EXAM PAPERS PRACTICE

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Group 2 - Alkaline Metals
A level only 1

CHEMISTRY

Question Paper

AQA

AS & A LEVEL

Inorganic Chemistry

1 The following pairs of compounds can be distinguished by simple test-tube reactions.

For each pair of compounds, give a reagent (or combination of reagents) that, when added separately to each compound, could be used to distinguish between them.
State what is observed in each case.

(a) Butan-2-ol and 2-methylpropan-2-ol

Reagent .....

Observation with butan-2-ol

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Observation with 2-methylpropan-2-ol

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(3)

(b) Propane and propene

Reagent .....

Observation with propane

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Observation with propene

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(3)

(c) Aqueous silver nitrate and aqueous sodium nitrate

Reagent .....

Observation with aqueous silver nitrate

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Observation with aqueous sodium nitrate

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(3)

(d) Aqueous magnesium chloride and aqueous barium chloride

Reagent .....

Observation with aqueous magnesium chloride

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Observation with aqueous barium chloride

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(3)
(Total 12 marks)

2 The elements in Group 2 from Mg to Ba can be used to show the trends in properties down a group in the Periodic Table.

(a) State the trend in atomic radius for atoms of the elements down Group 2 from Mg to Ba
Give a reason for this trend.

Trend .....

Reason .....

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(2)

(b) The Group 2 elements react with water.

(i) State the trend in reactivity with water of the elements down Group 2 from Mg to Ba

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(1)

(ii) Write an equation for the reaction of strontium with water.

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(1)

(c) Give the **formula** of the hydroxide of the element in Group 2 from Mg to Ba that is most soluble in water.

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(1)
(Total 5 marks)

3 Zinc is similar to Group 2 metals and forms compounds containing Zn^{2+} ions.

Write an equation for the thermal decomposition of zinc carbonate to zinc oxide.

Calculate the percentage atom economy for the formation of zinc oxide from zinc carbonate in this reaction.

Equation .....

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Percentage atom economy .....

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(Total 3 marks)

4 A laboratory technician discovered four badly–labelled bottles, each containing one pure white solid. Each bottle contained a compound of a different Group 2 metal (magnesium, calcium, strontium and barium).

Some tests were carried out on the solids or, if the compound was soluble, on the aqueous solution. The results are given in the table.

Test	**Compound 1**	**Compound 2**	**Compound 3**	**Compound 4**
Added to water	Dissolves	Insoluble	Dissolves	Dissolves
Solution or solid added to HCl(aq)	Solution remains colourless	Gives off carbon dioxide gas and a colourless solution forms	Solution remains colourless	Solution remains colourless and heat released
Solution or solid added to NaOH(aq)	Solution gives a white precipitate	Solid remains insoluble	Solution gives a slight white precipitate	Solution has no visible change
Solution or solid added to H_2SO_4(aq)	Solution has no visible change	Gives off carbon dioxide gas and a white solid remains	Solution slowly forms a slight white precipitate	Solution forms a white precipitate

(a) One of the bottles has a very faint label that could be read as 'Magnesium Sulfate'.

Use the information in the table to deduce which **one** of the four compounds is magnesium sulfate and explain your answer.

Compound .....

Explanation .....

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(3)

(b) The bottle containing **Compound 2** has a 'TOXIC' hazard symbol.

Use the information in the table to identify **Compound 2**.

Explain both observations in the reaction with $H_2SO_4(aq)$.

Identity of **Compound 2** .....

Explanation .....

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(3)

(c) Identify the compound that is strontium hydroxide.

Give an equation for the reaction of strontium hydroxide with sulfuric acid.

Compound .....

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Equation .....

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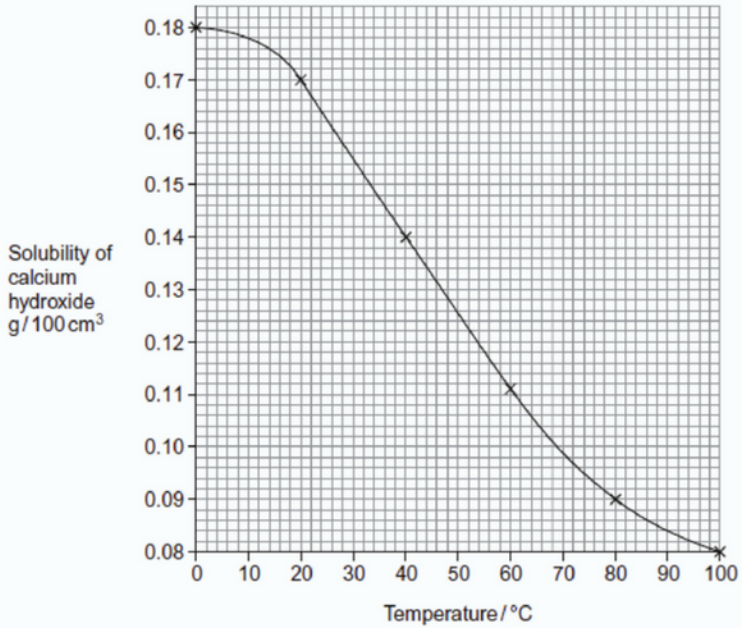
(2)
(Total 8 marks)

5 Calcium hydroxide is slightly soluble in water at room temperature. As the temperature rises, the solubility decreases. When the maximum amount of solid has dissolved at a particular temperature the solution is said to be **saturated**.

In an experiment, the solubility of calcium hydroxide was measured over a range of temperatures. The results are shown in the graph.



(a) Use data from the graph to calculate the concentration, in mol dm^{-3}, of a saturated solution of calcium hydroxide at 30 °C. Give your answer to 3 significant figures.

Show your working.

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(3)

(b) You are given a sample of saturated calcium hydroxide solution. Outline the practical steps that you would take to determine the solubility of calcium hydroxide in this solution.

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(3)
(Total 6 marks)

6 This question is about the elements in Group 2 and their compounds.

(a) Use the Periodic Table to deduce the full electron configuration of calcium.

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(1)

(b) Write an ionic equation, with state symbols, to show the reaction of calcium with an excess of water.

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(1)

(c) State the role of water in the reaction with calcium.

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(1)

(d) Write an equation to show the process that occurs when the first ionisation energy of calcium is measured.

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(1)

(e) State and explain the trend in the first ionisation energies of the elements in Group 2 from magnesium to barium.

Trend .....

Explanation .....

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(3)

(Total 7 marks)

7 State the trends in solubility of the hydroxides and of the sulphates of the Group II elements Mg–Ba.

Describe a chemical test you could perform to distinguish between separate aqueous solutions of sodium sulphate and sodium nitrate. State the observation you would make with each solution. Write an equation for any reaction which occurs.

(Total 6 marks)

8 Compound **A** is an oxide of sulphur. At 415 K, a gaseous sample of **A**, of mass 0.304 g, occupied a volume of 127 cm^3 at a pressure of 103 kPa.

State the ideal gas equation and use it to calculate the number of moles of **A** in the sample, and hence calculate the relative molecular mass of **A**.
(The gas constant $R = 8.31$ J K^{-1} mol^{-1})

Ideal gas equation .....

Calculation .....

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(Total 5 marks)

9 Which one of the following statements is correct?

A The first ionisation energies of the elements in Period 3 show a general decrease from sodium to chlorine.

B The electronegativities of Group 2 elements decrease from magnesium to barium.

C The strength of the intermolecular forces increases from hydrogen fluoride to hydrogen chloride.

D The ability of a halide ion to act as a reducing agent decreases from fluoride to iodide.

(Total 1 mark)

10 An aqueous solution of a sodium salt gave no precipitate when treated with either silver nitrate solution or barium chloride solution. Which one of the following could be the formula of the sodium salt?

A NaI

B Na_2SO_4

C NaBr

D NaF

(Total 1 mark)

11 Which one of the following solutions would **not** give a white precipitate when added to barium chloride solution?

A silver nitrate solution

B dilute sulphuric acid

C sodium sulphate solution

D sodium nitrate solution

(Total 1 mark)

12 This question concerns the chemistry of the Group II metals Mg to Ba.
An aqueous solution of a Group II metal chloride, $\mathbf{X}Cl_2$, forms a white precipitate when dilute aqueous sodium hydroxide is added. A separate sample of the solution of $\mathbf{X}Cl_2$ does **not** form a precipitate when dilute aqueous sodium sulphate is added.

An aqueous solution of a different Group II metal chloride, $\mathbf{Y}Cl_2$, does **not** form a precipitate when dilute aqueous sodium hydroxide is added. A separate sample of the solution of $\mathbf{Y}Cl_2$ forms a white precipitate when dilute aqueous sodium sulphate is added.

Suggest identities for the Group II metals **X** and **Y**. Write equations, including state symbols, for the reactions which occur.

(Total 6 marks)

13 The following two-stage method was used to analyse a mixture containing the solids magnesium, magnesium oxide and sodium chloride.

Stage 1
A weighed sample of the mixture was treated with an excess of dilute hydrochloric acid. The sodium chloride dissolved in the acid. The magnesium oxide reacted to form a solution of magnesium chloride. The magnesium also reacted to form hydrogen gas and a solution of magnesium chloride. The hydrogen produced was collected.

(a) Write equations for the two reactions involving hydrochloric acid.

(b) State how you would collect the hydrogen. State the measurements that you would make in order to calculate the number of moles of hydrogen produced. Explain how your results could be used to determine the number of moles of magnesium metal in the sample.

(8)

Stage 2
Sodium hydroxide solution was added to the solution formed in **Stage 1** until no further precipitation of magnesium hydroxide occurred. This precipitate was filtered off, collected, dried and heated strongly until it had decomposed completely into magnesium oxide. The oxide was weighed.

(c) Write equations for the formation of magnesium hydroxide and for its decomposition into magnesium oxide.

(d) When a 2.65 g sample of the mixture of the three solids was analysed as described above, the following results were obtained.

Hydrogen obtained in **Stage 1**	0.0528 mol
Mass of magnesium oxide obtained in **Stage 2**	6.41 g

Use these results to calculate the number of moles of original magnesium oxide in 100 g of the mixture.

(7)
(Total 15 marks)

14 (i) For the elements Mg–Ba, state how the solubilities of the hydroxides and the solubilities of the sulphates change down Group II.

(ii) Describe a test to show the presence of sulphate ions in an aqueous solution.
Give the results of this test when performed on separate aqueous solutions of magnesium chloride and magnesium sulphate. Write equations for any reactions occurring.

(iii) State the trend in the reactivity of the Group II elements Mg–Ba with water.

Write an equation for the reaction of barium with water.

(Total 11 marks)

15 Which one of the following is the electron arrangement of the strongest reducing agent?

A $1s^2\ 2s^2\ 2p^5$

B $1s^2\ 2s^2\ 2p^6\ 3s^2$

C $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^5$

D $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2$

(Total 1 mark)

16 Which one of the following is a correct procedure for isolating a sample of hydrated copper(II) sulphate from a mixture of hydrated copper(II) sulphate and barium sulphate?

A filter, crystallise filtrate, dry the crystals

B filter, dry the solid on the filter paper

C add water, filter, dry the solid left on the filter paper

D add water, filter, crystallise filtrate, dry the crystals

(Total 1 mark)

17 Desalination is a technique for making drinking water by the removal of salts from sea water. It is used in parts of the world where fresh water is in short supply. A problem with this technique is the increase in the concentration of salts, particularly of sodium chloride, in the effluent (the solution returned to the sea).

Desalination uses a process called reverse osmosis. In this process, sea water under high pressure is passed over a special membrane which allows only pure water to pass through it.

The owners of a desalination plant have asked for the effluent to be analysed at different operating pressures. This is needed to find an **approximate** value for the maximum operating pressure that gives an effluent that has a minimum harmful effect on the environment.

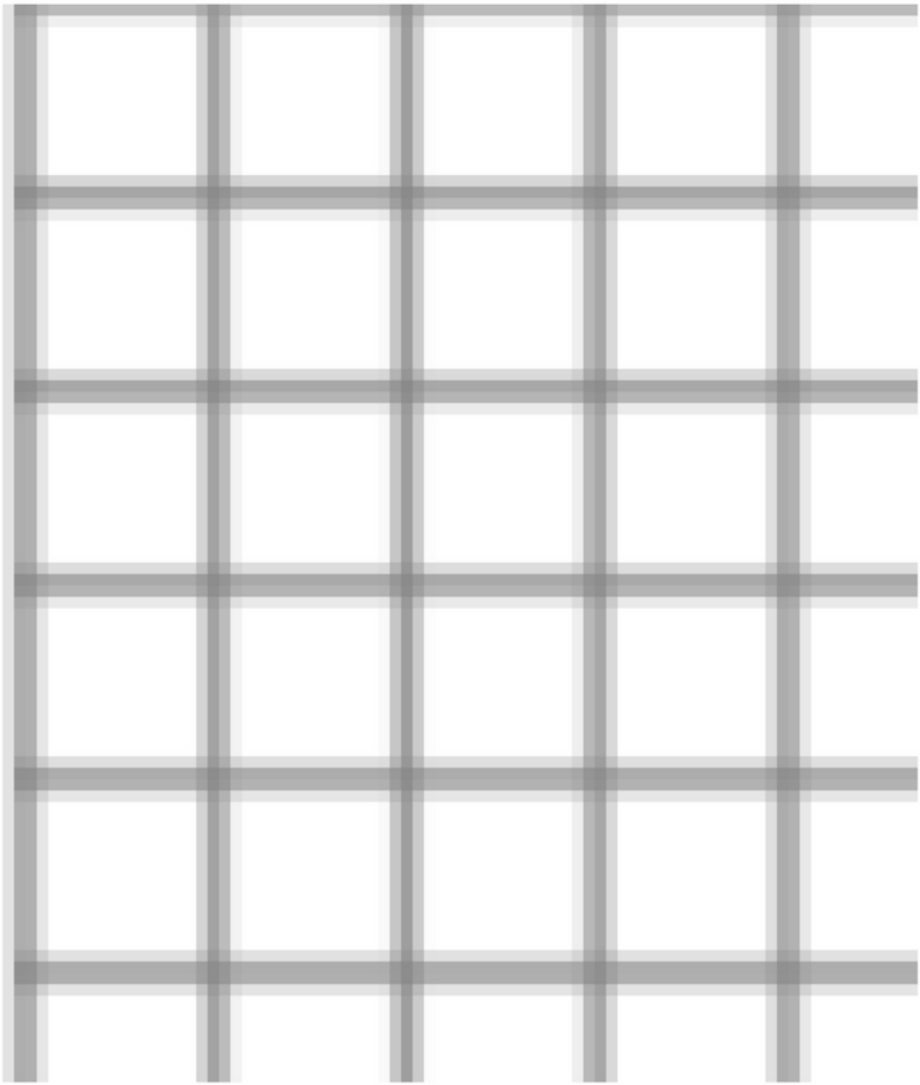
A chemist sampled the effluent at different pressures. For each pressure, a 250 cm^3 sample of effluent was taken in a measuring cylinder and poured into a weighed beaker. The water was evaporated by heating and the beaker reweighed. The following results were obtained.

Experiment	**1**	**2**	**3**	**4**	**5**	**6**
Pressure / MPa	0.1	0.5	1.0	2.5	4.0	8.0
Beaker mass before heating / g	55.3	55.5	55.0	55.1	55.3	56.3
Beaker mass after heating / g	62.5	64.9	65.3	66.6	67.5	69.4
Mass of solid in beaker / g						

(a) Complete the table above to determine the mass of solid that remains in the beaker at each pressure.

Plot a graph of mass of solid (y-axis) against pressure on the graph paper.

Draw a smooth curve through the points.



(4)

(b) To minimise harmful effects on the environment, the concentration of sodium chloride in the effluent should not exceed 44.0 g dm^{-3}. Use your graph to find a value for the pressure, in MPa, that the chemist should advise to be the maximum operating pressure.

Assume that all the solid left in the beaker is sodium chloride.

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(1)

(c) In Experiment **1** the 250 cm^3 sample of the effluent contained the same amount of sodium chloride as the original sea water. Calculate the concentration, in mol dm^{-3}, of sodium chloride in sea water.

Assume that all the solid left in the beaker is sodium chloride.
Show your working.

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(2)

(d) For the measuring cylinder and the balance, the maximum total errors are shown below. These errors take into account multiple measurements.

250 cm^3 measuring cylinder	±1.0 cm^3
balance	±0.1 g

Estimate the maximum percentage error in using these pieces of apparatus, and hence estimate their combined error.

You should use the mass of the solid in the beaker in Experiment **1** to estimate the percentage error in using the balance.
Show your working.

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(2)

(e) Consider your graph.

(i) Is the curve good enough to use with confidence to predict the intermediate values? Explain your answer.

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(1)

(ii) Identify the anomalous results, if any.

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(1)

(f) Give **one** reason why the owners of the plant were satisfied with the maximum operating pressure determined in part (b) despite the combined errors you have calculated in part (d).

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(1)

(g) (i) Suggest **one** harmful effect that effluent with a high concentration of sodium chloride might have if it is returned to the sea.

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(1)

(ii) Suggest **one** low cost method of treating the effluent so that this harmful effect could be reduced.

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(1)

(h) Bromine can be obtained by reacting the bromide ions in the concentrated sea water using chlorine gas in a displacement reaction. Write an equation for this reaction.

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(1)

(i) The solid obtained by the chemist after heating the effluent to dryness was treated with concentrated sulfuric acid. A vigorous reaction resulted, including the formation of a purple vapour of iodine. Give **one** reason why this procedure could **not** be adapted to be an economic method for producing iodine from sea water on an industrial scale.

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(1)

(j) Sea water contains some organic material. After removing all the water, by heating the effluent samples strongly, it was noticed that the solid formed contained black particles. These particles are insoluble in water.

On heating very strongly in air these particles burned to give a colourless gas.

(i) Identify these black particles.

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(1)

(ii) Suggest how these black particles are formed by heating the effluent strongly.

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(1)

(iii) Suggest how a sample of the black particles could be separated from the solid formed.

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(2)

(k) The water produced by some desalination plants is acidic due to the presence of hydrochloric acid. Lime, $Ca(OH)_2$, is added to neutralise this acid. Write an equation for this reaction.

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(1)

(l) Lime is used because it is relatively inexpensive and available in large quantities. Identify **one** other large-scale use of lime.

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(1)

(Total 22 marks)

18 The elements in Group 2 can be used to show the trends in properties down a group in the Periodic Table.

(a) State the trend in atomic radius down Group 2 from Mg to Ba and give a reason for this trend.

Trend .....

Reason .....

(2)

(b) State and explain the trend in melting points of the elements down Group 2 from Mg to Ba.

Trend .....

Explanation .....

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(3)

(c) State the trend in reactivity with water of the elements down Group 2 from Mg to Ba. Write an equation for the reaction of magnesium with steam and an equation for the reaction of strontium with water.

Trend .....

Equation for magnesium .....

Equation for strontium .....

(3)

(d) Sulfates of the Group 2 elements from Mg to Ba have different solubilities. Give the formula of the least soluble of these sulfates and state **one** use that depends upon the insolubility of this sulfate.

Formula .....

Use .....

(2)
(Total 10 marks)

19 Both strontium carbonate and strontium sulfate are white solids which are insoluble in water. Strontium carbonate reacts with hydrochloric acid to produce a solution of strontium chloride. Strontium sulfate does not react with hydrochloric acid.

Describe how you would obtain strontium sulfate from a mixture of strontium carbonate and strontium sulfate.

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(Total 2 marks)

20 A chemical company's records refer to the following acids

hydrochloric acid
hydrobromic acid
hydriodic acid
nitric acid
sulfuric acid

A waste tank was thought to contain a mixture of two of these acids. A chemist performed test-tube reactions on separate samples from the waste tank. The results of these tests are shown below.

Test	Reagent	Observations
A	Barium chloride solution	White precipitate
B	Silver nitrate solution	White precipitate

(a) Use the result from Test **A** to identify an acid in the company's records which must be **present** in the waste tank.

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(1)

(b) Use the results from Test **A** and Test **B** to identify an acid in the company's records which must be **absent** from the waste tank.

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(1)

(c) The chemist suspected that the waste tank contained hydrochloric acid. State how the precipitate formed in Test **B** could be tested to confirm the presence of hydrochloric acid in the waste tank. State what you would observe.

Test .....

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Observation .....

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(2)

(d) Suggest one reason why carbonate ions could not be present in the waste tank.

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(1)
(Total 5 marks)

21 Barium can be extracted from barium oxide (BaO) in a process using aluminium. A mixture of powdered barium oxide and powdered aluminium is heated strongly. The equation for this extraction process is shown below.

$$3BaO(s) + 2Al(s) \rightarrow 3Ba(s) + Al_2O_3(s)$$

Some standard enthalpies of formation are given in the table below.

Substance	BaO(s)	$Al_2O_3(s)$
$\Delta H_f^\ominus$ / kJ mol^{-1}	–558	–1669

(a) (i) State what is meant by the term *standard enthalpy of formation*.

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(3)

(ii) State why the standard enthalpy of formation of barium and that of aluminium are both zero.

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(1)

(iii) Use the data to calculate the standard enthalpy change for the reaction shown by the equation above.

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(3)

(b) (i) Suggest the major reason why this method of extracting barium is expensive.

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(1)

(ii) Using barium oxide and aluminium powders increases the surface area of the reactants. Suggest **one** reason why this increases the rate of reaction.

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(1)

(c) (i) Write an equation for the reaction of barium with water.

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(1)

(ii) A solution containing barium ions can be used to test for the presence of sulfate ions in an aqueous solution of sodium sulfate.

Write the **simplest ionic** equation for the reaction which occurs and state what is observed.

Simplest ionic equation

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Observation .....

(2)

(iii) State how barium sulfate can be used in medicine. Explain why this use is possible, given that solutions containing barium ions are poisonous.

Use .....

Explanation .....

.....

(2)
(Total 14 marks)

22 Pure hydrogen peroxide is a colourless liquid with a boiling point of 150 °C. Hydrogen peroxide was originally produced commercially in a two-stage process. In the first stage barium was heated in air to form barium peroxide. In the second stage barium peroxide was added to aqueous nitric acid. The equations for the reactions are shown below.

Stage **1** $Ba(s) + O_2(g) \longrightarrow BaO_2(s)$

Stage **2** $BaO_2(s) + 2HNO_3(aq) \longrightarrow H_2O_2(aq) + Ba(NO_3)_2(aq)12$

(a) Suggest **one** method of separating hydrogen peroxide from the reaction mixture in Stage **2**.

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(1)

(b) Apart from cost, suggest **one** reason why nitric acid was eventually replaced by sulfuric acid in Stage **2**.

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(1)

(c) Suggest **one** reason why infrared spectroscopy could **not** be used to indicate the presence of a small amount of water in hydrogen peroxide.

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(1)
(Total 3 marks)

23 Group 2 metals and their compounds are used commercially in a variety of processes and applications.

(a) State a use of magnesium hydroxide in medicine.

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(1)

(b) Calcium carbonate is an insoluble solid that can be used in a reaction to lower the acidity of the water in a lake.

Explain why the rate of this reaction decreases when the temperature of the water in the lake falls.

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(3)

(c) Strontium metal is used in the manufacture of alloys.

(i) Explain why strontium has a higher melting point than barium.

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(2)

(ii) Write an equation for the reaction of strontium with water.

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(1)

(d) Magnesium can be used in the extraction of titanium.

(i) Write an equation for the reaction of magnesium with titanium(IV) chloride.

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(1)

(ii) The excess of magnesium used in this extraction can be removed by reacting it with dilute sulfuric acid to form magnesium sulfate.

Use your knowledge of Group 2 sulfates to explain why the magnesium sulfate formed is easy to separate from the titanium.

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(1)
(Total 9 marks)

24 The table below shows observations of changes from some test-tube reactions of aqueous solutions of compounds **Q**, **R** and **S** with five different aqueous reagents. The initial colours of the solutions are not given.

	$BaCl_2$ + HCl	**$AgNO_3$ + HNO_3**	**NaOH**	**Na_2CO_3**	**HCl (conc)**
Q	no change observed	pale cream precipitate	white precipitate	white precipitate	no change observed
R	no change observd	white precipitate	white precipitate, dissolves in excess of NaOH	white precipitate, bubbles of a gas	no change observed
S	white precipitate	no change observed	brown precipitate	brown precipitate, bubbles of a gas	yellow solution

(a) Identify each of compounds **Q**, **R** and **S**.
You are **not** required to explain your answers.

Identity of **Q** .....

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Identity of **R** .....

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Identity of **S** .....

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(6)

(b) Write ionic equations for each of the positive observations with **S**.

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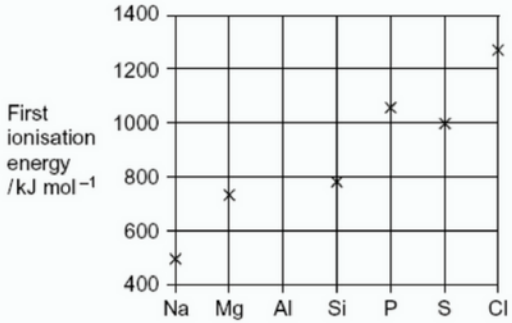
(4)
(Total 10 marks)

25 The following diagram shows the first ionisation energies of some Period 3 elements.



(a) Draw a cross on the diagram to show the first ionisation energy of aluminium.

(1)

(b) Write an equation to show the process that occurs when the first ionisation energy of aluminium is measured.

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(2)

(c) State which of the first, second or third ionisations of aluminium would produce an ion with the electron configuration $1s^2\ 2s^2\ 2p^6\ 3s^1$

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(1)

(d) Explain why the value of the first ionisation energy of sulfur is less than the value of the first ionisation energy of phosphorus.

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(2)

(e) Identify the element in Period 2 that has the highest first ionisation energy and give its electron configuration.

Element .....

Electron configuration .....

(2)

(f) State the trend in first ionisation energies in Group 2 from beryllium to barium.
Explain your answer in terms of a suitable model of atomic structure.

Trend .....

Explanation .....

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(3)
(Total 11 marks)

26 The method of extraction of zinc has changed as different ores containing the element have been discovered and as technology has improved.

Extraction process 1
In the earliest process, calamine (impure zinc carbonate) was heated with charcoal in earthenware pots. This two-stage process gave a low yield of zinc.

$$ZnCO_3(s) \rightarrow ZnO(s) + CO_2(g)$$

$$ZnO(s) + C(s) \rightarrow Zn(s) + CO(g)$$

Extraction process 2
Deposits of calamine were being used up and a new two-stage process was developed using zinc sulfide ores. All of the waste gases from this process were released into the atmosphere.

$$2ZnS(s) + 3O_2(g) \rightarrow 2ZnO(s) + 2SO_2(g)$$

$$ZnO(s) + C(s) \rightarrow Zn(s) + CO(g)$$

Extraction process 3

The modern process uses the electrolysis of aqueous solutions of very pure zinc sulfate. The first step in this process is the same as the first step in Extraction process **2**. The second step uses sulfuric acid made from the SO_2 collected in the first step. The third step involves the electrolysis of zinc sulfate solution to form pure zinc.

$$2ZnS(s) + 3O_2(g) \rightarrow 2ZnO(s) + 2SO_2(g)$$

$$ZnO(s) + H_2SO_4(aq) \rightarrow ZnSO_4(aq) + H_2O(l)$$

$$ZnSO_4(aq) \xrightarrow{\text{electrolysis}} Zn(s)$$

(a) In the first stage of Extraction process **1** the following equilibrium is established when zinc carbonate is heated in a closed container.

$$ZnCO_3(s) \rightleftharpoons ZnO(s) + CO_2(g)$$

Use Le Chatelier's principle to suggest and explain the effect on the yield of zinc oxide of allowing the carbon dioxide to escape from the container.

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(3)

(b) State and explain **one** environmental reason why Extraction process **3** is an improvement over Extraction process **2**.

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(3)

(c) Give **one** reason why Extraction process **3** is an expensive method of making zinc but one which is justified in terms of the product formed.

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(2)

(d) Deduce the half-equation for the formation of zinc from zinc ions during the electrolysis of zinc sulfate solution and identify the electrode at which this reaction occurs.

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(2)

(e) Identify **one** reaction from the three extraction processes that is **not** a redox reaction and state the type of reaction that it is. In terms of redox, state what happens to the carbon in Extraction process **2**.

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(3)

(f) Zinc and magnesium both react with steam in a similar way. Write an equation for the reaction of zinc with steam and name the products of this reaction.

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(2)

(Total 15 marks)

27 There are many uses for Group 2 metals and their compounds.

(a) State a medical use of barium sulfate.
State why this use of barium sulfate is safe, given that solutions containing barium ions are poisonous.

Use .....

Why this use is safe .....

.....

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(2)

(b) Magnesium hydroxide is used in antacid preparations to neutralise excess stomach acid.

Write an equation for the reaction of magnesium hydroxide with hydrochloric acid.

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(1)

(c) Solutions of barium hydroxide are used in the titration of weak acids.

State why magnesium hydroxide solution could **not** be used for this purpose.

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(1)

(d) Magnesium metal is used to make titanium from titanium(IV) chloride.

Write an equation for this reaction of magnesium with titanium(IV) chloride.

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(1)

(e) Magnesium burns with a bright white light and is used in flares and fireworks.

Use your knowledge of the reactions of Group 2 metals with water to explain why water should **not** be used to put out a fire in which magnesium metal is burning.

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(Extra space) .....

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(2)
(Total 7 marks)

28 (a) Some scientists thought that the waste water from a waste disposal factory contained **two** sodium halides.

They tested a sample of the waste water.

They added three reagents, one after the other, to the same test tube containing the waste water.

The table below shows their results.

Reagent added	Observations
1. Silver nitrate solution (acidified with dilute nitric acid)	A cream precipitate formed
2. Dilute ammonia solution	A yellow precipitate remained
3. Concentrated ammonia solution	The yellow precipitate did not dissolve

(i) Identify the yellow precipitate that did **not** dissolve in concentrated ammonia solution.
Write the **simplest** ionic equation for the formation of this precipitate from silver ions and the correct halide ion.
Identify the other sodium halide that must be present in this mixture of two sodium halides.

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(3)

(ii) Give **one** reason why the silver nitrate solution was acidified before it was used in this test.

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(1)

(iii) The method that the scientists used could **not** detect one type of halide ion. Identify this halide ion.
Give **one** reason for your answer.

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(2)

(b) The scientists thought that the waste water also contained dissolved barium ions. An aqueous solution of sodium sulfate can be used to test for the presence of dissolved barium ions.

Write the **simplest** ionic equation for the reaction between barium ions and sulfate ions to form barium sulfate.

State what is observed in this reaction.

Give a use for barium sulfate in medicine and explain why this use is possible, given that solutions containing barium ions are poisonous.

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(4)

(c) The scientists also analysed the exhaust gases from an incinerator used to destroy waste poly(ethene).
Mass spectrometry showed that there was a trace gas with a precise $M_r = 28.03176$ in the exhaust gases from the incinerator.

The table below contains some precise relative atomic mass data.

Atom	Precise relative atomic mass
^{12}C	12.00000
^{1}H	1.00794
^{16}O	15.99491

Use the data to show that the trace gas is ethene. Show your working.

Suggest why both ethene and carbon monoxide might have been identified as the trace gas if the scientists had used relative atomic masses to a precision of only one decimal place.

Write an equation for the incomplete combustion of ethene to form carbon monoxide and water only.

Ethene is used to make poly(ethene).
Draw the displayed formula for the repeating unit of poly(ethene).
Name this type of polymer.

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(5)
(Total 15 marks)

29 (a) A solution of barium hydroxide is often used for the titration of organic acids. A suitable indicator for the titration is thymol blue. Thymol blue is yellow in acid and blue in alkali. In a titration a solution of an organic acid was added from a burette to a conical flask containing 25.0 cm^3 of a barium hydroxide solution and a few drops of thymol blue.

(i) Describe in full the colour change at the end-point of this titration.

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(1)

(ii) Thymol blue is an acid. State how the average titre would change if a few cm^3, rather than a few drops, of the indicator were used by mistake in this titration.

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(1)

(iii) Barium hydroxide is toxic. Suggest **one** safety precaution you would take to minimise this hazard when wiping up a spillage of barium hydroxide solution.

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(1)

(iv) Suggest **one** reason why a 250 cm^3 conical flask is preferred to a 250cm^3 beaker for a titration.

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(1)

(v) Suggest **one** reason why repeating a titration can improve its reliability

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(1)

(b) Solubility data for barium hydroxide and calcium hydroxide are given in the table below.

Compound	Solubility at 20 °C / g dm^{-3}
barium hydroxide	38.9
calcium hydroxide	1.73

(i) Use the data given in the table to calculate the concentration, in mol dm^{-3}, of a saturated solution of calcium hydroxide (M_r = 74.1) at 20°C.

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(1)

(ii) Suggest **one** reason why calcium hydroxide solution is **not** used in the titration of a 0.200 mol dm^{-3} solution of an acid.

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(1)
(Total 7 marks)

30 In an experiment to determine its solubility in water, solid barium hydroxide was added to 100cm^3 of water until there was an excess of the solid. The mixture was filtered and an excess of sulfuric acid was added to the filtrate. The barium sulfate produced was obtained from the reaction mixture, washed with cold water and dried. The mass of barium sulfate was then recorded.

(a) Explain why the mixture was filtered before the addition of sulfuric acid.

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(1)

(b) State how the barium sulfate produced was obtained from the reaction mixture.

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(1)

(c) Explain why the barium sulfate was washed before it was dried.

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(1)

(d) Write an equation for the reaction between barium hydroxide and sulfuric acid.

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(1)

(e) In an experiment, 4.25 g of barium sulfate were formed when an excess of sulfuric acid was added to 100 cm^3 of a saturated solution of barium hydroxide.

(i) Use data from the Periodic Table to calculate the M_r of barium sulfate. Give your answer to one decimal place.

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(1)

(ii) Calculate the amount, in moles, of $BaSO_4$ in 4.25 g of barium sulfate.

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(1)

(iii) Use your answer from part (ii) to calculate the mass of barium hydroxide (M_r = 171.3) present in 1 dm^3 of saturated solution. Show your working.

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(2)

(f) Barium sulfate is taken by mouth by patients so that an outline of a human digestive system can be viewed using X-rays. Explain why patients do **not** suffer any adverse effects from barium sulfate when it is known that solutions containing barium ions are toxic.

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(1)
(Total 9 marks)

31 Copper(II) sulfate solution, together with copper(II) carbonate ($CuCO_3$) powder, can be used to determine the identity of three solutions **A, B** and **C**. The three solutions are known to be hydrochloric acid, barium chloride, and sodium chloride.

In **Experiment 1** a small amount of copper(II) carbonate powder was added to each of the three solutions.

In **Experiment 2** a dropping pipette was used to add 2 cm^3 of copper(II) sulfate solution to each of the three solutions.

The results of these experiments are shown in the table below.

	Experiment 1 Addition of copper(II) carbonate powder	**Experiment 2** Addition of copper(II) sulfate solution
Solution **A**	no visible change	white precipitate
Solution **B**	no visible change	no visible change
Solution **C**	effervescence (bubbles of gas)	no visible change

(a) Use the observations in the table to deduce which of the solutions, **A, B** or **C** is

hydrochloric acid .....

barium chloride .....

(2)

(b) Explain why a precipitate was formed when copper(II) sulfate solution was added to solution **A**.
Write an equation for the reaction that occurred.

Explanation .....

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Equation .....

(2)

(c) Suggest the identity for the colourless gas produced when copper(II) carbonate powder was added to solution **C**.

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(1)

(d) Identify the two reagents that could be used in a test to confirm that the solutions contained chloride ions, **not** bromide ions. State what would be observed on addition of each reagent.

Reagent 1 .....

Observation 1 .....

.....

Reagent 2 .....

Observation 2 .....

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(4)

(e) Copper(II) sulfate is toxic. Suggest **one** safety precaution you would take to minimise this hazard when wiping up a spillage of copper(II) sulfate solution.

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(1)
(Total 10 marks)

32 (a) Strontium chloride is used in toothpaste for sensitive teeth.
Both strontium carbonate and strontium sulfate are white solids that are insoluble in water.

(i) Write an equation for the reaction between strontium chloride solution and sodium sulfate solution.
Include state symbols in your equation.

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(1)

(ii) Strontium carbonate reacts with nitric acid to produce a solution of strontium nitrate.
Strontium sulfate does not react with nitric acid.

Describe briefly how you could obtain strontium sulfate from a mixture of strontium carbonate and strontium sulfate.
You are **not** required to describe the purification of the strontium sulfate.

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(2)

(b) A solution of magnesium sulfate is sometimes given as first aid to someone who has swallowed barium chloride.

Explain why drinking magnesium sulfate solution is effective in the treatment of barium poisoning.

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(1)

(c) Medicines for the treatment of nervous disorders often contain calcium bromide.
Silver nitrate, acidified with dilute nitric acid, can be used together with another reagent to test for the presence of bromide ions in a solution of a medicine.

Describe briefly how you would carry out this test and state what you would observe.

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(3)
(Total 7 marks)

33 (a) Give the **formula** of a Group 2 metal hydroxide used in agriculture.

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(1)

(b) Identify a sodium halide that does **not** undergo a redox reaction when added as a solid to concentrated sulfuric acid.

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(1)

(c) Chlorine gas reacts with cold dilute sodium hydroxide solution to form sodium chloride and another chlorine-containing compound, **X**.

Give the **formula** of **X**.

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(1)

(d) Give the **formula** of the substance responsible for the orange colour when chlorine gas is bubbled through an aqueous solution of sodium bromide.

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(1)

(e) Solid sodium iodide undergoes a redox reaction with concentrated sulfuric acid.

Give the **formula** for each of the following in this reaction.

Formula of the solid reduction product .....

Formula of the oxidation product .....

(2)

(f) Draw the structure of each of the following organic compounds.

(i) The hydrocarbon that is a chain isomer of methylpropene, but does **not** exhibit E–Z stereoisomerism.

(1)

(ii) The alcohol that is a position isomer of butan-2-ol.

(1)

(iii) The hydrocarbon that has a peak, due to its molecular ion, at $m/z = 44$ in its mass spectrum.

(1)

(iv) The bromoalkane that reacts with sodium cyanide to produce propanenitrile.

(1)
(Total 10 marks)

34 (a) Anhydrous strontium chloride is not used in toothpaste because it absorbs water from the atmosphere. The hexahydrate, $SrCl_2.6H_2O$, is preferred.

A chemist was asked to determine the purity of a sample of strontium chloride hexahydrate. The chemist weighed out 2.25 g of the sample and added it to 100 cm^3 of water. The mixture was warmed and stirred for several minutes to dissolve all of the strontium chloride in the sample. The mixture was then filtered into a conical flask. An excess of silver nitrate solution was added to the flask and the contents swirled for 1 minute to make sure that the precipitation was complete.

The silver chloride precipitate was separated from the mixture by filtration. The precipitate was washed several times with deionised water and dried carefully. The chemist weighed the dry precipitate and recorded a mass of 1.55 g.

(i) Calculate the amount, in moles, of AgCl in 1.55 g of silver chloride (M_r = 143.4).

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(1)

(ii) The equation for the reaction between strontium chloride and silver nitrate is

$$SrCl_2 + 2AgNO_3 \longrightarrow 2AgCl + Sr(NO_3)_2$$

Use your answer from part (i) and this equation to calculate the amount, in moles, of $SrCl_2$ needed to form 1.55 g of silver chloride.

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(1)

(iii) Use data from the Periodic Table to calculate the M_r of strontium chloride hexahydrate. Give your answer to 1 decimal place.

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(1)

(iv) Use your answers from parts (a)(ii) and (a)(iii) to calculate the percentage by mass of strontium chloride hexahydrate in the sample. Show your working.
Give your answer to the appropriate precision.

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(2)

(v) Several steps in the practical procedure were designed to ensure an accurate value for the percentage by mass of strontium chloride hexahydrate in the sample.

1 Explain why the solution of strontium chloride was filtered to remove insoluble impurities before the addition of silver nitrate.

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(1)

2 Explain why the precipitate of silver chloride was washed several times with deionised water.

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(1)

(b) Magnesium hydroxide and magnesium carbonate are used to reduce acidity in the stomach. Magnesium hydroxide can be prepared by the reaction of solutions of magnesium chloride and sodium hydroxide.

(i) Write the **simplest ionic** equation for the reaction that occurs between magnesium chloride and sodium hydroxide.
Include state symbols in your equation.

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(1)

(ii) Other than cost, explain one advantage of using magnesium hydroxide rather than magnesium carbonate to reduce acidity in the stomach.

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(1)

(c) Calcium ethanoate, $(CH_3COO)_2Ca$, is used in the treatment of kidney disease.
Thermal decomposition of calcium ethanoate under certain conditions gives propanone and **one** other product.

Write an equation for the thermal decomposition of calcium ethanoate.

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(1)

(d) Salts containing the chromate(VI) ion are usually yellow in colour.
Calcium chromate(VI) is soluble in water.
Strontium chromate(VI) is insoluble in water, but will dissolve in a solution of ethanoic acid.
Barium chromate(VI) is insoluble in water and is also insoluble in a solution of ethanoic acid.

Describe a series of tests using solutions of sodium chromate(VI) and ethanoic acid that would allow you to distinguish between separate solutions of calcium chloride, strontium chloride and barium chloride.
State what you would observe in each test.

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(3)

(e) The strontium salt of ranelic acid is used to promote bone growth. Analysis of a pure sample of ranelic acid showed that it contained 42.09% of carbon, 2.92% of hydrogen, 8.18% of nitrogen, 37.42% of oxygen and 9.39% of sulfur by mass.

Use these data to calculate the empirical formula of ranelic acid.
Show your working.

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(2)
(Total 15 marks)

35 A student investigated how the initial rate of reaction between sulfuric acid and magnesium at 20 °C is affected by the concentration of the acid.

The equation for the reaction is

$$H_2SO_4(aq) + Mg(s) \longrightarrow MgSO_4(aq) + H_2(g)$$

(a) The student made measurements every 20 seconds for 5 minutes. The student then repeated the experiment using double the concentration of sulfuric acid.

State a measurement that the student should make every 20 seconds. Identify the apparatus that the student could use to make this measurement.

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(2)

(b) State **one** condition, other than temperature and pressure, that would need to be kept constant in this investigation.

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(1)

(c) When the student had finished the investigation, an excess of sodium hydroxide solution was added to the reaction mixture. This was to neutralise any unreacted sulfuric acid. The student found that a further reaction took place, producing magnesium hydroxide.

(i) Draw a diagram to show how the student could separate the magnesium hydroxide from the reaction mixture.

(2)

(ii) Suggest **one** method the student could use for removing soluble impurities from the sample of magnesium hydroxide that has been separated.

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(1)
(Total 6 marks)

36 Group 2 metals and their compounds are used commercially in a variety of processes.

(a) Strontium is extracted from strontium oxide (SrO) by heating a mixture of powdered strontium oxide and powdered aluminium.

Consider these standard enthalpies of formation.

	SrO(s)	$Al_2O_3(s)$
$\Delta H_f^{\ominus}$ / kJ mol^{-1}	– 590	– 1669

$$3SrO(s) + 2Al(s) \longrightarrow 3Sr(s) + Al_2O_3(s)$$

Use these data and the equation to calculate the standard enthalpy change for this extraction of strontium.

The use of powdered strontium oxide and powdered aluminium increases the surface area of the reactants.
Suggest **one** reason why this increases the reaction rate.

Suggest **one** major reason why this method of extracting strontium is expensive.

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(5)

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(2)

(c) Magnesium is used in fireworks. It reacts rapidly with oxygen, burning with a bright white light. Magnesium reacts slowly with cold water.

Write an equation for the reaction of magnesium with oxygen.

Write an equation for the reaction of magnesium with cold water.

Give a medical use for the magnesium compound formed in the reaction of magnesium with cold water.

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(3)
(Total 10 marks)

37 Group 2 elements and their compounds have a wide range of uses.

(a) For parts (a)(i) to (a)(iii), draw a ring around the correct answer to complete each sentence.

(i) From $Mg(OH)_2$ to $Ba(OH)_2$, the solubility in water

decreases.
increases.
stays the same.

(1)

(ii) From Mg to Ba, the first ionisation energy

- decreases.
- increases.
- stays the same.

(1)

(iii) From Mg to Ba, the atomic radius

- decreases.
- increases.
- stays the same.

(1)

(b) Explain why calcium has a higher melting point than strontium.

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(Extra space) .....

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(2)

(c) Acidified barium chloride solution is used as a reagent to test for sulfate ions.

(i) State why sulfuric acid should **not** be used to acidify the barium chloride.

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(1)

(ii) Write the **simplest ionic** equation for the reaction that occurs when acidified barium chloride solution is added to a solution containing sulfate ions.

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(1)
(Total 7 marks)

38 There are many uses for compounds of barium.

(a) (i) Write an equation for the reaction of barium with water.

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(1)

(ii) State the trend in reactivity with water of the Group 2 metals from Mg to Ba

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(1)

(b) Give the formula of the **least** soluble hydroxide of the Group 2 metals from Mg to Ba

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(1)

(c) State how barium sulfate is used in medicine.
Explain why this use is possible, given that solutions containing barium ions are poisonous.

Use .....

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Explanation .....

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(Extra space) .....

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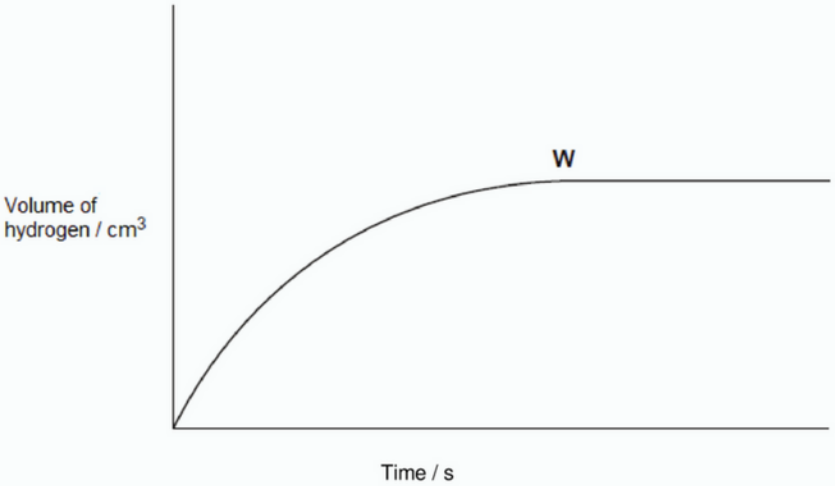
(2)
(Total 5 marks)

39 (a) **Figure 1** shows the volume of hydrogen gas collected when a sample of magnesium reacted with an excess of dilute hydrochloric acid.

The rate of this reaction can be studied by measuring the time it takes for a given volume of hydrogen to be collected.

Figure 1



(i) State the meaning of the term *rate of reaction*.

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(1)

(ii) State and explain what has happened to the rate of this reaction at point **W** in **Figure 1**.

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(2)

(iii) In terms of collision theory explain why, at a fixed temperature, the rate of this reaction doubles when the concentration of the hydrochloric acid doubles.

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(2)

(b) In a study of the reaction in part (a), a student referred to activation energy.

(i) State the meaning of the term *activation energy*.

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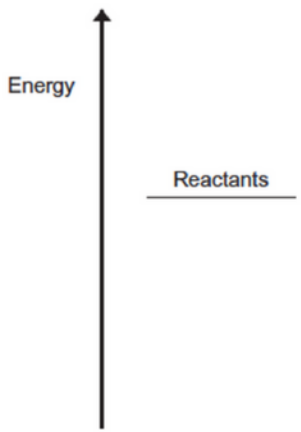
(1)

(ii) Complete **Figure 2** by drawing the shape of the reaction profile from reactants to products for an exothermic reaction.
Show the position of the products. Show and label the activation energy.

Figure 2



(2)

(c) Barium metal reacts very quickly with dilute hydrochloric acid, but it reacts more slowly with water.

(i) Write an equation for the reaction of barium with water.

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(1)

(ii) A solution containing barium ions can be used to show the presence of sulfate ions in an aqueous solution of sodium sulfate.

Write the **simplest ionic** equation for the reaction that occurs and state what is observed.

Simplest ionic equation

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Observation

.....

(2)

(iii) State **one** use of barium sulfate in medicine.
Explain why this use is possible, given that solutions containing barium ions are poisonous.

Use .....

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Explanation .....

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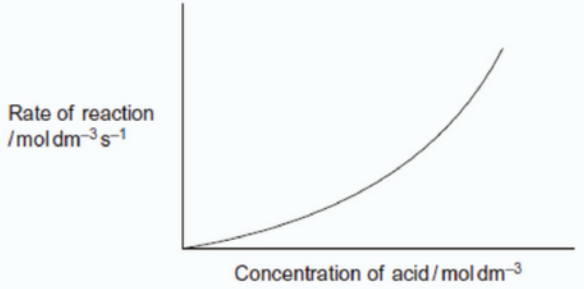
(2)
(Total 13 marks)

40 (a) In an investigation of the rate of reaction between hydrochloric acid and pure magnesium, a student obtained the following curve.



The reaction of magnesium with dilute hydrochloric acid is exothermic.

Use your understanding of collision theory to explain why the student did **not** obtain a straight line.

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(3)

(b) The magnesium used in a laboratory experiment was supplied as a ribbon. The ribbon was stored in an open plastic bag exposed to the air.

Explain why it is important to clean the surface of this magnesium ribbon when investigating the rate of its reaction with hydrochloric acid.

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(2)

(c) Magnesium ribbon reacts with hot water. Heated magnesium ribbon reacts with steam.
State **two** differences between these reactions.

Difference 1 .....

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Difference 2 .....

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(2)

(d) Pure magnesium reacts completely with an excess of dilute sulfuric acid.
The reaction of pure calcium with an excess of dilute sulfuric acid is very rapid initially.
This reaction slows down and stops before all of the calcium has reacted.

Use your knowledge of the solubilities of Group 2 sulfates to explain why these reactions of magnesium and calcium with dilute sulfuric acid are so different.

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(3)
(Total 10 marks)

41 Barium chloride solution was added, dropwise, to magnesium sulfate solution until no more white precipitate was formed. The mixture was filtered.

Give the formulae of the **two** main ions in the filtrate.

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(Total 1 mark)