Transition Elements

Question Paper

Level	Pre U
Subject	Chemistry
Exam Board	Cambridge International Examinations
Topic	Transition elements- Inorganic Chemistry
Booklet	Question Paper

Time Allowed: **50 minutes**

Score: **/42**

Percentage: **/100**

Grade Boundaries:

1. The familiar light blue colour of copper(II) sulfate solution is due to the presence of the hexaaquacopper(II) ion, $[Cu(H_2O)_6]^{2+}(aq)$.

Equations for two different partial ligand substitution reactions of the hexaaquacopper(II) ion are shown. In the first of these equations 'en' represents diaminoethane, $H_2NCH_2CH_2NH_2$.

$$[Cu(H_2O)_6]^{2+}(aq) + en(aq) \rightarrow [Cu(en)(H_2O)_4]^{2+}(aq) + 2H_2O(l)$$

$$\Delta_r H^{\ominus} = -54\,kJ\,mol^{-1};$$

$$\Delta_r S^{\ominus} = +23\,J\,K^{-1}\,mol^{-1}$$

$$[Cu(H_2O)_6]^{2+}(aq) + 2NH_3(aq) \rightarrow [Cu(NH_3)_2(H_2O)_4]^{2+}(aq) + 2H_2O(l)$$

$$\Delta_r H^{\ominus} = -46\,kJ\,mol^{-1};$$

$$\Delta_r S^{\ominus} = -8.4\,J\,K^{-1}\,mol^{-1}$$

(a) Explain why the enthalpy changes, $\Delta_r H^{\ominus}$, of the two partial ligand substitution reactions shown are so similar.

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.....[2]

(b) Comment on the values of the entropy changes, $\Delta_r S^{\ominus}$, of the two partial ligand substitution reactions shown and explain why they are different.

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.....[2]

(c) The cation produced in the reaction with ammonia, NH_3, can exist as two different isomers.

(i) State the type of isomerism exhibited by this cation.

.....[1]

(ii) Draw and label the two different isomers of this cation.

[2]

(d) Further ligand substitution leads to the production of the complex ion $[Cu(en)_3]^{2+}$, which also exhibits isomerism.

(i) State the type of isomerism exhibited by $[Cu(en)_3]^{2+}$.

.....[1]

(ii) Draw 3-D representations of the two isomers of $[Cu(en)_3]^{2+}$.

[2]

[Total: 10]

2. In most metals the atoms pack in one of three possible ways. One of these is called *body-centred cubic (bcc)*, in which there is 32% empty space between the atoms. In the other two common metal structures there is only 26% empty space, so these structures are described as *close-packed*.

(a) Give the coordination number of a metal atom in a *close-packed* metal structure.

..... [1]

(b) Complete the table to give the names and layer structures of the two close-packed metal structures.

name	layer structure

[4]

(c) Explain the differences between the lattice structures of sodium chloride, NaC*l*, and calcium fluoride, CaF_2, by completing the following sentences.

(i) NaC*l* can be considered to consist of a close-packed structure of sodium ions with chloride ions occupying the ..... holes. [1]

(ii) CaF_2 can be considered to consist of a close-packed lattice of ..... ions with ..... ions occupying the ..... holes. [2]

(d) Table 4.1 gives the electronegativities of sodium, silver and the halogens.

Table 4.1

element	sodium	silver	fluorine	chlorine	bromine	iodine
electronegativity	0.87	1.87	4.19	2.87	2.69	2.36

Table 4.2 gives the theoretical (from the Born-Landé equation) and experimental (from a Born-Haber cycle) lattice energies for the sodium and silver halides.

Table 4.2

compound	experimental lattice energy / kJ mol^{-1}	theoretical lattice energy / kJ mol^{-1}
NaF	918	912
NaCl	780	770
NaBr	742	735
NaI	705	687
AgF	958	920
AgCl	905	833
AgBr	891	816
AgI	889	778

(i) Use the data in Table 4.1 to explain why there is generally good agreement between the experimental and theoretical values of the lattice energies for the sodium halides.

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..... [2]

(ii) Identify and explain the trend that is evident in the magnitudes of the differences between the experimental and theoretical values of the lattice energies for the silver halides.

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..... [3]

(e) Restless Legs Syndrome (RLS), also known as Wittmaack-Ekbom's syndrome, is a condition characterised by an uncontrollable urge to move one's legs to alleviate odd or uncomfortable sensations. The condition is not well understood but one possible cause is thought to be low iron levels in the body. Conversely, if iron levels are too high then this can also cause problems as free iron readily produces insoluble compounds and either iron(II) or iron(III) can catalyse the Fenton reaction, which leads to cell damage and eventually cell death.

(i) What is the name of the iron-containing protein found in red-blood cells?

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(ii) What role does ferritin play in preventing the problems associated with high or low levels of iron?

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..... [2]

(f) With reference to the data in equations 4.1 and 4.2 explain why solutions of iron(II) compounds in the laboratory are normally made up and stored in the presence of acid.

equation 4.1 $Fe(OH)_3(s) + e^- \longrightarrow Fe(OH)_2(s) + OH^-(aq)$ $\quad E^{\ominus} = -0.56\,V$

equation 4.2 $Fe^{3+}(aq) + e^- \longrightarrow Fe^{2+}(aq)$ $\quad E^{\ominus} = +0.77\,V$

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..... [3]

[Total: 19]

3. The complex compound diamminedichloroplatinum(II) has two isomeric forms, one of which can be prepared from potassium tetrachloroplatinate(II) as shown in the reaction sequence in Fig. 4.1.

$K_2[PtCl_4] \longrightarrow K_2[PtI_4] \longrightarrow \mathbf{X} \longrightarrow [Pt(H_2O)_2(NH_3)_2](NO_3)_2 \longrightarrow$ diamminedichloroplatinum(II)

Fig. 4.1

Compound **X** has the composition by mass Pt 40.37%, I 52.59%, N 5.80% and H 1.24% and a relative molecular mass of 483.

(a) Calculate the molecular formula of **X**, draw its two possible structures and indicate the ligand-platinum-ligand bond angle.

[6]

(b) Cobalt forms both octahedral and tetrahedral complexes. Give the identities of one complex ion of cobalt with each shape and, in each case, state the ligand-cobalt-ligand bond angle.

octahedral	tetrahedral
bond angle	bond angle ..... [3]

(c) With reference to the **3-D orientation** of d orbitals in an octahedral transition metal complex explain why such complexes are usually coloured.

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.....[4]

[Total: 13]