Q1. 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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(b) State and explain **one** environmental reason why Extraction process **3** is an improvement over Extraction process **2**.

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(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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(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)

Q2. 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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(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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(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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(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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(Total 9 marks)

Q3. 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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(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)

Q4. 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.

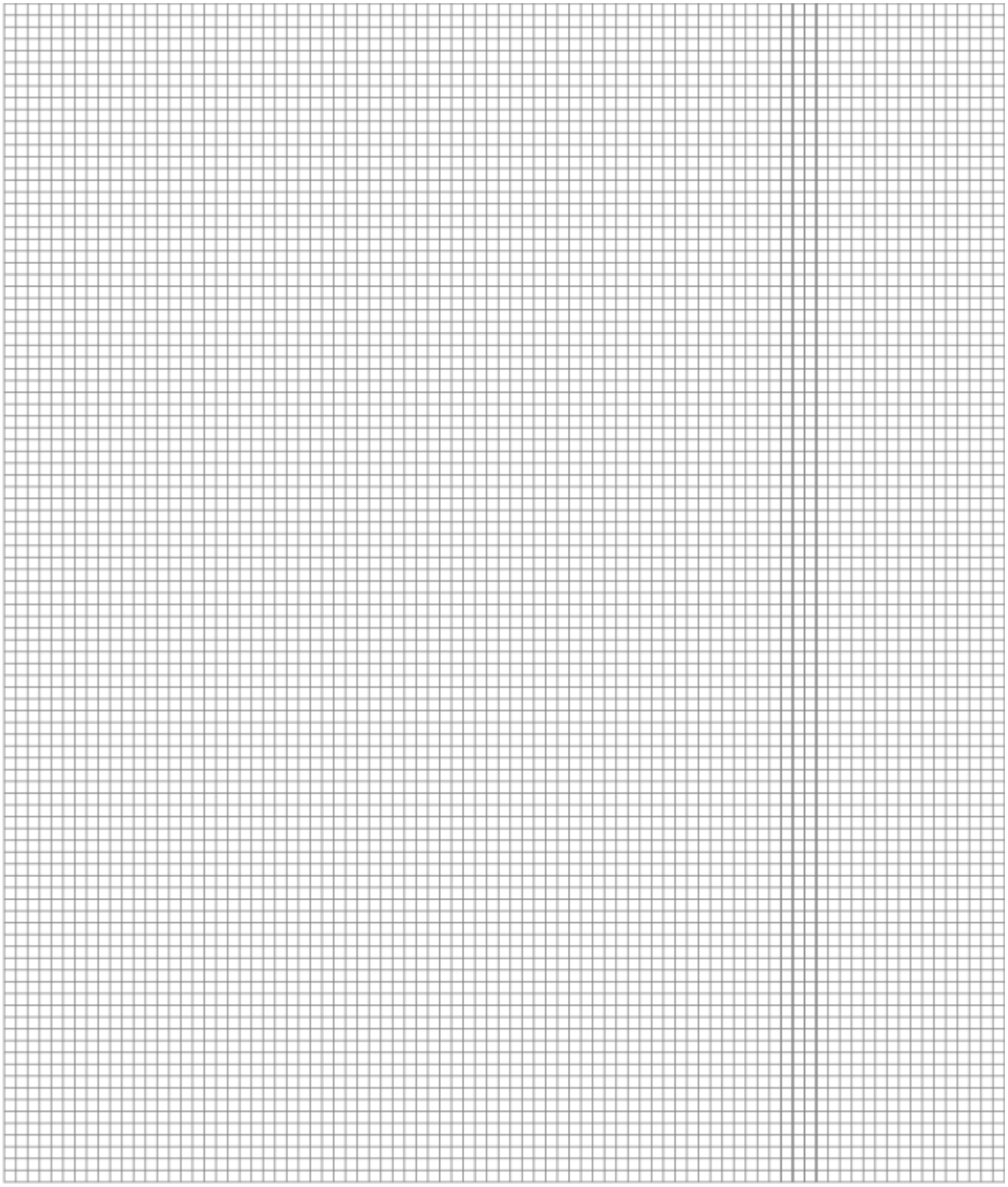
A chemist sampled the effluent at different pressures. For each pressure, a 250 cm^3 sample of effluent was taken in a measuring cylinder and poured into a weighed beaker. The water was evaporated by heating and the beaker reweighed. The following results were obtained.

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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(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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(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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(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)