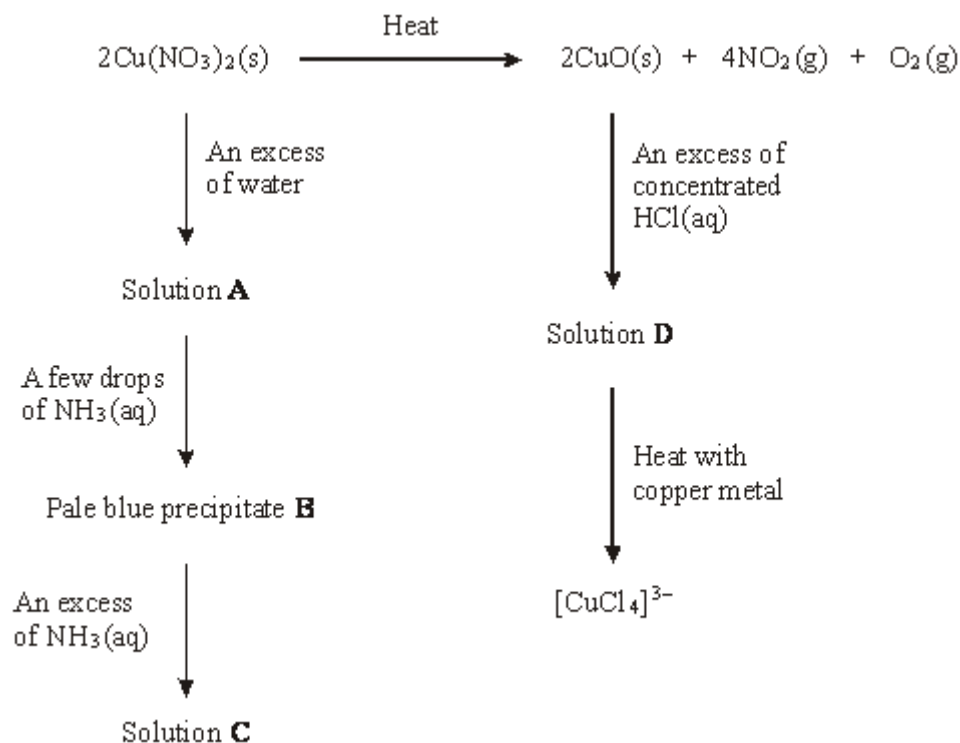


**Q1.** Consider the reaction scheme below and answer the questions which follow.



- (a) A redox reaction occurs when  $\text{Cu}(\text{NO}_3)_2$  is decomposed by heat. Deduce the oxidation state of nitrogen in  $\text{Cu}(\text{NO}_3)_2$  and in  $\text{NO}_2$  and identify the product formed by oxidation in this decomposition.

*Oxidation state of nitrogen in  $\text{Cu}(\text{NO}_3)_2$  .....*

*Oxidation state of nitrogen in  $\text{NO}_2$  .....*

*Oxidation product .....*

.....

(3)

- (b) Identify and state the shape of the copper-containing species present in solution **A**.

*Copper-containing species .....*

*Shape .....*

(2)

- (c) (i) Identify the pale blue precipitate **B** and write an equation, or equations, to show how **B** is formed from the copper-containing species in solution **A**.

*Identity of precipitate **B** .....*

Equation(s) .....

.....

(ii) In what way does the  $\text{NH}_3$  behave as a Brønsted–Lowry base?

.....

(3)

(d) (i) Identify the copper-containing species present in solution **C**. State the colour of this copper-containing species and write an equation for its formation from precipitate **B**.

Identity .....

Colour .....

Equation .....

.....

(ii) In what way does the  $\text{NH}_3$  behave as a Lewis base?

.....

(4)

(e) Identify the copper-containing species present in solution **D**. State the colour and shape of this copper-containing species.

Identity .....

Colour .....

Shape .....

.....

(3)

(f) The oxidation state of copper in  $[\text{CuCl}_4]^{3-}$  is +1.

(i) Give the electron arrangement of a  $\text{Cu}^+$  ion.

.....

- (ii) Deduce the role of copper metal in the formation of  $[\text{CuCl}_4]^{3-}$  from the copper-containing species in solution **D**.

.....

(2)

(Total 17 marks)

- Q2.** (a) Octahedral and tetrahedral complex ions are produced by the reaction of transition metal ions with ligands which form co-ordinate bonds with the transition metal ion.  
Define the term *ligand* and explain what is meant by the term *co-ordinate bond*.

(3)

- (b) (i) Some complex ions can undergo a ligand substitution reaction in which both the co-ordination number of the metal and the colour change in the reaction. Write an equation for one such reaction and state the colours of the complex ions involved.

- (ii) Bidentate ligands replace unidentate ligands in a metal complex by a ligand substitution reaction. Write an equation for such a reaction and explain why this reaction occurs.

(8)

- (c) The frequency,  $\nu$ , of light absorbed by a transition metal complex ion can be determined using the relationship  $\Delta E = h\nu$ . State what is meant by the symbols  $\Delta E$  and  $h$ . Give **three** factors which result in a change in the frequency of light absorbed as a result of the reaction of a complex ion.

(5)

(Total 16 marks)

**Q3.** (a) State what is meant by each of the following terms.

(i) *Ligand* .....

.....

(ii) *Complex ion* .....

.....

(iii) *Co-ordination number* .....

.....

**(3)**

(b) Using complex ions formed by  $\text{Co}^{2+}$  with ligands selected from  $\text{H}_2\text{O}$ ,  $\text{NH}_3$ ,  $\text{Cl}^-$ ,  $\text{C}_2\text{O}_4^{2-}$  and  $\text{EDTA}^{4-}$ , give an equation for each of the following.

(i) A ligand substitution reaction which occurs with no change in either the co-ordination number or in the charge on the complex ion.

.....

(ii) A ligand substitution reaction which occurs with both a change in the co-ordination number and in the charge on the complex ion.

.....

(iii) A ligand substitution reaction which occurs with no change in the co-ordination number but a change in the charge on the complex ion.

.....

(iv) A ligand substitution reaction in which there is a large change in entropy.

.....

**(8)**

(c) An aqueous solution of iron(II) sulphate is a pale-green colour. When aqueous

sodium hydroxide is added to this solution a green precipitate is formed. On standing in air, the green precipitate slowly turns brown.

(i) Give the formula of the complex ion responsible for the pale-green colour.

.....

(ii) Give the formula of the green precipitate.

.....

(iii) Suggest an explanation for the change in the colour of the precipitate.

.....

.....

(4)  
(Total 15 marks)

**Q4.** (a) Give **one** example of a bidentate ligand.

.....

(1)

(b) Give **one** example of a linear complex ion formed by a transition metal.

.....

(1)

(c) Write an equation for a substitution reaction in which the complete replacement of ligands in a complex ion occurs with a change in **both** the co-ordination number and the overall charge of the complex ion.

.....

(2)

- (d) Write an equation for a substitution reaction in which the complete replacement of ligands in a complex ion occurs without a change in either the co-ordination number or the overall charge of the complex ion.

.....

(2)

- (e) When a solution containing  $[\text{Co}(\text{H}_2\text{O})_6]^{2+}$  ions is treated with a solution containing  $\text{EDTA}^{4-}$  ions, a more stable complex is formed. Write an equation for this reaction and explain why the complex is more stable.

*Equation* .....

*Explanation* .....

.....

(3)

(Total 9 marks)