

OCR A-LEVEL CHEMISTRY B (SALTERS) • H433

CHEMISTRY



EXAM QUESTION PACK

ELEMENTS OF LIFE (EL): INORGANIC CHEMISTRY AND THE PERIODIC TABLE

SCORE

/206

PERCENTAGE

%

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- 1 A group of students set out to investigate the heating effect of volcanic lava on any carbonate rocks that it may flow over. They decide to devise an experiment to compare the thermal stability of magnesium carbonate and calcium carbonate.

The students have access to magnesium carbonate powder, lumps of calcium carbonate, calcium hydroxide powder, distilled water and whatever apparatus they need.

- (i) * Describe how the students could carry out their experiment.

You should include in your answer:

- a labelled diagram of the apparatus used to safely heat the carbonate compounds
- the main steps in the experimental procedure and the names of the key apparatus (not included in the labelled diagram)
- the observations and measurements that should be recorded
- how to ensure the comparison is fair and the results are as accurate as possible.

[6]

- (ii) The students find that the magnesium carbonate decomposes more readily than calcium carbonate and believe this can be explained by the difference in *charge density* of the magnesium and calcium ions.

What is meant by the term *charge density*?

_____ [1]

- (iii) Explain, in terms of the charge densities of the cations, the relative thermal stabilities of magnesium

carbonate and calcium carbonate.

----- [2]

- (iv) The enthalpy change of reaction, $\Delta_r H$, for the decomposition of magnesium carbonate is $+118 \text{ kJ mol}^{-1}$.

The entropies for the compounds in this reaction are given in the table below.

	MgCO_3	MgO	CO_2
$S / \text{J mol}^{-1} \text{K}^{-1}$	66	27	214

What is the minimum temperature to which the students must heat the magnesium carbonate powder for decomposition to occur?

Include units in your answer.

Show **all** your working.

minimum temperature = ----- [3]

2(a) Concrete contains calcium hydroxide, $\text{Ca}(\text{OH})_2$, and is alkaline when damp. The steel reinforcements in concrete do **not** corrode in an alkaline environment. When the calcium hydroxide reacts with carbon dioxide from the air to form calcium carbonate, 'carbonatation' occurs and the pH falls. The increased acidity can cause the steel to corrode.

(i) Write the equation for carbonatation.

[1]

(ii) Calculate the mass of calcium carbonate that is formed when 15 cm^3 of carbon dioxide (measured at room temperature and pressure) react with excess calcium hydroxide.

Give your answer to an **appropriate** number of significant figures.

mass = _____ g [2]

(b) Carbonatation produces calcium carbonate. The carbonate ion is alkaline in aqueous solution.

(i) Write an equation for the reaction that occurs between the carbonate ion and water.

[1]

(ii) Explain how the carbonatation reaction in (a)(i) accounts for the fall in pH.

[2]

3(a) In enclosed spaces, such as submarines, it is necessary to remove carbon dioxide from the air. Solid calcium hydroxide, $\text{Ca}(\text{OH})_2$, can be used to remove the carbon dioxide.

Suggest the equation for the reaction that takes place.

Include state symbols.

[1]

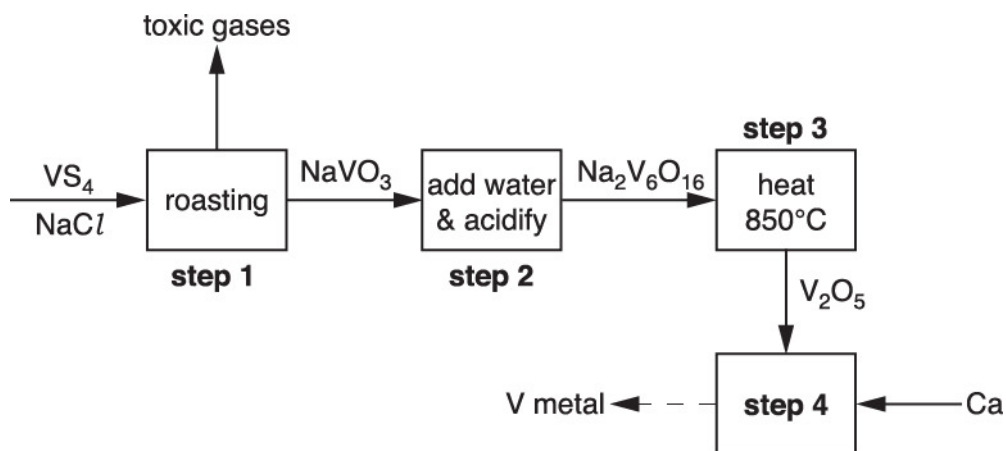
(b) Air is 0.040% CO_2 by volume.

What mass of calcium hydroxide is needed to absorb the carbon dioxide from 5.0 m^3 of air at 23°C and 95 kPa?

mass of calcium hydroxide = _____ g [3]

- 4 In 1908, Henry Ford advertised his Model T car by boasting that 'vanadiumsteel is used throughout the entire car and has superior properties to other steels'.

The flow diagram below outlines one method of extracting vanadium from its ore, VS_4 .



- (i) **Name** a possible toxic gas given off in **step 1**.

----- [1]

- (ii) The anion in VS_4 has the formula S_2^{2-} .

Complete the table below giving the oxidation state of vanadium in each of the four vanadium compounds involved in the extraction process.

Compound	Oxidation state of vanadium
VS_4	
$NaVO_3$	
$Na_2V_6O_{16}$	
V_2O_5	

[2]

- (iii) In which of steps 1-3 is vanadium involved in a redox reaction?

Give a reason for your answer.

step(s) -----

reason _____

[2]

- (iv) NaVO_3 forms a yellow solution with water.

Explain, in terms of frequencies, why solutions of transition metal ions are often coloured.



In your answer, you should use appropriate technical terms, spelled correctly.

[2]

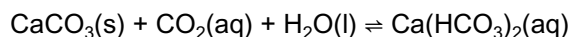
- (v) Give the equation for the reaction in **step 4**. State symbols are not required.

→

[1]

- 5 Limestone, consisting mainly of calcium carbonate, CaCO_3 , is a major constituent of some rocks.

When rainwater runs over limestone rocks, the reaction shown in **equation 1.2** takes place.



equation 1.2

- (i) Give the systematic name for $\text{Ca}(\text{HCO}_3)_2$.

-----[1]

- (ii) Where does the CO_2 in **equation 1.2** come from?

-----[1]

- (iii) When water containing $\text{Ca}(\text{HCO}_3)_2$ is boiled, a reaction occurs and a precipitate of limescale is formed.

Use information from **equation 1.2** to suggest why this happens.

-----[3]

6(a) Calcium carbide, CaC_2 , can be made by reacting calcium oxide with carbon at high temperatures.

Write a possible equation for the formation of calcium carbide from calcium oxide, CaO .

[1]

- (b) Calcium carbide is heated with nitrogen under pressure. Calcium cyanamide is formed.



Calcium cyanamide is used as a fertiliser because it reacts with water to give ammonia, NH_3 .

- (i) Suggest an equation for the reaction of calcium cyanamide with water.

[2]

- (ii) The formation of calcium cyanamide is an example of 'nitrogen fixation' as it converts atmospheric nitrogen to its compounds.

Suggest and explain why there are not many nitrogen fixation reactions.

[1]

- (iii) Explain why nitrogen fixation is important for plants.

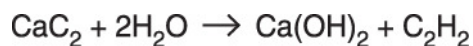
[1]

- (iv) Calculate the percentage by mass of nitrogen in calcium cyanamide.

Give your answer to an **appropriate** number of significant figures.

Percentage = _____ % [2]

- (c) Calcium carbide has been used as a source of ethyne, C_2H_2 , because it reacts with water as shown below.



- (i) Suggest the **full** structural formula for ethyne, showing a bond angle in the molecule with its value.

[2]

- (ii) Ethyne can be polymerised in the presence of a catalyst to give cycloocta-1,3,5,7-tetraene.

Draw a **skeletal** formula for cycloocta-1,3,5,7-tetraene.

[2]

- (iii) A molecule of cycloocta-1,3,5,7-tetraene does **not** have delocalised electrons.

Suggest the **skeletal** formula of the compound formed when cycloocta-1,3,5,7-tetraene reacts with excess bromine.

[1]

(d) The ethyne produced by the method above is often contaminated with phosphane, PH_3 . Phosphane is produced when calcium phosphide (an impurity in the calcium carbide) reacts with water.

(i) Give the formula of calcium phosphide.

-----[1]

(ii) Draw a 'dot-and-cross' diagram for phosphane, PH_3 .

Show outer shell electrons only.

[1]

(iii) Unlike ammonia, phosphane, PH_3 , is not very soluble in water.

Explain this difference in solubility.

Answer in terms of intermolecular bonding and the differences between P and N atoms.

-----[4]

- 7 A student has three solutions, X, Y, Z. Each contains one of potassium chloride, potassium bromide and potassium iodide but it is not known which solution is which.

A student adds drops of chlorine solution separately to each of X, Y and Z. In each case the student also adds a few drops of cyclohexane. The colours of the cyclohexane layer are shown below.

Solution X	red / brown colour
Solution Y	colourless
Solution Z	violet colour

Which represents the correct identities of solutions X, Y and Z?

- A X = potassium chloride, Y = potassium bromide, Z = potassium iodide
- B X = potassium bromide, Y = potassium chloride, Z = potassium iodide
- C X = potassium chloride, Y = potassium iodide, Z = potassium bromide
- D X = potassium iodide, Y = potassium chloride, Z = potassium bromide

Your answer

[1]

- 8 A teacher tests a solution that has been used by students in some experiments with potassium halides to see if it can be used with a different class.

The teacher adds silver nitrate solution to the solution that the students were using. A pale yellow precipitate is formed. The teacher adds a few drops of dilute ammonia solution to the precipitate. Some of the precipitate appears to dissolve and the precipitate remaining has a stronger yellow tinge. The teacher adds excess concentrated ammonia solution to the remaining precipitate. The precipitate does not dissolve.

What is the most likely conclusion that the teacher will reach about the solution that the students were using?

- A The solution contains chloride ions.
- B The solution contains bromide ions.
- C The solution contains chloride and bromide ions.
- D The solution contains chloride and iodide ions.

Your answer

[1]

9 Which of the following quantities increase from left to right along the series:
 MgSO_4 ; CaSO_4 ; SrSO_4 ; BaSO_4 ?

- 1: Size of the metal ions
- 2: The magnitude of enthalpy change of hydration of the metal ions
- 3: The magnitude of lattice enthalpy of the compounds

- A 1, 2 and 3
- B Only 1 and 2
- C Only 2 and 3
- D Only 1

Your answer

[1]

10(a) Aluminium is produced by the electrolysis of molten aluminium oxide, Al_2O_3 .

Demonstrate how the formula of aluminium oxide can be deduced using the periodic table.

----- [1]

(b)

(i) Aluminium is not produced at the cathode when a solution of an aluminium salt is electrolysed.

A solution of aluminium sulfate is electrolysed.

Suggest equations for:

- the reaction at the cathode
- the reaction at a carbon anode.

[2]

(ii) Give details of a simple test that can be used to test for the sulfate ion in solution.

----- [2]

11 Which change is oxidation?

- A $\text{NO}_3^- \rightarrow \text{NH}_3$
- B $\text{NO}_2^- \rightarrow \text{NO}_3^-$
- C $\text{HNO}_3 \rightarrow \text{NO}_3^-$
- D $\text{NH}_4^+ \rightarrow \text{NH}_3$

Your answer

[1]

- (i) Give the equation for the first ionisation enthalpy of magnesium.

[1]

- (ii) How does the difference in ionisation enthalpies of calcium and magnesium account for the difference in the reactions of the elements?

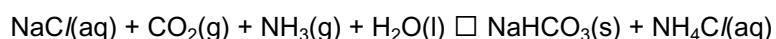
[2]

13(a) Calcium chloride is made by the Solvay process. This also produces another useful substance, sodium carbonate.

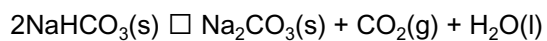
The Solvay process consists of the following reactions:



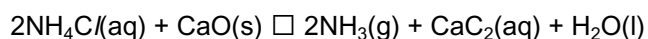
Equation 2.1



Equation 2.2



Equation 2.3



Equation 2.4

(i) Write an equation in the box for the overall reaction that occurs to form just two products.

[2]

(ii) State the atom economy of the Solvay process and explain why this is important for the environment.

----- [1]

(b) Give the systematic names of NaHCO_3 and NH_4Cl .

NaHCO_3 -----

NH_4Cl ----- [2]

(c) The reaction in **Equation 2.1** has a positive ΔS_{sys} .

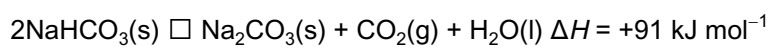


Equation 2.1

Explain the term *entropy* and give **one** reason why ΔS_{sys} is positive for this reaction.

[2]

(d) The standard entropies for the compounds in **Equation 2.3** are given below.



Equation 2.3

Compound	$S^\ominus / \text{J K}^{-1} \text{ mol}^{-1}$
$\text{NaHCO}_3(\text{s})$	+102
$\text{Na}_2\text{CO}_3(\text{s})$	+135
$\text{CO}_2(\text{g})$	+214
$\text{H}_2\text{O}(\text{l})$	+70

Calculate the minimum temperature for the reaction in **Equation 2.3** to occur.

Show all your working.

minimum temperature = _____ K **[3]**

14(a) Some students set out to make a sample of dry crystals of the soluble salt strontium chloride. They react excess strontium carbonate with hydrochloric acid.

They place the acid in a beaker and add spatula measures of strontium carbonate to the acid while stirring.

Describe the rest of their procedure.

[4]

(b)

- (i) Write an equation for the reaction that occurs in the previous question to form SrCl_2 .
Show state symbols.

[2]

- (ii) Calculate the mass of strontium carbonate that will react with 50 cm^3 of 2.0 mol dm^{-3} hydrochloric acid.

mass = _____ g [2]

(c) The strontium chloride formed is a hydrated salt with formula $\text{SrCl}_2 \cdot x\text{H}_2\text{O}$.

The students take 2.00 g of the dry salt, dissolve it in water and add an excess of silver nitrate solution so the total volume is 200 cm^3 . They filter off the precipitate of silver chloride, wash it and heat it to constant mass to remove all the water.

(i) Suggest how the students would 'heat the silver chloride to constant mass'.

----- [2]

(ii) 2.16 g of silver chloride, AgCl , is formed.

Calculate the value of x in $\text{SrCl}_2 \cdot x\text{H}_2\text{O}$.

$x =$ ----- [4]

(iii) A student says that the mass of silver chloride formed is not accurate because silver chloride is slightly soluble in water.

The solubility product of AgCl is $2.0 \times 10^{-10} \text{ mol}^2 \text{ dm}^{-6}$.

Use calculations to comment on the student's statement.

[2]

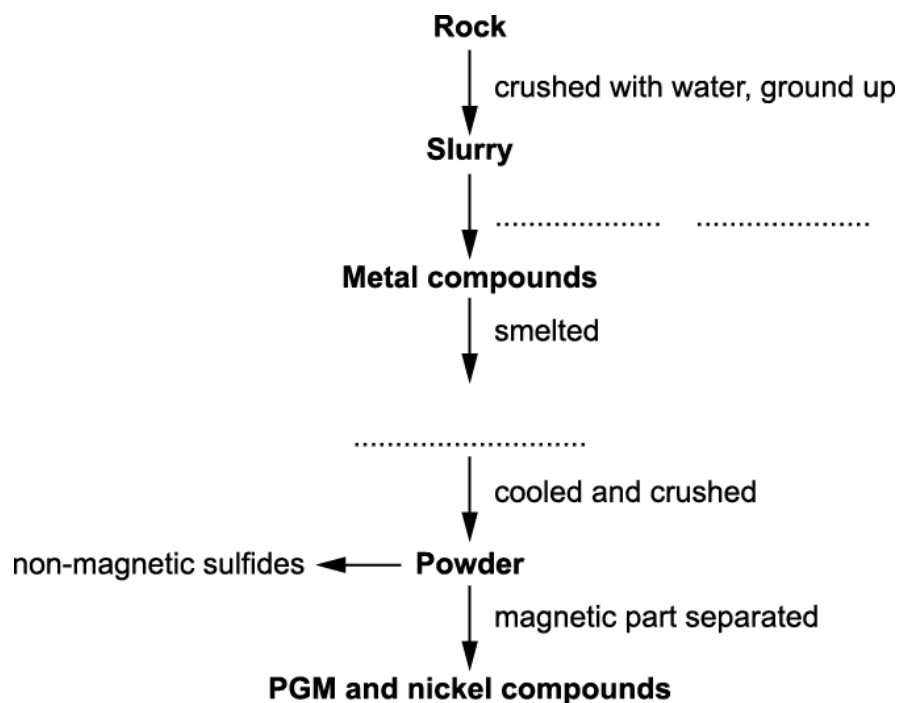
(iv) Another hydrated strontium chloride has formula $\text{SrCl}_2 \cdot 2\text{H}_2\text{O}$.

Calculate the percentage loss in mass when all the water is driven off by heating.

loss in mass = ----- % [1]

15(a) This question is based on the article *The Platinum Group Metals* which is included as an insert to this paper.

- (i) Write words on the dotted lines to complete the flowchart below to summarise the extraction of PGM from rocks.



[1]

- (ii) Suggest an equation for the reaction of one of the 'non-magnetic sulfides' with sulfuric acid to form a sulfate.

[1]

- (iii) How is the metal obtained from the solution of its sulfate?

[1]

(b)

- (i) Suggest **two** reasons why PGM are used in catalytic converters rather than other equally effective catalysts.

----- [1]

- (ii) Write the equation for a reaction in which both CO and NO are removed from exhaust gases in a catalytic converter.

[1]

- (c) Complete the electron configuration of Rh^{3+} , by comparison with Co^{3+} .

[Kr] ----- [1]

(d)

- (i) $[\text{Ru}_2\text{OCl}_{10}]^{4-}$ has an oxygen atom connecting two Ru atoms.

Draw a three-dimensional diagram to suggest the shape of this ion. Give the co-ordination number of Ru in your structure.

co-ordination number ----- [2]

- (ii) Suggest a **name** for the shape of $[\text{AuCl}_4]^-$.

----- [1]

- (e) Give the formula of a 'bulky organic monocation' from the article and explain why three such species are needed by $[\text{MC}_6]^{3-}$.

----- [2]

(f) Estimate how much faster $[\text{Ag}(\text{H}_2\text{O})_2]^+$ exchanges chloride ions compared with $[\text{Ru}(\text{H}_2\text{O})_6]^{3+}$.

----- [1]

(g) Give the equation for a ligand exchange reaction of copper involving ammonia. Give the starting and finishing colours involved.

[2]

(h) A student says that silver(I) salts are colourless because the d subshells are not split by the ligands.

Discuss this statement. (Ag has the same outer electron configuration as Cu.)

----- [3]

- (i) *Describe how compounds of palladium, platinum and osmium are each extracted from a mixture of PGM chlorides, giving chemical details from the article.

[6]

- 16 Which statement is correct about the melting points and structures of the elements in Period 2?

- A** The melting points increase across the Period.
B Elements on the left have ionic structures.
C Elements on the right have covalent structures.
D Metals have the highest melting points.

Your answer

11

- 17 What is a reason that the first ionisation enthalpy increases across a Period?

- A** Each electron is attracted to more protons.
B The electrons are further from the nucleus.
C The atoms get larger.
D The charge density of the ions increases.

Your answer

11

18 Which compound does **not** exist?

- A Fe_2SO_4
- B Ag_2SO_4
- C PbSO_4
- D $\text{Fe}_2(\text{SO}_4)_3$

Your answer

[1]

19 Tests are done on an aqueous solution containing two sodium salts.

The results are shown below.

Test	Result
Add aqueous chlorine followed by an organic solvent	Brown aqueous layer and brown organic layer
Add aqueous barium nitrate	White precipitate

What are the anions in the solution?

- A bromide and sulfate
- B sulfate and iodide
- C sulfate and chloride
- D bromide and chloride

Your answer

[1]

- 20 Bromine is increasingly used as an alternative to chlorine to treat water, as it is less affected by sunlight. Both chlorine and bromine are extracted from seawater.

Bromine is obtained by the reaction between chlorine and bromide ions.

- (i) Give an ionic equation for the reaction and explain which is the oxidising agent in the reaction.

----- [2]

- (ii) In the Dead Sea the concentration of bromide ions is higher than in other seas. Much bromine extraction is carried out near the Dead Sea.

Some Dead Sea water has a chloride ion concentration of 20.8% (mass of solute per volume of solution). The bromide concentration is 500 mg per 100 cm³.

Calculate the ratio of the chloride ion concentration to the bromide ion concentration, both measured in mol dm⁻³.

ratio [Cl⁻]: [Br⁻] = ----- :1 [3]

- (iii) Many of the industries using bromine are sited near the Dead Sea to avoid transportation of the bromine.

Suggest **two** reasons why transportation of bromine is dangerous.

1

2

----- [1]

*Describe an experiment (involving gas collection) they could do to **measure** the rate of the reaction between each metal and water and explain the expected observations.

[6]

- (b) Students decide to investigate the solubility of calcium hydroxide by shaking solid calcium hydroxide with deionised water and filtering the mixture to remove undissolved solid. They then titrate the dissolved hydroxide ions with hydrochloric acid.

- (i) They titrate 25.0 cm^3 of their saturated solution of calcium hydroxide with $0.0400 \text{ mol dm}^{-3} \text{ HCl}$.

Their results are shown below.

	Trial	Repeat 1	Repeat 2	Repeat 3	Repeat 4
Titre/ cm^3	15.00	13.80	13.90	14.00	14.60

Use their results to find the solubility product of calcium hydroxide.

solubility product of calcium hydroxide = _____

units _____ [4]

- (ii) Describe and explain what difference they would see in their titre if they repeated their titration with saturated magnesium hydroxide solution.

 _____ [1]

22(a) Industries using chlorine are often located close to the electrolysis plant.

Why is the transportation of chlorine dangerous?

----- [1]

(b) Chlorine is manufactured by the electrolysis of sodium chloride solution. The equation is shown below.



Hydrogen chloride can be prepared by reacting potassium chloride with concentrated sulfuric acid.

Give the equation for the reaction.

[1]

(c) The reaction in (e) is repeated with potassium iodide.

The hydrogen iodide formed is oxidised to iodine and the sulfuric acid is reduced to hydrogen sulfide.

Give the oxidation states of the elements in the compounds.

iodine in HI ----- iodine in I₂ -----

sulfur in H₂SO₄ ----- sulfur in H₂S -----

Use these oxidation states to write a balanced equation for the reaction of HI with H₂SO₄.

Equation

[3]

23(a) One suggested method of carbon capture and storage is reacting carbon dioxide with naturally occurring metal oxides in the Earth’s crust.

Magnesium oxide and calcium oxide could have formed when dolomite marble was subjected to high temperatures in the Earth.

(b) A student finds that magnesium carbonate decomposes at a lower temperature than calcium carbonate.

Suggest the reason for this in terms of the ions present.

----- [2]

(c) Strontianite may also contain small amounts of barium carbonate, lead carbonate or iron(II) carbonate.

Some students took separate samples of barium carbonate, lead carbonate and iron(II) carbonate and reacted them with nitric acid. They then devised tests on the resulting nitrate solutions that would show the presence of each metal ion and distinguish it from the other two.

Give three reagents they could use and the expected observations for each.
Within the table there must be a positive reaction for each ion.

Reagent solution	Observation for Ba ²⁺	Observation for Pb ²⁺	Observation for Fe ²⁺

[3]

In order to find the value of x in the formula, a student follows the procedure below.

A known mass of magnesium sulfate crystals is dissolved in water. Aqueous sodium carbonate is added to precipitate magnesium carbonate, MgCO_3 .



 Describe how the student would use the results of the experiment to find a value for x . Suggest possible sources of inaccuracy and how they might be overcome.

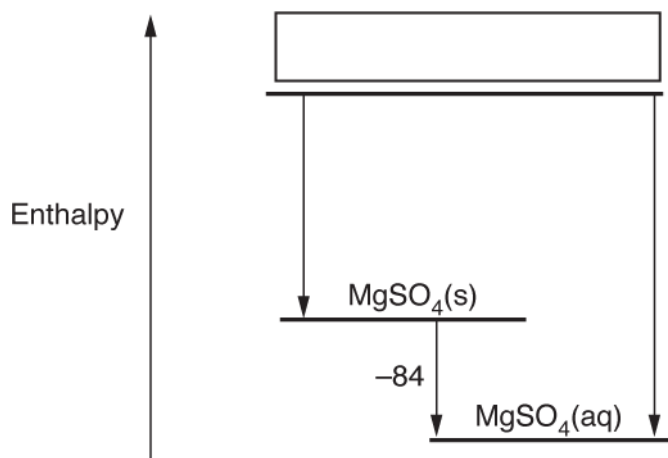
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[6]

(b) $\Delta_{\text{hyd}}H$ values for the ions in magnesium sulfate are given in the table below.

Ion	$\Delta_{\text{hyd}}H / \text{kJ mol}^{-1}$
Mg^{2+}	-1922
SO_4^{2-}	-1099

Fill in the missing species in the box and use the diagram to calculate $\Delta_{\text{LE}}H$ for magnesium sulfate.



$\Delta_{\text{LE}}H = \text{-----} \text{ kJ mol}^{-1}$ [2]

(c) Strontium sulfate is much less soluble than magnesium sulfate.

Use ideas of hydration enthalpy to suggest an explanation.

[2]

25 Which solutions when mixed would give a solution of a salt?

- A barium hydroxide and sulfuric acid
- B lead nitrate and sulfuric acid
- C silver nitrate and hydrochloric acid
- D lithium hydroxide and hydrochloric acid

Your answer

[1]

26 Which observation is correct?

- A A solution of bromine water forms a purple layer when hexane is added.
- B Aqueous silver nitrate forms a yellow precipitate when added to sodium bromide solution.
- C When iodobutane and chlorobutane are separately refluxed with aqueous silver nitrate, a precipitate forms faster with iodobutane.
- D Steamy fumes of hydrogen bromide are formed as the only gas when concentrated sulfuric acid is warmed with sodium bromide.

Your answer

[1]

27(a) Iodine, I_2 , is an essential dietary element. The recommended maximum daily intake of iodine for an adult is 1.5×10^{-4} g (150 μ g).

A group of chemistry students read that fish is a good source of iodine in the form of iodide ions. They decide to extract the iodine from 600 g of fish.

The students blend the fish in a food processor with 100 cm³ of water, leave it to stand overnight and then filter the mixture into a beaker.

One of the students suggests that if they add silver nitrate solution they can confirm the presence of iodide ions in the solution.

- (i) Describe what the students would observe if the only halide ion present in the solution was the iodide.

-----[1]

- (ii) Write an ionic equation for this reaction. Include state symbols.

[1]

- (b) The students pour the filtered mixture into a separating funnel containing 20 cm³ of hexane, 5 cm³ of dilute sulfuric acid and 5 cm³ of hydrogen peroxide solution.

Iodine is formed and dissolves in the hexane layer which goes purple. The purple layer is separated from the aqueous layer and transferred to a conical flask.

The purple coloured solution is titrated with standard 0.0010 mol dm⁻³ sodium thiosulfate solution. The end point is indicated by the disappearance of the purple colour.

- (i) The hydrogen peroxide oxidises the iodide ions in the fish to iodine.

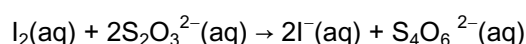
Write a half equation for this oxidation reaction.

Explain why this reaction is classified as oxidation.

Half equation

Explanation [1]

- (ii) The equation for the titration reaction is given below.



Name the element oxidised in this reaction. Give its oxidation state before and after the reaction.

Element oxidised

Oxidation state before reaction Oxidation state after reaction [2]

- (iii) The students obtained an average titre of 5.30 cm³ of 0.0010 mol dm⁻³ sodium thiosulfate.

Calculate the **mass** of iodine in µg in a **120 g** portion of fish.

Give your answer to **two** significant figures.

mass of iodine = ... μg [4]

- (iv) One of the students suggests that the titre value is too small and will lead to an unacceptably high percentage error.

Calculate the percentage error based on the students' titre value.

percentage error = ... % [1]

- (v) Suggest how the experiment could be modified to improve the accuracy of the result.

.....

.....

..... [1]

28(a) Magnesium has a higher first ionisation enthalpy than calcium.

- (i) Write an equation for the reaction for the first ionisation enthalpy of magnesium.

Include state symbols.

[1]

- (ii) Explain why magnesium has a higher first ionisation enthalpy than calcium.

----- [2]

- (b) Some students are given a mixture of magnesium carbonate with another Group 2 carbonate. They dissolve the mixture in an acid. They test the solution of salts formed as shown in the table below.

Test	Result
Flame test	Green flame
Add dilute nitric acid followed by silver nitrate solution	White precipitate

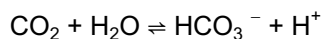
- (i) Name the acid that the students used to dissolve the mixture of carbonates.

----- [1]

- (ii) Name the other Group 2 carbonate that was mixed with the magnesium carbonate.

----- [1]

- 29 The pH of human blood needs to be held within strict limits for good health.
The pH is controlled using buffer systems. One buffer system is based on the equilibrium in **equation 4.1**.



Equation 4.1

- (i) Give the **systematic** name for HCO_3^- .

-----[1]

- (ii) HCO_3^- can act as either an acid or a base.

Give the **formula** of the conjugate **base** of HCO_3^- .

-----[1]

- 30 A solution of salt X gives a green precipitate with sodium hydroxide solution.

What is X?

- A Iron(II) chloride
- B Iron(III) sulfate
- C Barium chloride
- D Barium sulfate

Your answer

[1]

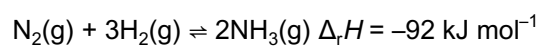
31 What occurs as Group 2 is descended?

- A There is a greater attraction between Group 2 cations and Cl^- ions.
- B The hydration enthalpies of the Group 2 cations become less negative.
- C The charge density of the Group 2 cations increases.
- D The lattice enthalpies of the sulfates become more negative.

Your answer

[1]

32 Ammonia is made by the reaction shown in **equation 31.1**.



Equation 31.1

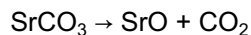
The reaction can be allowed to reach dynamic equilibrium.

Explain what is meant by **dynamic equilibrium**.

[2]

33(a) Strontium carbonate is used in fireworks to colour the flames red.

Strontium carbonate decomposes to give strontium oxide when heated.



(i) 12.0 g of SrCO_3 are heated.

Calculate the volume of CO_2 (in cm^3) that would be collected at 290 K and 155 kPa.

Give your answer to an **appropriate** number of significant figures.

volume of CO_2 = ... cm^3 [4]

(ii) A student says 'Strontium ions are larger than calcium ions, so the attraction to carbonate ions is weaker. This means that strontium carbonate has a lower thermal stability than calcium carbonate.'

Discuss the student's statement, giving the correct chemistry where necessary.

[4]

(b) The melting point of strontium is higher than the melting point of rubidium.

(i) To which block of the Periodic Table do these elements belong?

-----[1]

(ii) Explain the difference in melting point.

-----[2]

34(a)

From data in **Table 3.1**, the student knows that chlorine reacts with iodide ions in aqueous solution.

(i) Write an equation for the reaction that occurs.

[1]

(ii) **Name** the reducing agent in your reaction in (i).

[1]

(iii) What will be **seen** when the reaction in (i) occurs?

[1]

(iv) Explain, in terms of electrons, why chlorine is more reactive than iodine.

[1]

- (b) The student uses a simple apparatus to prepare a test-tube full of hydrogen chloride gas in the laboratory.
Draw a diagram of an apparatus the student could use, labelling the reactants.

[2]

35 A student is investigating the properties of some s-block metals and their compounds.

The enthalpy change of hydration is less negative for barium ions than for calcium ions.

Student **A** says this is because barium is more reactive than calcium.

Student **B** says it is due to the differences between Ca^{2+} and Ba^{2+} ions.

Comment on the students' statements giving the correct chemistry.

[4]

36 A solution of lead nitrate is added to sodium sulfate and potassium iodide solutions.

What is observed?

	Observation with:	
	Sodium sulfate	Potassium iodide
A	Yellow precipitate	White precipitate
B	No precipitate	White precipitate
C	White precipitate	Yellow precipitate
D	White precipitate	No precipitate

Your answer

[1]

37 Mg^{2+} has a higher charge density than Ca^{2+} .

Which statement is correct?

- A MgCO_3 is more thermally stable than CaCO_3 .
- B The Mg^{2+} ion has a less exothermic enthalpy change of hydration than that of Ca^{2+} .
- C The ionic radius of Mg^{2+} is greater than that of Ca^{2+} .
- D The lattice enthalpy of MgCl_2 is more exothermic than that of CaCl_2 .

Your answer

☐

[1]

38 Some students want to find the concentration of chloride ions in seawater. They look up a method in a textbook.

They dilute the seawater and then titrate with standard silver nitrate, AgNO_3 , solution.

(i) Describe what is observed when silver nitrate is added to the seawater.

----- [1]

(ii) Give an ionic equation for the reaction, including state symbols.

[1]

END OF QUESTION PAPER

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
1	i <i>* Please refer to point 10 of the marking instructions of this mark scheme for guidance on how to mark this question.</i> Level 3 (5–6 marks) Develops a safe, fully detailed and accurate method that correctly includes apparatus. The full accurately labelled diagram reflects the method. The accurate observations / measurements recorded allow for a fair and accurate comparison between MgCO_3 and CaCO_3. <i>The method is detailed, clear and logically structured. Accuracy is discussed in terms of the apparatus chosen. Observations / measurements are detailed and allows for a full comparison.</i> Level 2 (3–4 marks) Develops a safe, detailed method that includes relevant apparatus. The diagram reflects this method and is labelled correctly. Details refer to accurate measurements. The observations / measurements recorded allow for a fair comparison between MgCO_3 and CaCO_3. <i>The method is detailed and logical. Relevant apparatus is identified and there is reference to the accuracy of the measurements to be taken. The observations / measurements are relevant and supply evidence to allow a fair comparison.</i> Level 1 (1–2 marks) Develops a basic safe method that includes relevant apparatus either in a correctly labelled diagram or named in the method. Suggests which observation(s) / measurement(s) need to be recorded to allow some comparison between MgCO_3 and CaCO_3. <i>The method is basic and unstructured. Although relevant apparatus is labelled / referred to it lacks detail and accuracy. The observations / measurements are relevant</i>	6	Indicative scientific points may include Method with details - Crush lumps of calcium carbonate to a powder using a pestle and mortar - Add calcium hydroxide to distilled water and filter - Glass test tube / boiling tube to contain the solid fitted with a bung carrying a delivery tube which dips into a solution of calcium hydroxide in a test tube / boiling tube. - Tube is heated and is approximately horizontal, - solid (metal carbonate) and solution (calcium hydroxide) are clearly labelled in diagram. Measurements - Measure time for cloudiness to first appear. - Measure time taken to obscure a cross on paper OR alternative way of measuring relative thickness of ppt (of calcium carbonate) Fair comparison - Equal mass of MgCO_3 and CaCO_3 - Same volume and concentration of calcium hydroxide solution

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
			<i>but do not supply sufficient evidence to ensure a fair comparison.</i> 0 marks No response or no response worthy of credit.		
		ii	The ratio of charge on ion to its volume ✓	1	ALLOW charge / volume ALLOW size instead of volume
		iii	Magnesium carbonate is less thermally stable than calcium carbonate (because) the smaller magnesium (Mg^{2+}) ion ✓ distorts the (large) carbonate (CO_3^{2-}) ion ✓	2	ORA
		iv	FIRST CHECK THE ANSWER ON THE ANSWER LINE minimum temperature = 674 K award 3 marks $\Delta_{\text{sys}}S = 27 + 214 - 66 = +175 \text{ J mol K}^{-1}$ ✓ Minimum temperature is where $\Delta_{\text{sys}}S = \Delta_{\text{surr}}S$ $- \frac{118000}{T} = 175 \Delta$ $T = 11800 / 175 = 674 \text{ K}$ ✓	3	ALLOW ECF from first marking point Correct unit required for mark. ALLOW 401 °C
			Total	12	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
2	a	i	$\text{CO}_2 + \text{Ca}(\text{OH})_2 \rightarrow \text{CaCO}_3 + \text{H}_2\text{O}$ ✓	1	IGNORE state symbols
		ii	FIRST CHECK THE ANSWER ON THE ANSWER LINE mass = 0.0625 award 1 mark mass = 0.063 g to 2 sig figs award 2 marks moles $\text{CO}_2 = 15/24000$ OR 6.25×10^{-4} ✓ mass $\text{CaCO}_3 = (6.25 \times 10^{-4} \times 100) = 0.063$ g to 2 sig figs ✓	2	ALLOW ECF from first marking point
	b	i	$\text{CO}_3^{2-} + \text{H}_2\text{O} \rightleftharpoons \text{HCO}_3^- + \text{OH}^-$ OR $\text{CO}_3^{2-} + \text{H}_2\text{O} \rightleftharpoons \text{CO}_2 + 2\text{OH}^-$ ✓	1	ALLOW equilibrium signs IGNORE state symbols
		ii	CaCO_3 is less soluble / weaker base than $\text{Ca}(\text{OH})_2$ ✓ so fewer OH^- (aq) ions are present (as $\text{Ca}(\text{OH})_2$ reacts / CaCO_3 forms) ✓	2	
			Total	6	
3	a		$\text{Ca}(\text{OH})_2(\text{s}) + \text{CO}_2(\text{g}) \rightarrow \text{CaCO}_3(\text{s}) + \text{H}_2\text{O}(\text{l})$	1	State symbols must be included
	b		FIRST CHECK ANSWER ON ANSWER LINE answers rounding to 5.7 (g) award 3 marks Amount $\text{CO}_2 = \text{PV}/\text{RT}$ ✓ $0.0004 \times 5.0 \times 9.5 \times 10^4 / 8.314 \times 296$ OR 0.0772... (= amount $\text{Ca}(\text{OH})_2$) ✓ Mass $\text{Ca}(\text{OH})_2 = 0.0772 \times 74.1 = 5.7$ (g) ✓	3	Ecf from second point ALLOW 74 for formula mass of $\text{Ca}(\text{OH})_2$ ALLOW answer to 2 or more sf
			Total	4	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance										
4		i	sulfur dioxide / sulfur trioxide OR chlorine ✓	1	IGNORE formulae ALLOW hydrogen chloride NOT hydrochloric acid or sulfur (di)chloride Examiner's Comments If the gas was correctly recognised the mark was often lost for giving the formula instead of the name.										
		ii	<table><tr><th>compound</th><th>oxidation state of vanadium</th></tr><tr><td>VS₄</td><td>+4</td></tr><tr><td>NaVO₃</td><td>+5</td></tr><tr><td>Na₂V₆O₁₆</td><td>+5</td></tr><tr><td>V₂O₅</td><td>+5</td></tr></table> VS ₄ correct ✓ rest correct ✓	compound	oxidation state of vanadium	VS ₄	+4	NaVO ₃	+5	Na ₂ V ₆ O ₁₆	+5	V ₂ O ₅	+5	2	ONLY penalise ONCE for lack of sign sign must be before number, ecf after first error Examiner's Comments Unlike (i), this part was very well done; the main error being that the vanadium in VS ₄ was often given an oxidation state of +8. A few also had +32 for the vanadium in Na ₂ V ₆ O ₁₆ .
compound	oxidation state of vanadium														
VS ₄	+4														
NaVO ₃	+5														
Na ₂ V ₆ O ₁₆	+5														
V ₂ O ₅	+5														
		iii	step 1 ✓ oxidation state of V changes / increases ✓	2	more than step 1 is a CON but mark explanation separately ALLOW electron loss by V ALLOW ecf for the 2 nd mark, from wrong oxidation state for VS ₄ in table in ii, <i>e.g.</i> +8 (for VS ₄) to +5, so oxidation state decreases If two steps in first part , both reasons must refer correctly to the data in ii Examiner's Comments Well answered with the majority clearly stating the change in oxidation number										

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iv	absorb (specific) frequencies (or wavelengths) in (specific) parts of the visible spectrum ✓  absorb must be spelled correctly to gain this mark transmit complementary colour / frequencies (or wavelengths) not absorbed / yellow light ✓	2	MUST use frequency / frequencies / wavelength (s) for 1st mark IGNORE any reference to energy levels and electrons ALLOW 'light' for visible or any of its variants e.g. absorbed, absorbing, absorption etc. ALLOW only complementary colour / frequencies (or wavelengths) can be seen DO NOT ALLOW reflect / emit / absorption Examiner's Comments Many gained both marks eventually, but candidates wanted to explain d orbital splitting and electron promotion. This sometimes resulted in them arguing that energy is emitted when electrons fall back to the ground state, or omitting to mention the terms frequency or wavelength.
		v	$\text{V}_2\text{O}_5 + 5\text{Ca} \rightarrow 2\text{V} + 5\text{CaO}$	1	IGNORE state symbols Examiner's Comments Very variable responses; a concerning number seem to think that vanadium is diatomic or that calcium oxide might be CaO5 or Ca2O5.
			Total	8	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
5		i	calcium hydrogencarbonate ✓	1	IGNORE gaps and capital letters ALLOW calcium(II) hydrogencarbonate NOT (calcium hydrogen) carbonate(IV) IGNORE 'bicarbonate'
		ii	air / atmosphere ✓	1	ALLOW 'dissolved in rainwater' (not just 'in rainwater') IGNORE 'from fossil fuels' etc
		iii	CaCO ₃ is formed / CaCO ₃ is limescale ✓ Position of equilibrium moves to left / towards reactants ✓ Gas / CO ₂ is released from solution AW ✓	3	ALLOW water boils away / is removed IGNORE references to endothermic reaction Examiner's Comments Tested some basic Chemistry. Many could name calcium hydrogencarbonate and knew that CO ₂ came from the air. Relatively few realised that CO ₂ would be released from the solution on boiling. Some failed to say that the position of equilibrium moved.
			Total	5	

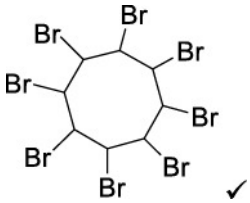
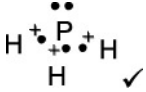
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
6	a		$\text{CaO} + 3\text{C} \rightarrow \text{CO} + \text{CaC}_2$ OR $2\text{CaO} + 5\text{C} \rightarrow \text{CO}_2 + 2\text{CaC}_2 \checkmark$	1	IGNORE state symbols Examiner's Comments Required understanding of inorganic chemistry that was possessed by some candidates. Many gave oxygen as a possible product, which candidates should have realised would not form in the presence of hot carbon.
	b	i	$\text{CaCN}_2 + 3\text{H}_2\text{O} \rightarrow \text{CaCO}_3 + 2\text{NH}_3 \checkmark \checkmark$	2	<i>For one mark:</i> • correct substances but unbalanced equation • the correct balanced equation with an error (eg $\text{Ca}(\text{CO}_3)$) • $\text{CaCN}_2 + 3\text{H}_2\text{O} \rightarrow \text{CaO} + \text{CO}_2 + 2\text{NH}_3$ • $\text{CaCN}_2 + 4\text{H}_2\text{O} \rightarrow \text{Ca}(\text{OH})_2 + \text{CO}_2 + 2\text{NH}_3$ Examiner's Comments Required understanding of inorganic chemistry that was possessed by some candidates. Many gave oxygen as a possible product in part (a) which candidates should have realised would not form in the presence of hot carbon.
		ii	(nitrogen is unreactive / inert) (nitrogen) has a (strong) triple bond ~~($\text{O}=\text{N}=\text{N}$)~~ $\checkmark$ OR high (AW) (activation) energy / enthalpy... ... to break bond	1	Examiner's Comments Was better, with more candidates suggesting that CaO and CO₂ would be formed, though CaCO₃ was the more likely product. Many candidates correctly suggested a triple (or strong) bond between the nitrogen atoms and some went on to say that nitrogen compounds were needed for plant growth.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iii	nitrogen compounds are needed (by plants) for: growth / making protein / making amino acids / DNA ✓	1	ALLOW for 'nitrogen compounds': named (appropriate) nitrogen compounds or 'nitrates' or 'ammonium ions' (or formulae) IGNORE references to fertilisers Examiner's Comments Lack of the word 'compounds' caused some loss of the mark.
		iv	$(28 \times 100 / 80.1 =) 35.0\%$ ✓ to 3sf ✓	2	Any answer that rounds to 35 scores first mark Second mark is for correct answer to 3sf i.e. 35.0 Examiner's Comments Involved a simple mole calculation, which most got right. Realisation that atomic mass data is to three significant figures was slightly more complicated.
	c	i	$180(^{\circ})$ ✓ $\text{H}-\text{C}\equiv\text{C}-\text{H}$ ✓	2	Structure mark can be awarded if not linear Angle mark depends on: • correct structure being given. • structure being linear • curve indicating the angle starting and finishing on bonds rather than an atom <i>Give benefit of doubt on rubbed out structures where possible (also in following parts)</i> Examiner's Comments There were many correct answers, though some of the curved lines attempting to show the bond angle did not start and finish on bonds. The next two parts were often well done.
		ii	 ring of eight carbons ✓ correct double bonds ✓	2	If a correct non-skeletal structural formula is given, award one mark only. Do not award either mark if there are any extra carbons on ring. Second mark depends on first. Examiner's Comments There were many correct answers.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iii		1	must be skeletal to score Examiner's Comments There were many correct answers.
	d	i	Ca ₃ P ₂ ✓	1	Examiner's Comments Some managed Ca₃P₂ but many attempts involved an H atom as well.
		ii		1	Examiner's Comments Some managed Ca₃P₂, had a high rate of scoring.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iii	1. ammonia / NH_3 (not just N) forms hydrogen bonds with / in water ✓ 2. phosphane / PH_3 (not just P) forms id-id bonds with / in water ✓ 3. P is less electronegative (than N) ora ✓ 4. <i>consideration of relative energies</i> more energy is needed to break the hydrogen bonds in water than is released / made by making the imb / named imb (between phosphane and water) OR hydrogen bonds in water are stronger than imb / named imb (between phosphane and water) OR similar energy is needed to break the hydrogen bonds in water than is released / made by forming the hydrogen bonds (between) ammonia (and water) OR hydrogen bonds in water are of similar strength(AW) to those (between) ammonia (and water).✓	4	ALLOW forms no / weaker hydrogen bonds OR forms permanent dipole-permanent dipole bonds / forms Van der Waals ALLOW abbreviations / spelling errors and 'forces' for 'bonds' IGNORE 'more energy is needed to break the hydrogen bonds in water than is needed to break the imb' etc 'in water' must be stated or implied IGNORE reference to number of bonds broken and made ALLOW statements that suggest that the hydrogen bonding in water is weaker than that between ammonia and water Examiner's Comments Was an area where planning would have paid dividends. Some candidates sailed through the first three marks but others tripped up by saying either that nitrogen (rather than ammonia) formed hydrogen bonds with water or that ammonia was more electronegative than phosphane. For the fourth mark a clear statement about the relative strength of bonds or the amount of energy released in breaking bonds and use in making bonds was needed. Some achieved this but others failed to express themselves clearly, particularly not saying that the hydrogen bonds they were talking about were in water.
			Total	18	
7			B	1	
			Total	1	
8			D	1	
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
9			D	1	
			Total	1	
10	a		Al^{3+} since group 3, O^{2-} since Group 6; charges balance (in Al_2O_3) ✓	1	
	b	i	cathode: $2H_2O + 2e^- \rightarrow H_2 + 2OH^-$ ✓ anode: $2H_2O \rightarrow 4H^+ + O_2 + 4e^-$ ✓	2	ALLOW 'e' without minus IGNORE state symbols ALLOW multiples and halves ALLOW $2H^+ + 2e^- \rightarrow H_2$ and $4OH^- \rightarrow O_2 + 2H_2O + 4e^-$
		ii	white ppt ✓ after adding Ba^{2+} / solution of (named) barium salt OR (formation of) barium sulfate/ $BaSO_4$ ✓	2	Any named barium salt must be soluble
			Total	5	
11			B	1	
			Total	1	
12		i	$Mg(g) \rightarrow Mg^+(g) + e^-$ ✓	1	ALLOW 'e' for 'e' IGNORE state symbol on e^-
		ii	Ca more reactive as ionisation energy is lower ✓ outer electron(s) more easily removed ✓	2	
			Total	3	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
13	a	i	$\text{CaCO}_3 + 2\text{NaCl} \rightarrow \text{Na}_2\text{CO}_3 + \text{CaCl}_2$ ✓✓	2	Unbalanced equation with just these species OR <i>Balanced</i> equation involving CaO, CO_2 instead of CaCO_3 scores 1 mark IGNORE state symbols IGNORE omission of plus signs or arrow if meaning is clear Examiner's Comments Most managed to unravel the equations given to get the overall equation for the reaction between calcium carbonate and sodium chloride to give sodium carbonate and calcium chloride.
		ii	Atom economy 100% AND No waste or both products useful✓	1	Examiner's Comments This was another high-scoring question with most candidates spotting that it was 100% atom economy and that this resulted in no waste. Comments like 'little waste' did not score.
	b		sodium hydrogencarbonate ✓ ammonium chloride ✓	2	allow 'sodium hydrogen carbonate' and (l) after sodium (but not ammonium) Examiner's Comments A gratifyingly large number of candidates could name sodium hydrogencarbonate and ammonium chloride. Occasional errors were to put oxidation states after the carbonate or the ammonium.
	c		Entropy is a measure of disorder or number of ways of arrangement/distribution of molecules/particles/energy quanta ✓ (more) gas formed has more/higher entropy/disorder/ways of arrangement ✓	2	ALLOW 'disorder' or 'ways of arrangement' for 'entropy' NOT arrangement of a molecule IGNORE 'more molecules formed' needs to be mention of gas formed and it having higher/more entropy Examiner's Comments Defining entropy presented few problems. Many spotted that a gas was evolved but fewer clearly stated that gases had higher entropy than solids.

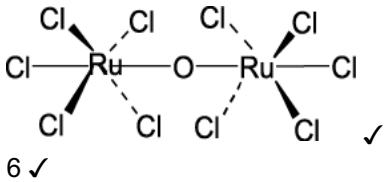
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	d		$\Delta S_{\text{sys}} = (+) 215 \text{ (J K}^{-1} \text{ mol}^{-1}) \checkmark$ $T = \Delta H / \Delta S_{\text{sys}} \text{ OR } T = 91000 / 215 \checkmark$ $T = (+) 423 \text{ (K)} \checkmark$	3	ALLOW ecf from each step Second marking point can subsume first ALLOW two or more significant figures Negative answers do not score the third marking point even if they follow by ecf. If 423 shows in working but 424 given, mark can be awarded. Correct answer on answer line scores 3 marks Examiner's Comments This calculation was often done correctly. Negative answers scored few marks.
			Total	10	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
14	a		add until no more fizzing ✓ filter ✓ evaporate and allow to crystallise ✓ filter (or pick out crystals) and dry ✓	4	ALLOW until no more dissolves
	b	i	$\text{SrCO}_3(\text{s}) + 2\text{HCl}(\text{aq}) \rightarrow \text{SrCl}_2(\text{aq}) + \text{H}_2\text{O}(\text{l})$ equation ✓ state symbols ✓	2	ALLOW state symbol mark if formulae or balancing wrong but no species is missing or extra.
		ii	FIRST CHECK THE ANSWER ON ANSWER LINE If answer = 7.4 (g) award 2 marks amount HCl = $2 \times 50/1000$ OR $0.1(0)$ ✓ mass $\text{SrCO}_3 = (0.1 \times 147.6 \times 0.5) = 7.4$ (g) ✓	2	ALLOW ecf from first mark to second or from wrong formula for SrCO_3 in (b)(i) ALLOW 2 or more sf
	c	i	Heat, cool (in desiccator), weigh, ✓ Repeat until mass constant ✓	2	
		ii	FIRST CHECK THE ANSWER ON ANSWER LINE If answer = 6 award 4 marks amount AgCl = $2.16/143.4$ OR 1.506×10^{-2} ✓ amount $\text{SrCl}_2 = 0.5 \times 2.16/143.4$ OR 7.531×10^{-3} ✓ $M_r \text{SrCl}_2 \cdot x\text{H}_2\text{O} = (2/7.531 \times 10^{-3}) = 266$ ✓ $x = ((266 - 158.6)/18) = 6$	4	ALLOW ecf Second mark subsumes first OR mass $\text{SrCl}_2 = 7.531 \times 10^{-3} \times 158.6$ (or 1.19g) and mass $\text{H}_2\text{O} = 2 - 1.19 = 0.81$ g ✓ $(0.81/18) = 0.045 / (1.19/158.6) = 0.0075 = 6$ ✓
		iii	Solubility of silver chloride = $\sqrt{K_{sp}} = 1.4 \times 10$ (mol dm ⁻³) ✓ Moles in 200 cm ³ 3×10^{-6} which is negligible compared with 1.5×10^{-2} ✓	2	OR compare masses 4×10^{-4} g with 1.19g
		iv	$(36 \times 100/194.6) = 18.5$ or 18(%) ✓	1	ALLOW more sf
			Total	17	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
15	a	i	froth/detergent flotation AND matte ✓	1	
		ii	$\text{NiS} + \text{H}_2\text{SO}_4 \rightarrow \text{NiSO}_4 + \text{H}_2\text{S}$ OR $\text{CuS} + \text{H}_2\text{SO}_4 \rightarrow \text{CuSO}_4 + \text{H}_2\text{S}$	1	IGNORE state symbols
		iii	electrolysis	1	
	b	i	high melting AND unreactive	1	
		ii	$2\text{CO} + 2\text{NO} \rightarrow \text{N}_2 + 2\text{CO}_2$	1	ALLOW halves or multiples IGNORE state symbols
	c		$4d^6$	1	
	d	i	 6 ✓	2	ALLOW bridging oxygen bonding in axial or equatorial positions IGNORE brackets and charges.
		ii	square planar OR tetrahedral	1	
	e		R_2NH_2^+ ✓ 3 + balances 3– (AW) ✓	2	
	f		$10^7 - 10^{10}$ or any value in that range ✓	1	
	g		$[\text{Cu}(\text{H}_2\text{O})_6]^{2+} + 4\text{NH}_3 \rightarrow [\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+} + 4\text{H}_2\text{O}$ ✓ (light)blue dark blue/violet/purple/mauve ✓	2	ALLOW $[\text{Cu}(\text{H}_2\text{O})_6]^{2+} + 6\text{NH}_3 \rightarrow [\text{Cu}(\text{NH}_3)_6]^{2+} + 6\text{H}_2\text{O}$ IGNORE state symbols
	h		Wrong: d subshells still split ✓ Ag^+ is d^{10} OR Ag has full d subshell ✓ so no movement possible (AW) ✓	3	

Mark Scheme

Question		Answer/Indicative content	Marks	Guidance
	i	<i>*Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question.</i> Level 3 (5–6 marks) Describes in detail the methods of extraction and gives chemical details from the article of all three compounds. <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3–4 marks) Describes in detail the methods of extraction of all three compounds AND Gives the chemical details from the article for either Pd, Pt or Os <i>There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.</i> Level 1 (1–2 marks) Outlines the methods of extractions for of all three compounds AND Gives the chemicals details from the article for either Pd, Pt or Os. OR Describes in detail the method of extraction for one of the compounds and gives chemical details from the article concerning this compound. <i>The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.</i> 0 marks No response or no response worthy of credit	6	Indicative Scientific points include: Description of extraction of Pd: - extracted by ligand exchange - followed by dissolving in organic solvent Chemical details from article concerning Pd: - equation, eg $[\text{Pd}(\text{H}_2\text{O})_6]^{2+}(\text{aq}) + 4\text{Cl}^-(\text{aq}) \rightarrow [\text{PdCl}_4]^{2-}(\text{aq}) + 6\text{H}_2\text{O}(\text{l})$ - this reaction is much slower for other PGMs Description of extraction of Pt: - anion exchange - reacted with $\text{R}_2\text{NH}_2^+ \text{Cl}^-$. Chemical details from article concerning Pt: $2[\text{R}_2\text{NH}_2^+ \text{Cl}^-] + [\text{PtCl}_6]^{2-}(\text{aq}) \rightleftharpoons (\text{R}_2\text{NH}_2^+)_2 [\text{PtCl}_6]^{2-} + 2\text{Cl}^-$ $(\text{R}_2\text{NH}_2^+)_2 [\text{PtCl}_6]^{2-}$ is soluble in organic solvents whereas the equivalent salts of other PGMs have lower solubility. Description of extraction of Os: - oxidation - oxide volatile and can be removed by heating Chemical details from article concerning Os: - oxidised to OsO_4 - may be mixed with RuO_4
		Total	23	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
16			C	1	
			Total	1	
17			A	1	
			Total	1	
18			A	1	
			Total	1	
19			A	1	
			Total	1	
20		i	$\text{Cl}_2 + 2\text{Br}^- \rightarrow 2\text{Cl}^- + \text{Br}_2$ ✓ Chlorine is the oxidising agent: it gains electrons OR oxidation state lowered ✓	2	ALLOW reference to oxidation state of Br increasing or Cl decreasing
		ii	FIRST CHECK THE ANSWER ON THE ANSWER LINE If the answer = 93.6 award 3 marks Moles of Cl^- ions/dm ³ : $208/35.5 = 5.86$ ✓ Moles of Br ions/dm ³ : $5/79.9 = 0.0626$ ✓ Ratio $5.86/0.0626 = 93.6$ ✓	3	ALLOW 2 or more significant figures ALLOW in moles per 100 cm ³
		iii	Bromine is toxic OR volatile ✓	2	ALLOW poisonous DO NOT ALLOW harmful
			Total	6	

Mark Scheme

Question		Answer/Indicative content	Marks	Guidance
21	a	<i>*Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question.</i> Level 3 (5–6 marks) Describes the set-up of the experiment in detail. AND States and explains some of the expected observations in detail. <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3–4 marks) Describes the set-up of the experiment in detail. AND States a number of observations. OR States and explains a few of the expected observations in detail. <i>There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.</i> Level 1 (1–2 marks) Describes the set-up of the experiment in outline. AND States a couple of observations. OR States and explains an expected observation.	6	Indicative scientific points may include: Set-up of experiment in detail: • Suitable means of collecting hydrogen produced, can exemplified via a diagram • Collection method has volume measurements • Idea of measuring vol of hydrogen per unit time. • Fair testing, same no of moles of metal, same surface area, same temperature etc. Observations: • Gas bubbles produced • Metal decreases in size/disappears • Faster rate of reaction for Ba • Ca cloudier than Ba (AW) Explanations: • Both metals react to produce hydroxides and hydrogen gas • Equation eg $\text{Ca} + 2\text{H}_2\text{O} \rightarrow \text{Ca}(\text{OH})_2 + \text{H}_2$ • Hydroxides more soluble down the group • Rate of reaction increases down the group as electrons lost more easily down the group • Weaker attraction between outer electron and nucleus as atomic radius increases.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
			<i>The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.</i> 0 marks No response or no response worthy of credit.		
	b	i	FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = $5.47 \times 10^{-6} \text{ mol}^3 \text{ dm}^{-9}$ award 4 marks Mean titre = 13.90 (exclude trial and anomaly)✓ Concentration of OH^- = $13.90 \times 0.04/25 = 0.02224 \text{ mol dm}^{-3}$✓ Concentration of Ca^{2+} is therefore $0.02224/2 = 0.01112 \text{ mol dm}^{-3}$✓ $K_{\text{sp}} = 0.0111 \times 0.0222^2 = 5.47 \times 10^{-6}$ AND units $\text{mol}^3 \text{ dm}^{-9}$✓	4	ALLOW answers that round to 5.5×10^{-5}
		ii	Titre would be (much) lower as magnesium hydroxide is less soluble ✓	1	
			Total	11	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
22	a		Chlorine is toxic AW ✓	1	Incorrect refs to physical state / flammability are CON IGNORE harmful Examiner Comments This was well answered question but occasionally the answers given were vague, such as 'harmful', or included incorrect detail such as 'toxic and flammable'.
	b		$\text{H}_2\text{SO}_4 + \text{KCl} \rightarrow \text{KHSO}_4 + \text{HCl}$ ✓	1	ALLOW $\text{H}_2\text{SO}_4 + 2\text{KCl} \rightarrow \text{K}_2\text{SO}_4 + 2\text{HCl}$ / ALLOW elements in any order in KHSO_4 IGNORE state symbols Examiner Comments This question was well done.
	c		I, -1 and 0 ✓ S, +6 and -2 ✓ $8\text{HI} + \text{H}_2\text{SO}_4 \rightarrow 4\text{I}_2 + \text{H}_2\text{S} + 4\text{H}_2\text{O}$ ✓	3	NOT signs after the numbers. ALLOW ecf on signs after numbers for second point. ALLOW '8H⁺ + 8I⁻' for '8HI' IGNORE state symbols Examiner Comments The oxidation states were rarely incorrect, but constructing the equation was more difficult for some candidates.
			Total	5	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance																
23	a		They are in group 2/ same group / same no of outer electrons / lose 2 electrons when they react ✓	1	Examiner Comments This question was very well done.																
	b		Magnesium (ions) are smaller / have a smaller radius / have higher charge density ORA ✓ Distort (the charge on) the carbonate (ion)/ polarise the carbonate (ion) more ORA ✓	2	NOT magnesium carbonate / magnesium atoms have a higher charge density. Comparison is essential in both parts. Examiner Comments A significant number of candidates knew the answer to this question. If marks were lost it was due to using incorrect particles such as atoms or molecules, or relating the observations to the different reactivities of calcium and magnesium.																
	c		<table><tr><th>Reagent</th><th>Ba²⁺</th><th>Pb²⁺</th><th>Fe²⁺</th></tr><tr><td>(Dilute) Sulfuric acid OR any named soluble sulfate</td><td>White ppt</td><td>White ppt</td><td>Green solution / no reaction</td></tr><tr><td>Sodium/ potassium hydroxide / ammonia</td><td>Colourless solution / no reaction</td><td>White ppt</td><td>Green solution / no reaction</td></tr><tr><td>Any named soluble iodide</td><td>Colourless solution / no reaction</td><td>Yellow ppt</td><td>Green solution / no reaction</td></tr></table>	Reagent	Ba ²⁺	Pb ²⁺	Fe ²⁺	(Dilute) Sulfuric acid OR any named soluble sulfate	White ppt	White ppt	Green solution / no reaction	Sodium/ potassium hydroxide / ammonia	Colourless solution / no reaction	White ppt	Green solution / no reaction	Any named soluble iodide	Colourless solution / no reaction	Yellow ppt	Green solution / no reaction	3	ALLOW 1 mark for each correct row. OR 1 mark for a column of correct observations, as long as 3 reagents used. Cross incorrect boxes and tick remaining columns OR rows to give the higher score. ALLOW anion name instead of full reagent. ALLOW a dash in a box as 'no reaction', but not an empty box. ALLOW white ppt for Ba ²⁺ and NaOH ALLOW formulae for names of reagents as long as correct. Examiner Comments This proved to be a very difficult question. The most common areas of difficulty were with lead, either thinking its salts and hydroxide were soluble or thinking all its precipitates were yellow like its iodide. Not using the word 'precipitate' or not giving its colour were also causes of lost marks.
Reagent	Ba ²⁺	Pb ²⁺	Fe ²⁺																		
(Dilute) Sulfuric acid OR any named soluble sulfate	White ppt	White ppt	Green solution / no reaction																		
Sodium/ potassium hydroxide / ammonia	Colourless solution / no reaction	White ppt	Green solution / no reaction																		
Any named soluble iodide	Colourless solution / no reaction	Yellow ppt	Green solution / no reaction																		
			Total	6																	

Mark Scheme

Question		Answer/Indicative content	Marks	Guidance								
24	a	<i>Please refer to the marking instructions on page 5 of this mark scheme for guidance on how to mark this question.</i> Level 3 (5–6 marks) Gives a clear account with at least 1 fine detail point in all 3 sections. <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3–4 marks) Gives a point from each of the 3 sections. OR Gives an account of 2 areas, both including a fine detail point. <i>There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.</i> Level 1 (1–2 marks) Makes at least 2 relevant points. <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 0 marks No response or no response worthy of credit.	6	Indicative scientific points might include: AO3.2 Make judgements – Interpret practical procedure 1 Use of ppt • Weigh ppt Fine detail: • Filter to collect ppt • Rinse ppt with distilled / deionized water • Dry precipitate. This may be in the remedies for inaccuracy 2 Use of mass of ppt to find x • Find moles of MgCO_3 Fine detail: • Appreciation that mass ppt related to moles MgSO_4 • Subtract mass of MgSO_4 from original mass of crystals to find mass of water • calculate no. moles water and find the ratio. 3 AO3.4 Develop and refine At least one point from: <table><tr><th>Inaccuracy</th><th>Remedy (fine detail)</th></tr><tr><td>Not Enough sodium carbonate added to precipitate all the magnesium ions or not all MgSO_4 dissolved</td><td>Add excess sodium carbonate Add more water</td></tr><tr><td>Mass of ppt inaccurate due to water</td><td>dry ppt IGNORE means of drying</td></tr><tr><td>Losses of substances when filtering / pouring etc</td><td>Rinse all containers with distilled water and add to the filter.</td></tr></table>	Inaccuracy	Remedy (fine detail)	Not Enough sodium carbonate added to precipitate all the magnesium ions or not all MgSO_4 dissolved	Add excess sodium carbonate Add more water	Mass of ppt inaccurate due to water	dry ppt IGNORE means of drying	Losses of substances when filtering / pouring etc	Rinse all containers with distilled water and add to the filter.
Inaccuracy	Remedy (fine detail)											
Not Enough sodium carbonate added to precipitate all the magnesium ions or not all MgSO_4 dissolved	Add excess sodium carbonate Add more water											
Mass of ppt inaccurate due to water	dry ppt IGNORE means of drying											
Losses of substances when filtering / pouring etc	Rinse all containers with distilled water and add to the filter.											

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
					Examiner Comments This proved a challenging question as it asked candidates to respond to an unfamiliar method. A significant number of candidates scored level 3, but some thought the addition of sodium carbonate was a titration or they reacted the carbonate and collected the gas given off. Sources of inaccuracy often involved using a better balance.
	b		Top box: $\text{Mg}^{2+}(\text{g})$ AND $\text{SO}_4^{2-}(\text{g})$ ✓ $\Delta_{\text{LE}}H (= -1922 - 1099 + 84) = -2937$ ✓	2	Examiner Comments This question was well done.
	c		Strontium (ions) are larger / have a lower charge density ✓ so forces between water and strontium / ion-dipole forces less strong OR fewer water molecules surround it OR Not enough energy released in making ion-dipole bonds OR $\Delta_{\text{hyd}}H$ is less exothermic / releases less energy ✓	2	1 Charge density / radius. 2 Correct statement on the interactions between strontium ions and water. IGNORE smaller / larger in relation to $\Delta_{\text{hyd}}H$. ORA throughout Examiner Comments Many candidates lost marks by using inappropriate language such as 'atomic' or 'molecular' when describing ionic species. Candidates also focused on ΔH_{hyd} being 'smaller' or 'larger' rather than more or less exothermic or on the strength of ion-dipole forces.
			Total	10	
25			D	1	Examiner's Comments Slightly fewer than half the candidates scored here with incorrect responses covering all the possible answers, but A was seen most frequently.
			Total	1	
26			C	1	
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
27	a	i	(pale) yellow precipitate ✓	1	<u>Examiner's Comments</u> This question was particularly well-answered.
		ii	$\text{Ag}^+(\text{aq}) + \text{I}^-(\text{aq}) \rightarrow \text{AgI}(\text{s})$ ✓	1	All correct, allow IAg. Allow multiples. <u>Examiner's Comments</u> Done well, however a minority used Ag^{2+} and some candidates wrote full equations. For questions which require writing of equations, candidates are encouraged to check that they write the type of equation specified in the question stem.
	b	i	$2\text{I}^- \rightarrow \text{I}_2 + 2\text{e}^-$ ✓ loss of electrons	1	one mark for both correct ALLOW description of oxidation in terms of oxidation state of iodine increasing (from -1 to 0)
		ii	Sulfur ✓ +2, +2½ ✓	2	Sign needed NO ecf for iodine or oxygen
		iii	FIRST CHECK THE ANSWER ON ANSWER LINE If answer = 130 (µg) award 4 marks Mole of thio = $0.0053 \times 0.010 = 5.30 \times 10^{-6}$ and moles of iodine = half above 2.65×10^{-6} ✓ Mass of iodine = above $\times 253.8 = 6.72 \times 10^{-4}$ ✓ Mass of iodine in 120g = above $\div 5 = 1.345 \times 10^{-4}\text{g}$ ✓ 130(µg) (2 sig figs) ✓	4	ALLOW calculation method (and appropriate progress marks) where moles of I_2 in a 120g sample are calculated first, then mass. Look for any ecfs. This value has to be calculated from correct conversion to microgrammes <u>Examiner's Comments</u> The relationship between micrograms and grams caused some problem with a number of candidates being unable to convert between them A number of answers were given to 3 or more significant figures. The need to use the formula mass of molecular iodine, I_2 was commonly missed, with the atomic mass of iodine used instead.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iv	% error = $\frac{0.1}{5.3} \times 100 = 1.886/1.9(\%)$	1	1.89 <u>Examiner's Comments</u> This question proved difficult for many candidates. Common errors included answers being a factor of 10 too big. Some candidates also forgot that, as two burette readings are necessary to take a titre reading (initial and final), the uncertainty for individual readings (0.05 cm ³) must be doubled when calculating the percentage uncertainty.
		v	Dilute/lower concentration of thiosulphate solution OR increase mass of cod used OR increase volume of iodine solution used ✓	1	IGNORE answers which suggest more repeats needed, / "bigger"/"larger" sample <u>Examiner's Comments</u> Many candidates simply wanted to repeat the number of titrations involved without realising that accuracy is about closeness to the 'correct value'. This is improved by a method which gives a greater titre value (reducing the percentage error), hence using less concentrated standard thiosulfate .
			Total	11	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
28	a	i	$\text{Mg(g)} \rightarrow \text{Mg}^+(\text{g}) + \text{e}^-$ ✓	1	ALLOW $\text{Mg(g)} - \text{e}^- \rightarrow \text{Mg}^+(\text{g})$
		ii	Electron in Mg is nearer nucleus (ora) ✓ Stronger attraction (ora) (AW) ✓	2	ALLOW less shielding in Mg (ora) / fewer electron shells in Mg / smaller atomic radius IGNORE 'charge density' IGNORE 'held more strongly' <u>Examiner's Comments</u> Most candidates scored well on d(i); the only common error was the incorrect state symbols being used with (s) for both the Mg atom and the Mg^+ ion. In part d(ii) many candidates scored full marks as they were able to explain that as a result of magnesium being above calcium in the periodic table the magnesium atom was smaller, and therefore the electrons were closer to the nucleus and were attracted more strongly by its positive charge. In d(ii) many candidates did not score full marks. Many correctly identified that the atom was smaller (or the electrons were closer to the nucleus), but did not then link this to the fact that the electrons are more strongly attracted to the nucleus.
	b	i	hydrochloric (acid) / HCl ✓	1	IGNORE 'dil' / 'conc'
		ii	barium (carbonate) ✓	1	ALLOW BaCO_3 but NOT Ba on its own <u>Examiner's Comments</u> In general, these final two elements of question 1 were well answered by most candidates. The only common errors were the use of sulfuric acid in e(i), or the presence of calcium (carbonate) in e(ii). Both of these potentially came as a result of misinterpreting the cause of the white precipitate stated in the results table.
			Total	5	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
29		i	hydrogen carbonate	1	ALLOW 'hydrogencarbonate'/hydrogen carbonate(IV) but no other oxidation states IGNORE bicarbonate
		ii	CO_3^{2-}	1	IGNORE 'carbonate' <u>Examiner's Comments</u> This question produced mixed responses. A variety of (incorrect) oxidation states were quoted for the hydrogen carbonate ion in part (i) which negated the mark. In part (ii) common incorrect responses included H_2O , CO_2 and CO_3^- .
			Total	2	
30			A	1 AO 1.1	<u>Examiner's Comments</u> This was also very well done. The best answers had identified Fe^{2+} in the stem of the question before looking at the suggestions for X. A few were distracted by the apple green flame colour of barium.
			Total	1	
31			B	1 AO 1.1	<u>Examiner's Comments</u> This was another more difficult question. The incorrect answers were equally spread over the other responses, suggesting group 2 trends were not well known by some candidates.
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
32			Any 2 of: Rate of forward reaction = rate of reverse ✓ closed system ✓ Overall concentrations remain constant OR the same BUT NOT concentrations ARE the same✓	2 AO 1.1	Any 2 out of 3 mps <u>Examiner's Comments</u> This was generally well answered, especially as they could give two out of three features of dynamic equilibrium. There was some confusion in wording, such as 'The concentration of reactants and products is the same' or 'The forward and reverse reactions occur at a constant rate'.
			Total	2	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
33	a	i	FIRST CHECK THE ANSWER ON ANSWER LINE If answer = 1260 (cm³) award 4 marks amount SrCO₃ (= 12.0/147.6) = 0.0813 (mol) ✓ $V = nRT/P$ ✓ $V = 0.0813 \times 8.314 \times 290 \times 10^6 / 155000 = 1260 \text{ (cm}^3\text{)} (3 \text{ or more sf})$ ✓ Answer to 3sf ✓	4(AO2.8 x 4)	ALLOW ECF ALLOW answers rounding to 1260 for 3 marks If values inserted into equation that clearly demonstrates use of MP2 this scores MP2 ALLOW sf mark for any calculated volume to 3 sf. <u>Examiner's Comments</u> This was the first multi-step calculation on this paper, requiring candidates to demonstrate their maths skills by manipulating an expression they should have been familiar with, and also to convert units within the identified values. Finally, they had to give their answer to an appropriate number of significant figures, which in this case was three. In order to arrive at an appropriate value candidates had to calculate the number of moles of strontium carbonate used in the reaction. They then had to identify that they needed to use the ideal gas equation and re-arrange this making V the subject of the equation. The mark for this could be given from a clearly laid out calculation where "$V =$" may have been used. Next they had to convert from kPa to Pa for the pressure. Finally, they had to convert from m³ to cm³ giving their final value to 3 significant figures. Exemplar 2 shows a well laid out response of this calculation, illustrating how showing what is being calculated makes the candidate's working easy to follow. This can help candidates gain error carried forwards marks in the event of arriving at an incorrect answer. Many candidates only scored three marks on this calculation rather than the full 4 marks. Errors included not converting the final value to three significant figures. Others made a single error in scaling from kPa to Pa, e.g. dividing by 1000 rather than

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
					multiplying by 1000, or from m^3 to cm^3, e.g. by multiplying by 10^3 rather than 10^6, however provided that their working was clearly laid out these errors were only penalised once. It was pleasing to note that there were very few scripts where candidates had not attempted the calculation, and also that very few scripts contained an incorrect answer that was unsupported by evidence of the working carried out. Exemplar 1 $\frac{12}{147.6} = 0.0813 \text{ moles} \quad 1:1$ $PV = nRT$ $V = \frac{nRT}{P} \quad V = \frac{0.0813 \times 8.314 \times 290}{155000}$ $V = 1.26465 \times 10^{-3} \text{ m}^3 \quad 1264.65 \text{ cm}^3$ 1.26 dm^3 volume of $\text{CO}_2 = 1260 \text{ cm}^3$ [4]

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	strontium ions are larger (and attraction less) ✓ strontium (ions) have lower charge density ✓ they distort/polarise the carbonate (ions) less ✓ thermal stability of strontium (carbonate) is higher ✓	4(AO3.2 x 4)	ALLOW ora throughout DO NOT ALLOW atomic radius ALLOW thermal stability increases down the group. <u>Examiner's Comments</u> This question was designed to assess whether or not candidates could explain a trend in a property of the elements in Group 2, thermal stability. The first mark was an easy mark in that all that was required was for students to identify that the first part of the statement was correct, but that from then on they had to explain why the rest of the statement was incorrect. Many had clearly learnt the trend for this property for the Group and correctly stated that as you descend Group 2 the thermal stability of the compounds increases. After this, some candidates struggled to explain why this trend exists. They often stated that strontium ions have a higher charge density compared to calcium, which resulted in them having a stronger attraction to the carbonate ions, thus requiring a greater amount of energy to overcome the electrostatic attraction between the ions. The correct explanation is that the strontium ions have a lower charge density as the ion is larger than calcium and so the nuclear charge is distributed over a larger volume. Therefore the lower charge density has less of a distortion effect on the carbonate ion and so the ionic bond formed is more stable.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	b	i	s(-block) ✓	1(AO1.1)	<u>Examiner's Comments</u> There were a couple of regularly seen errors in responses to this question, the most common of which was 5 on its own, or Period 5. This may be the correct row of the Periodic Table for these elements, but it is not the correct block.
		ii	Any two from: Sr^{2+} and Rb^+/ Sr loses 2 electrons and Rb loses 1 electron ✓ more (delocalised) electrons in Sr ✓ Sr^{2+} attracts (more) electrons (in metallic structure) more strongly ✓	2(AO1.1 x 2)	DO NOT ALLOW more outer shell electrons DO NOT ALLOW references to Sr nuclei <u>Examiner's Comments</u> This question proved to be quite tricky for a number of candidates who tried to link the difference in melting point to reactivity and the ease with which the atoms would lose electrons to form compounds. A significant number of candidates tried to discuss the difference in melting point in terms of the differences in shielding resulting in strontium's nucleus having a stronger attraction for the valence electrons and so a higher melting point. Unfortunately, these arguments were all incorrect as they had to realise that melting point is a physical property that is linked to the metallic structure of the elements. For this to happen, the elements' outer shells overlap, creating a delocalised area of electron density. Strontium can donate more electrons to the delocalised field than rubidium. This also means that the strontium ion, Sr^{2+}, will have a stronger attraction to the delocalised electrons and so will have a higher melting point than rubidium.
			Total	11	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
34	a	i	$\text{Cl}_2 + 2\text{I}^- \rightarrow 2\text{Cl}^- + \text{I}_2$	1(AO1.2)	IGNORE state symbols <u>Examiner's Comments</u> For Question d(i), we did not allow the equation to be described as an equilibrium. The reason for this is that, under standard conditions, there is no possibility of iodine molecules reacting with chloride ions to reverse the accepted equation for this reaction.
		ii	iodide(ion)	1(AO1.2)	IGNORE formulae <u>Examiner's Comments</u> In this part, having written their equation, most candidates correctly identified the reducing agent as the iodide ion. We did not allow the formula to be used as the question specifically states 'Name..' in bold within the question.
		iii	brown/orange/yellow (solution)	1(AO1.2)	ALLOW these colours or any combination but no others. IGNORE reference to starting colour. PPT or (s) is CON <u>Examiner's Comments</u> In this part, purple or violet were not accepted as final colours for the iodine solution, as this is only seen in an organic solvent. Any given starting colours were ignored, but the identification of a precipitate was not allowed as the halogen would have been present dissolved in the aqueous solution. 'Brown liquid' was acceptable for 1 mark, 'it turns yellowy brown' was also acceptable for 1 mark, but 'a brown precipitate' was not allowed and scored 0 marks.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iv	Chlorine has a greater attraction for (AW) electrons (than iodine) (ora)	1(AO2.5)	Reference to molecules is CON IGNORE references to electronegativity / attraction to valence electrons <u>Examiner's Comments</u> Many students started their answer by trying to use ideas about the electron configuration of the elements. They then tried to use this to explain the trend in reactivity in terms of the nuclear attraction between the protons in the nucleus and the valence shell electrons. They were on the right track but what was needed was an appreciation that the halogens react by gaining an electron in order to complete their valence shell. This is more easily achieved by chlorine as the nucleus has a stronger attraction to electrons in other atoms (elements) and so can gain an electron more readily compared to iodine. 'Chlorine has a larger charge density compared to iodine and so can attract an additional electron more readily', was a correct answer that was seen from a number of candidates.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	b		Test tube or flask containing Sodium Chloride and concentrated sulphuric acid ✓ Delivery tube for downward delivery into a test tube or boiling tube ✓	2(AO3.3 x 2)	ALLOW formulae Collection over water, or into a sealed vessel CONs MP2 <u>Examiner's Comments</u> Describing this gas preparation was found challenging by the majority of candidates. Very few recognised that hydrogen chloride is a) denser than air, and b) highly soluble in water. Most opted to collect their gas by displacement over water which would not work. A correct method for collecting the gas by upward displacement of air from an open vessel, e.g. boiling tube, would have scored the second marking point. The methods chosen to prepare the gas were at times inventive, e.g. use of an acyl chloride with water(plausible), the use of sodium chloride solution with phosphoric acid (dangerous), and adding H₂ to Cl₂ in the presence of sunlight. The first two might seem viable responses but the hydrogen chloride produced in both would have dissolved in the aqueous solution present. The correct standard method for producing hydrogen chloride is in dry conditions using concentrated sulfuric acid with solid sodium chloride. The gas produced is then delivered via downward delivery into an open vessel to prevent the build-up of pressure that may result in a small explosion. Some students did identify the need for sulfuric acid and sodium chloride to be reacted together, but opted to use either, or both, of these reagents as aqueous solutions which negated the mark.
			Total	6	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
35			More reactive is correct but not reason / reactivities have nothing to do with it ✓ (Student B is correct): barium has lower charge density(ora) / Ba^{2+} is larger than Ca^{2+} ✓ attracts water molecules less (ora) ✓ less energy released (AW) (ora) ✓	4 (AO3.1) (AO3.2) (AO3.2) (AO2.1)	Look for “it isn’t the reason / not reason”
			Total	4	
36			C	1 (AO1.2)	
			Total	1	
37			D	1 (AO2.5)	
			Total	1	
38		i	White precipitate ✓	1 (AO1.2)	
		ii	$\text{Ag}^+(\text{aq}) + \text{Cl}^-(\text{aq}) \rightarrow \text{AgCl}(\text{s})$ ✓	1 (AO1.2)	
			Total	2	