



# **A-Level Chemistry**

## **Transition Metals**

### **Question Paper**

**Time available: 65 minutes**

**Marks available: 63 marks**

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**1.**

- (a) A co-ordinate bond is formed when a transition metal ion reacts with a ligand.

Explain how this co-ordinate bond is formed.

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**(2)**

- (b) Describe what you would observe when dilute aqueous ammonia is added dropwise, to excess, to an aqueous solution containing copper(II) ions.  
Write equations for the reactions that occur.

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**(4)**

- (c) When the complex ion  $[\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+}$  reacts with 1,2-diaminoethane, the ammonia molecules but not the water molecules are replaced.

Write an equation for this reaction.

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**(1)**

(d) Suggest why the enthalpy change for the reaction in part (c) is approximately zero.

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(2)

(e) Explain why the reaction in part (c) occurs despite having an enthalpy change that is approximately zero.

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(2)

(Total 11 marks)

2.

Due to their electron arrangements, transition metals have characteristic properties including catalytic action and the formation of complexes with different shapes.

(a) Give **two other** characteristic properties of transition metals. For each property, illustrate your answer with a transition metal of your choice.

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(4)

- (b) Other than octahedral, there are several different shapes shown by transition metal complexes. Name **three** of these shapes and for each one give the formula of a complex with that shape.

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(6)

- (c) It is possible for Group 2 metal ions to form complexes. For example, the  $[\text{Ca}(\text{H}_2\text{O})_6]^{2+}$  ion in hard water reacts with  $\text{EDTA}^{4-}$  ions to form a complex ion in a similar manner to hydrated transition metal ions. This reaction can be used in a titration to measure the concentration of calcium ions in hard water.

- (i) Write an equation for the equilibrium that is established when hydrated calcium ions react with  $\text{EDTA}^{4-}$  ions.

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(1)

- (ii) Explain why the equilibrium in part (c)(i) is displaced almost completely to the right to form the EDTA complex.

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(3)

- (iii) In a titration,  $6.25 \text{ cm}^3$  of a  $0.0532 \text{ mol dm}^{-3}$  solution of EDTA reacted completely with the calcium ions in a  $150 \text{ cm}^3$  sample of a saturated solution of calcium hydroxide. Calculate the mass of calcium hydroxide that was dissolved in  $1.00 \text{ dm}^3$  of the calcium hydroxide solution.

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(3)

(Total 17 marks)

3.

Transition metal ions can act as homogeneous catalysts in redox reactions. For example, iron(II) ions catalyse the reaction between peroxodisulfate ( $\text{S}_2\text{O}_8^{2-}$ ) ions and iodide ions.

- (a) State the meaning of the term *homogeneous*.

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(1)

- (b) Suggest why ions from s block elements do **not** usually act as catalysts.

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(1)

- (c) Write an equation for the overall reaction that occurs, in aqueous solution, between  $\text{S}_2\text{O}_8^{2-}$  ions and  $\text{I}^-$  ions.

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(1)

- (d) Give **one** reason why, in the absence of a catalyst, the activation energy for the reaction between  $\text{S}_2\text{O}_8^{2-}$  ions and  $\text{I}^-$  ions is high.

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(1)

- (e) Write two equations to show how  $\text{Fe}^{2+}$  ions can catalyse the reaction between  $\text{S}_2\text{O}_8^{2-}$  ions and  $\text{I}^-$  ions. Suggest **one** reason why the activation energy for each of these reactions is low.

Equation 1 \_\_\_\_\_

Equation 2 \_\_\_\_\_

Reason \_\_\_\_\_

\_\_\_\_\_

(3)

- (f) Explain why  $\text{Fe}^{3+}$  ions are as effective as  $\text{Fe}^{2+}$  ions in catalysing this reaction.

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(1)

(Total 8 marks)

4.

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

(i) *Ligand* \_\_\_\_\_

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(ii) *Complex ion* \_\_\_\_\_

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(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.

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

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- (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.

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

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(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.

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(ii) Give the formula of the green precipitate.

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

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(4)

(Total 15 marks)

5.

This question is about cobalt chemistry.

(a) Give the electron configuration of the Co atom and of the  $\text{Co}^{2+}$  ion.

State three characteristic features of the chemistry of cobalt and its compounds.

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(5)

- (b) Ethane-1,2-diamine can act as a bidentate ligand. When  $[\text{Co}(\text{H}_2\text{O})_6]^{2+}(\text{aq})$  ions are treated with an excess of ethane-1,2-diamine, the water ligands are replaced.

Explain what is meant by the term bidentate ligand.

Explain, with the aid of an equation, the thermodynamic reasons why this reaction occurs.

Draw a diagram to show the structure of the complex ion formed.

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(7)  
(Total 12 marks)