Transition Elements A Level only

Question Paper 1

Level	A Level
Subject	Chemistry
Exam Board	OCR
Module	Physical Chemistry & Transition Elements
Topic	Transition Elements
Paper	A Level only
Booklet	Question Paper 1

Time allowed: **80 minutes**

Score: **/59**

Percentage: **/100**

Grade Boundaries:

A*	A	B	C	D	E
>85%	73%	60%	47%	34%	21%

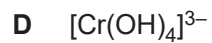What is the bonding between the ligands and the metal ion in $[Fe(H_2O)_6]^{2+}$?
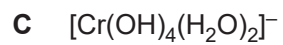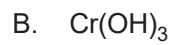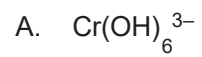
A. Metallic

B. Ionic

C. Hydrogen

D. Dative covalent **[1]**

Aqueous Cr^{3+} ions are reacted with an excess of aqueous sodium hydroxide.

Which product is formed?

A. $Cr(OH)_6^{3-}$

B. $Cr(OH)_3$

C $[Cr(OH)_4(H_2O)_2]^-$

D $[Cr(OH)_4]^{3-}$ **[1]**

This question looks at properties of transition elements, ions and complexes.

(a) What is the oxidation number of Cr in the complex ion $[CrOCl_5]^{2-}$? [1]

(b) Write the equation for a reaction catalysed by a named transition element, compound or ion.

Equation

Catalyst: [1]

(c) An octahedral complex ion **A**, $C_9H_{30}N_6Ni^{3+}$, exists as two optical isomers.

In complex ion **A**, Ni^{3+} is bonded to three molecules of a bidentate ligand **B**.

   (i) State what is meant by a *bidentate ligand*. [1]

   (ii) What is the molecular formula of the bidentate ligand **B**? [1]

   (iii) Draw a possible structure for **B** and explain how **B** is able to act as a bidentate ligand. [2]

(iv) What is the coordination number of complex ion **A**?   [1]

(v) Complete the 3-D diagrams of the shapes of the optical isomers of complex ion **A**.

You can show the bidentate ligand simply as
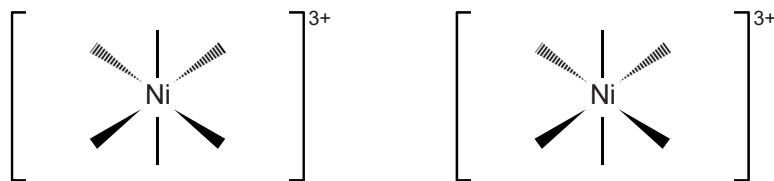
[1]

(d) Describe the reactions of **EITHER** aqueous copper(II) ions **OR** aqueous cobalt(II) ions with:
   •   aqueous sodium hydroxide
   •   excess aqueous ammonia
   •   hydrochloric acid.

In your answer you should link observations with equations.   [6]


[Total: 14 Marks]

Elements in the d-block of the Periodic Table form ions that combine with ligands to form complex ions. Most d-block elements are also classified as transition elements.

(a) Explain why two of the Period 4 d-block elements (Sc–Zn) are **not** also transition elements.

In your answer you should link full electron configurations to your explanations. [6]

(b) The cobalt(III) ion, Co^{3+}, forms a complex ion **A** with two chloride ligands and two ethanediamine, $H_2NCH_2CH_2NH_2$, ligands.

The structure of ethanediamine is shown below.

$$H_2N \qquad NH_2$$
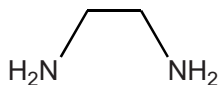
(i) Explain how ethanediamine is able to act as a bidentate ligand. [2]

(ii) Write the formula of complex ion **A**. [1]

(iii) What is the coordination number of cobalt in complex ion **A**? [1]

(iv) Complex ion **A** has *cis* and *trans* stereoisomers. One of these stereoisomers also has an optical isomer.
Draw 3-D diagrams to show the three stereoisomers. [3]

(c) The equilibrium reaction for the transport of oxygen by haemoglobin (Hb) in blood can be represented as **equation 5.1**.

$$Hb(aq) + O_2(aq) \rightleftharpoons HbO_2(aq) \qquad \textbf{equation 5.1}$$
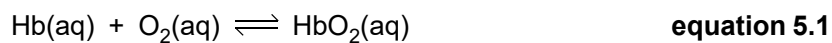
(i) Explain how ligand substitution reactions allow haemoglobin to transport oxygen in blood.

[2]

(ii) Write an expression for the stability constant, K_{stab}, for the equilibrium involved in the transport of oxygen by haemoglobin.

Use the simplified species in **equation 5.1**.

[1]

(iii) In the presence of carbon monoxide, less oxygen is transported in the blood.

Suggest why, in terms of bond strength and stability constants.

[2]

[Total: 18 Marks]

Iron is heated with chlorine to form an orange–brown solid, **A**.

Solid **A** is dissolved in water to form an orange–brown solution, **X**, containing the complex ion $[Fe(H_2O)_6]^{3+}$.

Separate portions of solution **X** are reacted as shown in **Experiments 1–4** below.

Experiment 1
Aqueous sodium hydroxide is added to solution **X**. An orange–brown precipitate **B** forms.

Experiment 2
Excess zinc powder is added to solution **X** and the mixture is heated. The excess zinc is removed leaving a pale-green solution containing the complex ion **C** and aqueous Zn^{2+} ions.

Experiment 3
An excess of aqueous potassium cyanide, KCN(aq), is added to solution **X**.
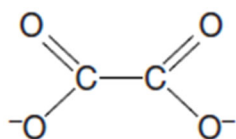The solution turns a yellow colour and contains the complex ion **E**.
E has a molar mass of $211.8 \, g \, mol^{-1}$.

Experiment 4
An aqueous solution containing ethanedioate ions, $(COO^-)_2$, is added to solution **X**.
A coloured solution forms containing a mixture of optical isomers **F** and **G**.

The structure of the ethanedioate ion is shown below.

(a) Write an equation for the formation of solid **A**.   [1]

(b) In **Experiment 1**, write an ionic equation for the formation of precipitate **B**.   [1]

(c) In **Experiment 2**,

    (i)   write an equation for the formation of complex ion **C**   [2]

    (ii) state the type of reaction taking place.   [1]

(d) In **Experiment 3**,

   (i)   write an equation for the formation of complex ion **E**   [2]

   (ii)   state the type of reaction taking place.   [1]

(e) In **Experiment 4**, optical isomers **F** and **G** are formed.

Show the 3-D shapes of **F** and **G**.
In your diagrams, show the ligand atoms that are bonded to the metal ions and any overall charges.   [3]

(f) In a separate experiment, iron metal is heated with potassium nitrate, KNO_3, a strong oxidising agent. A reaction takes place and the resulting mixture is poured into water. A dark red solution forms containing ferrate(VI) ions. The ferrate(VI) ion has a 2– charge.

Suggest a possible formula for the ferrate(VI) ion.   [1]

[Total 12 Marks]

9

Dimethylglyoxime, DMGH, can be used to analyse nickel(II) compounds.

An excess of a solution of DMGH is added to an acidic solution of a nickel(II) compound. Aqueous ammonia is added which precipitates out a nickel(II) complex, $Ni(DMG)_2$, as a red solid.

A sample of a hydrated nickel(II) salt is analysed using the procedure below.

Step 1
2.50 g of the hydrated nickel(II) salt is dissolved in dilute acid.
An excess of an aqueous solution of DMGH is added.

Step 2
An excess of aqueous ammonia is added and the mixture is heated.
A red precipitate of $Ni(DMG)_2$ forms.

An equation for the reaction is shown below.

$$Ni^{2+}(aq) + 2DMGH(aq) + 2NH_3(aq) \rightarrow Ni(DMG)_2(s) + 2NH_4^+(aq)$$
red precipitate
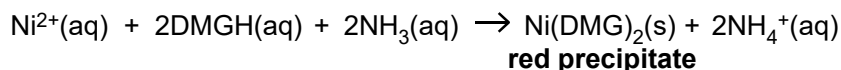
Step 3
The red precipitate is filtered, washed with water, dried and then weighed.
The precipitate of $Ni(DMG)_2$ has a mass of 2.57 g.
Assume that all $Ni^{2+}(aq)$ ions have been converted into $Ni(DMG)_2(s)$.
$M[Ni(DMG)_2] = 288.7 \, g \, mol^{-1}$.

Step 4
A second 2.50 g sample of the hydrated nickel(II) salt is heated in a crucible to remove the water of crystallisation.
1.38 g of the anhydrous salt remains.

(a) Complete the electron configurations of nickel as the element and in the +2 oxidation state. [2]

(b) The structure of Ni(DMG)₂ is shown below.
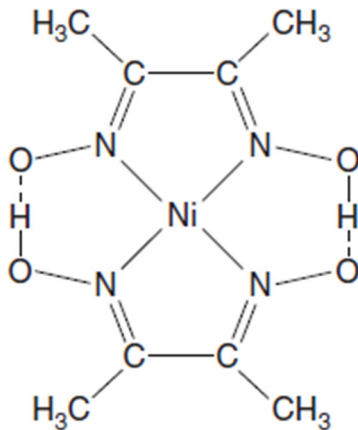
(i) State and explain the role of ammonia in **step 2** of this experiment. [1]

(ii) State the coordination number of Ni in Ni(DMG)₂. [1]

(iii) Why does the Ni(DMG)₂ complex have no overall charge? [1]

(iv) Draw the structure of dimethylglyoxime, DMGH. [1]

(c) Determine a possible formula of the hydrated nickel(II) salt.

Your answer **must** show relevant working.   [7]

[Total 13 Marks]