



CrackingCHEM

GCSE | A-LEVEL

UNDERSTAND • APPLY • SUCCEED

OCR A H432

Amount of Substance II

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

SPECIFICATION-LED. PROGRESSIVE. EXAM-REALISTIC.

OCR A SPECIFICATION	2.1.2(b) 2.1.3(b), (c), (d), (e)(i), (g) mass-based practical interpretation		
TEST IT	EXAM STYLE	HARDER MIXED	STRETCH
8	10	5	1
24 QUESTIONS ORIGINAL		148 MARKS TOTAL	

FINAL NOTES-ALIGNED EDITION | EQUATIONS • CALCULATIONS • FORMULAE • HYDRATES

Independent practice material. Every question is original and remains within the finished OCR A Amount of Substance II notes.



START HERE

How to use this pack

Attempt the questions independently, then use the worked answers to improve

- 1 Complete the question section without referring to the worked answers.
- 2 Show every stage of each calculation clearly in the dotted working space.
- 3 Give chemical formulae, state symbols, units and significant figures exactly as requested.
- 4 After marking, compare your route with the worked grid and identify the first point at which your method went wrong.

OCR A BOUNDARY

This pack assesses balanced and ionic equations, reacting masses, limiting reactants, empirical and molecular formulae, elemental analysis, hydrated salts and mass-based practical interpretation.

HELD BACK

Solution concentration, titration calculations, gas-volume calculations, percentage yield and atom economy belong to Amount of Substance III and are not assessed here.

EXAM CONDITIONS

The question pages contain no method grids, numbered routes or calculation prompts beyond the information required by the question.

MARKING

Marks reward a valid chemical route, correct formulae, appropriate units and the requested significant figures.

ANSWER SPACE

Question pages provide clear dotted working lines without method scaffolding. The worked-answer section shows complete calculation grids.



SECTION A

TEST IT

Eight direct checks of the finished-notes mastery outcomes

QUESTION 1

TEST IT

(a) Balance the equation and include the state symbols: $\text{Al} + \text{Cl}_2 \rightarrow \text{AlCl}_3$.

[2 marks]

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(b) Balance the equation and include the state symbols: $\text{KClO}_3 \rightarrow \text{KCl} + \text{O}_2$.

[2 marks]

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QUESTION 2

TEST IT

Aqueous barium nitrate reacts with aqueous sodium carbonate to form solid barium carbonate and aqueous sodium nitrate.

(a) Write the balanced full equation, including state symbols.

[2 marks]

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(b) Write the ionic equation, including state symbols.

[2 marks]

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(c) Name both spectator ions.

[1 mark]

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**QUESTION 3****TEST IT**

Aluminium reacts with chlorine: $2\text{Al} + 3\text{Cl}_2 \rightarrow 2\text{AlCl}_3$.

(a) State the mole ratio $n(\text{Al}) : n(\text{Cl}_2) : n(\text{AlCl}_3)$.

[1 mark]

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(b) Calculate $n(\text{AlCl}_3)$ formed from 0.240 mol Cl_2 when aluminium is in excess.

[2 marks]

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(c) Explain why the coefficients 2 : 3 must not be used as a mass ratio.

[1 mark]

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QUESTION 4**TEST IT**

Calcium carbonate decomposes: $\text{CaCO}_3 \rightarrow \text{CaO} + \text{CO}_2$. Calculate the mass of CaO formed from 12.5 g CaCO_3 . Give 3 significant figures. $M(\text{CaCO}_3) = 100.1$ and $M(\text{CaO}) = 56.1 \text{ g mol}^{-1}$.

[4 marks]

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QUESTION 5**TEST IT**

Sodium reacts with chlorine: $2\text{Na} + \text{Cl}_2 \rightarrow 2\text{NaCl}$. A mixture contains 4.60 g Na and 5.68 g Cl_2 . Use $M(\text{Na}) = 23.0$ and $M(\text{Cl}_2) = 70.9 \text{ g mol}^{-1}$. Identify the limiting reactant. Show your working.

[5 marks]

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QUESTION 6**TEST IT**

A compound contains 2.70 g aluminium and 2.40 g oxygen. Determine its empirical formula. $A_r(\text{Al}) = 27.0$ and $A_r(\text{O}) = 16.0$.

[4 marks]

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**QUESTION 7****TEST IT**

A molecular compound is 55.8% C, 7.0% H and 37.2% O by mass. Its M_r is 86.0. Determine its empirical formula and molecular formula. $A_r(\text{C}) = 12.0$, $A_r(\text{H}) = 1.0$ and $A_r(\text{O}) = 16.0$.

[5 marks]

QUESTION 8**TEST IT**

(a) State what is meant by an anhydrous salt.

[1 mark]

(b) State what is meant by water of crystallisation.

[2 marks]

(c) Explain the meaning of the dot and the 7 in $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$.

[2 marks]



SECTION B

EXAM STYLE

Ten original structured questions using OCR A quantitative conventions

QUESTION 9

EXAM STYLE

Aqueous calcium chloride is mixed with aqueous sodium phosphate. Solid calcium phosphate forms.

(a) Write the balanced full equation, including state symbols.

[2 marks]

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(b) Write the ionic equation, including state symbols.

[2 marks]

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(c) Name the spectator ions.

[1 mark]

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QUESTION 10

EXAM STYLE

Iron reacts with excess oxygen: $4\text{Fe} + 3\text{O}_2 \rightarrow 2\text{Fe}_2\text{O}_3$. Calculate the mass of Fe_2O_3 formed from 8.37 g Fe. Give 3 significant figures. $M(\text{Fe}) = 55.8$ and $M(\text{Fe}_2\text{O}_3) = 159.6 \text{ g mol}^{-1}$.

[5 marks]

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QUESTION 11

EXAM STYLE

Sodium hydrogencarbonate decomposes: $2\text{NaHCO}_3 \rightarrow \text{Na}_2\text{CO}_3 + \text{H}_2\text{O} + \text{CO}_2$. Calculate the mass of NaHCO_3 that must decompose to form 3.18 g Na_2CO_3 . $M(\text{NaHCO}_3) = 84.0$ and $M(\text{Na}_2\text{CO}_3) = 106.0 \text{ g mol}^{-1}$.

[5 marks]

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QUESTION 12

EXAM STYLE

Magnesium burns in excess oxygen: $2\text{Mg} + \text{O}_2 \rightarrow 2\text{MgO}$. A student uses 4.86 g Mg and writes: 'm(MgO) = $4.86 \times 2/2 = 4.86$ g.' Use $M(\text{Mg}) = 24.3$ and $M(\text{MgO}) = 40.3 \text{ g mol}^{-1}$.

(a) Identify the chemical error in the student's route.

[1 mark]

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(b) Correct the calculation and give m(MgO) to 3 significant figures.

[3 marks]

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(c) State one calculation practice that prevents a rounding error in a multi-step route.

[1 mark]

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QUESTION 13

EXAM STYLE

Aluminium reacts with bromine: $2\text{Al} + 3\text{Br}_2 \rightarrow 2\text{AlBr}_3$. A mixture contains 5.40 g Al and 31.96 g Br_2 . Identify the limiting reactant and calculate the maximum mass of AlBr_3 . $M(\text{Al}) = 27.0$, $M(\text{Br}_2) = 159.8$ and $M(\text{AlBr}_3) = 266.7 \text{ g mol}^{-1}$. [7 marks]

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QUESTION 14

EXAM STYLE

Iron(III) oxide reacts with carbon monoxide: $\text{Fe}_2\text{O}_3 + 3\text{CO} \rightarrow 2\text{Fe} + 3\text{CO}_2$. A mixture contains 7.98 g Fe_2O_3 and 4.20 g CO. Show that the reactants are in the exact stoichiometric ratio, then calculate the mass of Fe formed. $M(\text{Fe}_2\text{O}_3) = 159.6$, $M(\text{CO}) = 28.0$ and $M(\text{Fe}) = 55.8 \text{ g mol}^{-1}$. [5 marks]

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**QUESTION 15****EXAM STYLE**

A 1.395 g sample of iron reacts completely with oxygen to form 1.995 g of an oxide. Determine the empirical formula of the oxide. $A_r(\text{Fe}) = 55.8$ and $A_r(\text{O}) = 16.0$. Show how you obtain the mass of oxygen.

[6 marks]

QUESTION 16**EXAM STYLE**

A molecular compound is 62.1% C, 10.3% H and 27.6% O by mass. Its M_r is 116. Determine its empirical formula and molecular formula. $A_r(\text{C}) = 12.0$, $A_r(\text{H}) = 1.0$ and $A_r(\text{O}) = 16.0$.

[6 marks]

**QUESTION 17****EXAM STYLE**

Complete combustion of 0.580 g of a compound containing only C, H and O produces 1.320 g CO₂ and 0.540 g H₂O. Determine the empirical formula. $M(\text{CO}_2) = 44.0$ and $M(\text{H}_2\text{O}) = 18.0 \text{ g mol}^{-1}$; $A_r(\text{C}) = 12.0$, $A_r(\text{H}) = 1.0$ and $A_r(\text{O}) = 16.0$. **[7 marks]**

QUESTION 18**EXAM STYLE**

FeSO₄·xH₂O is heated. Only water is lost. Empty crucible = 24.850 g; crucible + hydrate = 27.629 g. Successive heat-cool readings are 26.455 g, 26.371 g, 26.369 g and 26.369 g. Determine x and the full formula. $M(\text{FeSO}_4) = 151.9$ and $M(\text{H}_2\text{O}) = 18.0 \text{ g mol}^{-1}$. Explain why heating, cooling and weighing are repeated. **[8 marks]**



SECTION C

HARDER MIXED

Five unfamiliar applications with less scaffolding

QUESTION 19

HARDER MIXED

Iron pyrite is roasted in oxygen. The unbalanced equation is $\text{FeS}_2(\text{s}) + \text{O}_2(\text{g}) \rightarrow \text{Fe}_2\text{O}_3(\text{s}) + \text{SO}_2(\text{g})$.

(a) Balance the equation using the smallest whole-number coefficients.

[4 marks]

(b) Use your balanced equation to calculate the mass of FeS_2 required to form 12.8 g SO_2 . $M(\text{FeS}_2) = 119.9$ and $M(\text{SO}_2) = 64.0 \text{ g mol}^{-1}$.

[4 marks]

QUESTION 20

HARDER MIXED

Iron reacts with chlorine: $2\text{Fe} + 3\text{Cl}_2 \rightarrow 2\text{FeCl}_3$. A mixture contains 8.37 g Fe and 14.18 g Cl_2 . Determine the limiting reactant, the maximum mass of FeCl_3 and the mass of the excess reactant remaining. $M(\text{Fe}) = 55.8$, $M(\text{Cl}_2) = 70.9$ and $M(\text{FeCl}_3) = 162.3 \text{ g mol}^{-1}$.

[9 marks]



QUESTION 21

HARDER MIXED

Complete combustion of 0.440 g of a compound containing only C, H and O produces 0.880 g CO_2 and 0.360 g H_2O . The compound has $M_r = 88.0$. Determine its empirical formula and molecular formula. $M(\text{CO}_2) = 44.0$ and $M(\text{H}_2\text{O}) = 18.0 \text{ g mol}^{-1}$. [9 marks]

QUESTION 22

HARDER MIXED

(a) $\text{CoCl}_2 \cdot x\text{H}_2\text{O}$ contains 45.4% water by mass. Calculate x and give the full formula. $M(\text{CoCl}_2) = 129.9$ and $M(\text{H}_2\text{O}) = 18.0 \text{ g mol}^{-1}$. [5 marks]

(b) A student claims that $x = 5$ is equally acceptable. Use your ratio to assess the claim. [1 mark]

(c) In a separate heating experiment, some solid is lost by spitting and all mass loss is treated as water. [2 marks]
Explain the effect on the calculated value of x.



QUESTION 23

HARDER MIXED

A hydrate $\text{ZnSO}_4 \cdot x\text{H}_2\text{O}$ is heated. Only water is lost. The balance reads to 0.01 g.

MEASUREMENT	MASS / g
Empty crucible	22.40
Crucible + hydrate	24.74
After first heating	24.18
After second heating	24.04
After third heating	24.02
After fourth heating	24.02

(a) Select the defensible constant-mass reading and justify your choice.

[1 mark]

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(b) Use $M(\text{ZnSO}_4) = 161.5$ and $M(\text{H}_2\text{O}) = 18.0 \text{ g mol}^{-1}$ to determine x and the full formula.

[6 marks]

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(c) Evaluate the claim: 'constant mass proves that no salt decomposed.'

[1 mark]

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SECTION D

STRETCH / SYNOPTIC

One integrated problem connecting formula, equation and limiting-reagent reasoning

QUESTION 24

STRETCH

Magnesium reacts with nitrogen to form magnesium nitride. In one experiment, 3.645 g Mg combines with 1.400 g N. $A_r(\text{Mg}) = 24.3$ and $A_r(\text{N}) = 14.0$.

(a) Determine the empirical formula of magnesium nitride.

[4 marks]

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(b) Write the balanced formation equation, including state symbols.

[2 marks]

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A second mixture contains 4.86 g Mg and 2.24 g N_2 . $M(\text{N}_2) = 28.0 \text{ g mol}^{-1}$ and $M(\text{Mg}_3\text{N}_2) = 100.9 \text{ g mol}^{-1}$.

(c) Identify the limiting reactant, calculate the maximum product mass and calculate the mass of excess reactant remaining.

[5 marks]

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GCSE | A-LEVEL

UNDERSTAND • APPLY • SUCCEED

OCR A H432

Amount of Substance II

Fully worked answers | OCR A-style marking guidance

SPECIFICATION-LED. PROGRESSIVE. EXAM-REALISTIC.

OCR A SPECIFICATION	2.1.2(b) 2.1.3(b), (c), (d), (e)(i), (g) mass-based practical interpretation		
TEST IT	EXAM STYLE	HARDER MIXED	STRETCH
8	10	5	1
24 QUESTIONS MARKED		148 MARKS EXPLAINED	

FINAL NOTES-ALIGNED EDITION | EQUATIONS • CALCULATIONS • FORMULAE • HYDRATES

Independent practice material. Every question is original and remains within the finished OCR A Amount of Substance II notes.



OCR A MAP

How this pack matches the specification

Every question maps to the finished notes; Amount of Substance III is held back

OCR A AREA	WHAT IS ASSESSED	FREQUENT TRAP	QUESTIONS
2.1.2(b)	Balanced full and ionic equations; states; spectators; conservation of atoms and charge.	Changing formula subscripts or splitting solids into ions.	1-3, 9, 19, 24
2.1.3(e)(i), (g)	Coefficient ratios, reacting masses, reverse routes, limiting reactants and excess remaining.	Using a mass ratio or all of an excess reactant.	3-5, 10-14, 19-20, 24
2.1.3(b), (c)	Empirical and molecular formulae from masses, percentages and elemental-analysis data.	Rounding 1.5 instead of scaling the whole ratio.	6-7, 15-17, 21, 24
2.1.3(d)	Anhydrous and hydrated salts; water of crystallisation; formulae from percentage and heating data.	Using container mass or initial hydrate mass as salt mass.	8, 18, 22-23
PAG1 links	Constant mass, measurement interpretation, significant figures and direction of experimental error.	Saying only 'human error' without tracing the ratio.	12, 18, 22-23
METHOD	Question pages are deliberately unscaffolded. Worked calculations in the answers reproduce the notes' numbered down → across → up route, including limiting-reactant, empirical-formula and hydrate grids.		
BOUNDARY	No concentration, titration, gas-volume, ideal-gas, percentage-yield or atom-economy calculation is assessed.		



SECTION A

TEST IT ANSWERS

Direct notes-matched methods with precise marking points

QUESTION 1 | TEST IT ANSWER

4 MARKS

(a)

- $2\text{Al(s)} + 3\text{Cl}_2\text{(g)} \rightarrow 2\text{AlCl}_3\text{(s)}$: smallest whole-number coefficients [1]
- All three state symbols correct [1]

(b)

- $2\text{KClO}_3\text{(s)} \rightarrow 2\text{KCl(s)} + 3\text{O}_2\text{(g)}$: smallest whole-number coefficients [1]
- All three state symbols correct [1]

QUESTION 2 | TEST IT ANSWER

5 MARKS

(a)

- $\text{Ba(NO}_3)_2\text{(aq)} + \text{Na}_2\text{CO}_3\text{(aq)} \rightarrow \text{BaCO}_3\text{(s)} + 2\text{NaNO}_3\text{(aq)}$ [1]
- Correct state symbols throughout [1]

(b)

- $\text{Ba}^{2+}\text{(aq)} + \text{CO}_3^{2-}\text{(aq)} \rightarrow \text{BaCO}_3\text{(s)}$ [1]
- Correct states; atoms and total charge are conserved [1]

(c)

- Sodium ions and nitrate ions (Na^+ and NO_3^-); both names required [1]

EXAMINER GUIDANCE

Split aqueous ionic compounds into ions, but keep the solid precipitate together. Spectator ions appear unchanged on both sides and are cancelled.

QUESTION 3 | TEST IT ANSWER

4 MARKS

(a)

- $n(\text{Al}) : n(\text{Cl}_2) : n(\text{AlCl}_3) = 2 : 3 : 2$ [1]

(b)

- $n(\text{AlCl}_3) = 0.240 \times 2 \div 3$ [1]
- $n(\text{AlCl}_3) = 0.160 \text{ mol}$ [1]

(c)

- Coefficients compare amounts in moles; particle masses differ, so they are not a mass ratio [1]

QUESTION 4 | TEST IT ANSWER

4 MARKS

① known mass ↓ ② known relative mass ↓ ③ known amount → ④ coefficient ratio → ⑤ required amount ↑ ⑥ required mass

$\text{CaCO}_3 \rightarrow \text{CaO} + \text{CO}_2$	CaCO_3	CaO
Mass, m / g	① 12.5	⑥ $0.124875... \times 56.1 = 7.00549...$
M_r / A_r^* (no unit)	② 100.1	⑤ 56.1
Moles, n / mol	③ $12.5 \div 100.1 = 0.124875...$	④ $0.124875... \times 1 \div 1$

- $n(\text{CaCO}_3) = 12.5 \div 100.1 = 0.124875... \text{ mol}$ [1]
- The coefficient ratio $\text{CaCO}_3 : \text{CaO}$ is 1 : 1, so $n(\text{CaO}) = 0.124875... \text{ mol}$ [1]
- $m(\text{CaO}) = 0.124875... \times 56.1 = 7.00549... \text{ g}$ [1]
- Final answer = 7.01 g to 3 significant figures [1]



QUESTION 5 | TEST IT ANSWER

5 MARKS

① down both reactants ↓ ② compare $n \div \text{coefficient}$ → ③ identify the smaller value and limiting reactant

$2\text{Na} + \text{Cl}_2 \rightarrow 2\text{NaCl}$	Na available	Cl_2 available
Mass, m / g	4.60	5.68
M_r / A_r^* (no unit)	23.0	70.9
Moles, n / mol	$4.60 \div 23.0 = 0.200$	$5.68 \div 70.9 = 0.0801128\dots$
$n \div \text{coefficient}$	$0.200 \div 2 = 0.100$	$0.0801128\dots \div 1 = 0.0801128\dots$ LIMITING

- $n(\text{Na}) = 0.200 \text{ mol}$ [1]
- $n(\text{Cl}_2) = 0.0801128\dots \text{mol}$ [1]
- $n(\text{Na}) \div 2 = 0.100 \text{ mol}$ [1]
- $n(\text{Cl}_2) \div 1 = 0.0801128\dots \text{mol}$ [1]
- Cl_2 is limiting because it gives the smaller $n \div \text{coefficient}$ value [1]

QUESTION 6 | TEST IT ANSWER

4 MARKS

ELEMENT GRID	Al	O
Mass, m / g	2.70	2.40
A_r (no unit)	27.0	16.0
Moles, n / mol	$2.70 \div 27.0 = 0.100$	$2.40 \div 16.0 = 0.150$
$\div$ smallest amount	1	1.5
Whole-number ratio	2	3

- Amounts give Al : O = $0.100 : 0.150$ [1]
- Divide by 0.100 to obtain 1 : 1.5 [1]
- Multiply the complete ratio by 2 to obtain 2 : 3 [1]
- Empirical formula = Al_2O_3 [1]

EXAMINER GUIDANCE Do not round 1.5 to 2. Formula subscripts must come from a whole-ratio scaling step.

QUESTION 7 | TEST IT ANSWER

5 MARKS

ELEMENT GRID	C	H	O
Mass, m / g	55.8	7.0	37.2
A_r (no unit)	12.0	1.0	16.0
Moles, n / mol	4.65	7.00	2.325
$\div$ smallest amount	2.00	$3.01 \approx 3$	1.00
Whole-number ratio	2	3	1

- The calculated amounts divide to C : H : O = 2 : 3 : 1 [1]
- Empirical formula = $\text{C}_2\text{H}_3\text{O}$ [1]
- Empirical formula mass = $(2 \times 12.0) + (3 \times 1.0) + 16.0 = 43.0$ [1]
- Multiplier = $86.0 \div 43.0 = 2$ [1]
- Molecular formula = $\text{C}_4\text{H}_6\text{O}_2$ [1]



QUESTION 8 | TEST IT ANSWER

5 MARKS

(a)

- An anhydrous salt contains no water of crystallisation [1]

(b)

- Water molecules incorporated into a crystal structure [1]
- They occur in a fixed ratio to the salt [1]

(c)

- The dot separates MgSO_4 from its water of crystallisation [1]
- There are seven H_2O molecules per MgSO_4 formula unit [1]

SECTION B

EXAM STYLE ANSWERS

Worked grids and OCR-style marking guidance

QUESTION 9 | EXAM STYLE ANSWER

5 MARKS

- $3\text{CaCl}_2(\text{aq}) + 2\text{Na}_3\text{PO}_4(\text{aq}) \rightarrow \text{Ca}_3(\text{PO}_4)_2(\text{s}) + 6\text{NaCl}(\text{aq})$ [1]
- Correct state symbols throughout [1]
- $3\text{Ca}^{2+}(\text{aq}) + 2\text{PO}_4^{3-}(\text{aq}) \rightarrow \text{Ca}_3(\text{PO}_4)_2(\text{s})$ [1]
- Correct ionic states; total charge is zero on each side [1]
- Spectator ions: sodium ions and chloride ions (Na^+ and Cl^-) [1]

QUESTION 10 | EXAM STYLE ANSWER

5 MARKS

① known mass ↓ ② known relative mass ↓ ③ known amount → ④ coefficient ratio → ⑤ required amount ↑ ⑥ required mass

$4\text{Fe} + 3\text{O}_2 \rightarrow 2\text{Fe}_2\text{O}_3$	Fe	Fe_2O_3
Mass, m / g	① 8.37	⑥ $0.0750 \times 159.6 = 11.97$
M_r / A_r^* (no unit)	② 55.8	⑤ 159.6
Moles, n / mol	③ $8.37 \div 55.8 = 0.150$	④ $0.150 \times 2 \div 4 = 0.0750$

- $n(\text{Fe}) = 0.150 \text{ mol}$ [1]
- Use the coefficient ratio 4 : 2 [1]
- $n(\text{Fe}_2\text{O}_3) = 0.0750 \text{ mol}$ [1]
- $m(\text{Fe}_2\text{O}_3) = 11.97 \text{ g}$ [1]
- Final answer = 12.0 g to 3 significant figures [1]

QUESTION 11 | EXAM STYLE ANSWER

5 MARKS

① product mass ↓ ② product amount → ③ coefficient ratio → ④ reactant amount ↑ ⑤ reactant mass

$2\text{NaHCO}_3 \rightarrow \text{Na}_2\text{CO}_3 + \text{H}_2\text{O} + \text{CO}_2$	NaHCO_3	Na_2CO_3
Mass, m / g	⑥ $0.0600 \times 84.0 = 5.04$	① 3.18
M_r / A_r^* (no unit)	⑤ 84.0	② 106.0
Moles, n / mol	④ $0.0300 \times 2 \div 1 = 0.0600$	③ $3.18 \div 106.0 = 0.0300$

- $n(\text{Na}_2\text{CO}_3) = 3.18 \div 106.0 = 0.0300 \text{ mol}$ [1]
- Use $\text{NaHCO}_3 : \text{Na}_2\text{CO}_3 = 2 : 1$ [1]
- $n(\text{NaHCO}_3) = 0.0600 \text{ mol}$ [1]
- $m(\text{NaHCO}_3) = 0.0600 \times 84.0 = 5.04 \text{ g}$ [1]
- Correct labelled reverse route and final unit [1]



QUESTION 12 | EXAM STYLE ANSWER

5 MARKS

(a)

- The coefficient ratio is a mole ratio, not a mass ratio [1]

(b)

- $n(\text{Mg}) = 4.86 \div 24.3 = 0.200 \text{ mol}$ [1]
- $\text{Mg} : \text{MgO} = 2 : 2$, so $n(\text{MgO}) = 0.200 \text{ mol}$ [1]
- $m(\text{MgO}) = 0.200 \times 40.3 = 8.06 \text{ g}$ [1]

(c)

- Keep unrounded calculator values until the final answer / round only once at the end [1]

QUESTION 13 | EXAM STYLE ANSWER

7 MARKS

① down both reactants ↓ ② compare $n \div \text{coefficient}$ → ③ use the limiting reactant → ④ product amount ↑ ⑤ product mass

$2\text{Al} + 3\text{Br}_2 \rightarrow 2\text{AlBr}_3$	Al available	Br ₂ available	AlBr ₃ formed
Mass, m / g	5.40	31.96	$0.133333... \times 266.7 = 35.56$
M_r / A_r^* (no unit)	27.0	159.8	266.7
Moles, n / mol	$5.40 \div 27.0 = 0.200$	$31.96 \div 159.8 = 0.200$	$0.200 \times 2 \div 3 = 0.133333...$
$n \div \text{coefficient}$	$0.200 \div 2 = 0.100$	$0.200 \div 3 = 0.0666667...$ LIMITING	Not compared

- $n(\text{Al}) = 0.200 \text{ mol}$ [1]
- $n(\text{Br}_2) = 0.200 \text{ mol}$ [1]
- $n \div \text{coefficient}$ values are 0.100 and 0.0666667...; Br₂ is limiting [2]
- $n(\text{AlBr}_3) = 0.133333... \text{ mol}$ [1]
- Calculated mass = 35.56 g [1]
- Maximum mass = 35.6 g to 3 significant figures [1]

QUESTION 14 | EXAM STYLE ANSWER

5 MARKS

$\text{Fe}_2\text{O}_3 + 3\text{CO} \rightarrow 2\text{Fe} + 3\text{CO}_2$	Fe ₂ O ₃	CO	Fe
Mass, m / g	7.98	4.20	$0.100 \times 55.8 = 5.58$
M_r / A_r^* (no unit)	159.6	28.0	55.8
Moles, n / mol	0.0500	0.150	$0.0500 \times 2 = 0.100$
$n \div \text{coefficient}$	$0.0500 \div 1 = 0.0500$	$0.150 \div 3 = 0.0500$	Not compared

- $n(\text{Fe}_2\text{O}_3) = 0.0500 \text{ mol}$ and $n(\text{CO}) = 0.150 \text{ mol}$ [1]
- Both $n \div \text{coefficient}$ values equal 0.0500 [1]
- Neither reactant is in excess [1]
- $n(\text{Fe}) = 0.100 \text{ mol}$ [1]
- $m(\text{Fe}) = 0.100 \times 55.8 = 5.58 \text{ g}$ [1]



QUESTION 15 | EXAM STYLE ANSWER

6 MARKS

ELEMENT GRID	Fe	O
Mass, m / g	1.395	1.995 – 1.395 = 0.600
A _r (no unit)	55.8	16.0
Moles, n / mol	0.0250	0.0375
÷ smallest amount	1	1.5
Whole-number ratio	2	3

- $m(\text{O}) = 1.995 - 1.395 = 0.600 \text{ g}$ [1]
- $n(\text{Fe}) = 0.0250 \text{ mol}$ [1]
- $n(\text{O}) = 0.0375 \text{ mol}$ [1]
- Divide by 0.0250 to obtain 1 : 1.5 [1]
- Multiply both values by 2 to obtain 2 : 3 [1]
- Empirical formula = Fe_2O_3 [1]

QUESTION 16 | EXAM STYLE ANSWER

6 MARKS

ELEMENT GRID	C	H	O
Mass, m / g	62.1	10.3	27.6
A _r (no unit)	12.0	1.0	16.0
Moles, n / mol	5.175	10.3	1.725
÷ smallest amount	3.00	5.97 ≈ 6	1.00
Whole-number ratio	3	6	1

- The calculated amounts give the simplest ratio 3 : 6 : 1 [1]
- Empirical formula = $\text{C}_3\text{H}_6\text{O}$ [1]
- Empirical formula mass = 58 [1]
- Multiplier = $116 \div 58 = 2$ [1]
- Every subscript is multiplied by 2 [1]
- Molecular formula = $\text{C}_6\text{H}_{12}\text{O}_2$ [1]

QUESTION 17 | EXAM STYLE ANSWER

7 MARKS

- $n(\text{C}) = n(\text{CO}_2) = 1.320 \div 44.0 = 0.0300 \text{ mol}$ [1]
- $n(\text{H}_2\text{O}) = 0.540 \div 18.0 = 0.0300 \text{ mol}$; $n(\text{H}) = 2 \times 0.0300 = 0.0600 \text{ mol}$ [1]
- $m(\text{C}) = 0.0300 \times 12.0 = 0.360 \text{ g}$ [1]
- $m(\text{H}) = 0.0600 \times 1.0 = 0.0600 \text{ g}$ [1]
- $m(\text{O}) = 0.580 - 0.360 - 0.0600 = 0.160 \text{ g}$ [1]
- $n(\text{O}) = 0.160 \div 16.0 = 0.0100 \text{ mol}$ [1]

ELEMENT GRID	C	H	O
Mass, m / g	0.360	0.0600	0.160
A _r (no unit)	12.0	1.0	16.0
Moles, n / mol	0.0300	0.0600	0.0100
÷ smallest amount	3	6	1
Whole-number ratio	3	6	1

- Empirical formula = $\text{C}_3\text{H}_6\text{O}$ [1]

EXAMINER GUIDANCE

Oxygen in the combustion products may come from O_2 . For a stated C/H/O sample, obtain the sample's oxygen mass by difference.



QUESTION 18 | EXAM STYLE ANSWER

8 MARKS

- Use 26.369 g because two successive readings are identical [1]

HYDRATE GRID	FeSO ₄	H ₂ O
Mass, m / g	26.369 – 24.850 = 1.519	27.629 – 26.369 = 1.260
M _r / A _r * (no unit)	151.9	18.0
Moles, n / mol	1.519 ÷ 151.9 = 0.0100	1.260 ÷ 18.0 = 0.0700
Salt : water ratio	1	7

- Mass of anhydrous FeSO₄ = 1.519 g [1]
- Mass of water = 1.260 g [1]
- n(FeSO₄) = 0.0100 mol [1]
- n(H₂O) = 0.0700 mol [1]
- Salt : water = 1 : 7, so x = 7 [1]
- Full formula = FeSO₄·7H₂O [1]
- Repeating heat-cool-weigh cycles checks whether further mass is lost and supports complete dehydration [1]

SECTION C

HARDER MIXED ANSWERS

Less-scaffolded applications with explicit reasoning chains

QUESTION 19 | HARDER MIXED ANSWER

8 MARKS

(a)

- 4FeS₂(s) + 11O₂(g) → 2Fe₂O₃(s) + 8SO₂(g): Fe coefficient 4 [1]
- O₂ coefficient 11 [1]
- Fe₂O₃ coefficient 2 [1]
- SO₂ coefficient 8; smallest whole-number set [1]

(b)

① product mass ↓ ② product amount → ③ coefficient ratio → ④ reactant amount ↑ ⑤ reactant mass

4FeS ₂ + 11O ₂ → 2Fe ₂ O ₃ + 8SO ₂	FeS ₂	SO ₂
Mass, m / g	0.100 × 119.9 = 11.99	12.8
M _r / A _r * (no unit)	119.9	64.0
Moles, n / mol	0.200 × 4 ÷ 8 = 0.100	12.8 ÷ 64.0 = 0.200

- n(SO₂) = 0.200 mol [1]
- Use FeS₂ : SO₂ = 4 : 8 [1]
- n(FeS₂) = 0.100 mol [1]
- m(FeS₂) = 11.99 g = 12.0 g to 3 significant figures [1]



QUESTION 20 | HARDER MIXED ANSWER

9 MARKS

① down both reactants ↓ ② compare $n \div \text{coefficient}$ → ③ use the limiting reactant → ④ product amount ↑ ⑤ product mass

$2\text{Fe} + 3\text{Cl}_2 \rightarrow 2\text{FeCl}_3$	Fe available	Cl_2 available	FeCl_3 formed
Mass, m / g	8.37	14.18	$0.133333... \times 162.3 = 21.64$
M_r / A_r^* (no unit)	55.8	70.9	162.3
Moles, n / mol	0.150	0.200	$0.200 \times 2 \div 3 = 0.133333...$
$n \div \text{coefficient}$	$0.150 \div 2 = 0.0750$	$0.200 \div 3 = 0.0666667...$ LIMITING	Not compared
Amount used / mol	$0.200 \times 2 \div 3 = 0.133333...$	0.200	0.133333...
Reactant left / g	$8.37 - (0.133333... \times 55.8) = 0.930$	0	Not a reactant

- $n(\text{Fe}) = 0.150 \text{ mol}$ and $n(\text{Cl}_2) = 0.200 \text{ mol}$ [2]
- $n \div \text{coefficient}$ values are 0.0750 and 0.0666667... [1]
- Cl_2 is limiting [1]
- $n(\text{FeCl}_3) = 0.133333... \text{ mol}$ [1]
- $m(\text{FeCl}_3) = 21.64 \text{ g} = 21.6 \text{ g}$ to 3 significant figures [1]
- $n(\text{Fe}) \text{ used} = 0.133333... \text{ mol}$ [1]
- $m(\text{Fe}) \text{ used} = 7.44 \text{ g}$ [1]
- $m(\text{Fe}) \text{ remaining} = 8.37 - 7.44 = 0.930 \text{ g}$ [1]

EXAMINER GUIDANCE

The available amount of an excess reactant is not the amount used. Work back from the limiting reactant before subtracting.

QUESTION 21 | HARDER MIXED ANSWER

9 MARKS

- $n(\text{C}) = n(\text{CO}_2) = 0.880 \div 44.0 = 0.0200 \text{ mol}$ [1]
- $n(\text{H}) = 2 \times (0.360 \div 18.0) = 0.0400 \text{ mol}$ [1]
- $m(\text{C}) = 0.240 \text{ g}$ [1]
- $m(\text{H}) = 0.0400 \text{ g}$ [1]
- $m(\text{O}) = 0.440 - 0.240 - 0.0400 = 0.160 \text{ g}$; $n(\text{O}) = 0.0100 \text{ mol}$ [2]

ELEMENT GRID	C	H	O
Mass, m / g	0.240	0.0400	0.160
A_r (no unit)	12.0	1.0	16.0
Moles, n / mol	0.0200	0.0400	0.0100
$\div$ smallest amount	2	4	1
Whole-number ratio	2	4	1

- Empirical formula = $\text{C}_2\text{H}_4\text{O}$ [1]
- Empirical formula mass = 44.0; multiplier = $88.0 \div 44.0 = 2$ [1]
- Molecular formula = $\text{C}_4\text{H}_8\text{O}_2$ [1]



QUESTION 22 | HARDER MIXED ANSWER

8 MARKS

(a)

HYDRATE GRID	CoCl ₂	H ₂ O
Mass, m / g	100 - 45.4 = 54.6	45.4
M _r / A _r * (no unit)	129.9	18.0
Moles, n / mol	54.6 ÷ 129.9 = 0.420323...	45.4 ÷ 18.0 = 2.52222...
Salt : water ratio	1	6.00067... ≈ 6

- Assume 100 g: m(CoCl₂) = 54.6 g and m(H₂O) = 45.4 g [1]
- n(CoCl₂) = 0.420323... mol [1]
- n(H₂O) = 2.52222... mol [1]
- x = 2.52222... ÷ 0.420323... = 6.00067... ≈ 6 [1]
- Full formula = CoCl₂·6H₂O [1]

(b)

- The ratio is approximately 6.00, so x = 6; x = 5 is not supported [1]

(c)

- Solid loss makes the residue / calculated amount of anhydrous salt too low [1]
- It also makes apparent water loss too high, so x is too high [1]

QUESTION 23 | HARDER MIXED ANSWER

8 MARKS

(a)

- Use 24.02 g because two successive readings agree to the 0.01 g balance resolution [1]

(b)

HYDRATE GRID	ZnSO ₄	H ₂ O
Mass, m / g	24.02 - 22.40 = 1.62	24.74 - 24.02 = 0.72
M _r / A _r * (no unit)	161.5	18.0
Moles, n / mol	1.62 ÷ 161.5 = 0.0100310...	0.72 ÷ 18.0 = 0.0400
Salt : water ratio	1	3.98765... ≈ 4

- Masses of ZnSO₄ and water are 1.62 g and 0.72 g [2]
- Amounts are 0.0100310... mol and 0.0400 mol [2]
- Water : salt ratio is 3.98765... : 1, so x = 4 [1]
- Full formula = ZnSO₄·4H₂O [1]

(c)

- Constant mass supports complete water removal but does not prove that the salt has not decomposed [1]



SECTION D

STRETCH / SYNOPTIC ANSWER

One complete route from composition to a limiting-reagent calculation

QUESTION 24 | STRETCH ANSWER

11 MARKS

(a)

ELEMENT GRID	Mg	N
Mass, m / g	3.645	1.400
A_r (no unit)	24.3	14.0
Moles, n / mol	0.150	0.100
÷ smallest amount	1.5	1
Whole-number ratio	3	2

- $n(\text{Mg}) = 0.150 \text{ mol}$ and $n(\text{N}) = 0.100 \text{ mol}$ [1]
- Divide by 0.100 to obtain 1.5 : 1 [1]
- Multiply both values by 2 to obtain 3 : 2 [1]
- Empirical formula = Mg_3N_2 [1]

(b)

- $3\text{Mg}(\text{s}) + \text{N}_2(\text{g}) \rightarrow \text{Mg}_3\text{N}_2(\text{s})$: balanced formulae [1]
- Correct state symbols [1]

(c)

$3\text{Mg} + \text{N}_2 \rightarrow \text{Mg}_3\text{N}_2$	Mg available	N_2 available	Mg_3N_2 formed
Mass, m / g	4.86	2.24	$0.0666667... \times 100.9 = 6.72667...$
M_r / A_r^* (no unit)	24.3	28.0	100.9
Moles, n / mol	0.200	0.0800	$0.200 \times 1 \div 3 = 0.0666667...$
n ÷ coefficient	$0.200 \div 3 = 0.0666667...$ LIMITING	$0.0800 \div 1 = 0.0800$	Not compared
Reactant left / g	0	$2.24 - (0.0666667... \times 28.0) = 0.373333...$	Not a reactant

- $n(\text{Mg}) = 0.200 \text{ mol}$ and $n(\text{N}_2) = 0.0800 \text{ mol}$ [1]
- n ÷ coefficient values are 0.0666667... and 0.0800, so Mg is limiting [2]
- Maximum $m(\text{Mg}_3\text{N}_2) = 6.72667... \text{ g} = 6.73 \text{ g}$ [1]
- $m(\text{N}_2) \text{ remaining} = 2.24 - (0.0666667... \times 28.0) = 0.373 \text{ g}$ [1]