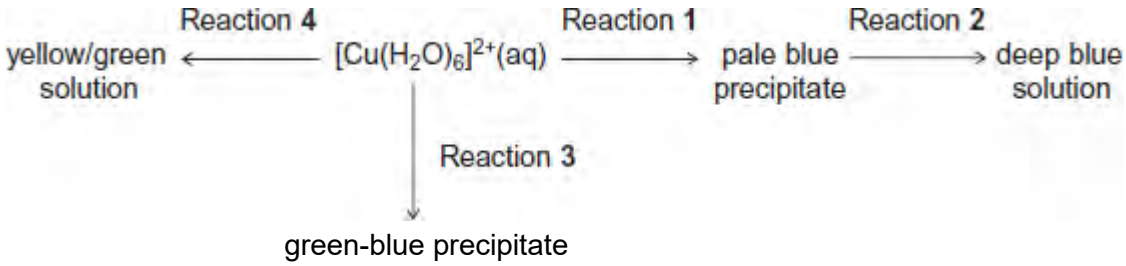
Q1. Consider the following reaction scheme that starts from aqueous $[Cu(H_2O)6]^{2+}$ ions.



For each of the reactions **1** to **4**, identify a suitable reagent, give the formula of the copper-containing species formed and write an equation for the reaction.

(a) Reaction **1**

Reagent .....

Copper-containing species .....

Equation .....

(3)

(b) Reaction **2**

Reagent .....

Copper-containing species .....

Equation .....

(3)

(c) Reaction **3**

Reagent .....

Copper-containing species .....

Equation .....

(3)

(d) Reaction **4**

Reagent .....

Copper-containing species .....

Equation .....

(3)
(Total 12 marks)

Q2. 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

$2CH_3CHO + O_2 \longrightarrow 2CH_3COOH$

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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(4)

(b) In aqueous solution, the $[Co(H_2O)_6]^{2+}$ 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 $[Co(H_2O)_6]^{2+}$ complex ion.

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(3)

(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.

(3)

(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 cm^3 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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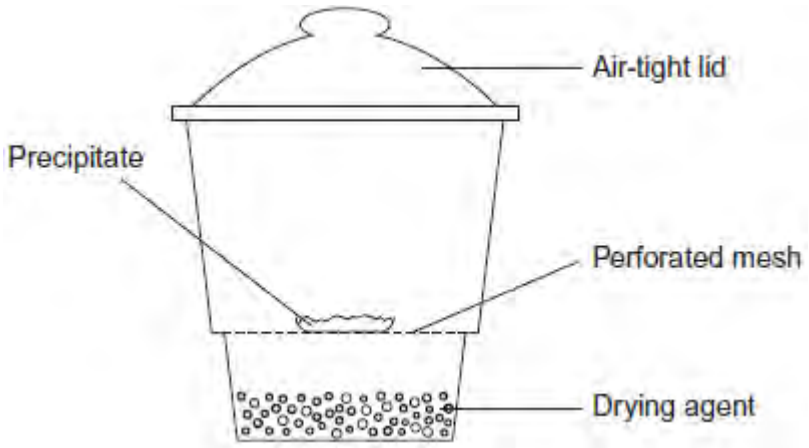
(5)
(Total 15 marks)

Q3.A desiccator can be used to dry precipitates as shown in the diagram.



(a) Explain briefly how the precipitate in the desiccator becomes dry.

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(1)

(b) Anhydrous cobalt(II) chloride is blue. It is often added to the drying agent to indicate the amount of moisture in the drying agent.

State the colour change of this cobalt compound that you would observe as the drying process takes place.

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(1)
(Total 2 marks)

Q4. In its reactions with transition metal ions, ammonia can act as a Brønsted–Lowry base and as a Lewis base.

(a) Define the term *Lewis base*.

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(1)

(b) Write an equation for a reaction between aqueous copper(II) ions ($[Cu(H_2O)_6]^{2+}$) and ammonia in which ammonia acts as a Brønsted–Lowry base. State what you would observe.

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(Extra space) .....

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(2)

(c) Write an equation for a different reaction between aqueous copper(II) ions ($[Cu(H_2O)_6]^{2+}$) and ammonia in which ammonia acts as a Lewis base but **not** as a Brønsted–Lowry base. State what you would observe.

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(Extra space) .....

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(2)

(d) An excess of dilute ammonia solution is added to an aqueous solution containing iron(II) ions in a test tube that is then left to stand for some time.
State and explain what you would observe.

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(4)

(e) Diaminoethane ($H_2NCH_2CH_2NH_2$), like ammonia, can react as a base and as a ligand.

(i) Write an equation for the reaction that occurs between an aqueous solution of aluminium chloride and an excess of aqueous diaminoethane.
Describe the appearance of the aluminium-containing reaction product.

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(Extra space) .....

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(3)

(ii) Write an equation for the reaction that occurs between an aqueous solution of cobalt(II) sulfate and an excess of aqueous diaminoethane.
Draw a diagram to show the shape of and bonding in the complex product.
Write an equation for the reaction that would occur if the complex product of

this reaction were allowed to stand in contact with oxygen gas.

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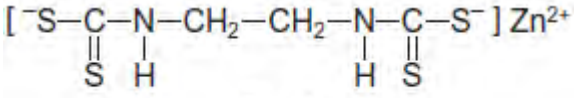
(5)
(Total 17 marks)

Q5.(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.



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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(1)

(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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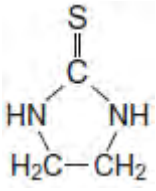
(1)

(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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(4)
(Total 8 marks)