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EDEXCEL A LEVEL CHEMISTRY: QUESTIONS BY TOPIC

Inorganic Chemistry and the Periodic Table (4)

A Level Chemistry Topic 4

18 questions · 178 marks · Mark schemes included

Pearson Edexcel A Level Chemistry (9CH0), June 2017 - June 2025

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 Piccadilly Business Centre, Unit C, Aldow Enterprise Park
Blackett Street, Manchester, M12 6AE

HOW TO USE THIS BOOKLET

Questions are grouped by specification sub-topic; within each sub-topic they run from the lowest mark tariff to the highest.

Click any sub-topic heading or question row below to jump straight to it.

On every question page, click ANSWER in the top-right corner to jump to its mark scheme.

Diagrams, graphs, tables and data are printed exactly as they appeared in the original papers.

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QUESTIONS

18 questions · 178 marks · grouped by sub-topic



SUB-TOPIC 4(a)

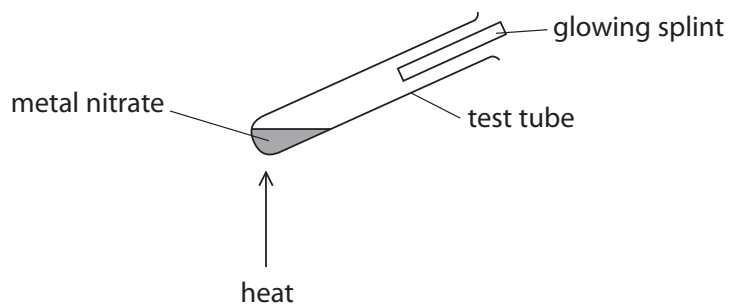
GROUP 2

6 questions in this sub-topic · 76 marks · lowest tariff first



4 Thermal decomposition is the breaking down of a substance by heat.

- (a) An experiment was carried out to investigate the thermal decomposition of a metal nitrate using the apparatus shown.



- (i) The glowing splint is used as a test for one of the gases given off in this experiment. Identify this gas and the positive result of the test.

(1)

- (ii) Give the name and appearance of the other gas given off in this experiment when a Group 2 nitrate is heated.

(1)

- (iii) Write the equation for the decomposition if the Group 1 compound, sodium nitrate, was used in this experiment. State symbols are not required.

(1)

(iv) Describe the apparatus that would be used to compare the decomposition of metal carbonates. Include how the rate of decomposition would be compared.

(2)

(b) Explain why magnesium carbonate decomposes much more readily on heating than barium carbonate.

(3)

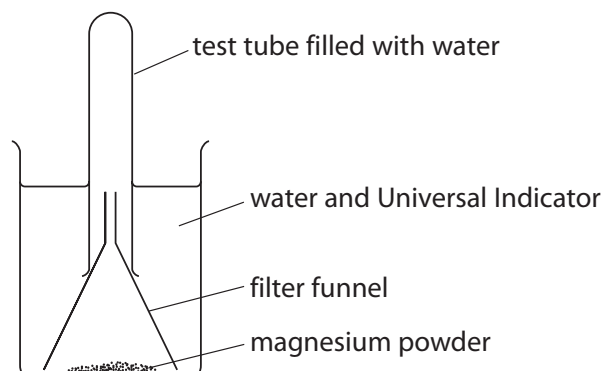
(Total for Question 4 = 8 marks)



2 This question is about the elements in Group 2 of the Periodic Table.

- (a) Magnesium powder is added to a beaker of water containing a few drops of Universal Indicator.

The apparatus is set up as shown and allowed to stand for a few days.



State **two** changes that will be **seen** after a few days.

(2)

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- (b) Explain how the trend in the reactivity of the Group 2 elements is determined by their electronic configurations.

(3)

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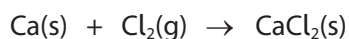
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(c) Calcium reacts with chlorine.



Explain, in terms of electrons, why this is a redox reaction.

(2)

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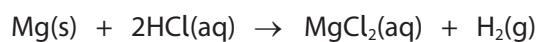
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(d) An experiment was carried out to determine the molar volume of hydrogen at room temperature.

0.035 g of magnesium was added to excess hydrochloric acid and 32 cm³ of hydrogen was produced.



Calculate the molar volume of hydrogen from the results of this experiment. Include units in your answer.

(2)

(Total for Question 2 = 9 marks)



2 This question is about some reactions of the elements of Group 1 and Group 2 of the Periodic Table and their compounds.

(a) Group 2 metals react vigorously with oxygen when heated.

(i) Write the equation for the reaction between magnesium and oxygen.
Include state symbols.

(1)

(ii) Explain the trend in reactivity of the elements down Group 2.

(3)

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(b) (i) State the trend in solubility of the Group 2 sulfates.

(1)

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(ii) Explain why the reaction between calcium and excess sulfuric acid stops
before all of the metal has reacted.

(2)

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(c) Sodium nitrate undergoes thermal decomposition to produce oxygen as one of the products.

(i) Describe the test, with the positive result, for oxygen.

(1)

(ii) Write the equation for this decomposition.
State symbols are not required.

(1)

(iii) Show, by reference to oxidation number changes, that the decomposition of sodium nitrate is a redox reaction.

(2)

(Total for Question 2 = 11 marks)



5 This question is about the chemistry of hydrated magnesium nitrate, $\text{Mg}(\text{NO}_3)_2 \cdot x\text{H}_2\text{O}$.

(a) Group 2 nitrates decompose when heated.

(i) State **two** observations you would see when hydrated magnesium nitrate is heated. (2)

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(ii) Explain the trend in thermal stability of Group 2 nitrates. (3)

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(b) In an experiment, a sample of hydrated magnesium nitrate, $\text{Mg}(\text{NO}_3)_2 \cdot x\text{H}_2\text{O}$, with a mass of 0.765 g, was dissolved in water and reacted with an excess of sodium hydroxide solution, $\text{NaOH}(\text{aq})$. The precipitate of magnesium hydroxide, $\text{Mg}(\text{OH})_2$, produced was removed and dried. The mass of the dried sample was 0.174 g.

(i) Draw dot-and-cross diagrams for the ions in magnesium hydroxide. Show the outer electrons only. (2)



- (ii) Use the experimental data to calculate the value for x in the formula $\text{Mg}(\text{NO}_3)_2 \cdot x\text{H}_2\text{O}$.
You **must** show all your working.

(5)

(Total for Question 5 = 12 marks)



3 This question is about the identification of a Group 2 carbonate.

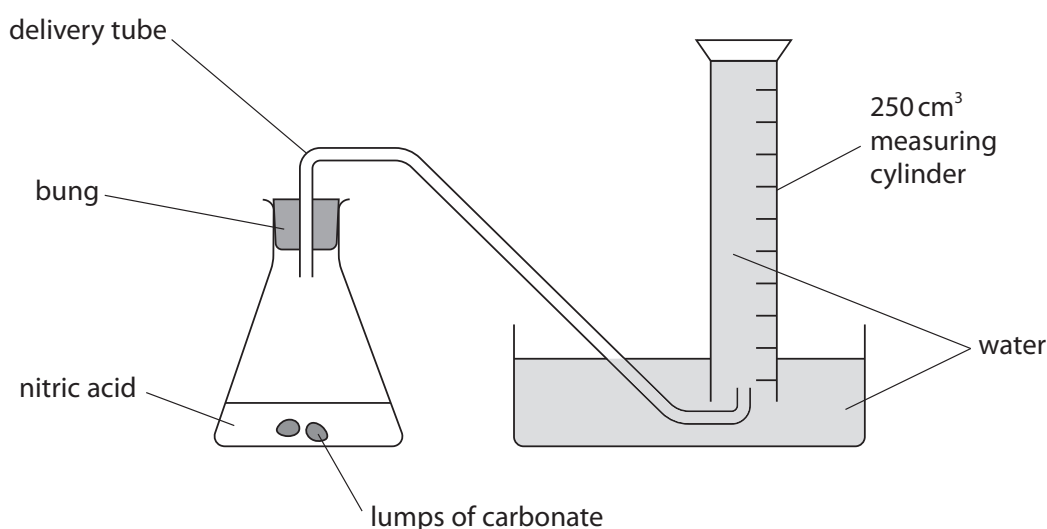
A chemistry teacher found a bottle containing lumps of a white solid. The original label was missing from the bottle. However, someone had written 'Group 2 carbonate' on the bottle. The lumps of the anhydrous white solid were pure and dry.

The chemistry teacher tried to identify the carbonate with the help of three students. The three students worked under identical conditions and shared the same weighing balance.

Student 1 recognised that if an acid is added to a carbonate, carbon dioxide is evolved. The student decided to measure the volume of carbon dioxide evolved when the Group 2 carbonate reacts with excess nitric acid.

The student knew that 1 mol of a Group 2 carbonate produces 1 mol of carbon dioxide.

Student 1 set up the apparatus shown below.



- Student 1 weighed out some of the Group 2 carbonate and added it to a 250 cm³ conical flask.
- Student 1 then added 100 cm³ of 0.200 mol dm⁻³ nitric acid to the conical flask and replaced the bung.
- Student 1 measured the volume of gas collected in the inverted measuring cylinder at room temperature and pressure (r.t.p.) when all the Group 2 carbonate had reacted.
- Student 1 obtained the results shown in Table 1.

Measurement		Value
Mass of weighing bottle and carbonate	/ g	13.247
Mass of empty weighing bottle	/ g	12.431
Mass of carbonate used	/ g	
Volume of acid used	/ cm ³	100
Volume of gas collected	/ cm ³	225

Table 1

- (a) Complete Table 1 to show the mass of the carbonate used. (1)
- (b) Calculate the amount, in moles, of carbon dioxide collected in the measuring cylinder at r.t.p. (1)
- (c) Calculate the molar mass of the Group 2 carbonate to an appropriate number of significant figures and hence deduce the identity of the Group 2 metal. (4)



(d) Student **2** carried out the same experiment as Student **1**, using the same mass of the Group 2 carbonate.

Student **2** made no errors in their measurements or calculations but obtained a value for the molar mass which was 10 g mol^{-1} greater than the value obtained by Student **1**.

(i) Explain **one** procedural error which could have resulted in Student **2** obtaining a molar mass greater than that of Student **1**.

(2)

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(ii) It was later discovered that Student **2** had used 110 cm^3 of $0.200 \text{ mol dm}^{-3}$ dilute nitric acid, instead of 100 cm^3 of $0.200 \text{ mol dm}^{-3}$ dilute nitric acid.

Give a reason why this mistake would **not** have affected Student **2**'s result.

No calculation is required.

(1)

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(iii) The teacher noticed that Student **2** had used the Group 2 carbonate in powdered form rather than in lumps.

Explain how, if at all, this would affect the rate of reaction and the final volume of gas produced in the reaction.

(2)

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(e) Student **3** suggested a different experiment.

Student **3** realised that, by heating the carbonate, carbon dioxide would be lost and an oxide would remain.

Student **3** decided to measure the change in mass of the carbonate and to use this information to calculate its molar mass.

- Student **3** weighed an empty test tube.
- Using a spatula, Student **3** added some of the carbonate to the test tube.
- The test tube containing the carbonate was then weighed.
- The test tube and its contents were heated to constant mass.
- The results obtained by Student **3** are shown in Table 2.

Measurement		Value
Mass of carbonate + test tube	/ g	20.447
Mass of oxide + test tube	/ g	20.205
Mass of empty test tube	/ g	19.996

Table 2

(i) Write an equation, including state symbols, for the thermal decomposition of a Group 2 carbonate, MCO_3 , where M represents the metal.

(1)

(ii) Using Student **3**'s results, calculate the molar mass of the Group 2 carbonate.

(3)



- (f) Student **3** used the same balance as Student **1**.

Give a reason why the mass of the carbonate measured by Student **3** has a greater percentage uncertainty than that measured by Student **1**.

(1)

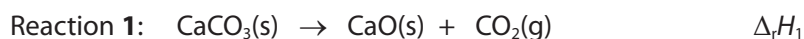
- (g) Student **3** noticed that on heating the test tube some solid was lost.
Explain how this would affect the calculated value for the molar mass of the Group 2 carbonate.

(2)

(Total for Question 3 = 18 marks)



- 3** A student carried out an investigation to determine indirectly the enthalpy change for the thermal decomposition of calcium carbonate. The reaction equation is shown.

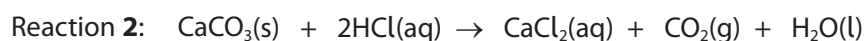


- (a) State why the enthalpy change for the thermal decomposition of calcium carbonate cannot be determined directly.

(1)

- (b) The student placed a known mass of calcium carbonate in a polystyrene cup. 30.0 cm^3 of hydrochloric acid of concentration 3.00 mol dm^{-3} was added. The mixture was stirred, and the highest temperature reached was recorded.

The equation for the reaction is shown.



- (i) Complete the missing data in the table for Reaction 2.

(1)

Measurement	Value
Mass of weighing boat with calcium carbonate / g	4.30
Mass of weighing boat after emptying out calcium carbonate / g	0.20
Mass of calcium carbonate used / g	
Temperature at the start / °C	19.0
Highest temperature / °C	
Temperature change / °C	5.5

- (ii) 0.041 mol of $\text{CaCO}_3(\text{s})$ was used in the experiment.

Show, by calculation, that the hydrochloric acid is in excess for Reaction 2.

(2)



- (iii) Calculate the enthalpy change, $\Delta_r H_2$, for Reaction 2 in kJ mol^{-1} .
Include a sign in your answer.

[Assume the specific heat capacity of the solution = $4.18 \text{ J g}^{-1} \text{ }^\circ\text{C}^{-1}$
and the mass of the solution = 30 g]

(3)

- (iv) The student carried out a similar procedure with calcium oxide.
The enthalpy change, $\Delta_r H_3$, calculated for Reaction 3 was $-176.3 \text{ kJ mol}^{-1}$.

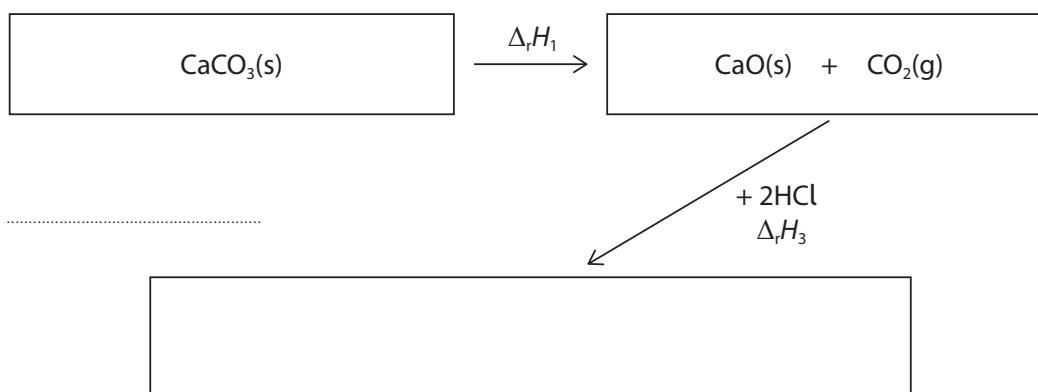


Complete the enthalpy cycle.

Include the correct substances with state symbols in the lower box.

Add an appropriately labelled arrow.

(2)



- (v) Calculate a value for the enthalpy change $\Delta_r H_1$ for the thermal decomposition of calcium carbonate by using your cycle.

(1)



(c) A data book value for the thermal decomposition of calcium carbonate, $\Delta_r H^\ominus$ (Reaction 1), under standard conditions is $+178.2 \text{ kJ mol}^{-1}$.

- (i) Deduce the feasibility of the thermal decomposition of calcium carbonate at 298 K using the data in the table.

(3)

Compound	Entropy / $\text{J K}^{-1} \text{ mol}^{-1}$
calcium carbonate, $\text{CaCO}_3(\text{s})$	92.9
calcium oxide, $\text{CaO}(\text{s})$	39.7
carbon dioxide, $\text{CO}_2(\text{g})$	213.6

- (ii) Calculate the **minimum** temperature, in $^\circ\text{C}$, at which thermal decomposition would occur.
Give your answer to 3 significant figures.

(2)



(d) Explain why magnesium carbonate undergoes thermal decomposition at a **lower** temperature than calcium carbonate.

(3)

(Total for Question 3 = 18 marks)



SUB-TOPIC 4(b)

GROUP 7 (HALOGENS AND HALIDES)

4 questions in this sub-topic · 40 marks · lowest tariff first



3 This question is about halogens and redox reactions.

(a) The boiling temperatures of three halogens are shown in the table.

Halogen	Boiling temperature / °C
chlorine	–35
bromine	59
iodine	184

Explain why the boiling temperatures increase from chlorine to iodine.

(2)

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- (b) Potassium halides react with concentrated sulfuric acid to form potassium hydrogensulfate and the different products shown in the table.

Potassium halide	Products
potassium chloride	hydrogen chloride
potassium bromide	hydrogen bromide, bromine and sulfur dioxide
potassium iodide	hydrogen iodide, iodine, hydrogen sulfide and sulfur

By referring to any changes in oxidation numbers when these halides react with concentrated sulfuric acid, explain which halide is the strongest reducing agent.

(3)

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(c) Use these electrode potentials to answer the following questions.

Electrode reaction	$E^{\ominus} / V$
$I_2(aq) + 2e^{-} \rightleftharpoons 2I^{-}(aq)$	+0.54
$Fe^{3+}(aq) + e^{-} \rightleftharpoons Fe^{2+}(aq)$	+0.77
$Br_2(aq) + 2e^{-} \rightleftharpoons 2Br^{-}(aq)$	+1.09
$MnO_2(s) + 4H^{+}(aq) + 2e^{-} \rightleftharpoons Mn^{2+}(aq) + 2H_2O(l)$	+1.23
$Cl_2(aq) + 2e^{-} \rightleftharpoons 2Cl^{-}(aq)$	+1.36
$MnO_4^{-}(aq) + 8H^{+}(aq) + 5e^{-} \rightleftharpoons Mn^{2+}(aq) + 4H_2O(l)$	+1.51

(i) Which species will oxidise $Fe^{2+}(aq)$ to $Fe^{3+}(aq)$?

(1)

- ☒ **A** $Br_2(aq)$
- ☒ **B** $Cl^{-}(aq)$
- ☒ **C** $I_2(aq)$
- ☒ **D** $Mn^{2+}(aq)$

(ii) Write the ionic equation and calculate the $E_{cell}^{\ominus}$ value for the reaction between MnO_4^{-} ions and Br^{-} ions in acidic solution.
State symbols are not required.

(3)

(Total for Question 3 = 9 marks)



3 This question is about the elements in Group 7 of the Periodic Table and some of their compounds.

(a) What is the colour of iodine in the solid and gas states?

(1)

	Colour of iodine solid	Colour of iodine gas
☐ A	purple	brown
☐ B	purple	purple
☐ C	grey/black	brown
☐ D	grey/black	purple

(b) Which of these reactions occurs?

(1)

- ☐ **A** $\text{Br}_2(\text{aq}) + 2\text{NaCl}(\text{aq}) \rightarrow 2\text{NaBr}(\text{aq}) + \text{Cl}_2(\text{aq})$
- ☐ **B** $\text{Br}_2(\text{aq}) + 2\text{NaF}(\text{aq}) \rightarrow 2\text{NaBr}(\text{aq}) + \text{F}_2(\text{aq})$
- ☐ **C** $\text{Cl}_2(\text{aq}) + 2\text{NaBr}(\text{aq}) \rightarrow 2\text{NaCl}(\text{aq}) + \text{Br}_2(\text{aq})$
- ☐ **D** $\text{Cl}_2(\text{aq}) + 2\text{NaF}(\text{aq}) \rightarrow 2\text{NaCl}(\text{aq}) + \text{F}_2(\text{aq})$

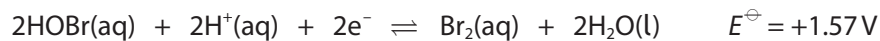
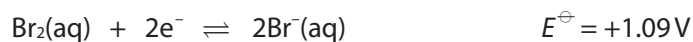
(c) The halogens can form halide ions during reactions.

Complete the electronic configuration of the chloride ion.

(1)

$1s^2$

- (d) The standard electrode potentials for two half-equations involving bromine are given.



- (i) Explain why the disproportionation of bromine in water is **not** thermodynamically feasible under standard conditions.
Include the overall equation for the disproportionation and its $E_{\text{cell}}^\ominus$ value.

(3)

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- (ii) Bromine disproportionates in water to a small extent at 298 K.

Give a possible reason why this reaction occurs.

(1)

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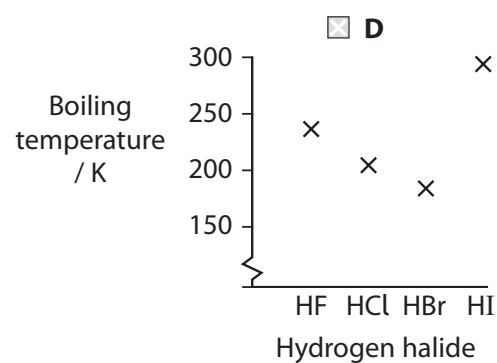
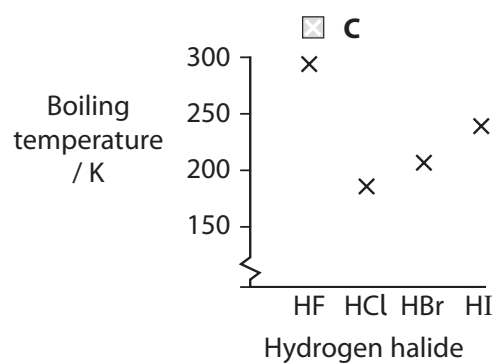
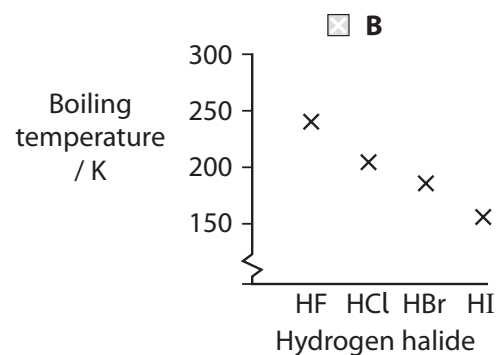
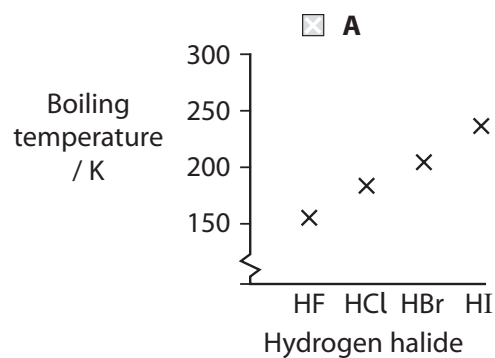
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(e) The hydrogen halides have the general formula HX, where X represents the symbol of the halogen.

(i) Which diagram shows the trend in the boiling temperatures of the hydrogen halides?

(1)



(ii) What type of reaction occurs when ammonia gas reacts with hydrogen chloride gas?

(1)

- ☒ **A** acid-base
- ☒ **B** displacement
- ☒ **C** redox
- ☒ **D** substitution

(Total for Question 3 = 9 marks)

3 This question is about compounds containing elements from Group 7.

(a) Which change occurs when concentrated sulfuric acid is added to potassium bromide?

(1)

- ☐ **A** bromide ions oxidise sulfuric acid forming sulfur
- ☐ **B** bromide ions oxidise sulfuric acid forming sulfur dioxide
- ☐ **C** bromide ions reduce sulfuric acid forming sulfur
- ☐ **D** bromide ions reduce sulfuric acid forming sulfur dioxide

(b) Chemists can test for the presence of bromide ions in solution by adding a small amount of acidified silver nitrate solution.
The solubility of the precipitate in aqueous ammonia is then tested.

(i) Which statement is correct for bromide ions?

(1)

- ☐ **A** a white precipitate forms that dissolves in concentrated ammonia only
- ☐ **B** a white precipitate forms that dissolves in both dilute and concentrated ammonia
- ☐ **C** a cream precipitate forms that dissolves in concentrated ammonia only
- ☐ **D** a cream precipitate forms that dissolves in both dilute and concentrated ammonia

(ii) Give a reason why the silver nitrate must be acidified.

(1)

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(iii) Explain which acid needs to be used to acidify the silver nitrate solution and why other acids are unsuitable.

(2)

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- (c) Iodine trichloride forms a dimer, I_2Cl_6 , in the solid state.
When molten, it is suggested that it breaks down as shown.



- (i) Draw a labelled diagram of a simple experiment to confirm this dissociation has occurred, stating the positive result.

(2)

Result

- (ii) What is the shape of the ICl_4^- ion?

(1)

- ☐ **A** octahedral
- ☐ **B** square planar
- ☐ **C** tetrahedral
- ☐ **D** trigonal bipyramidal

- (iii) The equilibrium position for the dissociation of molten I_2Cl_6 lies to the left.



What is the most likely numerical value of K_c for this equilibrium?

(1)

- ☐ **A** 1.0×10^6
- ☐ **B** 5.0×10^3
- ☐ **C** 1.0
- ☐ **D** 5.0×10^{-3}

(Total for Question 3 = 9 marks)

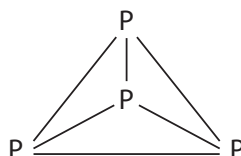


5 The halogens are elements in Group 7 of the Periodic Table.

(a) Chlorine compounds have many uses, including water treatment.

(i) Chlorine and phosphorus (P_4) can react to form phosphorus(V) chloride.

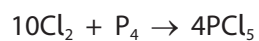
The structure of a molecule of phosphorus is



Some mean bond enthalpy values are shown in the table.

Bond	Mean bond enthalpy / kJ mol^{-1}
P—P	+198
Cl—Cl	+243
P—Cl	+326

Calculate the enthalpy change for the reaction between chlorine and phosphorus to form phosphorus(V) chloride.



(3)



(ii) Give a reason why bond enthalpy values are always positive.

(1)

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(b) Sodium chlorate(I) is a bleaching agent.

(i) Sodium chlorate(I) can be made by the reaction of chlorine with sodium hydroxide.

Show, by using oxidation numbers, that this reaction is disproportionation.



(2)

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(ii) A different bleaching agent can be made by the reaction of chlorine with sodium hydroxide under different conditions.

Balance this equation.



(1)

(iii) What conditions are required for the reaction in (b)(ii)?

(1)

- ☐ **A** cold and dilute alkali
- ☐ **B** cold and concentrated alkali
- ☐ **C** hot alkali
- ☐ **D** excess chlorine



- (c) The halogens can be identified by their colour in an organic solvent such as hexane or cyclohexane.

Which sequence of colours is correct for chlorine, bromine and iodine dissolved in an organic solvent?

(1)

	Chlorine	Bromine	Iodine
☒ A	orange	red-brown	black
☒ B	pale green	orange	black
☒ C	orange	red-brown	purple
☒ D	pale green	orange	purple

- (d) Halide ions can be identified by their reaction with silver nitrate.

- (i) Write the **ionic** equation for the reaction between aqueous solutions of sodium iodide and silver nitrate.
Include state symbols.

(2)

- (ii) A solution containing 0.010 mol of a halide ion was reacted with excess silver nitrate and produced 1.88 g of precipitate.

Identify the halide ion.
Justify your answer.

(2)

(Total for Question 5 = 13 marks)



SUB-TOPIC 4(c)

TESTS FOR IONS AND INORGANIC ANALYSIS

8 questions in this sub-topic · 62 marks · lowest tariff first



2 Barium ions can be identified by their flame colour.

(a) Which of the following should be used for a flame test on barium carbonate?

(1)

- ☐ A iron wire and water
- ☐ B iron wire and concentrated hydrochloric acid
- ☐ C nichrome wire and water
- ☐ D nichrome wire and concentrated hydrochloric acid

(b) What colour do barium ions give in a flame test?

(1)

- ☐ A green
- ☐ B lilac
- ☐ C red
- ☐ D yellow

(c) A flame test was carried out on a mixture of barium chloride and magnesium chloride.

How does the presence of magnesium ions affect the appearance of the flame colour of barium ions?

(1)

- ☐ A the colour is more intense
- ☐ B a bright white colour completely masks the barium colour
- ☐ C there is no change
- ☐ D the barium colour is decreased by the white magnesium flame colour

(Total for Question 2 = 3 marks)



- 1 An inorganic salt **A** contains one cation and one anion.
The results of two tests on salt **A** are shown in the table.

Test	Observation
Add aqueous sodium hydroxide to solid A . Warm the mixture. Test any gas evolved with damp red litmus paper.	A gas was evolved. The gas turned red litmus paper blue.
Add dilute nitric acid followed by aqueous silver nitrate to an aqueous solution of A .	A cream precipitate formed.

- (a) Deduce the **name** of salt **A**.

(2)

- (b) Describe additional tests, with the results, that will confirm the identity of the **anion** in the cream precipitate.

(2)

(Total for Question 1 = 4 marks)



***7** Colour is often used in chemistry to identify substances.

Compare and contrast the origin of the colour of a copper(II) complex with the origin of the colour of the copper(II) ion in a flame test.

You do not need to state any specific colours.

(6)



(Total for Question 7 = 6 marks)



(Total for Question 3 = 6 marks)

4 Compound **C** is a pink crystalline solid containing two cations and one anion.

(a) Three tests were carried out on **C**. The observation made for each test was recorded in the table.

(i) Complete the statements in the inference column by writing the names or formulae of the species.

(6)

Test	Observation	Inference
Test 1 Aqueous sodium hydroxide was added to solid C and the mixture warmed The gas evolved was tested with damp red litmus paper	The red litmus paper turned blue	The gas evolved was One of the cations in C is
Test 2 Concentrated hydrochloric acid was added to an aqueous solution of C	The pink solution turned blue	The other cation in C is The formula of the complex ion in the blue solution is
Test 3 Dilute hydrochloric acid and aqueous barium chloride were added to an aqueous solution of C	A white precipitate formed	The white precipitate is The anion in C is

(ii) Use the results of the tests in (a)(i) to give a formula of **C**.
Do not include water of crystallisation.

(1)



- (b) Write the **ionic** equation for the reaction between the cation in **C** and sodium hydroxide producing the gas in **Test 1**.
State symbols are not required.

(1)

- (c) State the type of reaction occurring in **Test 2**.

(1)

- (d) Give a reason why dilute hydrochloric acid is needed in **Test 3**.

(1)

(Total for Question 4 = 10 marks)



2 This question is about flame tests for Group 1 and 2 metal ions.

- (a) (i) State the colour of the flame produced by separate samples of potassium and strontium ions.

(1)

Potassium ions

Strontium ions

- (ii) Give a reason why carrying out a flame test on a mixture of potassium chloride and strontium chloride does not clearly show that two different metal ions are present.

(1)

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- (b) In the first stage of the flame test, the nichrome wire is dipped into concentrated hydrochloric acid and then heated in a Bunsen flame.

In the second stage, this nichrome wire is dipped into fresh hydrochloric acid and then into the metal salt to be tested before being reheated in the Bunsen flame.

- (i) Give **two** reasons why the wire is made of nichrome and not iron.

(2)

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- (ii) Give a reason why the wire is dipped into acid and then heated in the first stage.

(1)

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(iii) State why **fresh** concentrated hydrochloric acid is used in the second stage of the flame test.

(1)

(iv) State why **hydrochloric acid** is used in the second stage of the flame test.

(1)

(c) Explain, with reference to electron transitions, the formation of the colour in a flame test.

(3)

(Total for Question 2 = 10 marks)



3 This question is about compounds and their chemical analysis.

Three containers of soluble white solids have lost their labels but are known to be calcium bromide, calcium iodide and potassium sulfate.

(a) (i) Describe how to carry out a flame test on these samples.

(3)

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(ii) Give the expected observation for each of the flame tests.

(2)

calcium bromide

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calcium iodide

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potassium sulfate

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- (b) Separate aqueous solutions of calcium bromide and of calcium iodide reacted with acidified silver nitrate to produce a precipitate.
Concentrated aqueous ammonia was added to each precipitate.

Complete the table.

(2)

Solution	Formula of precipitate with silver nitrate	Colour of precipitate with silver nitrate	Observation with concentrated aqueous ammonia
calcium bromide(aq)			
calcium iodide(aq)			

- (c) Describe a chemical test for the sulfate ion giving the positive result.

(2)

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- (d) What mass of potassium sulfate (K_2SO_4) would be needed to prepare 250 cm^3 of a solution of concentration $0.0450\text{ mol dm}^{-3}$?

The molar mass of K_2SO_4 is 174.3 g mol^{-1} .

(1)

- ☐ A 1.96 g
- ☐ B 7.84 g
- ☐ C 19.6 g
- ☐ D 31.4 g

(Total for Question 3 = 10 marks)



- 3 A group of students design and carry out experiments to deduce the formulae of two salts, **X** and **Y**.

X contains one cation and one anion.

Y contains water of crystallisation.

- (a) (i) A flame test is carried out on **X**.

Describe how to carry out a flame test.

(3)

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- (ii) The colour of the flame is yellow.

Give the **formula** of the metal ion present in salt **X**.

(1)

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- (b) A sample of **X** is placed in a test tube and dissolved in deionised water.
The solution is acidified with hydrochloric acid and barium chloride solution is added.

A white precipitate forms.

- (i) Give the **formula** of the anion present in **X**.

(1)

.....

- (ii) Deduce the **formula** of **X**, using your answers to (a)(ii) and (b)(i).

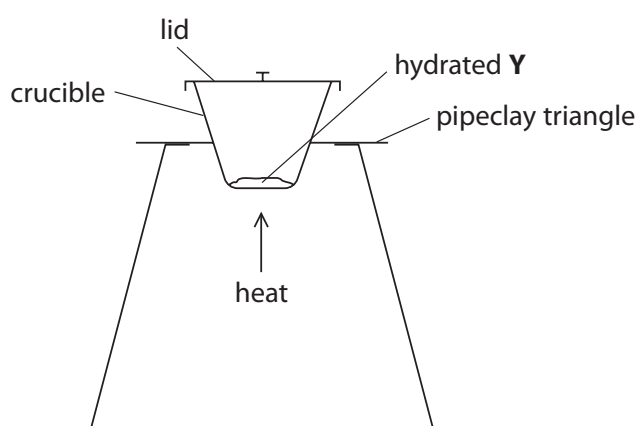
(1)

.....

(c) **Y** is identified as hydrated potassium carbonate, $K_2CO_3 \cdot nH_2O$.

Two of the students were asked to determine the number of moles of water of crystallisation, n , in **Y** using the procedure shown:

- weigh a sample of hydrated **Y** into a pre-weighed crucible
- place a lid loosely on the crucible and heat it for five minutes to remove the water of crystallisation
- allow the crucible and lid to cool, remove the lid and then reweigh the crucible with its contents.



(i) The first student carried out the experiment but forgot to use the lid.

Explain how this mistake would affect the calculated value of n .

(2)

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(ii) The second student carried out the experiment but heated the apparatus for only **one** minute.

Explain how this mistake would affect the calculated value of n .

(2)

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(iii) In an accurate experiment, **Y** is found to consist of 71.9% K_2CO_3 by mass.

Calculate the value of n .

(3)

(Total for Question 3 = 13 marks)



MARK SCHEMES

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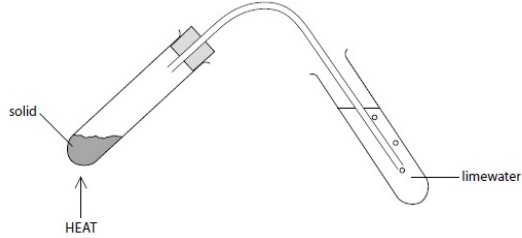


Question Number	Answer	Additional Guidance	Mark
4(a)(i)	An answer that makes reference to the following point: (Identity of gas is) oxygen/O₂ and (test result is that the splint) relights	Do not award just 'O' Allow 'rekindle'/'reignites'	(1)

Question Number	Answer	Additional Guidance	Mark
4(a)(ii)	An answer that makes reference to the following point: (Identity of gas is) nitrogen dioxide and (appearance is) brown (gas/fumes)	If name and formula given then both must be correct Allow NO₂ Do not award NO or N₂O₄ Do not award if liquid referred to Do not award if two gases are given unless one of the gases stated is colourless oxygen Ignore shades of colour	(1)

Question Number	Answer	Additional Guidance	Mark
4(a)(iii)	equation	<u>Example of equation</u> $2\text{NaNO}_3 \rightarrow 2\text{NaNO}_2 + \text{O}_2$ Accept multiples Ignore state symbols even if incorrect	(1)



Question Number	Answer	Additional Guidance	Mark
4(a)(iv)	An description that makes reference to following points: • use of a delivery tube to bubble gas into limewater (1) • compare the time taken for the limewater to go cloudy (1)	Allow annotated diagrams to illustrate the marking points Example of a diagram that could be given credit  Do not award if the apparatus setting would not be feasible such as • missing cork/bung or gaps around delivery tube • horizontal tube with limewater in • bung in the test tube with limewater Allow TE from an incorrect/unsuitable method Allow Any length of time, e.g. 10 minutes	(2)

Question Number	Answer	Additional Guidance	Mark
4(b)	An explanation that makes reference to - the magnesium ion/cation is smaller (than the barium ion/cation) (1) - which polarises the (large) carbonate (ion)/anion (1) - and weakens the carbon-oxygen bond (C-O/C=O) bonds (1)	Accept reverse arguments Penalise omission of ion once only Allow magnesium ion/cation has a higher charge density Do not award reference to just atom Accept 'which distorts the carbonate electron cloud' Do not award if molecules of carbonate are referred to Allow 'weakens the bonds in the carbonate ion' Allow 'less energy needed to break the C-O bond' Do not award if the bonds referred to are the ionic bonds between the metal ion and the carbonate ion	(3)

(Total Question 4 = 8 marks)

Question Number	Answer	Additional Guidance	Mark
2(a)	An answer that makes reference to the following points: (the Universal Indicator changes from green) to blue / purple (1) - water level in the test tube drops or gas collects at the top of the test tube (1)	Allow to dark blue/ blue-green or green-blue Do not award from blue Do not award if the solution is described as 'acidic' or $[H^+]$ increases Do not award any other starting colour Allow water level in the beaker rises Allow hydrogen / H_2 for gas Do not award named incorrect gases (e.g. oxygen/air) Do not award magnesium oxide Do not award magnesium is a white powder Ignore magnesium disappears/dissolves	(2)

Question Number	Answer	Additional Guidance	Mark
2(b)	An explanation that makes reference to the following points: - the outer/ valence electron is / the outer electrons are/ further from the nucleus (1) - there is more shielding (from shells of inner electrons) or there is an increase in repulsion between the filled inner shells and the electron removed (1) - so the (first) ionisation energy decreases (down the group) and so the reactivity increases (1)	Allow the outer (s) electron is in a higher (quantum) shell / higher energy level Ignore the atomic / ionic radius increases Allow there is reduced attraction between the nucleus and the outer electrons Do not award any reference to charge or charge density for M2 Allow the outer (s) electron(s) are removed more easily / it takes less energy to remove the (outer) electrons and so the reactivity increase	(3)



Question Number	Answer	Additional Guidance	Mark
2(c)	An explanation that makes reference to the following points: - calcium is oxidised as it loses electrons (1) - Chlorine / Cl₂ / Cl is reduced as it gains electron(s) (1)	Allow $\text{Ca} \rightarrow \text{Ca}^{2+} + 2\text{e}^-$ / $\text{Ca} - 2\text{e}^- \rightarrow \text{Ca}^{2+}$ and oxidation Do not allow calcium loses 1 electron Allow $\text{Cl}_2 + 2\text{e}^- \rightarrow 2\text{Cl}^-$ and reduction	(2)



Question Number	Answer	Additional Guidance	Mark
2(d)	- calculation of mol of magnesium (1) - calculation of molar volume of H₂ and units (1)	<u>Example of calculation</u> mol Mg = $0.035 \div 24.3$ $= 1.4403 \times 10^{-3} / 0.0014403$ (mol) (mol H₂ = mol Mg) molar volume of H₂ = $32 \div 1.4403 \times 10^{-3}$ $= 22\,217 / 22\,220 / 22\,200 / 22\,000 / 2.2217 \times 10^4 / 2.220 \times 10^4 / 2.22 \times 10^4 / 2.2 \times 10^4$ and cm³(mol⁻¹/mol⁻¹) Allow value converted to dm³ e.g. 22.2 and dm³(mol⁻¹/ mol⁻¹) If they have rounded to 1.4×10^{-3} in step 1 then an example of a correct answer would be 22857 and cm³mol⁻¹ or 23 and dm³mol⁻¹ TE on mol Mg Additional guidance Allow 1.4583×10^{-3} and 2.1942×10^4 if 24 used for Mg Correct answer with no working scores (2) Ignore SF except 1 SF	(2)

(Total for Question 2 = 9 marks)



Question Number	Answer	Additional Guidance	Mark
2(a)(i)	balanced equation and state symbols	<u>Example of equation</u> $2\text{Mg(s)} + \text{O}_2\text{(g)} \rightarrow 2\text{MgO(s)}$ Accept multiples	(1)

Question Number	Answer	Additional Guidance	Mark
2(a)(ii)	An explanation that makes reference to the following points: - reactivity increases and since ionisation energy decreases (because) - outer/valence electrons are further from the nucleus (electrons) more shielded or (electrons) more repelled by inner electron shells	(1) Allow specific references of reactivity trend or that ‘barium is the most reactive’ Allow reactivity increases and easier to lose electron(s) Allow reactivity increases and reduced attraction between the nucleus and the (outer) electron(s) (1) Allow atomic radius increases down the group Ignore just more electron shells Do not award ionic radius Do not award reference to charge density (1) Ignore reference to increasing nuclear charge If response refers to trend going up Group 2 then allow reverse argument	(3)



Question Number		Additional Guidance	Mark
2(b)(i)	An answer that makes reference to the following point: solubility decreases down the group	Accept reverse argument Allow answers which compare specific sulfates such as 'barium sulfate is less soluble than magnesium sulfate'	(1)

Question Number	Answer	Additional Guidance	Mark
2(b)(ii)	An explanation that makes reference to the following points: - the (calcium) sulfate / CaSO_4 formed is insoluble/ CaSO_4 sparingly soluble (the reaction stops because) the layer/barrier formed (on the surface) prevents further reaction	Mark independently Allow calcium sulfate solid/precipitate/ppt/ppte formed Ignore just calcium sulfate is less soluble If name and formula given then both must be correct Allow the layer/barrier prevents the sulfuric acid from coming into contact with the calcium	(2)

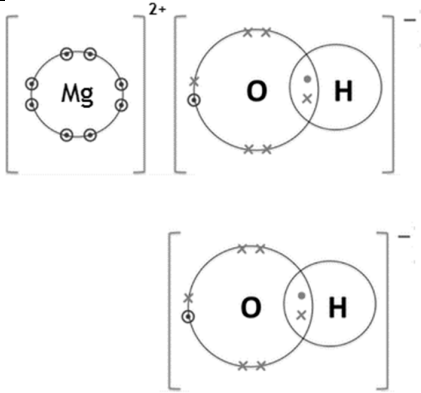
Question Number	Answer	Additional Guidance	Mark
2(c)(i)	An answer that makes reference to the following point: relights a glowing splint	Allow relit/rekindle/reignite Do not award relights a lit splint Do not award reference to 'squeaky pop' or similar description of hydrogen result	(1)



Question Number	Answer	Additional Guidance	Mark
5(a)(i)	Any two observations from - solid dissolves / melts - condensation on sides of test tube - brown gas/ brown fumes/ brown NO₂(g) produced - white solid / powder forms	(1) Do not award magnesium dissolved / just 'solid disappears' (1) Allow 'steam given off' (1) Ignore NO ₂ / O ₂ / gas given off/ bubbles/ effervescence / gas relights a glowing splint Allow red-brown (1) Ignore 'precipitate' Ignore 'magnesium oxide forms' Do not award 'Mg ²⁺ forms'	(2)

Question Number	Answer	Additional Guidance	Mark
5(a)(ii)	An answer that makes reference to the following points: - Nitrates increase in stability down Group 2 as ionic radius increases (as you go down group) - so polarising ability of metal (ion) decreases / distorts (the electron cloud of) the anion less - weakening of N-O bonds (in nitrate ion) is less	(1) Allow charge density decreases as you go down Group 2 Do not award just 'atomic radius increases' There has to be a mention of ions somewhere in M1 or M2 (1) (1) Allow reverse argument	(3)



Question Number	Answer	Additional Guidance	Mark
5(b)(i)	- magnesium ion (1) - hydroxide ion (1)	 Allow all dots or all crosses Allow M1 for magnesium ion outer shell shown with no electrons Allow M2 even if only 1 hydroxide ion is shown Ignore inner shells Ignore absence of square brackets and circles Ignore any indication of 2 hydroxide ions e.g. 1 hydroxide ion with '2' preceding it Penalise missing charges once only	(2)

Question Number	Answer	Additional Guidance	Mark
5(b)(ii)	- calculation of moles of $\text{Mg}(\text{OH})_2$ (1) - calculation of mass of $\text{Mg}(\text{NO}_3)_2$ (1) - calculation of mass of H_2O (1) - calculation of moles of H_2O (1) - deduction of $\text{Mg}(\text{NO}_3)_2 : \text{H}_2\text{O}$ ratio (and hence formula) (1) OR - Calculation of moles of $\text{Mg}(\text{OH})_2$ (1) - deduction of moles of $\text{Mg}(\text{NO}_3)_2 \cdot x\text{H}_2\text{O}$ (1) - expression for / calculation of molar mass of $\text{Mg}(\text{NO}_3)_2 \cdot x\text{H}_2\text{O}$ (1) - expression for moles of $\text{Mg}(\text{NO}_3)_2 \cdot x\text{H}_2\text{O}$ in terms of mass and molar mass / calculation mass of water in 1 mole (1) - calculation of x (and hence formula) (1)	<u>Example of calculation</u> $0.174 \div 58.3 = 2.98456 \times 10^{-3} \text{ (mol)}$ $2.98456 \times 10^{-3} \times 148.3 = 0.44261 \text{ (g)}$ $0.765 - 0.44261 = 0.32239 \text{ (g)}$ $0.32239 \div 18 = 0.017911 \text{ (mol)}$ $0.017911 \div 2.98456 \times 10^{-3} = 6.0011$ 1:6, (so $\text{Mg}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$) $0.174 \div 58.3 = 2.98456 \times 10^{-3} \text{ (mol)}$ 1:1 so $= 2.98456 \times 10^{-3} \text{ (mol)}$ $148.3 + 18x \div 0.765 \div 2.98456 \times 10^{-3} = 256.3$ $0.765 \div (148.3 + 18x) = 2.98456 \times 10^{-3} \text{ (mol)} /$ $256.3 - 148.3 = 108$ $0.32239 = 0.0537x$, so $x = 0.32239 \div 0.0537 = 6.0035 /$ 108 ÷ 18 so $x = 6$; (so $\text{Mg}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$) Correct answer with no working scores M5 only. Ignore SF from M1 to M4, allow TE throughout	(5)

(Total Question 5 = 12 marks)



Question Number	Acceptable Answers	Additional Guidance	Mark
3(a)	$0.816 / 8.16 \times 10^{-1} \text{ (g)}$		(1)

Question Number	Acceptable Answers	Additional Guidance	Mark
3(b)	calculation of moles of CO_2	<u>Example of calculation:</u> (moles CO_2 = $\frac{225}{24000}$ =) 0.009375 Allow $9.375 \times 10^{-3} / 9.38 \times 10^{-3} / 9.4 \times 10^{-3}$ Ignore SF except 1SF	(1)

Question Number	Acceptable Answers	Additional Guidance	Mark
3(c)	- moles of MCO_3 (1) - method for calculation of molar mass of MCO_3 (1) - molar mass final answer to 1, 2 or 3 SF (1) - consequential identification of Group 2 metal by name or formula (1) NOTE Alternative method can score 3 MAX Calculation of moles of CO_3^{2-} (1) (Calculation of mass of CO_3^{2-}) Deduction of mass of M by subtraction (1) Calculation of Ar of M to 1, 2 or 3 SF AND Identification of group 2 metal (1)	<u>Example of calculation:</u> Moles of MCO_3 = moles CO_2 = 0.009375 (mol) Molar mass of MCO_3 = $\frac{0.816}{0.009375}$ (= 87.04 (g mol⁻¹)) M2 subsumes mark for M1 = 87.0 / 87 / 90 (g mol⁻¹) NOTE M3 mark subsumes mark for M2 and M1 (87.0 – 60) = 27 AND Mg / Magnesium / MgCO_3 Allow TE on answers to parts (a) and (b), with Metal consequential on calculated molar mass but M must be a Group 2 element Moles CO_3^{2-} = 0.009375 (Mass of CO_3^{2-} = 0.009375 x 60 = 0.5625 g) Mass of M = 0.2535 g Ar = 0.2535/0.009375 = 27.0 / 27 / 30 (g mol⁻¹) AND Mg / Magnesium / MgCO_3	(4)



Question Number	Acceptable Answers	Additional Guidance	Mark
3(d)(i)	An explanation that makes reference to the following points: - the bung was not replaced quickly enough (1) (So) CO₂ / gas lost (to the surroundings) (1)	Allow bung not fitting tightly resulting in leaks Ignore references to CO₂ dissolving Ignore references to other types of gas leak Allow 'smaller volume of gas collected' / lower reading of gas volume Mark points M1 and M2 independently	(2)

Question Number	Acceptable Answers	Additional Guidance	Mark
3(d)(ii)	An answer that makes reference to the following point: The acid was (already) in excess (and more acid won't affect this)	Allow The carbonate is the limiting reactant / the acid is not the limiting reactant	(1)

Question Number	Acceptable Answers	Additional Guidance	Mark
3(d)(iii)	An explanation that makes reference to the following points: - rate of reaction is faster and powder has greater surface area (1) - no effect on (final) volume of gas and moles of (metal) carbonate are unchanged or because the rate is faster more gas will be lost before the bung is replaced so the (final) volume will be less (1)	Mark points M1 and M2 independently Both parts of statement needed Both parts of statement needed Allow mass / amount for moles Allow reactant for metal carbonate	(2)



Question Number	Acceptable Answers	Additional Guidance	Mark
3(e)(i)	balanced equation with state symbols	<u>Example of equation:</u> $\text{MCO}_3(\text{s}) \rightarrow \text{MO}(\text{s}) + \text{CO}_2(\text{g})$ Allow a correct equation for the decomposition of any Group 2 carbonate	(1)

Question Number	Acceptable Answers	Additional Guidance	Mark
3(e)(ii)	- subtractions to obtain masses - calculation of moles of CO_2 - calculation of molar mass of MCO_3	<u>Example of calculation:</u> $(\text{mass of } \text{CO}_2 = 20.447 - 20.205) = 0.242$ AND $(\text{mass of } \text{MCO}_3 = 20.447 - 19.996) = 0.451$ moles of $\text{CO}_2 = \frac{0.242}{44}$ $= 0.0055(0) \text{ (mol)} / 5.5(0) \times 10^{-3} \text{ (mol)}$ ALLOW TE from M2 to M3 $\text{Mr of } \text{MCO}_3 = \frac{0.451}{0.0055(0)}$ $= 82 \text{ (g mol}^{-1}\text{)}$ Correct answer with or without working scores 3 Ignore SF except 1 Ignore attempts to identify the metal	(3)

Question Number	Acceptable Answers	Additional Guidance	Mark
3(f)	An answer that makes reference to the following point: Student 3 used a smaller mass / less (and the uncertainty of the balance was the same) or Student 1 used a larger mass / more (and the uncertainty of the balance was the same)	Allow calculations comparing the two percentage errors: e.g. Student 1:- $(0.001/0.816) \times 100\% = 0.12\%$ and Student 3:- $0.001/0.451 \times 100\% = 0.22\%$	(1)

Question Number	Acceptable Answers	Additional Guidance	Mark
3(g)	An explanation that makes reference to the following points: • more CO₂ (would appear to be) given off (1) • (So) calculated molar mass is smaller (1) OR • Less MO would appear to have been formed (1) • Calculated molar mass would be greater (1)	M2 dependent on M1 M2 dependent on M1	(2)

(Total for Question 3 = 18 marks)

Question Number	Answer	Additional Guidance	Mark
3(a)	An answer that makes reference to the following point: heat energy must be supplied so the energy change is not just due to the thermal decomposition reaction or it is difficult to determine when the (decomposition) reaction is complete or it's difficult to (accurately) measure the temperature of a solid (whilst heating)	Allow it is impossible to measure ΔT when heat energy is supplied / cannot measure temperature (easily) whilst heating Ignore the reaction is not complete Allow you cannot measure the temperature of a solid (easily)	(1)

Question Number	Answer	Additional Guidance		Mark
3(b)(i) Clip all of (b)	correct values in table for mass and temperature			(1)
		Substance	Value	
		Mass of weighing boat with calcium carbonate / g	(4.30)	
		Mass of weighing boat after emptying out calcium carbonate / g	(0.20)	
		Mass of calcium carbonate used / g	4.10	
		Start temperature / °C	(19.0)	
		Highest temperature / °C	24.5	
		Temperature change / °C	(5.5)	



Question Number	Answer	Additional Guidance	Mark
3(b)(ii)	- mol of HCl - mol of HCl required and more mol HCl present than required	(1) <u>Example of calculation</u> $= 3.00 \times \frac{30}{1000} = 0.090$ (1) $= 0.041 \times 2 = 0.082$ and $0.09 > 0.082$ (mol) Allow $0.090 \div 2 = 0.045$ (mol CaCO_3 that you would need to react with 0.09 mol HCl and) $0.045 > 0.041$ (mol) Ignore SF Allow calculation of excess HCl by subtraction from 0.090	(2)

Question Number	Answer	Additional Guidance	Mark
3(b)(iii)	- energy change (Q) for Reaction 2 - enthalpy change ($\Delta_r H_2$) for Reaction 2 - answer with negative sign	(1) <u>Example of calculation</u> energy change = $30 \times 4.18 \times 5.5$ $= 689.7$ (J) / 0.6897 (kJ) (1) Ignore any signs in M1 enthalpy change = $\frac{0.6897}{0.041}$ (kJ) / $\frac{689.7}{0.041}$ (J) (1) $= -16.822$ (kJ mol⁻¹) / $-16\,822$ J mol⁻¹ / -17.0 (kJ mol⁻¹) / $-17\,000$ J mol⁻¹ Accept correct answer with no working Allow TE throughout Ignore SF except 1SF	(3)



Question Number	Answer	Additional Guidance	Mark
3(b)(iv)	An answer that makes reference to the following points: - correct species with state symbols in the bottom box - arrow on left hand side in correct direction and labelled with 2HCl(aq)	<u>Example of cycle</u> Ignore any additional labels for arrows, including values or 'Reaction 1' and 'Reaction 2' unless incorrect	(2)
3(b)(v)	calculation of enthalpy change of thermal decomposition of calcium carbonate	<u>Example of calculation</u> $\Delta_r H_1 = -16.8 - -176.3 = (+) 159.5 \text{ kJ mol}^{-1}$ TE on their incorrect value from 3(b)(iii) No TE on incorrect cycle	(1)



Question Number	Answer	Additional Guidance	Mark
3(c)(i)	An explanation that makes reference to the following points: • calculation of $\Delta S^\circ_{\text{system}}$ • calculation of ΔG° • reason why not feasible Alternative for M2 and 3 using ΔS_{total} • $\Delta S_{\text{surroundings}} = \frac{-178\,200}{298} = -597.99 \text{ (J K}^{-1} \text{ mol}^{-1}\text{)}$ • $\Delta S_{\text{total}} = 160.4 - 597.99 = -437.59 \text{ (J K}^{-1} \text{ mol}^{-1}\text{)}$ and Value is negative and so not feasible	<u>Example of calculation</u> (1) $= (39.7 + 213.6) - (92.9)$ $= (+) 160.4 \text{ (J K}^{-1} \text{ mol}^{-1}) / (+) 0.1604 \text{ (kJ K}^{-1} \text{ mol}^{-1})$ (1) $(\Delta G = \Delta H - T\Delta S_{\text{system}})$ $= (+ 178.2 \times 1000) - (298 \times 160.4)$ $= (+) 130\,400 \text{ (J mol}^{-1}\text{)} / (+) 130.4 \text{ (kJ mol}^{-1}\text{)}$ Allow TE from M1 to M2 (1) ΔG positive / > 0 so not feasible No TE on negative value of ΔG (1) Ignore minor rounding error in decimal places of ΔS_{total} Ignore SF except 1SF	(3)

Question Number	Answer	Additional Guidance	Mark
3(c)(ii)	- rearrangement of ΔG expression and calculation of feasible temperature (1) - conversion to degrees Celsius (1)	<u>Example of calculation</u> $T = \Delta H / \Delta S_{\text{system}}$ $T = 178.2 / 0.1604 = 1111 \text{ (K)}$ Allow 1110 (K) for M1 $1111 - 273 = 838 \text{ (}^{\circ}\text{C)}$ Allow $1110 - 273 = 837 \text{ (}^{\circ}\text{C)}$ Accept method that uses $\Delta S_{\text{total}} = 0$ $\Delta S_{\text{total}} = 0 = 160.4 - (178\,200 / T)$ $T = -178\,200 / -160.4 = 1111 \text{ (K)}$ $1111 - 273 = 838$ 838 / 837 with or without working scores both marks Do not award 840°C Allow TE from M1 to M2 for values $> -273^{\circ}\text{C}$	(2)

Question Number	Answer	Additional Guidance	Mark
3(d)	An explanation that makes reference to the following points: • Mg^{2+} is a smaller cation / ion / has a smaller ionic radius / has a greater charge density (1) • Mg^{2+} polarises the carbonate / CO_3^{2-} / anion more (1) • (so in MgCO_3) the bond between C and O is weakened more (1)	Accept reverse argument Penalise reference to just Mg or Ca once only Ignore ‘more covalent character’ / comments related to atomic radius unless they contradict the relative size of the ions Allow Mg^{2+} has greater polarising power / Mg^{2+} distorts the electron cloud more Ignore Mg^{2+} polarises the C-O bond more Allow bond(s) within the anion are weakened more Allow C-O (bond) / C=O (bond) is weakened more	(3)

(Total for Question 3 = 18 marks)

Question Number	Answer	Additional Guidance	Mark
3(a)	An explanation that makes reference to the following points: - from chlorine to iodine / down the group, the number of electrons (in the molecule / atom) increases / changes from 34 to 106 / 17 to 53 (1) - so the strength of the London / instantaneous dipole-(induced) dipole forces increases / there are more London / instantaneous dipole-(induced) dipole forces and more energy is needed to separate the molecules (1)	An answer that states 'covalent bonds break' or 'bonds between atoms break' or refers to 'ions' scores (0) overall Allow reverse argument for M1 and M2 Allow iodine has more / most electron shells (than chlorine and/or bromine) Ignore 'the size of the atoms / molecules increases from chlorine to iodine' Do not allow incorrect numbers of electrons Allow iodine has the strongest London force and most energy is needed to separate the molecules Allow more energy is need to overcome / break the London forces / bonds instead of separate the molecules Allow dispersion forces / van der Waals forces for London forces Ignore higher temperature needed to separate the molecules Do not award dipole-dipole forces / just 'intermolecular forces'	(2)



Question Number	Answer	Additional Guidance	Mark
3(b)	An explanation that makes reference to the following points: - iodide ions are the strongest reducing agent because iodide ions / I^- / (potassium) iodide reduces sulfur (in sulfuric acid) from +6 to 0 in sulfur / -2 in H_2S (1) (whereas) bromide ions / Br^- / (potassium) bromide reduces sulfur (in sulfuric acid) from +6 to +4 (1) (whereas) chloride ions / Cl^- / (potassium) chloride do not reduce sulfuric acid / sulfur / S (as there is no change in oxidation number of Cl or S) (1)	Allow the oxidation numbers written by the species in the table (+)6 only needs to be mentioned once in M1 or M2 Allow references to potassium halides / halogens / hydrogen halides instead of halide ions For full marks, the answer must identify iodide as the strongest reducing agent Only 1 oxidation number change is needed. If both are given, both must be correct Allow bromide ions are stronger reducing agents than chloride ions because they are oxidised from -1 to 0 Allow just 'it is not a redox reaction'	(3)

Question Number	Answer	Mark
3(c)(i)	The only correct answer is A <i>B is not correct because Cl^- is not an oxidising agent</i> <i>C is not correct because I_2 is not a powerful enough oxidising agent</i> <i>D is not correct because Mn^{2+} is not an oxidising agent</i>	(1)

Question Number	Answer	Additional Guidance	Mark
3(c)(ii)	- all species on correct sides of equation and no electrons / electrons cancelled (1) - balancing correct species (1) $E^\ominus_{\text{cell}}$ value (1)	<u>Example of ionic equation</u> $2\text{MnO}_4^- + 16\text{H}^+ + 10\text{Br}^- \rightarrow 2\text{Mn}^{2+} + 8\text{H}_2\text{O} + 5\text{Br}_2$ Allow $\rightleftharpoons$ Allow correct species if shown in working with half-equations but slip made in final equation e.g. charge missing Ignore state symbols Allow multiples Allow M2 for almost correct species $E^\ominus_{\text{cell}}$ (= $1.51 - 1.09$) = (+)0.42 (V) No TE on incorrect equation	(3)

(Total for Question 3 = 9 marks)



Question number	Answer	Mark
3(a)	The only correct answer is D (grey/black solid, purple gas) <i>A is incorrect because iodine solid is not purple and iodine gas is not brown</i> <i>B is incorrect because iodine solid is not purple</i> <i>C is incorrect because iodine gas is not brown</i>	(1)

Question number	Answer	Mark
3(b)	The only correct answer is C ($\text{Cl}_2(\text{aq}) + 2\text{NaBr}(\text{aq}) \rightarrow 2\text{NaCl}(\text{aq}) + \text{Br}_2(\text{aq})$) <i>A is incorrect because bromine is less reactive than chlorine so no reaction occurs</i> <i>B is incorrect because bromine is less reactive than fluorine so no reaction occurs</i> <i>D is incorrect because chlorine is less reactive than fluorine so no reaction occurs</i>	(1)

Question Number	Answer	Additional Guidance	Mark
3(c)	electronic configuration of chloride ion	<u>Example of electronic configuration</u> $(1s^2)2s^22p^63s^23p^6$ Allow $2p^6 / 3p^6$ shown as e.g. $2p_x^22p_y^22p_z^2$ Ignore $1s^2$ repeated Ignore working Do not award correct answer if one or more incorrect answers are given	(1)



Question Number	Answer	Additional Guidance	Mark
3(d)(i)	An explanation that makes reference to the following points: - balanced equation (1) - calculation of $E^\ominus_{\text{cell}}$ value (1) $E^\ominus_{\text{cell}}$ / answer is negative / <0 and the reaction is not (thermodynamically) feasible (1)	<u>Example of equation</u> $\text{Br}_2(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightarrow \text{HOBr}(\text{aq}) + \text{HBr}(\text{aq})$ Allow multiples Allow $\text{H}^+(\text{aq}) + \text{Br}^-(\text{aq})$ for $\text{HBr}(\text{aq})$ Allow reversible arrows Ignore state symbols even if incorrect $E^\ominus_{\text{cell}} = 1.09 - 1.57 = -0.48 \text{ (V)}$ Allow correct answer without calculation Allow 3 marks for reverse argument $\text{HOBr}(\text{aq}) + \text{HBr}(\text{aq}) \rightarrow \text{Br}_2(\text{aq}) + \text{H}_2\text{O}(\text{aq})$ (1) $E^\ominus_{\text{cell}} = 1.57 - 1.09 = (+) 0.48 \text{ (V)}$ (1) $E^\ominus_{\text{cell}}$ is positive / >0 so the reverse of disproportionation is (thermodynamically) feasible (1)	(3)

Question Number	Answer	Additional Guidance	Mark
3(d)(ii)	An answer that makes reference to the following point: disproportionation is an equilibrium system (and although K is very small, there is still a small concentration of disproportionation products) or excess water is used or concentration is not 1 mol dm^{-3} or HBr undergoes further disproportionation	Ignore just 'non-standard conditions' Ignore references to activation energy / collision theory Ignore H^+ / ions from the water	(1)

Question number	Answer	Mark
3(e)(i)	The only correct answer is C (graph C) A is incorrect because HF has a much higher boiling temperature than expected due to hydrogen bonding B is incorrect because there is an increase in boiling temperature from HCl to HI as the number of electrons in the molecules increases so the London forces increase in strength D is incorrect because HBr has a higher boiling temperature than HCl as there are more electrons in the molecules	(1)

Question number	Answer	Mark
3(e)(ii)	The only correct answer is A (acid-base) B is incorrect there is no displacement taking place C is incorrect because neither substance is oxidised or reduced D is incorrect because there is no substitution taking place	(1)

(Total for Question 3 = 9 marks)



Question Number	Answer	Mark
3(a)	The only correct answer is D (bromide ions reduce sulfuric acid forming sulfur dioxide) <i>A is not correct because bromide ions reduce sulfuric acid</i> <i>B is not correct because bromide ions reduce sulfuric acid</i> <i>C is not correct because bromide ions are not strong enough reducing agents to form sulfur</i>	(1)

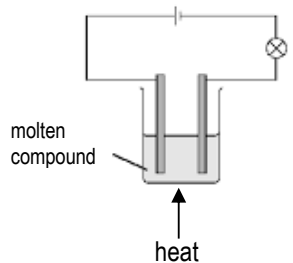
Question Number	Answer	Mark
3(b)(i)	The only correct answer is C (a cream precipitate forms that dissolves in concentrated ammonia only) <i>A is not correct because bromide ions do not form a white precipitate</i> <i>B is not correct because bromide ions do not form a white precipitate</i> <i>D is not correct because the cream precipitate does not dissolve in dilute ammonia</i>	(1)



Question Number	Answer	Additional Guidance	Mark
3(b)(ii)	An answer that makes reference to the following point: to react with / remove carbonate / CO_3^{2-} / hydroxide / OH^- (ions, which could lead to a false positive)	Allow name or formula of ion but if both are given, both must be correct Allow other specified anions that would form a precipitate with Ag^+ / AgNO_3 e.g. hydrogencarbonate / sulfite Ignore just 'to prevent a false positive' Ignore just 'it reacts with impurities' Ignore just 'so it only reacts with Br^-'	(1)

Question Number	Answer	Additional Guidance	Mark
3(b)(iii)	An explanation that makes reference to the following points: - nitric acid / HNO_3 (1) - so that the anion (from the acid) does not form a precipitate (with silver ions) (1)	Mark independently Do not award incorrect formula for nitric acid / use of NH_3 Allow forms a precipitate with HCl / H_2SO_4 / other acids (giving a false positive) Allow so it doesn't form precipitates with HCl / H_2SO_4 / other acids (giving a false positive) Allow solid / ppt / ppte for precipitate Ignore colour of precipitate	(2)



Question Number	Answer	Additional Guidance	Mark
3(c)(i)	An answer that makes reference to the following points: - a diagram of a simple electrical circuit, containing electrodes, power supply and a bulb in series - bulb lights	 (1) Allow alternatives to bulb e.g. buzzer / ammeter Allow low voltage supply instead of cell Allow a cell and electrodes dipping into the liquid but with no bulb / ammeter etc. Allow cell with connecting wires to filter paper on microscope slide Ignore missing heat / labels for molten compound / electrodes, wires, etc. Do not award voltmeter instead of cell unless electrodes made from two different materials are specified (1) Allow correct observation from alternatives buzzer – rings ammeter - shows a current Allow observation for formation of iodine or chlorine e.g. brown colour / purple vapour / bubbles / green gas	(2)

Question Number	Answer	Mark
3(c)(ii)	The only correct answer is B (square planar) <i>A is not correct because the central iodine atom only has four atoms attached and has two lone pairs of electrons</i> <i>C is not correct because the central iodine atom has four bond pairs and two lone pairs of electrons</i> <i>D is not correct because the central iodine atom only has four atoms attached and has two lone pairs of electrons</i>	(1)

Question Number	Answer	Mark
3(c)(iii)	The only correct answer is D (5.0×10^{-3}) <i>A is not correct because the value is greater than 1, which implies equilibrium lies to product side</i> <i>B is not correct because the value is greater than 1, which implies equilibrium lies to product side</i> <i>C is not correct because the value of 1 implies equilibrium concentrations of reactants and products are similar in magnitude</i>	(1)

(Total for Question 3 = 9 marks)



Question Number	Answer	Additional Guidance	Mark
5(a)(i)	- sum of bonds broken (1) - and sum of bonds made (1) - answer and with negative sign (1)	<u>Example of calculation</u> bonds broken = $(6 \times 198) + (10 \times 243)$ $= 3618 \text{ (kJ mol}^{-1}\text{)}$ bonds made = $(20 \times 326) = (-)6520 \text{ (kJ mol}^{-1}\text{)}$ enthalpy change $= \text{Bonds broken} - \text{bonds made}$ $= (3618 - 6520)$ $= -2902 \text{ (kJ mol}^{-1}\text{)}$ Correct answer with no working scores (3) TE on bonds broken and made	(3)

Question Number	Answer	Additional Guidance	Mark
5(a)(ii)	bond breaking requires energy or by convention bond enthalpies refer to dissociation and so are endothermic	ALLOW bond breaking is endothermic ALLOW bond making is exothermic Ignore just 'bonds are broken' / 'it is endothermic'	(1)



Question Number	Answer	Additional Guidance	Mark
5(b)(i)	- chlorine is oxidised and from 0 to +1 (in NaClO) (1) - chlorine is reduced and from 0 to -1 (in NaCl) (1)	Check the equation Allow (1) for three correct oxidation numbers if no other mark is awarded. Allow (1) max for general definition of disproportionation	(2)

Question Number	Answer	Additional Guidance	Mark
5(b)(ii)	equation	6 NaOH + 3 Cl₂ → NaClO₃ + 5 NaCl + 3 H₂O Allow multiples	(1)

Question Number	Answer	Mark
5(b)(iii)	The only correct answer is C (hot alkali) <i>A is not correct because high temperature is required</i> <i>B is not correct because high temperature is required</i> <i>D is not correct because high temperature and not excess chlorine is required</i>	(1)



Question Number	Answer	Mark
5(c)	The only correct answer is D (pale green – orange - purple) <i>A is not correct because chlorine is not orange and the colour stated for bromine is for the pure liquid state and solid iodine can appear black but not in an organic solvent</i> <i>B is not correct because solid iodine can appear black but not in an organic solvent</i> <i>C is not correct because chlorine is not orange and the colour stated for bromine is in the pure liquid state</i>	(1)

Question Number	Answer	Additional Guidance	Mark
5(d)(i)	ionic equation	Example of equation $\text{Ag}^+(\text{aq}) + \text{I}^-(\text{aq}) \rightarrow \text{AgI}(\text{s})$ Allow multiples	(2)
	state symbols	M2 dependent on M1 or near miss	

Question Number	Answer	Additional Guidance	Mark
5(d)(ii)	An answer that includes - halide ion with some justification attempt - calculation of expected mass of silver halides	Incorrect halide scores (0) Bromide (ion)/Br⁻ Do not award 'bromine (ion)' 0.01 mol of AgCl = 1.43 (g) AgBr = 1.88 (g) AgI = 2.35 (g) OR Mass of 1.0 mol is 188 g so subtraction of 107.9 for Ag means X = 80.1 so closest is Br TE on incorrect formula silver halide in d(i)	(2)

(Total Question 5 = 13 marks)



Question Number	Answer	Mark
2(a)	The only correct answer is D (nichrome wire and concentrated hydrochloric acid) <i>A is not correct because iron wire is not used</i> <i>B is not correct because iron wire is not used</i> <i>C is not correct because concentrated hydrochloric acid and not water is needed</i>	(1)

Question Number	Answer	Mark
2(b)	The only correct answer is A (green) <i>B is not correct because this is the colour for potassium ions</i> <i>C is not correct because this is the colour for lithium, calcium and strontium ions</i> <i>D is not correct because this is the colour for sodium ions</i>	(1)

Question Number	Answer	Mark
2(c)	The only correct answer is C (there is no change) <i>A is not correct because magnesium ions have no effect on flame colour</i> <i>B is not correct because the elemental magnesium and not the metal ions give a white colour</i> <i>D is not correct because magnesium ions have no effect on flame colour</i>	(1)

(Total Question 2 = 3 marks)



Question Number	Acceptable Answer	Additional Guidance	Mark
1(a)	An answer that makes reference to the following points: • ammonium • bromide	Mark independently Allow names in either order Ignore symbols as well as names (1) Do not award ammonia (1) Do not award bromine Allow (1) for just NH_4Br	(2)

Question Number	Acceptable Answer	Additional Guidance	Mark
1(b)	A description that makes reference to the following points: - add (excess) dilute ammonia / dilute NH_3 (to the precipitate) and the precipitate is insoluble /does not dissolve (1) - add (excess) concentrated (aqueous) ammonia / concentrated NH_3 (to the precipitate) and it is soluble / dissolves / forms a colourless solution (1)	Allow ammonium hydroxide for ammonia Ignore pure ammonia / ammonia with no concentration / ammonia gas Allow no change for the observation Allow 'if it dissolves it is not bromide' Allow redissolves for soluble Note If no other mark is awarded allow (1) for adding dilute and concentrated ammonia with no / incorrect observation(s) Alternative test: add concentrated sulfuric acid (1) brown fumes (1)	(2)

(Total for Question 1 = 4 marks)



Question Number	Answer	Additional Guidance	Mark																
*7	This question assesses the student's ability to show a coherent and logically structured answer with linkages and fully sustained reasoning. Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning. The following table shows how the marks should be awarded for indicative content. <table><tr><th>Number of indicative marking points seen in answer</th><th>Number of marks awarded for indicative marking points</th></tr><tr><td>6</td><td>4</td></tr><tr><td>5-4</td><td>3</td></tr><tr><td>3-2</td><td>2</td></tr><tr><td>1</td><td>1</td></tr><tr><td>0</td><td>0</td></tr></table> The following table shows how the marks should be awarded for structure and lines of reasoning <table><tr><th></th><th>Number of marks awarded for structure of answer and sustained lines of reasoning</th></tr><tr><td>Answer shows a coherent logical structure with linkages and fully sustained lines of reasoning demonstrated throughout</td><td>2</td></tr></table>	Number of indicative marking points seen in answer	Number of marks awarded for indicative marking points	6	4	5-4	3	3-2	2	1	1	0	0		Number of marks awarded for structure of answer and sustained lines of reasoning	Answer shows a coherent logical structure with linkages and fully sustained lines of reasoning demonstrated throughout	2	Guidance on how the mark scheme should be applied: The mark for indicative content should be added to the mark for lines of reasoning. For example, a response with four indicative marking points that is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning). If there were no linkages between the points, then the same indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and zero marks for linkages). If there is any incorrect chemistry, deduct mark(s) from the reasoning. If no reasoning mark(s) awarded do not deduct mark(s). More than one indicative marking point may be made within the same comment or explanation	(6)
Number of indicative marking points seen in answer	Number of marks awarded for indicative marking points																		
6	4																		
5-4	3																		
3-2	2																		
1	1																		
0	0																		
	Number of marks awarded for structure of answer and sustained lines of reasoning																		
Answer shows a coherent logical structure with linkages and fully sustained lines of reasoning demonstrated throughout	2																		



	Answer is partially structured with some linkages and lines of reasoning	1	Deduct a reasoning mark if no comparison made
	Answer has no linkages between points and is unstructured	0	
Indicative content			Penalise the use of 'atom' instead of ion once only against any indicative point Ignore incorrect colours
Similarities			
• (IP1) the differences in energy levels determines the colour of the flame test and complex ion			This can be mentioned separately or as a comparison
Differences			
Flame test			Allow electrons excited by heat
• (IP2) heat (energy) results in electron promotion			
• (IP3) return of an (excited) electron to a lower (energy) state			Allow electron is 'de-excited' to a lower (energy) state Do not award if d-d transitions stated
Complex ion			
• (IP4) d orbitals are split (in energy by the ligands)			Allow d subshell splitting Do not award singular "d orbital" splitting
• (IP5) light (energy) is needed for electron promotion			
• (IP6) the colour not absorbed is the colour seen			Accept "The colour seen is complimentary to that absorbed" Allow 'colour reflected is the colour seen' Do not award if colour attributed to 'fall' of electron to lower energy d orbital Do not award 'emission of light'

(Total Question 7 = 6 marks)



Question Number	Answer	Additional Guidance	Mark																				
*3	This question assesses a student’s ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning. Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning. The following table shows how the marks should be awarded for indicative content. <table><tr><th>Number of indicative marking points seen in answer</th><th>Number of marks awarded for indicative marking points</th></tr><tr><td>6</td><td>4</td></tr><tr><td>5–4</td><td>3</td></tr><tr><td>3–2</td><td>2</td></tr><tr><td>1</td><td>1</td></tr><tr><td>0</td><td>0</td></tr></table> The following table shows how the marks should be awarded for structure and lines of reasoning. <table><tr><th></th><th>Number of marks awarded for structure of answer and sustained line of reasoning</th></tr><tr><td>Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout.</td><td>2</td></tr><tr><td>Answer is partially structured with some linkages and lines of reasoning.</td><td>1</td></tr><tr><td>Answer has no linkages between points and is unstructured.</td><td>0</td></tr></table>	Number of indicative marking points seen in answer	Number of marks awarded for indicative marking points	6	4	5–4	3	3–2	2	1	1	0	0		Number of marks awarded for structure of answer and sustained line of reasoning	Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout.	2	Answer is partially structured with some linkages and lines of reasoning.	1	Answer has no linkages between points and is unstructured.	0	Guidance on how the mark scheme should be applied: The mark for indicative content should be added to the mark for lines of reasoning. For example, an answer with five indicative marking points, which is partially structured with some linkages and lines of reasoning, scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning). If there are no linkages between points, the same five indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages). In general it would be expected that 5 or 6 indicative points would get 2 reasoning marks, and 3 or 4 indicative points would get 1 mark for reasoning, and 0, 1 or 2 indicative points would score zero marks for reasoning. If there is any incorrect chemistry, deduct mark(s) from the reasoning. If no reasoning mark(s) awarded do not deduct mark(s).	(6)
Number of indicative marking points seen in answer	Number of marks awarded for indicative marking points																						
6	4																						
5–4	3																						
3–2	2																						
1	1																						
0	0																						
	Number of marks awarded for structure of answer and sustained line of reasoning																						
Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout.	2																						
Answer is partially structured with some linkages and lines of reasoning.	1																						
Answer has no linkages between points and is unstructured.	0																						



Question Number	Answer	Additional Guidance	Mark
*3 contd	Indicative content: IP1 Carbonate (test) linked to Add $\text{HNO}_3(\text{aq})$ / $\text{HCl}(\text{aq})$ (to all 3 samples) IP2 Carbonate result Solutions that effervesce / bubble / fizz (must be a carbonate) / either $(\text{NH}_4)_2\text{CO}_3$ or K_2CO_3 IP3 Ammonium ion test linked to Add $\text{NaOH}(\text{aq})$ gently heat / warm / put in water bath IP4 Ammonium ion result (produces a gas) turns (damp) red litmus blue (when held over the mouth of the test tube) proves $(\text{NH}_4)_2\text{CO}_3$ IP5 and IP6 on next page.	Only listed reagents can be used. Ignore tests carried out to identify potassium ions / flame tests Ignore minor slips e.g. missing charges on ions, wrong formulae of reagents, missing state symbols that have been listed in the question. Ignore flame tests Ignore equations even if incorrect For all tests listed the reagent and the ion test and the result must be dependent on the correct reaction except for the limited exceptions that are listed in the additional guidance. Ignore just 'produce a gas' Allow gas turns $\text{Ca}(\text{OH})_{2(\text{aq})}$ cloudy Ignore gas turns limewater cloudy Do not award subsequent inappropriate gas tests e.g. pop test Do not award Bunsen burner for heating Do not award dip red litmus paper into the solution Do not award bleaches litmus. Allow a near miss for IP4 if the ammonium carbonate solution has been heated without NaOH being added / adding sodium hydroxide without heating Ignore white smoke seen with a glass rod dipped in $\text{HCl}(\text{aq})$ and held above the tube	(6)



Question Number	Acceptable Answers	Additional Guidance	Mark
4(a)(i)	Test 1 (gas is) ammonia / NH_3 (1) (cation is) ammonium / NH_4^+ (1) Test 2 (cation is) cobalt(II) / Co^{2+} / $[\text{Co}(\text{H}_2\text{O})_6]^{2+}$ (1) (complex ion is) $[\text{CoCl}_4]^{2-}$ (1) Test 3 (precipitate is) barium sulfate / BaSO_4 (1) (anion is) sulfate(VI) / SO_4^{2-} (1)	If name and formula are given, both must be correct Mark independently Do not award gas is ammonium / NH_4 Do not award cation is ammonia / NH_3^+ Oxidation number of cobalt is needed in the name but allow cobalt with Co^{2+} Charge is needed on the ion Allow +2 and -2 for the charges on the ions Allow brackets around Cl Ignore missing square brackets in complex ions Do not award $[\text{CoCl}_6]^{4-}$ Note If cation in Test 2 is identified as copper(II) / Cu^{2+}, do not award M3 but M4 can be awarded as TE for $[\text{CuCl}_4]^{2-}$ Oxidation number of sulfate is not needed but if given must be correct e.g. do not award sulfate(IV)	(6)



Question Number	Acceptable Answers	Additional Guidance	Mark
4(a)(ii)	correct formula	<u>Examples of correct formula</u> $(\text{NH}_4)_2\text{Co}(\text{SO}_4)_2$ $(\text{NH}_4)_2\text{SO}_4 \cdot \text{CoSO}_4$ Allow NH_4, Co and SO_4 in any order Allow multiples Allow any combination of Co^{2+} / NH_4^+ / SO_4^{2-} that gives a neutral complex TE on the three ions identified in (a)(i) Ignore missing dot in second formula Ignore any amount of water of crystallisation	(1)

Question Number	Acceptable Answers	Additional Guidance	Mark
4(b)	correct equation	<u>Example of equation</u> $\text{NH}_4^+ + \text{OH}^- \rightarrow \text{NH}_3 + \text{H}_2\text{O}$ Allow multiples Allow Na^+ on both sides if crossed through Ignore state symbols even if incorrect	(1)



Question Number	Acceptable Answers	Additional Guidance	Mark
4(c)	ligand exchange	Allow ligand substitution / ligand replacement Ignore change in co-ordination number Do not award ligand change Do not award any other type of reaction in addition to correct answer e.g. reduction / acid-base / deprotonation	(1)

Question Number	Acceptable Answers	Additional Guidance	Mark
4(d)	An answer that makes reference to the following point: to react with / remove any carbonate / sulfite / sulfate(IV) (ions)	Allow equation for the reaction with acid e.g. $2\text{H}^+ + \text{CO}_3^{2-} \rightarrow \text{H}_2\text{O} + \text{CO}_2$ Allow to prevent any other ions forming a precipitate (with barium ions / Ba^{2+}) Allow to rule out the possibility of carbonate / sulfite / sulfate(IV) ions giving a false result Ignore just 'to remove impurities / other (an)ions' / 'react with precipitates' Ignore to dissolve barium carbonate / sulfite Ignore reference to hydrogencarbonate	(1)

(Total for Question 4 = 10 marks)



Question Number	Answer	Additional Guidance	Mark
2(a)(i)	An answer that makes reference to: (potassium ions) lilac and (strontium ions) crimson / red	Allow scarlet Ignore 'shades' except Do not award 'brick red' / 'orange-red'	(1)

Question Number	Answer	Additional Guidance	Mark
2(a)(ii)	An answer that makes reference to: the crimson/red colour will mask/hide/obscure the (lighter) lilac colour	Allow 'one colour will hide the other' Allow only one colour seen Allow difficult to distinguish the two colours Allow TE from colours in (a)(i) Do not award colour from chloride ions Do not award idea of new colour resulting from both Ignore reference to impurities	(1)



Question Number	Answer	Additional Guidance	Mark
2(b)(i)	An answer that makes reference to: - nichrome produces no colour (when heated in the flame test) or iron can produce a colour/sparks (1) - nichrome is inert/ stable to heat/unreactive or iron reacts with oxygen/air and or hydrochloric acid (1)	Allow does not change the flame colour Ignore references to melting/cost Ignore reference to nichrome not being a transition element	(2)

Question Number	Answer	Additional Guidance	Mark
2(b)(ii)	An answer that makes reference to: (the wire is heated) to remove the residue of any previous sample being tested	Allow 'to clean the wire' Ignore 'to sterilise/sanitise/disinfect the wire'	(1)

Question Number	Answer	Additional Guidance	Mark
2(b)(iii)	An answer that makes reference to: the acid can become contaminated with residue from previous tests (which can give incorrect results)		(1)



Question Number	Answer	Additional Guidance	Mark
2(b)(iv)	An answer that makes reference to: (concentrated hydrochloric acid) forms volatile chlorides	Allow (the wire is moistened) to enable some of the solid metal salt to become attached/stick to the wire (and then tested in the Bunsen flame) Do not award reference to bonding or reacting or adsorb or absorb with the wire	(1)

Question Number	Answer	Additional Guidance	Mark
2(c)	An explanation that makes reference to: - electrons are excited/ promoted (by heat to higher energy levels / orbitals) (1) - electrons fall from the excited state (to their ground state/to lower energy levels) (1) - electrons release energy/photons as (visible) light/ in visible region (1)	Lack of reference to 'electrons' results in a maximum of (2) for an otherwise correct answer Allow raised/jump/moved up for 'excited' Allow return/drop/de-excite for 'fall' Allow Wavelength/ frequency/ radiation for 'energy' Do not award reflected for 'release' Do not award colour for 'energy'	(3)

(Total Question 2 = 10 marks)



Question Number	Acceptable Answer	Additional Guidance	Mark
3(a)(i)	An explanation that makes reference to the following points: - platinum / nichrome wire - dip (the wire) into (concentrated) hydrochloric acid / HCl(aq) / HCl - dip the wire / silica rod into the sample and place in a (blue / roaring / non-luminous) flame	(1) Allow NiCr for nichrome Allow silica rod Allow loop for wire Ignore inoculating / sterilising Do not award just nickel or chromium Do not award splint (1) Allow mention of HCl((aq)) before or after dipping wire into solid eg cleaning or mixing solid and HCl((aq)) to make a paste Ignore just acid Do not award other acids Allow salt / compound / paste / solid for sample Do not award element / metal for sample (1) Allow on / over / above / under the flame for 'in' Do not award reference to safety / yellow flame Do not award burn in the flame	(3)



Question Number	Acceptable Answer	Additional Guidance	Mark
3(a)(ii)	A description that makes reference to the following points: - calcium bromide and calcium iodide: orange-red / brick-red - potassium sulfate: lilac	(1) Allow orange / red / yellow-red / yellow- orange Do not award brown, crimson, dark-red, carmine or ruby (1) Do not award purple / mauve / violet / pink / blue-lilac	(2)

Question Number	Acceptable Answer	Additional Guidance				Mark
3(b)	A description that makes reference to the following points:					(2)
	• calcium bromide correct	(1)				
	• calcium iodide correct	(1)				

Solution	Formula of precipitate with silver nitrate	Colour of precipitate with silver nitrate	Observation with concentrated aqueous ammonia
calcium bromide(aq)	AgBr	cream / pale-yellow / off white	dissolves / disappears / Allow soluble
calcium iodide(aq)	AgI	yellow	does not dissolve / remains / no change Allow insoluble / no reaction

If no other mark is awarded then award 1 mark for 4 correct boxes
Ignore state symbols



Question Number	Acceptable Answer	Additional Guidance	Mark
3(c)	A description that makes reference to the following points: - add (dilute) HCl / (dilute) HNO₃ and (a solution of) barium chloride / BaCl₂ / barium nitrate / Ba(NO₃)₂ (to a sulfate solution) (1) - white precipitate / solid (1)	Allow concentrated HCl Do not award just 'acidified' Do not award incorrect formulae Do not award powder M2 depends on M1 or near miss (i.e acidified barium chloride) Allow ppt / ppte	(2)

Question Number	Answer	Mark
3(d)	The only correct answer is A (1.96 g) <i>B is not correct because it is the mass for 1 dm³ of a solution of concentration 0.045 mol dm⁻³</i> <i>C is not correct because it is the mass for 250 cm³ of a solution of concentration 0.45 mol dm⁻³</i> <i>D is not correct because this would be the mass for 4.0 dm³ instead of 250 cm³</i>	(1)

(Total for Question 3 = 10 marks)



Question Number	Answer	Additional Guidance	Mark
3(a)(i)	A description that makes reference to the following points: - any mention of platinum / nichrome wire / loop (1) - dip the wire into (clean / fresh concentrated) hydrochloric acid / HCl (1) - dip the (wet) wire into the solid and place in a (non-luminous / roaring / blue Bunsen) flame (1)	Allow NiCr for nichrome Allow silica rod Ignore ‘inoculating’ / ‘sterilising’ Do not award just nickel or chromium Allow mention of HCl before or after dipping wire into solid e.g. cleaning or mixing solid and HCl to make a paste Ignore concentration of HCl Ignore just ‘acid’ / other acids specified Do not award HCl reacting with flame test wire Allow salt / compound / paste / sample / solution for solid Allow through the flame / on the edge of the flame for in the flame Do not award element / metal for solid Do not award over / above / under the flame Do not award just ‘into a Bunsen’ Do not award ‘burn in flame’ Do not award flame if Bunsen has air-hole closed / safety flame	(3)



Question Number	Answer	Additional guidance	Mark
3(a)(ii)	Na^+	Ignore state symbols Ignore sodium / sodium ion Do not award incorrect charge	(1)

Question Number	Answer	Additional Guidance	Mark
3(b)(i)	SO_4^{2-}	Ignore state symbols Ignore sulfate(VI) / sulfate/ sulphate Do not award sulfate(IV) / sulfite / hydrogensulfate Do not award incorrect charge	(1)

Question Number	Answer	Additional Guidance	Mark
3(b)(ii)	Na_2SO_4	Ignore state symbols Ignore names Allow TE from other ions , with correct charges, given in (a)(ii) and (b)(i) Allow large numbers e.g. Na_2SO_4 but not superscripts e.g. Na^2SO^4	(1)

Question Number	Answer	Additional Guidance	Mark
3(c)(i)	An explanation that makes reference to the following points: (not using a lid means) some of salt Y could be lost from crucible during heating (1) (mass loss greater than expected), so n / amount of water (of crystallisation) greater (than expected) (1)	Allow solid / product / crystals for 'salt' Allow 'salt spits / jumps out' / 'salt escapes' from crucible Ignore gas escapes Do not award 'salt evaporates' M2 dependent on M1 or salt evaporates	(2)

Question Number	Answer	Additional Guidance	Mark
3(c)(ii)	An explanation that makes reference to the following points: (heating for only 1 minute may mean) not all the water (of crystallisation) has been removed (1) (mass loss less than expected), so n / amount of water (of crystallisation) less (than expected) (1)	Allow evaporated / boiled off for removed Allow (only) partial dehydration Ignore incomplete reaction M2 dependent on M1 or incomplete reaction	(2)



Question Number	Answer	Additional Guidance	Mark												
3(c)(iii)	- calculation of moles of K₂CO₃ (1) - calculation of moles of H₂O (1) - deduction of <i>n</i> (1)	Example of calculation <table><tr><td></td><td>K₂CO₃</td><td>H₂O</td></tr><tr><td>Moles =</td><td>71.9 / (138.2) = 0.52026</td><td>(100 - 71.9) / 18 = 1.56111</td></tr><tr><td>Ratio =</td><td>= 0.52026 / 0.52026 = 1</td><td>= 1.56111 / 0.52026 = 3</td></tr><tr><td><i>n</i> =</td><td colspan="2">3</td></tr></table> Accept use of 0.719 / 0.281 in M1 Allow TE from M1 Allow use of 138 for <i>M_r</i> of K₂CO₃ – gives 0.52101 Ignore SF including 1SF in M1 and M2 M3 must be 1 SF Accept alternative methods e.g. $\frac{138.2}{138.2 + 18n} = 0.719$ (1) 38.8342 = 12.942<i>n</i> (1) so <i>n</i> = 3 (1) or <i>M_r</i> of hydrated salt = $\frac{138.2}{0.719} = 192.2$ (1) mass of water = 192.2 – 138.2 = 54 (1) <i>n</i> = 54/18 = 3 (1) or 138.2 = 71.9% so 28.1% is water (1) $\frac{138.2}{71.9} \times 28.1 = 54$ (1) <i>n</i> = 54/18 = 3 (1) Correct answer with no working scores (1) Correct answer with some correct working scores (3)		K ₂ CO ₃	H ₂ O	Moles =	71.9 / (138.2) = 0.52026	(100 - 71.9) / 18 = 1.56111	Ratio =	= 0.52026 / 0.52026 = 1	= 1.56111 / 0.52026 = 3	<i>n</i> =	3		(3)
	K ₂ CO ₃	H ₂ O													
Moles =	71.9 / (138.2) = 0.52026	(100 - 71.9) / 18 = 1.56111													
Ratio =	= 0.52026 / 0.52026 = 1	= 1.56111 / 0.52026 = 3													
<i>n</i> =	3														

(Total for Question 3 = 13 marks)

