



OCR A H432

Amount of Substance III

Original exam questions | TEST IT → EXAM STYLE → HARDER MIXED → STRETCH

SPECIFICATION-LED. PROGRESSIVE. CALCULATION-PRECISE.

OCR A SPECIFICATION		2.1.3(a)(v), (e)(ii)-(iii), (f)-(j) 2.1.4(a)-(e) PAG1/PAG2		
TEST IT	EXAM STYLE	HARDER MIXED		STRETCH
8	10	5		1
24 QUESTIONS ORIGINAL		168 MARKS TOTAL		

FINAL NOTES-ALIGNED EDITION | SOLUTIONS • TITRATIONS • GASES • EFFICIENCY

Independent practice material. Every question is original and mapped to OCR A Chemistry A H432 specification version 3.1 (May 2026).

START HERE

How to use this pack

Show a complete chemical route, then compare the first lost mark with the worked answer

- 1 Attempt each question independently and keep full calculator precision until the final answer.
- 2 Write the balanced equation before using a mole ratio; keep each amount attached to its substance.
- 3 Convert solution volumes to dm^3 and ideal-gas volumes to m^3 before substituting.
- 4 After marking, repair the first incorrect step and repeat the calculation without the model.

OCR A
BOUNDARY

This pack assesses concentration, dilution, standard solutions, the OCR acids companion, acid-base titrations, gas calculations, percentage yield and atom economy.

HELD
BACK

Quantitative pH, K_a , buffers, titration curves, detailed indicator theory and redox titrations belong later and are not assessed here.

QUESTION
PAGES

There are no method grids, route strips or calculation prompts. Every written response has one clearly visible grey dotted line per mark.

ANSWER
PAGES

Worked grids appear only where they make a calculation route clearer. Units, significant figures and OCR terminology are marked explicitly.

SECTION A

TEST IT

Eight direct checks of the finished-notes mastery outcomes

QUESTION 1

TEST IT

(a) State the equation linking concentration, amount of solute and solution volume.

[1 mark]

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(b) State the volume unit required when concentration is in mol dm^{-3} .

[1 mark]

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(c) State the units used for molar concentration and mass concentration.

[2 marks]

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QUESTION 2

TEST IT

(a) Give the formulae of ethanoic acid and ammonia.

[2 marks]

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(b) State the ion released by acids and the ion produced by alkalis in aqueous solution.

[2 marks]

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(c) Explain how aqueous ammonia produces OH^- ions even though NH_3 contains no oxygen.

[1 mark]

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QUESTION 3**TEST IT**

(a) Explain the difference between a strong acid and a weak acid.

[2 marks]

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(b) Explain why the word dilute does not mean the same as weak.

[1 mark]

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(c) Write the ionic equation, including state symbols, for neutralisation between H^+ and OH^- ions.

[2 marks]

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QUESTION 4**TEST IT**

A solution contains 0.0850 mol Na_2CO_3 in a final volume of 250.0 cm^3 . $M(\text{Na}_2\text{CO}_3) = 106.0 \text{ g mol}^{-1}$.

(a) Calculate the concentration in mol dm^{-3} .

[3 marks]

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(b) Calculate the concentration in g dm^{-3} .

[2 marks]

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QUESTION 5**TEST IT**

The molar gas volume at RTP is 24.0 $\text{dm}^3 \text{ mol}^{-1}$.

(a) Calculate the volume occupied by 0.0375 mol of gas at RTP in dm^3 .

[2 marks]

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(b) Convert this volume into cm^3 .

[2 marks]

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QUESTION 6**TEST IT**

(a) State the ideal gas equation.

[1 mark]

(b) State the SI unit required for each of p, V, n and T in this equation.

[4 marks]**QUESTION 7****TEST IT**

A pure solid has been weighed accurately. Describe how to use it to prepare a standard solution in a volumetric flask.

(a) Give an accurate method from dissolving the solid to obtaining a uniform solution of the required final volume.

[6 marks]**QUESTION 8****TEST IT**

(a) State the equation used to calculate percentage yield.

[1 mark]

(b) State the equation used to calculate atom economy from a balanced equation.

[2 marks]

(c) Explain why a high atom economy can make a process more sustainable.

[2 marks]

SECTION B

EXAM STYLE

Ten original structured questions using OCR A quantitative conventions

QUESTION 9

EXAM STYLE

A student dissolves 2.650 g of anhydrous Na_2CO_3 and makes the solution up to 250.0 cm^3 . $M(\text{Na}_2\text{CO}_3) = 106.0 \text{ g mol}^{-1}$.

- (a) Calculate the concentration of the solution in mol dm^{-3} . [3 marks]

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- (b) Explain how the final water should be added and how the meniscus should be read. [2 marks]

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- (c) State why the flask is stoppered and inverted several times. [1 mark]

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- (d) State what the student should do if the solution level passes the calibration mark. [1 mark]

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QUESTION 10

EXAM STYLE

A student prepares 250.0 cm^3 of solution by diluting 25.00 cm^3 of $0.8000 \text{ mol dm}^{-3}$ NaOH.

- (a) Calculate the concentration of the diluted solution. [3 marks]

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- (b) Name the two pieces of volumetric apparatus used to measure the 25.00 cm^3 sample and make the final solution. [2 marks]

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- (c) Explain why the first piece of apparatus is rinsed with the stock solution before use. [1 mark]

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QUESTION 11**EXAM STYLE**

25.00 cm³ of KOH is neutralised by 19.60 cm³ of 0.1250 mol dm⁻³ HNO₃.

(a) Write the balanced equation for the reaction.

[1 mark]

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(b) Calculate the concentration of the KOH solution in mol dm⁻³.

[5 marks]

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QUESTION 12**EXAM STYLE**

20.00 cm³ of H₂SO₄ is titrated with 0.1500 mol dm⁻³ NH₃. The mean titre is 24.80 cm³.

(a) State a suitable indicator for this strong-acid/weak-alkali titration.

[1 mark]

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(b) Write the balanced equation for the reaction.

[1 mark]

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(c) Calculate the concentration of the sulfuric acid in mol dm⁻³.

[6 marks]

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QUESTION 13

EXAM STYLE

A rough titre is 24.30 cm^3 . Four accurate titres are 24.05 , 24.00 , 24.45 and 24.05 cm^3 . A 25.00 cm^3 Na_2CO_3 sample is titrated with $0.1000 \text{ mol dm}^{-3}$ HCl . $\text{Na}_2\text{CO}_3 + 2\text{HCl} \rightarrow 2\text{NaCl} + \text{CO}_2 + \text{H}_2\text{O}$. Each burette reading has an uncertainty of $\pm 0.05 \text{ cm}^3$.

- (a) Select the concordant accurate titres. [1 mark]

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- (b) Calculate the mean titre. [1 mark]

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- (c) Calculate the concentration of the Na_2CO_3 solution in mol dm^{-3} . [5 marks]

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- (d) Calculate the percentage uncertainty in the mean titre. [2 marks]

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QUESTION 14

EXAM STYLE

0.450 g Mg reacts completely with excess hydrochloric acid: $\text{Mg} + 2\text{HCl} \rightarrow \text{MgCl}_2 + \text{H}_2$. $A_r(\text{Mg}) = 24.3$. The molar gas volume at RTP is $24.0 \text{ dm}^3 \text{ mol}^{-1}$.

- (a) Calculate the amount, in mol, of Mg used. [2 marks]

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- (b) Determine the volume of H_2 formed at RTP in cm^3 . [3 marks]

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- (c) Name a suitable piece of apparatus for collecting and measuring the gas. [1 mark]

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QUESTION 15

EXAM STYLE

A 0.823 g sample of gas occupies 420 cm³ at 98.5 kPa and 315 K. Use $R = 8.314 \text{ J mol}^{-1} \text{ K}^{-1}$.

(a) Calculate the molar mass of the gas in g mol⁻¹.

[7 marks]

QUESTION 16

EXAM STYLE

A 1.250 g limestone sample contains CaCO₃ and inert material. Reaction with excess acid produces 254 cm³ CO₂ at RTP. CaCO₃ and CO₂ react/form in a 1:1 mole ratio. $M(\text{CaCO}_3) = 100.1 \text{ g mol}^{-1}$.

(a) Calculate the percentage by mass of CaCO₃ in the sample.

[7 marks]

QUESTION 17

EXAM STYLE

Sodium hydrogencarbonate decomposes: $2\text{NaHCO}_3 \rightarrow \text{Na}_2\text{CO}_3 + \text{CO}_2 + \text{H}_2\text{O}$. Heating 8.40 g NaHCO_3 produces 4.70 g Na_2CO_3 . $M(\text{NaHCO}_3) = 84.0$ and $M(\text{Na}_2\text{CO}_3) = 106.0 \text{ g mol}^{-1}$.

(a) Calculate the theoretical mass of Na_2CO_3 .

[5 marks]

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(b) Calculate the percentage yield.

[2 marks]

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QUESTION 18

EXAM STYLE

Ethanol can be produced by either reaction. Route 1: $\text{C}_2\text{H}_4 + \text{H}_2\text{O} \rightarrow \text{C}_2\text{H}_5\text{OH}$. Route 2: $\text{C}_6\text{H}_{12}\text{O}_6 \rightarrow 2\text{C}_2\text{H}_5\text{OH} + 2\text{CO}_2$. M_r : $\text{C}_2\text{H}_4 = 28$, $\text{H}_2\text{O} = 18$, $\text{C}_2\text{H}_5\text{OH} = 46$, $\text{C}_6\text{H}_{12}\text{O}_6 = 180$, $\text{CO}_2 = 44$.

(a) Calculate the atom economy for ethanol in Route 1.

[2 marks]

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(b) Calculate the atom economy for ethanol in Route 2.

[2 marks]

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(c) Identify the route with the higher atom economy.

[1 mark]

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(d) Explain why atom economy and percentage yield describe different features of a process.

[2 marks]

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SECTION C

HARDER MIXED*Five less-scaffolded applications requiring careful chemical audits***QUESTION 19****HARDER MIXED**

A student calculates the concentration of NaOH placed in the conical flask from a titration with $0.1000 \text{ mol dm}^{-3}$ HCl in the burette. For each error, state whether the calculated NaOH concentration is too high, too low or unchanged, and explain why.

- (a) The burette is rinsed only with water before it is filled with HCl. [2 marks]

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- (b) The pipette is rinsed only with water before the NaOH aliquot is measured. [2 marks]

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- (c) The conical flask is rinsed with deionised water immediately before use. [2 marks]

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- (d) An air bubble in the burette tip is expelled during the titration. [2 marks]

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QUESTION 20

HARDER MIXED

Citric acid reacts as shown: $\text{C}_6\text{H}_8\text{O}_7 + 3\text{NaOH} \rightarrow \text{Na}_3\text{C}_6\text{H}_5\text{O}_7 + 3\text{H}_2\text{O}$. A 25.00 cm^3 sample requires 24.80 cm^3 of $0.1500 \text{ mol dm}^{-3}$ NaOH. $M(\text{C}_6\text{H}_8\text{O}_7) = 192.1 \text{ g mol}^{-1}$.

(a) Calculate the citric acid concentration in mol dm^{-3} and in g dm^{-3} .

[8 marks]

QUESTION 21

HARDER MIXED

A 1.100 g impure sample of NaOH contains an impurity that does not react with sulfuric acid. The sample is dissolved and made up to 250.0 cm^3 . A 25.00 cm^3 aliquot requires 12.50 cm^3 of $0.1000 \text{ mol dm}^{-3}$ H_2SO_4 . $\text{H}_2\text{SO}_4 + 2\text{NaOH} \rightarrow \text{Na}_2\text{SO}_4 + 2\text{H}_2\text{O}$. $M(\text{NaOH}) = 40.0 \text{ g mol}^{-1}$.

(a) Calculate the percentage purity of the NaOH sample.

[9 marks]

QUESTION 22

HARDER MIXED

50.0 cm³ of 0.800 mol dm⁻³ H₂O₂ decomposes: 2H₂O₂ → 2H₂O + O₂. The actual O₂ volume is 435 cm³ at 102 kPa and 323 K. Use R = 8.314 J mol⁻¹ K⁻¹.

(a) Use pV = nRT to calculate the percentage yield of O₂.

[9 marks]

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QUESTION 23

HARDER MIXED

5.00 cm³ of stock H₂SO₄ is diluted to 250.0 cm³. A 25.00 cm³ aliquot of the diluted acid requires 22.60 cm³ of 0.1500 mol dm⁻³ NaOH. H₂SO₄ + 2NaOH → Na₂SO₄ + 2H₂O. M(H₂SO₄) = 98.1 g mol⁻¹.

(a) Calculate the concentration of the original acid in mol dm⁻³ and in g dm⁻³.

[10 marks]

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SECTION D

STRETCH / SYNOPTIC

One final problem joining back titration, gas, yield and atom economy

QUESTION 24

STRETCH

A 3.000 g mineral containing CaCO_3 and other material that does not react with nitric acid is treated with 50.00 cm³ of 1.200 mol dm⁻³ HNO_3 . After reaction, all excess acid requires 18.50 cm³ of 0.4000 mol dm⁻³ NaOH . $\text{CaCO}_3 + 2\text{HNO}_3 \rightarrow \text{Ca}(\text{NO}_3)_2 + \text{CO}_2 + \text{H}_2\text{O}$. Use $R = 8.314 \text{ J mol}^{-1} \text{ K}^{-1}$. M: $\text{CaCO}_3 = 100.1$, $\text{HNO}_3 = 63.0$ and $\text{Ca}(\text{NO}_3)_2 = 164.1 \text{ g mol}^{-1}$.

(a) Calculate the percentage by mass of CaCO_3 in the mineral.

[6 marks]

(b) Calculate the CO_2 volume at 100 kPa and 298 K, in cm³.

[3 marks]

(c) If 3.600 g $\text{Ca}(\text{NO}_3)_2$ is isolated, calculate the percentage yield.

[3 marks]

(d) Calculate the atom economy for $\text{Ca}(\text{NO}_3)_2$ and state one valid sustainability interpretation.

[3 marks]



OCR A H432

Amount of Substance III

Fully worked answers | OCR A-style marking guidance

SPECIFICATION-LED. PROGRESSIVE. CALCULATION-PRECISE.

OCR A SPECIFICATION		2.1.3(a)(v), (e)(ii)-(iii), (f)-(j) 2.1.4(a)-(e) PAG1/PAG2		
TEST IT	EXAM STYLE	HARDER MIXED		STRETCH
8	10	5		1
24 QUESTIONS MARKED		168 MARKS EXPLAINED		

FINAL NOTES-ALIGNED EDITION | SOLUTIONS • TITRATIONS • GASES • EFFICIENCY

Independent practice material. Every question is original and mapped to OCR A Chemistry A H432 specification version 3.1 (May 2026).

OCR A MAP

How this pack matches the specification

The completed notes and OCR A H432 version 3.1 define the boundary

OCR A REF	WHAT IS ASSESSED	FREQUENT TRAP	QUESTIONS
2.1.3(e)(iii), (g)	Molar and mass concentration, dilution, aliquots and scale-up.	Using cm^3 in $c = n/V$ or using water added as the final volume.	1, 4, 9-13, 20-24
2.1.4(a)-(c)	Common acids/alkalis, strength, neutralisation and salt equations.	Confusing weak with dilute or omitting the salt formula.	2-3, 11-13, 20-21, 23-24
2.1.3(i); 2.1.4(d)-(e)	Standard solutions, titration technique, titres, errors and calculations.	Treating an aliquot as the whole flask or using $c_1V_1 = c_2V_2$ for a reaction.	7, 9-13, 19-24
2.1.3(a)(v), (e)(ii), (f)	Molar gas volume at RTP and $pV = nRT$ using SI units.	Using 24.0 away from RTP or leaving V in cm^3 .	5-6, 14-16, 22, 24
2.1.3(h), (j)	Percentage yield, atom economy and sustainability.	Using actual mass in atom economy or confusing yield with reaction design.	8, 17-18, 22, 24
1.1.3(c), 1.1.4(c)-(d)	Selection of data, uncertainty and directional evaluation of errors.	Using one burette-reading uncertainty for a titre, or giving an effect without its cause.	9, 13, 19, 22-24
BOUNDARY	Quantitative pH, K_a , buffers, titration curves, detailed indicator theory, redox titrations, empirical formulae and hydrated salts are not assessed.		
MARKING LOGIC	A calculation mark is earned by a chemically valid route: correct amount, equation ratio, volume scale, unit conversion and final unit. Retain calculator precision until the end.		
SECTION A	TEST IT ANSWERS <i>Definitions, practical language and first calculations</i>		

QUESTION 1 | TEST IT ANSWER

4 MARKS

- $c = n/V$ (or $n = cV$) [1]
- V must be in dm^3 when c is in mol dm^{-3} [1]
- Molar concentration: mol dm^{-3} [1]
- Mass concentration: g dm^{-3} [1]

QUESTION 2 | TEST IT ANSWER

5 MARKS

- Ethanoic acid: CH_3COOH [1]
- Ammonia: NH_3 [1]
- Acids release $\text{H}^+(\text{aq})$ [1]
- Alkalis produce $\text{OH}^-(\text{aq})$ [1]
- $\text{NH}_3 + \text{H}_2\text{O} \rightleftharpoons \text{NH}_4^+ + \text{OH}^-$; ammonia accepts H^+ from water [1]

QUESTION 3 | TEST IT ANSWER

5 MARKS

- A strong acid dissociates essentially completely in aqueous solution [1]
- A weak acid dissociates only partially in aqueous solution [1]
- Dilute describes a low amount of acid per unit volume; it does not describe the extent of dissociation [1]
- Correct reacting ions and products: $\text{H}^+(\text{aq}) + \text{OH}^-(\text{aq}) \rightarrow \text{H}_2\text{O}(\text{l})$ [1]
- Equation is balanced for atoms and charge and includes correct state symbols [1]

QUESTION 4 | TEST IT ANSWER

5 MARKS

WORKED ROUTE	SUBSTITUTION AND RESULT
V	$250.0 \text{ cm}^3 \div 1000 = 0.2500 \text{ dm}^3$
c	$0.0850 \div 0.2500 = 0.340 \text{ mol dm}^{-3}$
cM	$0.340 \times 106.0 = 36.04 \text{ g dm}^{-3} = 36.0 \text{ g dm}^{-3} \text{ (3 s.f.)}$

- Correct conversion to 0.2500 dm^3 [1]
- Uses $c = n/V$ with the correct values [1]
- $c = 0.340 \text{ mol dm}^{-3}$ [1]
- Uses mass concentration = cM [1]
- Mass concentration = 36.0 g dm^{-3} [1]

QUESTION 5 | TEST IT ANSWER

4 MARKS

- Uses $V = n \times 24.0$ at RTP [1]
- $V = 0.0375 \times 24.0 = 0.900 \text{ dm}^3$ [1]
- $1 \text{ dm}^3 = 1000 \text{ cm}^3$ [1]
- $V = 900 \text{ cm}^3$ [1]

QUESTION 6 | TEST IT ANSWER

5 MARKS

- $pV = nRT$ [1]
- p in Pa [1]
- V in m^3 [1]
- n in mol [1]
- T in K [1]

QUESTION 7 | TEST IT ANSWER

6 MARKS

- Dissolve the accurately weighed solid fully in deionised water in a beaker [1]
- Transfer the solution quantitatively into the correct volumetric flask [1]
- Rinse the beaker, glass rod and funnel into the flask [1]
- Add deionised water to near the calibration mark, then add the last drops carefully [1]
- Place the bottom of the meniscus on the mark at eye level [1]
- Stopper and invert the flask repeatedly to mix [1]

EXAMINER
GUIDANCE

If dissolving warmed the solution, allow it to reach room temperature before making up to the mark.

QUESTION 8 | TEST IT ANSWER

5 MARKS

- Percentage yield = (actual amount or mass of product $\div$ theoretical amount or mass of the same product) $\times 100$ [1]
- Atom economy numerator: coefficient $\times M_r$ of the desired product [1]
- Divide by $\Sigma(\text{coefficient} \times M_r \text{ of every reactant})$ and multiply by 100 [1]
- A larger fraction of reactant atoms enters the desired product / fewer atoms form by-products [1]
- This can reduce waste and raw-material use [1]

SECTION B

EXAM STYLE ANSWERS

Complete calculation routes and OCR-style marking guidance

QUESTION 9 | EXAM STYLE ANSWER

7 MARKS

WORKED ROUTE	SUBSTITUTION AND RESULT
n	$2.650 \div 106.0 = 0.02500 \text{ mol}$
V	$250.0 \text{ cm}^3 = 0.2500 \text{ dm}^3$
c	$0.02500 \div 0.2500 = 0.1000 \text{ mol dm}^{-3}$

- $n(\text{Na}_2\text{CO}_3) = 0.02500 \text{ mol}$ [1]
- $V = 0.2500 \text{ dm}^3$ [1]
- $c = 0.1000 \text{ mol dm}^{-3}$ [1]
- Add the final water dropwise / with a dropping pipette [1]
- Read the bottom of the meniscus at eye level [1]
- Stoppering and inverting makes the concentration uniform [1]
- If the mark is overshoot, remake the solution [1]

EXAMINER
GUIDANCE

Removing some mixed solution after overshooting removes solute and solvent in the same proportion; it does not restore the intended concentration.

QUESTION 10 | EXAM STYLE ANSWER

6 MARKS

WORKED ROUTE	SUBSTITUTION AND RESULT
n	$0.8000 \times 0.02500 = 0.02000 \text{ mol}$; amount is unchanged by dilution
c₂	$0.02000 \div 0.2500 = 0.08000 \text{ mol dm}^{-3}$

- Uses the amount in the transferred sample / $c_1V_1 = c_2V_2$ [1]
- Uses the final volume of 250.0 cm^3 , not the water added [1]
- $c_2 = 0.08000 \text{ mol dm}^{-3}$ [1]
- Use a 25.00 cm^3 volumetric pipette [1]
- Use a 250.0 cm^3 volumetric flask [1]
- Rinsing the pipette with stock solution prevents residual water from diluting the measured sample [1]

QUESTION 11 | EXAM STYLE ANSWER

6 MARKS

WORKED ROUTE	SUBSTITUTION AND RESULT
EQUATION	$\text{HNO}_3 + \text{KOH} \rightarrow \text{KNO}_3 + \text{H}_2\text{O}$
n(HNO₃)	$0.1250 \times 0.01960 = 0.002450 \text{ mol}$
RATIO	$\text{HNO}_3 : \text{KOH} = 1 : 1$, so $n(\text{KOH}) = 0.002450 \text{ mol}$
c(KOH)	$0.002450 \div 0.02500 = 0.09800 \text{ mol dm}^{-3}$

- Correct balanced equation [1]
- $n(\text{HNO}_3) = 0.002450 \text{ mol}$ [1]
- Uses the 1:1 ratio [1]
- $n(\text{KOH}) = 0.002450 \text{ mol}$ [1]
- Uses $c = n/V$ with $V = 0.02500 \text{ dm}^3$ [1]
- $c(\text{KOH}) = 0.09800 \text{ mol dm}^{-3}$ [1]

QUESTION 12 | EXAM STYLE ANSWER

8 MARKS

WORKED ROUTE	SUBSTITUTION AND RESULT
INDICATOR	Methyl orange
EQUATION	$\text{H}_2\text{SO}_4 + 2\text{NH}_3 \rightarrow (\text{NH}_4)_2\text{SO}_4$
$n(\text{NH}_3)$	$0.1500 \times 0.02480 = 0.003720 \text{ mol}$
RATIO	$n(\text{H}_2\text{SO}_4) = 0.003720 \div 2 = 0.001860 \text{ mol}$
$c(\text{H}_2\text{SO}_4)$	$0.001860 \div 0.02000 = 0.09300 \text{ mol dm}^{-3}$

- Methyl orange [1]
- Correct balanced equation [1]
- $n(\text{NH}_3) = 0.003720 \text{ mol}$ [1]
- Uses $\text{H}_2\text{SO}_4 : \text{NH}_3 = 1 : 2$ [1]
- $n(\text{H}_2\text{SO}_4) = 0.001860 \text{ mol}$ [1]
- Uses 0.02000 dm^3 for the acid volume [1]
- Correct division by sample volume [1]
- $c(\text{H}_2\text{SO}_4) = 0.09300 \text{ mol dm}^{-3}$ [1]

QUESTION 13 | EXAM STYLE ANSWER

9 MARKS

WORKED ROUTE	SUBSTITUTION AND RESULT
TITRES	Use 24.05, 24.00 and 24.05 cm^3 ; exclude the rough and 24.45 cm^3
MEAN	$(24.05 + 24.00 + 24.05) \div 3 = 24.03 \text{ cm}^3$
$n(\text{HCl})$	$0.1000 \times 0.0240333... = 0.00240333... \text{ mol}$
RATIO	$n(\text{Na}_2\text{CO}_3) = 0.00240333... \div 2 = 0.00120167... \text{ mol}$
c	$0.00120167... \div 0.02500 = 0.0480667... = 0.04807 \text{ mol dm}^{-3}$

- Selects the three concordant accurate titres [1]
- Mean titre = 24.03 cm^3 [1]
- $n(\text{HCl}) = 0.00240333... \text{ mol}$ [1]
- Uses the 2:1 $\text{HCl}:\text{Na}_2\text{CO}_3$ ratio [1]
- $n(\text{Na}_2\text{CO}_3) = 0.00120167... \text{ mol}$ [1]
- Divides by 0.02500 dm^3 [1]
- $c(\text{Na}_2\text{CO}_3) = 0.04807 \text{ mol dm}^{-3}$ [1]
- A titre uses two burette readings, so absolute uncertainty = $\pm 0.10 \text{ cm}^3$ [1]
- Percentage uncertainty = $(0.10 \div 24.03) \times 100 = 0.416... \% \approx 0.42\%$ [1]

QUESTION 14 | EXAM STYLE ANSWER

6 MARKS

WORKED ROUTE	SUBSTITUTION AND RESULT
EQUATION	$\text{Mg} + 2\text{HCl} \rightarrow \text{MgCl}_2 + \text{H}_2$
$n(\text{Mg})$	$0.450 \div 24.3 = 0.0185185... \text{ mol}$
$n(\text{H}_2)$	1:1 ratio gives $0.0185185... \text{ mol}$
V	$0.0185185... \times 24.0 = 0.444444... \text{ dm}^3 = 444 \text{ cm}^3$

- Uses $n = m/M$ [1]
- $n(\text{Mg}) = 0.0185185... \text{ mol}$ [1]
- Uses the 1:1 $\text{Mg}:\text{H}_2$ ratio [1]
- Uses $24.0 \text{ dm}^3 \text{ mol}^{-1}$ and converts the result to cm^3 [1]
- $V(\text{H}_2) = 444 \text{ cm}^3$ [1]
- Use a gas syringe [1]

QUESTION 15 | EXAM STYLE ANSWER

7 MARKS

WORKED ROUTE	SUBSTITUTION AND RESULT
SI DATA	$p = 98\,500\text{ Pa}$; $V = 420 \times 10^{-6}\text{ m}^3$; $T = 315\text{ K}$
n	$pV/RT = (98\,500 \times 420 \times 10^{-6})/(8.314 \times 315) = 0.0157966\dots\text{ mol}$
M	$0.823 \div 0.0157966\dots = 52.0997\dots\text{ g mol}^{-1}$

- Converts p to $98\,500\text{ Pa}$ and V to $420 \times 10^{-6}\text{ m}^3$ [2]
- Uses $T = 315\text{ K}$ [1]
- Uses $n = pV/RT$ correctly [1]
- $n = 0.0157966\dots\text{ mol}$ [1]
- Uses $M = m/n$ [1]
- $M = 52.1\text{ g mol}^{-1}$ to 3 significant figures [1]

QUESTION 16 | EXAM STYLE ANSWER

7 MARKS

WORKED ROUTE	SUBSTITUTION AND RESULT
$n(\text{CO}_2)$	$254 \div 24\,000 = 0.0105833\dots\text{ mol}$
$n(\text{CaCO}_3)$	1:1 ratio gives $0.0105833\dots\text{ mol}$
$m(\text{CaCO}_3)$	$0.0105833\dots \times 100.1 = 1.05939\dots\text{ g}$
PURITY	$(1.05939\dots \div 1.250) \times 100 = 84.751\dots\%$

- Uses $24\,000\text{ cm}^3\text{ mol}^{-1}$ at RTP [1]
- $n(\text{CO}_2) = 0.0105833\dots\text{ mol}$ [1]
- Uses the 1:1 ratio [1]
- Calculates pure CaCO_3 mass from nM [1]
- $m(\text{CaCO}_3) = 1.05939\dots\text{ g}$ [1]
- Uses $(\text{pure mass} \div \text{sample mass}) \times 100$ [1]
- Percentage purity = 84.8% to 3 significant figures [1]

QUESTION 17 | EXAM STYLE ANSWER

7 MARKS

WORKED ROUTE	SUBSTITUTION AND RESULT
$n(\text{NaHCO}_3)$	$8.40 \div 84.0 = 0.100\text{ mol}$
RATIO	$2\text{NaHCO}_3 : 1\text{Na}_2\text{CO}_3$, so $n(\text{Na}_2\text{CO}_3) = 0.0500\text{ mol}$
THEORETICAL	$0.0500 \times 106.0 = 5.30\text{ g Na}_2\text{CO}_3$
YIELD	$(4.70 \div 5.30) \times 100 = 88.679\dots\% = 88.7\%$

- $n(\text{NaHCO}_3) = 0.100\text{ mol}$ [1]
- Uses the 2:1 coefficient ratio [1]
- $n(\text{Na}_2\text{CO}_3) = 0.0500\text{ mol}$ [1]
- Uses $m = nM$ for the theoretical product [1]
- Theoretical $m(\text{Na}_2\text{CO}_3) = 5.30\text{ g}$ [1]
- Uses $\text{actual} \div \text{theoretical} \times 100$ [1]
- Percentage yield = 88.7% [1]

QUESTION 18 | EXAM STYLE ANSWER

7 MARKS

WORKED ROUTE	SUBSTITUTION AND RESULT
ROUTE 1	$46 \div (28 + 18) \times 100 = 100\%$
ROUTE 2	$(2 \times 46) \div 180 \times 100 = 51.1\%$

- Correct coefficient-weighted fraction for Route 1 [1]
- Route 1 atom economy = 100% [1]
- Correct coefficient-weighted fraction for Route 2 [1]
- Route 2 atom economy = 51.1% [1]
- Route 1 has the higher atom economy [1]
- Atom economy measures the theoretical fraction of reactant atoms entering the desired product [1]
- Percentage yield compares the actual and theoretical quantity of desired product obtained [1]

SECTION C

HARDER MIXED ANSWERS

Less-scaffolded routes with explicit error and unit reasoning

QUESTION 19 | HARDER MIXED ANSWER

8 MARKS

(a)

- Calculated concentration is too high [1]
- Residual water dilutes the HCl, so a larger recorded titre is required but the nominal $0.1000 \text{ mol dm}^{-3}$ is still used [1]

(b)

- Calculated concentration is too low [1]
- Residual water dilutes the NaOH aliquot, so fewer moles enter the flask and a smaller titre is used [1]

(c)

- Calculated concentration is unchanged [1]
- Water changes the concentration in the flask but not the amount of NaOH delivered by the pipette [1]

(d)

- Calculated concentration is too high [1]
- Some recorded burette volume fills the tip instead of entering the flask, so the recorded titre is too large [1]

QUESTION 20 | HARDER MIXED ANSWER

8 MARKS

WORKED ROUTE	SUBSTITUTION AND RESULT
n(NaOH)	$0.1500 \times 0.02480 = 0.003720 \text{ mol}$
RATIO	$n(\text{C}_6\text{H}_8\text{O}_7) = 0.003720 \div 3 = 0.001240 \text{ mol}$
c	$0.001240 \div 0.02500 = 0.04960 \text{ mol dm}^{-3}$
cM	$0.04960 \times 192.1 = 9.52816 \text{ g dm}^{-3} = 9.528 \text{ g dm}^{-3}$

- Converts 24.80 cm^3 to 0.02480 dm^3 [1]
- $n(\text{NaOH}) = 0.003720 \text{ mol}$ [1]
- Uses the 3:1 NaOH:acid ratio [1]
- $n(\text{citric acid}) = 0.001240 \text{ mol}$ [1]
- Divides by the 0.02500 dm^3 sample volume [1]
- $c = 0.04960 \text{ mol dm}^{-3}$ [1]
- Uses mass concentration = cM [1]
- Mass concentration = 9.528 g dm^{-3} [1]

QUESTION 21 | HARDER MIXED ANSWER

9 MARKS

WORKED ROUTE	SUBSTITUTION AND RESULT
n(H₂SO₄)	$0.1000 \times 0.01250 = 0.001250 \text{ mol}$
RATIO	$n(\text{NaOH}) \text{ in aliquot} = 2 \times 0.001250 = 0.002500 \text{ mol}$
SCALE	$250.0 \div 25.00 = 10.00$; total $n(\text{NaOH}) = 0.02500 \text{ mol}$
PURE MASS	$0.02500 \times 40.0 = 1.00 \text{ g}$
PURITY	$(1.00 \div 1.100) \times 100 = 90.909\ldots\% = 90.9\%$

- Uses the supplied balanced equation [1]
- $n(\text{H}_2\text{SO}_4) = 0.001250 \text{ mol}$ [1]
- Uses the 1:2 acid:NaOH ratio [1]
- $n(\text{NaOH}) \text{ in the aliquot} = 0.002500 \text{ mol}$ [1]
- Uses the scale factor 10.00 [1]
- Total $n(\text{NaOH}) = 0.02500 \text{ mol}$ [1]
- Pure NaOH mass = 1.00 g [1]
- Uses pure mass $\div$ sample mass $\times 100$ [1]
- Percentage purity = 90.9% [1]

QUESTION 22 | HARDER MIXED ANSWER

9 MARKS

WORKED ROUTE	SUBSTITUTION AND RESULT
THEORETICAL	$n(\text{H}_2\text{O}_2) = 0.800 \times 0.0500 = 0.0400 \text{ mol}$; $n(\text{O}_2) = 0.0200 \text{ mol}$
SI DATA	$p = 102\,000 \text{ Pa}$; $V = 435 \times 10^{-6} \text{ m}^3$; $T = 323 \text{ K}$
ACTUAL n	$pV/RT = (102\,000 \times 435 \times 10^{-6}) / (8.314 \times 323) = 0.0165225... \text{ mol}$
YIELD	$(0.0165225... \div 0.0200) \times 100 = 82.6127... \% = 82.6\%$

- $n(\text{H}_2\text{O}_2) = 0.0400 \text{ mol}$ [1]
- Uses the 2:1 $\text{H}_2\text{O}_2:\text{O}_2$ ratio to obtain 0.0200 mol theoretical O_2 [1]
- Converts pressure to 102 000 Pa [1]
- Converts volume to $435 \times 10^{-6} \text{ m}^3$ [1]
- Uses $T = 323 \text{ K}$ [1]
- Uses $n = pV/RT$ correctly [1]
- Actual $n(\text{O}_2) = 0.0165225... \text{ mol}$ [1]
- Uses actual $\div$ theoretical $\times 100$ [1]
- Percentage yield = 82.6% [1]

EXAMINER GUIDANCE

The gas measurement gives the actual amount. The solution concentration and equation ratio give the theoretical amount; do not reverse them.

QUESTION 23 | HARDER MIXED ANSWER

10 MARKS

WORKED ROUTE	SUBSTITUTION AND RESULT
n(NaOH)	$0.1500 \times 0.02260 = 0.003390 \text{ mol}$
RATIO	$n(\text{H}_2\text{SO}_4) \text{ in aliquot} = 0.003390 \div 2 = 0.001695 \text{ mol}$
DILUTED c	$0.001695 \div 0.02500 = 0.06780 \text{ mol dm}^{-3}$
DILUTION	Factor = $250.0 \div 5.00 = 50.0$; original $c = 0.06780 \times 50.0 = 3.39 \text{ mol dm}^{-3}$
MASS c	$3.39 \times 98.1 = 332.559 \text{ g dm}^{-3} = 333 \text{ g dm}^{-3}$

- $n(\text{NaOH}) = 0.003390 \text{ mol}$ [1]
- Uses the 2:1 $\text{NaOH}:\text{H}_2\text{SO}_4$ ratio [1]
- $n(\text{H}_2\text{SO}_4) \text{ in aliquot} = 0.001695 \text{ mol}$ [1]
- $c(\text{diluted H}_2\text{SO}_4) = 0.06780 \text{ mol dm}^{-3}$ [1]
- Uses the dilution factor $250.0/5.00 = 50.0$ [1]
- Calculates original concentration from the diluted concentration [1]
- Original $c = 3.39 \text{ mol dm}^{-3}$ to 3 significant figures [1]
- Uses mass concentration = cM [1]
- Unrounded mass concentration = $332.559 \text{ g dm}^{-3}$ [1]
- Mass concentration = 333 g dm^{-3} to 3 significant figures [1]

EXAMINER GUIDANCE

The 250.0 cm^3 is the final diluted volume. The dilution factor is final volume $\div$ transferred stock volume, not water added $\div$ stock volume.

SECTION D

STRETCH / SYNOPTIC ANSWER*A complete route joining four OCR A quantitative ideas***QUESTION 24 | STRETCH ANSWER****15 MARKS**

WORKED ROUTE	SUBSTITUTION AND RESULT
INITIAL ACID	$1.200 \times 0.05000 = 0.06000 \text{ mol HNO}_3$
ACID LEFT	$0.4000 \times 0.01850 = 0.007400 \text{ mol HNO}_3$
ACID USED	$0.06000 - 0.007400 = 0.05260 \text{ mol}$; $n(\text{CaCO}_3) = 0.05260 \div 2 = 0.02630 \text{ mol}$
PURITY	$m(\text{CaCO}_3) = 0.02630 \times 100.1 = 2.63263 \text{ g}$; purity = $2.63263/3.000 \times 100 = 87.8\%$
GAS	$V = nRT/p = (0.02630 \times 8.314 \times 298)/100\,000 = 6.516 \times 10^{-4} \text{ m}^3 = 652 \text{ cm}^3$
YIELD	Theoretical $m[\text{Ca}(\text{NO}_3)_2] = 0.02630 \times 164.1 = 4.31583 \text{ g}$; yield = $3.600/4.31583 \times 100 = 83.4\%$
ATOM ECONOMY	$164.1/[100.1 + 2(63.0)] \times 100 = 72.6\%$

- Calculates the initial and remaining HNO_3 amounts [2]
- Subtracts amounts to obtain $0.05260 \text{ mol HNO}_3$ consumed [1]
- Uses the 2:1 ratio to obtain $0.02630 \text{ mol CaCO}_3$ [1]
- Obtains 2.63263 g CaCO_3 and 87.8% purity [2]
- Uses $pV = nRT$ with P , m^3 and K [1]
- CO_2 volume = 652 cm^3 [2]
- Theoretical $\text{Ca}(\text{NO}_3)_2$ mass = 4.31583 g [2]
- Percentage yield = 83.4% [1]
- Atom economy = 72.6% [2]
- Interpretation: 72.6% of the reactant mass is theoretically incorporated into $\text{Ca}(\text{NO}_3)_2$; the remainder forms by-products [1]

EXAMINER GUIDANCE

Back titration requires subtraction in moles before the reaction ratio. The NaOH titre measures the acid left, not the acid consumed by the mineral.

EXAMINER GUIDANCE

Gas-law check: $100 \text{ kPa} = 100\,000 \text{ Pa}$, 298 K is already in kelvin, and $6.516 \times 10^{-4} \text{ m}^3 = 652 \text{ cm}^3$.

EXAMINER GUIDANCE

Yield can change with practical losses; atom economy is fixed by the balanced equation. A high value for one does not guarantee a high value for the other.

EXAMINER GUIDANCE

Sanity check: purity and yield should be below 100% here, while the atom economy is lower because CO_2 and H_2O are unavoidable by-products.