4\%$. The equation is unchanged; the useful product is different.

YIELD IS NOT ATOM ECONOMY Yield compares experiment with a theoretical maximum. Atom economy comes from the balanced equation. Collecting more product improves yield but does not change that reaction's atom economy.



TEST IT 16

a) $2\text{KClO}_3 \rightarrow 2\text{KCl} + 3\text{O}_2$. Calculate the atom economy when O₂ is the desired product. $M_r(\text{KClO}_3) = 122.6$; $M_r(\text{O}_2) = 32.0$. [3 marks]

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b) $\text{CH}_2=\text{CH}_2 + \text{H}_2\text{O} \rightarrow \text{CH}_3\text{CH}_2\text{OH}$. State the atom economy when ethanol is the only product, and explain whether an 80% yield changes it. [2 marks]

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✓ **DONE WHEN** you include coefficients and distinguish a theoretical atom-use measure from experimental yield.

17. Compare the efficiency of chemical routes



SPEC 3.1.2.5 Explain economic, environmental and ethical benefits of high atom economy.



CRACK IT A good process must be judged using yield and atom economy alongside energy, hazards, raw materials and waste handling.

MEASURE	WHAT IT CAN TELL YOU	WHAT IT DOES NOT PROVE
Yield	How much of the predicted product is obtained	That little waste forms in the equation
Atom economy	How much reactant mass can enter the desired product	That the experimental yield is high
Energy and hazards	Costs and risks of operating the process	A numerical yield or atom economy by themselves

Worked example Compare routes to the same product

ROUTE	ATOM ECONOMY	YIELD	OTHER INFORMATION
A	100%	70%	High energy demand; hazardous solvent
B	65%	95%	Lower energy demand; recoverable by-product

A incorporates all reactant atoms into the desired product in principle, so it creates no stoichiometric by-product. B obtains a higher fraction of its own theoretical product and may use less energy. Neither percentage alone decides the best route; compare overall costs, hazards, emissions and usable by-products.

High atom economy can reduce raw-material costs and waste treatment. Less waste can reduce pollution and exposure of workers and nearby communities. These are potential benefits; a hazardous feedstock or energy-intensive process can offset them.

EXAM LANGUAGE Name a benefit and explain the link. "Better for the environment" alone is too vague: specify less waste requiring disposal, fewer raw materials consumed or less harmful release.



TEST IT 17

a) Route X has 90% atom economy and 60% yield. Route Y has 55% atom economy and 92% yield. State which route has each advantage and explain why neither can be called best from these percentages alone. [3 marks]

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b) Explain one economic benefit and one benefit to people of reducing hazardous by-products. [2 marks]

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✓ **DONE WHEN** you support a process comparison with specific chemical and practical reasons.

18. Apply titration to an impure sample



SPEC 3.1.2.5 Combine titration, aliquot scaling and percentage purity.



CRACK IT Find the moles in the measured aliquot, scale to the whole solution, then calculate the mass of the pure reacting substance.

Worked example A carbonate mixture

A 2.00 g sample containing K_2CO_3 and inert impurities is dissolved and made up to 250.0 cm^3 . A 25.00 cm^3 aliquot requires 20.00 cm^3 of 0.1000 mol dm^{-3} HCl. $M(\text{K}_2\text{CO}_3) = 138.2 \text{ g mol}^{-1}$.



STEP	CALCULATION
1 Acid amount	$0.1000 \times 0.02000 = 0.002000 \text{ mol}$
2 Carbonate in aliquot	$0.002000 \times 1/2 = 0.001000 \text{ mol}$
3 Carbonate in full flask	$0.001000 \times 250.0/25.00 = 0.01000 \text{ mol}$
4 Pure carbonate mass	$0.01000 \times 138.2 = 1.382 \text{ g}$
5 Percentage purity	$1.382/2.00 \times 100 = 69.1\%$

Purity is the mass percentage of the named substance in the sample. The impurities must not consume the titrant in this calculation. Dissolving a mixture does not make the whole weighed mass pure carbonate.

EXAM TRAP The titration measures one aliquot. Omitting the full-flask factor here would make the calculated reacting mass ten times too small.



TEST IT 18

a) A 1.50 g sample containing Na_2CO_3 and inert impurities is dissolved and made up to 250.0 cm^3 . A 25.00 cm^3 aliquot requires 22.50 cm^3 of 0.1000 mol dm^{-3} HCl. Calculate the percentage purity. $\text{Na}_2\text{CO}_3 + 2\text{HCl} \rightarrow 2\text{NaCl} + \text{CO}_2 + \text{H}_2\text{O}$. $M(\text{Na}_2\text{CO}_3) = 106.0 \text{ g mol}^{-1}$. [6 marks]

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✓ **DONE WHEN** you apply both the chemical mole ratio and the separate aliquot scale factor.

19. Combine gas measurements and yield



SPEC 3.1.2.3; 3.1.2.5 Use experimental gas data to assess how much reaction has occurred.



CRACK IT Keep the theoretical amount from the equation separate from the actual amount calculated from measured gas data.

Worked example Measure oxygen from decomposition



20.0 cm³ of 0.500 mol dm⁻³ H₂O₂ releases 100 cm³ dry O₂ at 100 kPa and 300 K. R = 8.31 J mol⁻¹ K⁻¹.

ROUTE	CALCULATION	O ₂ AMOUNT
Theoretical from reactant	$n(\text{H}_2\text{O}_2) = 0.500 \times 0.0200 = 0.0100 \text{ mol}$; then $\times 1/2$	0.00500 mol
Actual from gas	$n = 100 \text{ 000} \times 1.00 \times 10^{-4} / (8.31 \times 300)$	0.0040112 mol

Percentage yield = $0.0040112 / 0.00500 \times 100 = 80.2\%$. Use gas collected without leaks; gas loss would make the apparent yield too low. If gas is collected over water, the pressure used must be the dry gas pressure, with any correction supplied or justified.

PLAN BEFORE CALCULATING Circle the target. Identify which measurements give actual moles and which give theoretical moles. Keep units and species beside every value.



TEST IT 19

a) 0.4904 g KClO₃ decomposes: $2\text{KClO}_3 \rightarrow 2\text{KCl} + 3\text{O}_2$. 120 cm³ dry O₂ is collected at 100 kPa and 300 K. Calculate the theoretical O₂ amount, actual O₂ amount and percentage yield. M(KClO₃) = 122.6 g mol⁻¹; R = 8.31 J mol⁻¹ K⁻¹. [6 marks]

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b) Explain why a gas leak makes the calculated yield too low. [1 mark]

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✓ **DONE WHEN** you compare actual and theoretical amounts without confusing the two routes.

20. Check your method before submitting



SPEC 3.1.2.2; 3.1.2.3; 3.1.2.5 Choose, justify and check calculation methods across this topic.



CRACK IT Find the unknown, write its equation, rearrange, then work backwards through any missing quantity. Keep unrounded values until the end.

IF YOU NEED...	START WITH...	CHECK...
Solution amount / concentration	$n = cV$ or $c = n/V$	V is solution volume in dm^3
An amount of another substance	$n(\text{target}) = n(\text{known}) \times \text{coefficient ratio}$	Equation balanced; limiting reactant used
Gas amount / volume	$pV = nRT$	Pa, m^3 , K and the supplied R
Percentage yield	$\text{actual/theoretical} \times 100$	Same product; same quantity units
Atom economy	balanced formula masses $\times$ coefficients	All reactants; desired product identified

Worked example Diagnose a plausible-looking answer

A student calculates $n = 0.100 \times 25.0 = 2.50 \text{ mol}$ for 25.0 cm^3 of $0.100 \text{ mol dm}^{-3}$ solution. The equation is suitable, but the volume is not in dm^3 . Correct $n = 0.100 \times 0.0250 = 0.00250 \text{ mol}$. The wrong value is 1000 times too large.

Final mastery check

You should now be able to prepare and dilute a standard solution, explain titration technique, select concordant titres, calculate uncertainty, use SI gas units, apply mole ratios and distinguish yield from atom economy. Use the answers to locate a specific step to practise again.



TEST IT 20

a) A student uses 20 as T for a gas at 20°C . Give the correct temperature and explain why the correction is needed. [2 marks]

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b) A carbonate reacts with acid in a 1:2 mole ratio. A student writes $c(\text{acid})V(\text{acid}) = c(\text{carbonate})V(\text{carbonate})$. Correct the relationship using matching volume units. [2 marks]

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c) A reaction has 100% atom economy and a 45% yield. Explain why these values are compatible. [2 marks]

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✓ **DONE WHEN** you choose a justified route, show units and reject results that fail a sense check.

Answers for TEST IT 1 to 7

These marking points accompany original practice questions. Equivalent valid working is acceptable. Answers retain enough intermediate figures to show the method.

TEST IT 1 | 6 marks

- a) $V = 0.0350 \text{ dm}^3$ [1]; $n = 0.160 \times 0.0350 = 0.00560 \text{ mol}$ [1].
 b) $V = 0.1500 \text{ dm}^3$ [1]; $c = 0.0180/0.1500 = 0.120 \text{ mol dm}^{-3}$ [1].
 c) $V = 0.0100/0.250 = 0.0400 \text{ dm}^3$ [1] = 40.0 cm^3 [1].

TEST IT 2 | 5 marks

- a) $n = 4.00/40.0 = 0.100 \text{ mol}$ [1]; $V = 0.2500 \text{ dm}^3$ [1]; $c = 0.400 \text{ mol dm}^{-3}$ [1].
 b) $c = 18.0/180.0$ [1] = $0.100 \text{ mol dm}^{-3}$ [1].

TEST IT 3 | 6 marks

- a) $n = 0.600 \times 0.0100 = 0.00600 \text{ mol}$ [1]; final $V = 0.2500 \text{ dm}^3$ [1]; $c = 0.0240 \text{ mol dm}^{-3}$ [1].
 b) $V_1 = 0.0750 \times 100.0/0.300$ [1] = 25.0 cm^3 [1].
 c) 100.0 cm^3 must be the final solution volume, not the water volume added [1].

TEST IT 4 | 4 marks

- a) $n = 0.0400 \times 0.2500 = 0.0100 \text{ mol}$ [1]; $m = 0.0100 \times 101.1 = 1.01 \text{ g}$ [1].
 b) Washings transfer remaining solute so the calculated amount reaches the flask [1]. Inversion makes the concentration uniform throughout [1].

TEST IT 5 | 4 marks

- a) Rinsing avoids dilution by residual water [1]. A bubble may fill during the titration, so some measured liquid does not reach the flask [1].
 b) The rough locates the approximate end point [1]. Washings return reagent to the mixture without changing the reacting moles [1].

TEST IT 6 | 5 marks

- a) Rough 19.50; run 1 18.90; run 2 18.95; run 3 19.15 cm^3 [2; one mark for two correct].
 b) Use runs 1 and 2 [1]. Mean = $18.925 \rightarrow 18.93 \text{ cm}^3$ [1]. Exclude the rough and run 3, which is more than 0.10 cm^3 from each selected titre [1].

TEST IT 7 | 5 marks

- a) $n(\text{H}_2\text{SO}_4) = 0.0500 \times 0.01860 = 0.000930 \text{ mol}$ [1]; ratio acid:alkali = 1:2 [1]; $n(\text{NaOH}) = 0.00186 \text{ mol}$ [1]; $c = 0.00186/0.02500 = 0.0744 \text{ mol dm}^{-3}$ [1].
 b) Each mole of sulfuric acid reacts with two moles of NaOH, so the equation ratio is not 1:1 [1].

Answers for TEST IT 8 to 14

TEST IT 8 | 5 marks

a) $n(\text{NaOH}) = 0.1000 \times 0.01600 = 0.001600 \text{ mol}$ [1]; $n(\text{HA})$ in aliquot = 0.001600 mol [1]; diluted $c = 0.001600/0.02500 = 0.06400 \text{ mol dm}^{-3}$ [1]; dilution factor = $250.0/20.00 = 12.50$ [1]; original $c = 0.8000 \text{ mol dm}^{-3}$ [1].

TEST IT 9 | 6 marks

a) Absolute uncertainty = 0.10 cm^3 [1]; percentage = $0.10/24.60 \times 100 = 0.41\%$ [1].

b) Water dilutes the alkali aliquot, reducing its moles [1]; less acid is needed so the titre falls [1]; the calculated alkali concentration is too low [1].

c) No. Concordance shows precision; a systematic error can affect every titre [1].

TEST IT 10 | 5 marks

a) $p = 9.50 \times 10^4 \text{ Pa}$ [1]; $V = 7.50 \times 10^{-4} \text{ m}^3$ [1]; $T = 305 \text{ K}$ [1].

b) $48.0 \times 10^{-6} = 4.80 \times 10^{-5} \text{ m}^3$ [1]; low pressure and high temperature [1].

TEST IT 11 | 9 marks

a) $p = 98\,000 \text{ Pa}$; $V = 6.00 \times 10^{-4} \text{ m}^3$ [1]. $n = pV/RT$ [1] = 0.0228 mol [1].

b) $V = 1.20 \times 10^{-3} \text{ m}^3$ [1]; $p = (0.0500 \times 8.31 \times 300)/0.00120 = 103\,875 \text{ Pa}$ [1] = 104 kPa [1].

c) $p = 120\,000 \text{ Pa}$; $V = 7.50 \times 10^{-4} \text{ m}^3$ [1]; $T = pV/nR$ [1] = 361 K [1].

TEST IT 12 | 6 marks

a) $p = 100\,000 \text{ Pa}$; $V = 1.25 \times 10^{-4} \text{ m}^3$ [1]; $n = pV/RT = 0.0042977 \text{ mol}$ [1]; $M = 0.250/n = 58.17 \text{ g mol}^{-1}$ [1]; $M_r = 58.2$ with no unit [1].

b) Measured vapour moles are less than the moles in the weighed sample [1]; dividing the full sample mass by this smaller n overestimates M_r [1].

TEST IT 13 | 5 marks

a) O_2 used = 80.0 cm^3 [1]; O_2 left = 20.0 cm^3 [1]; $\text{CO}_2 = 40.0 \text{ cm}^3$, so total gas = 60.0 cm^3 [1].

b) $V = 0.00750 \times 24.0 = 0.180 \text{ dm}^3$ [1] = 180 cm^3 [1].

TEST IT 14 | 6 marks

a) $n(\text{Al}) = 0.270/27.0 = 0.0100 \text{ mol}$ [1]; $n(\text{HCl}) = 0.500 \times 0.0400 = 0.0200 \text{ mol}$ [1]. $n/\text{coefficient}$: Al 0.00500 ; HCl 0.003333 , so HCl is limiting [1]. $n(\text{H}_2) = 0.0200 \times 3/6 = 0.0100 \text{ mol}$ [1]. $V = nRT/p = 2.493 \times 10^{-4} \text{ m}^3$ [1] = 249 cm^3 [1].

Answers for TEST IT 15 to 20

TEST IT 15 | 5 marks

a) $n(\text{CuO}) = 5.00/79.5 = 0.062893 \text{ mol}$ [1]; 1:1 gives the same Cu moles [1]; theoretical Cu mass = 3.99371 g [1]; yield = $3.60/3.99371 \times 100 = 90.1\%$ [1].

b) Water adds to the measured mass but is not the desired product [1].

TEST IT 16 | 5 marks

a) Desired mass = $3 \times 32.0 = 96.0$ [1]; reactant mass = $2 \times 122.6 = 245.2$ [1]; atom economy = $96.0/245.2 \times 100 = 39.2\%$ [1].

b) Atom economy is 100% because all reactant atoms enter the desired product [1]. An 80% experimental yield does not change this equation-based atom economy [1].

TEST IT 17 | 5 marks

a) X has greater theoretical incorporation of reactant mass [1]; Y gives more of its predicted product experimentally [1]; other factors such as energy, hazards, cost or waste recovery are needed [1].

b) Less waste treatment/disposal can reduce costs [1]; reduced exposure or environmental release can protect workers/local communities [1].

TEST IT 18 | 6 marks

a) $n(\text{HCl}) = 0.1000 \times 0.02250 = 0.002250 \text{ mol}$ [1]; carbonate:acid = 1:2 [1]; $n(\text{carbonate})$ in aliquot = 0.001125 mol [1]; whole flask = 0.01125 mol [1]; pure mass = 1.1925 g [1]; purity = $1.1925/1.50 \times 100 = 79.5\%$ [1].

TEST IT 19 | 7 marks

a) $n(\text{KClO}_3) = 0.4904/122.6 = 0.004000 \text{ mol}$ [1]; theoretical $\text{O}_2 = 0.004000 \times 3/2 = 0.006000 \text{ mol}$ [1]; $V = 1.20 \times 10^{-4} \text{ m}^3$ and $p = 100\,000 \text{ Pa}$ [1]; actual $n = pV/RT = 0.00481348 \text{ mol}$ [1]; yield = $\text{actual/theoretical} \times 100$ [1] = 80.2% [1].

b) It lowers measured gas volume and therefore actual moles, without changing theoretical moles [1].

TEST IT 20 | 6 marks

a) $T = 293 \text{ K}$ using +273 [1]; the ideal gas equation requires absolute temperature [1].

b) $c(\text{acid})V(\text{acid}) = 2c(\text{carbonate})V(\text{carbonate})$ [1], because acid moles are twice carbonate moles at complete neutralisation [1].

c) All atoms can enter the desired product according to the equation [1]; incomplete conversion or recovery losses can still reduce the amount actually collected [1].

Specification references

AQA 7405: solution calculations in 3.1.2.2; ideal gases in 3.1.2.3; solution/gas stoichiometry, yield, atom economy and Required Practical 1 in 3.1.2.5. Practical skills include selecting mean titres and evaluating uncertainty.

aqa.org.uk/subjects/chemistry/a-level/chemistry-7405/specification/subject-content/physical-chemistry

AQA AS and A-level Chemistry Practical Handbook, Required Practical 1 and uncertainty guidance:
filestore.aqa.org.uk/resources/chemistry/AQA-7404-7405-PHBK.PDF