

Q1. Zinc forms many different salts including zinc sulfate, zinc chloride and zinc fluoride.

- (a) People who have a zinc deficiency can take hydrated zinc sulfate ($\text{ZnSO}_4 \cdot x\text{H}_2\text{O}$) as a dietary supplement.

A student heated 4.38 g of hydrated zinc sulfate and obtained 2.46 g of anhydrous zinc sulfate.

Use these data to calculate the value of the integer x in $\text{ZnSO}_4 \cdot x\text{H}_2\text{O}$
Show your working.

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(3)

- (b) Zinc chloride can be prepared in the laboratory by the reaction between zinc oxide and hydrochloric acid.
The equation for the reaction is



A 0.0830 mol sample of pure zinc oxide was added to 100 cm³ of 1.20 mol dm⁻³ hydrochloric acid.

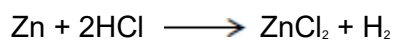
Calculate the maximum mass of anhydrous zinc chloride that could be obtained from the products of this reaction.

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- (c) Zinc chloride can also be prepared in the laboratory by the reaction between zinc and hydrogen chloride gas.



An impure sample of zinc powder with a mass of 5.68 g was reacted with hydrogen chloride gas until the reaction was complete. The zinc chloride produced had a mass of 10.7 g.

Calculate the percentage purity of the zinc metal.
Give your answer to 3 significant figures.

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- (d) Predict the type of crystal structure in solid zinc fluoride and explain why its melting point is high.

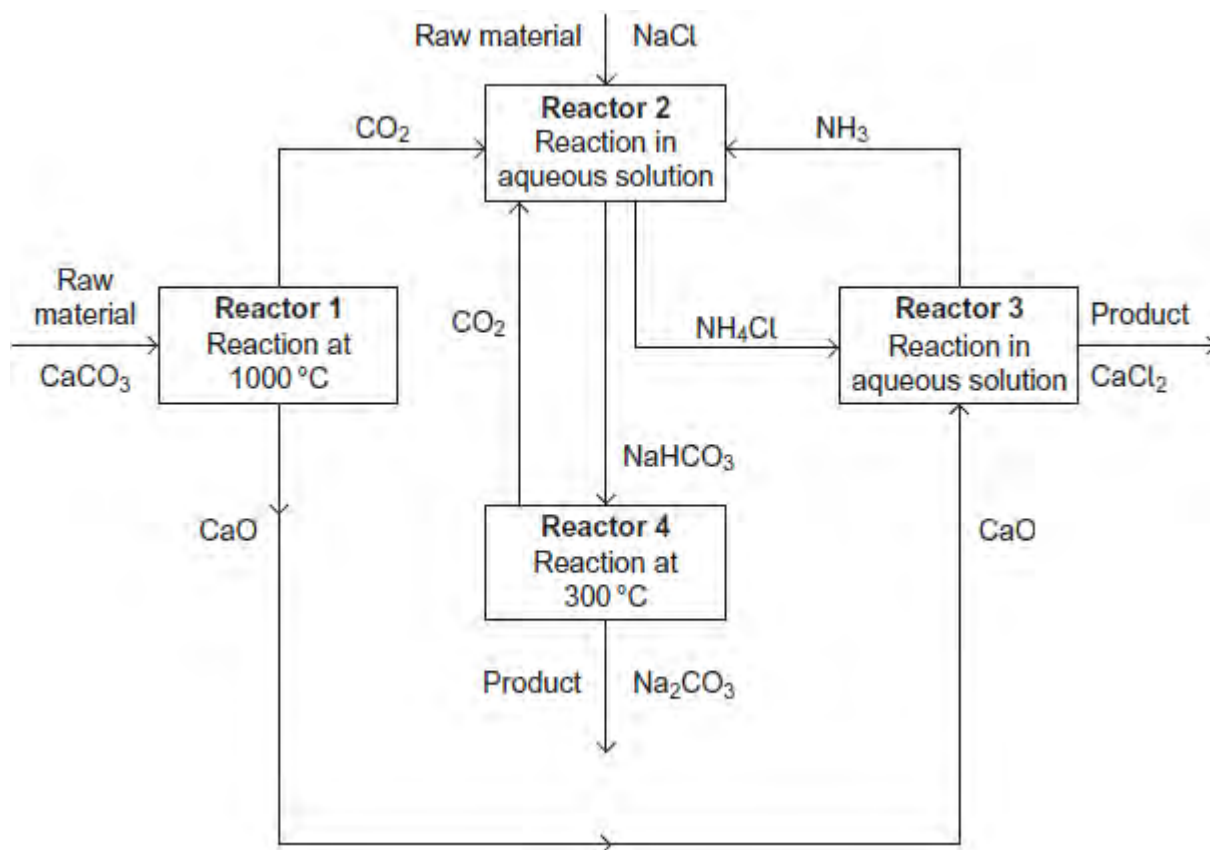
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(Total 14 marks)

Q2. Sodium carbonate is manufactured by the Solvay Process.

The separate stages involved in this process are shown in this diagram.



- (a) In **Reactor 1**, calcium carbonate is decomposed into calcium oxide and carbon dioxide. Despite no significant leakage of carbon dioxide from this decomposition, this part of the process results in an increase in carbon dioxide in the atmosphere.

State why this increase in carbon dioxide occurs.

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(1)

- (b) In **Reactor 2**, sodium chloride solution, carbon dioxide and ammonia react to form sodium hydrogencarbonate and ammonium chloride.

Write an equation for this reaction.

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- (c) Use information from the diagram to deduce an equation for the reaction taking place in **Reactor 3**.

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- (d) An equation for the overall reaction in the Solvay Process is



- (i) Calculate the percentage atom economy of this reaction to produce sodium carbonate. Show your working.

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- (ii) State what could be done to improve the percentage atom economy of the Solvay Process.

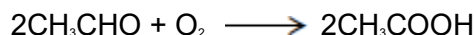
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- (e) Use information from the diagram to suggest why ammonia is **not** regarded as a raw material in the Solvay Process.

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(Total 7 marks)

Q3. This question explores some reactions and some uses of cobalt compounds.

- (a) Ethanal is oxidised to ethanoic acid by oxygen. The equation for this reaction is



This redox reaction is slow at room temperature but speeds up in the presence of cobalt compounds.

Explain why a cobalt compound is able to act as a catalyst for this process.

Illustrate your explanation with **two** equations to suggest how, in the presence of water and hydrogen ions, Co^{3+} and then Co^{2+} ions could be involved in catalysing this reaction.

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- (b) In aqueous solution, the $[\text{Co}(\text{H}_2\text{O})_6]^{2+}$ ion reacts with an excess of ethane-1,2-diamine to form the complex ion **Y**.

- (i) Write an equation for this reaction.

Explain, in terms of the chelate effect, why the complex ion **Y** is formed in preference to the $[\text{Co}(\text{H}_2\text{O})_6]^{2+}$ complex ion.

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- (ii) Draw a diagram that shows the shape of the complex ion **Y** and shows the type of bond between the ethane-1,2-diamine molecules and the cobalt.

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- (c) Compound **Z** is a complex that contains only cobalt, nitrogen, hydrogen and chlorine.

A solid sample of **Z** was prepared by reaction of 50 cm³ of 0.203 mol dm⁻³ aqueous cobalt(II) chloride with ammonia and an oxidising agent followed by hydrochloric acid.

When this sample of **Z** was reacted with an excess of silver nitrate, 4.22 g of silver chloride were obtained.

Use this information to calculate the mole ratio of chloride ions to cobalt ions in **Z**.

Give the formula of the complex cobalt compound **Z** that you would expect to be formed in the preparation described above.

Suggest **one** reason why the mole ratio of chloride ions to cobalt ions that you have calculated is different from the expected value.

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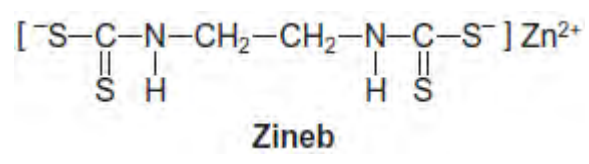
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 (Total 15 marks)

Q4.(a) Because of the toxic nature of the copper(II) ion, a wide range of alternative anti-fungal drugs has been developed for use in agriculture. One example is Zineb.



(i) The negative ion in Zineb could act as a bidentate ligand.

On the structure above, draw a ring around each of **two** atoms that could provide the lone pairs of electrons when this ion acts as a bidentate ligand.

(1)

(ii) Calculate the M_r of Zineb. Give your answer to the appropriate precision.

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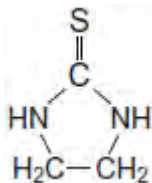
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(iii) Name the functional group formed at each end of the negative ion when all the sulfur atoms in the structure of Zineb are replaced by oxygen atoms.

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(1)

(b) Zineb has been investigated for harmful effects. Generally, Zineb has been found to be safe to use in agriculture. It is only slightly soluble in water and is sprayed onto plants. A breakdown product of Zineb is ethylene thiourea (ETU), which is very soluble in water. The structure of ETU is shown below.



Determine the percentage, by mass, of sulfur in ETU ($M_r = 102.1$).

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- (c) Chromatography is a technique used to show the presence of a small amount of ETU in Zineb.

Outline how this technique is used to separate and identify ETU from a sample of Zineb powder.

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(Total 8 marks)