Transition Elements
AS & A Level

Question Paper 1

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

Time allowed: **78 minutes**

Score: **/58**

Percentage: **/100**

Grade Boundaries:

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

Question 1

Which statement(s) is/are correct for the complex $Pt(NH_3)_2Cl_2$?

1 One of its stereoisomers is used as an anti-cancer drug.

2 It has bond angles of 109.5°.

3 It has optical isomers.

A. 1, 2 and 3

B. Only 1 and 2

C. Only 2 and 3

D. Only 1

[1]

Iron, copper and platinum are examples of transition elements.

(a) Define the term *transition element*.

Show that iron fits this definition by use of full electron configurations of iron as the element and in its common oxidation states. [4]

(b) Describe **one** precipitation reaction and **one** ligand substitution reaction of copper in the +2 oxidation state.

Your answer should include reagents, relevant observations and balanced equations. [6]

(c) Platinum is an extremely unreactive transition element. However, platinum does take part in a redox reaction with '*aqua regia*', a mixture of concentrated hydrochloric and nitric acids. Two products of this reaction are hexachloroplatinic acid, H_2PtCl_6, and nitrogen dioxide, NO_2.

(i) Use oxidation states to show that this is a redox reaction. [2]

(ii) Write an equation for the reaction of platinum metal with *aqua regia*. [2]

(d) Ammonium hexachloroplatinate, $(NH_4)_2PtCl_6$, is a complex of platinum used in platinum plating. Ammonium hexachloroplatinate contains the hexachloroplatinate ion.

Draw a 3-D diagram to show the shape of a hexachloroplatinate ion.

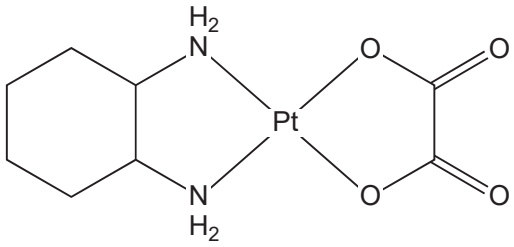
On your diagram, show

- the charge on the ion
- the value of the bond angle.

[3]

(e) Oxaliplatin is a neutral complex of platinum(II) used in cancer treatment.

A molecule of oxaliplatin has a square planar shape about the metal ion with two bidentate ligands. The structure of oxaliplatin is shown below.



(i) What is meant by a *bidentate ligand*? [2]

(ii) In the boxes below, show the structures of the two bidentate ligands in oxaliplatin.

[2]

[Total 21 Marks]

Nickel is a typical transition element in the d-block of the Periodic Table. Many nickel ions are able to interact with ligands to form complex ions, such as $[Ni(H_2O)_6]^{2+}$.

(a) Using the information about nickel above, explain the meaning of the terms *d-block element*, *transition element*, *ligand* and *complex ion*.

Include electron structures and diagrams in your answer. [7]

(b) A student dissolves nickel(II) sulfate in water. A green solution forms containing the complex ion $[Ni(H_2O)_6]^{2+}$.

The student then reacts separate portions of the green solution of nickel(II) sulfate as outlined below.

- Concentrated hydrochloric acid is added to the green solution of nickel(II) sulfate until there is no further change. The solution turns a lime-green colour and contains the four-coordinate complex ion **A**.
- Aqueous sodium hydroxide is added to the green solution of nickel(II) sulfate. A pale-green precipitate **B** forms.
- Concentrated aqueous ammonia is added to the green solution of nickel(II) sulfate until there is no further change. The solution turns a violet colour and contains the complex ion **C**.
  C has a molar mass of $160.7\,g\,mol^{-1}$.

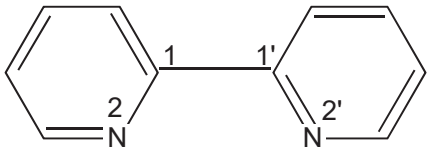
(i) Draw a 3-D diagram for the $[Ni(H_2O)_6]^{2+}$ ion.
Show a value for the bond angles on your diagram. [2]

(ii) Suggest the formulae of **A** and **B**. [2]

(iii) Deduce the formula of **C**. [1]

(iv) Write an equation for the formation of **C** from $[Ni(H_2O)_6]^{2+}$. [2]

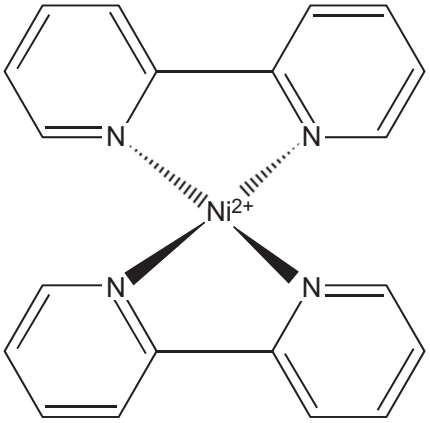
(c) 2,2'-Bipyridine (or 'bipy') is a bidentate ligand that forms complexes with many transition metals. The structure of 2,2'-bipyridine is shown below.



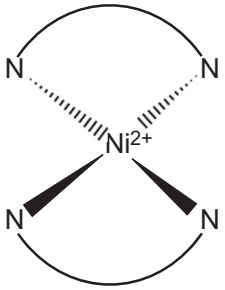
2,2'-bipyridine

In the naming of bipyridines, the numbering starts at the carbon atom that links to the other ring.

2,2'-Bipyridine forms a complex, $[Ni(bipy)_2]^{2+}$. The structure of $[Ni(bipy)_2]^{2+}$ is shown in **Fig 6.1** below.



structure



simplified diagram

$[Ni(bipy)_2]^{2+}$

Fig 6.1

(i) What is the molecular formula of 2,2'-bipyridine? [1]

(ii) What is the coordination number of the $[Ni(bipy)_2]^{2+}$ complex ion? [1]

(iii) 2,2'-Bipyridine forms a complex with the transition metal ruthenium with the formula $[Ru(bipy)_3]^{2+}$. This complex exists as two stereoisomers.

Draw 3-D diagrams to predict the structures for these stereoisomers of $[Ru(bipy)_3]^{2+}$. You can represent the 2,2'-bipyridine ligands as in the simplified diagram for $[Ni(bipy)_2]^{2+}$ in **Fig 6.1**.

[2]

(iv) 4,4'-Bipyridine (4,4'-bipy) can also form complexes with transition metal ions. Because of its structure, 4,4'-bipyridine can bridge between metal ions to form 'coordination polymers'. For example, nickel(II) can form a coordination polymer with 4,4'-bipyridine containing $\{[Ni(H_2O)_4(4,4'\text{-bipy})]^{2+}\}_n$ chains.

Draw a 3-D diagram to predict the repeat unit in this coordination polymer of nickel(II). Your diagram should show the complete structure of 4,4'-bipyridine and all coordinate bonds.

[3]

[Total 21 Marks]

Cobalt is a transition element. Solid compounds of cobalt are often complexes and in solution, complex ions are formed.

(a) In its complexes, the common oxidation numbers of cobalt are +2 and +3.

Complete the electron configurations of cobalt as the element and in the +3 oxidation state:

cobalt as the element: $1s^2\ 2s^2\ 2p^6$

cobalt in the +3 oxidation state: $1s^2\ 2s^2\ 2p^6$ [2]

(b) State **one** property of cobalt(II) and cobalt(III), other than their ability to form complex ions, which is typical of ions of a transition element. [1]

(c) Complex ions contain ligands.

State the meaning of the term *ligand*. [1]

(d) Aqueous cobalt(II) sulfate, $CoSO_4(aq)$, takes part in the following reactions.

For each reaction, state the formula of the transition element species formed and the type of reaction taking place.

(i) Aqueous cobalt(II) sulfate, $CoSO_4(aq)$, reacts with aqueous sodium hydroxide. [2]

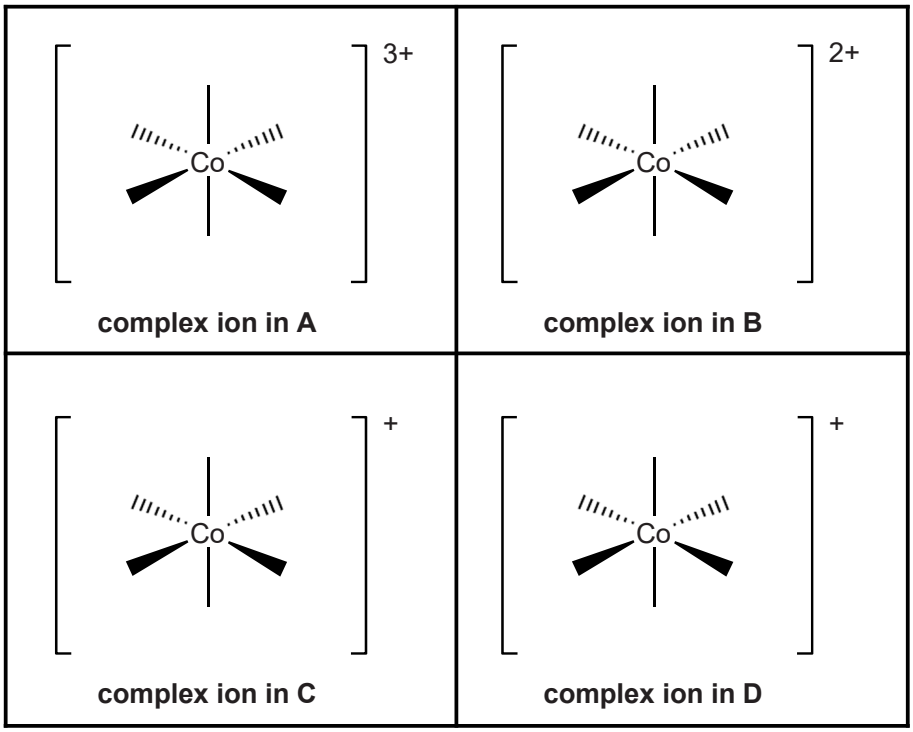
(ii) Aqueous cobalt(II) sulfate, $CoSO_4(aq)$, reacts with concentrated hydrochloric acid. [2]

(e) Cobalt(III) chloride, $CoCl_3$, reacts with ammonia to form a range of complexes. These complexes contain different amounts of ammonia. Information about these complexes is summarised below.

The complex ions **C** and **D** are stereoisomers.

complex	formula	formula of complex
A	$CoCl_3(NH_3)_6$	$[Co(NH_3)_6]^{3+}\ 3Cl^-$
B	$CoCl_3(NH_3)_5$	$[Co(NH_3)_5Cl]^{2+}\ 2Cl^-$
C	$CoCl_3(NH_3)_4$	$[Co(NH_3)_4Cl_2]^{+}\ Cl^-$
D	$CoCl_3(NH_3)_4$	$[Co(NH_3)_4Cl_2]^{+}\ Cl^-$

(i) Complete the diagrams below to suggest possible structures for the complex ion in complexes **A** to **D**.



[4]

(ii) Chemists provided evidence for the formulae of these complexes from their reactions with aqueous silver nitrate. Aqueous silver nitrate reacts with aqueous halide ions in a precipitation reaction.

An excess of silver nitrate solution was reacted with 0.0100 mol of one of the complexes **A** to **D**. 2.868 g of a precipitate was formed.

Determine which complex was reacted.

In your answer you should explain how the result of the experiment would allow the formula of the complex to be identified. [3]

[Total 15 Marks]