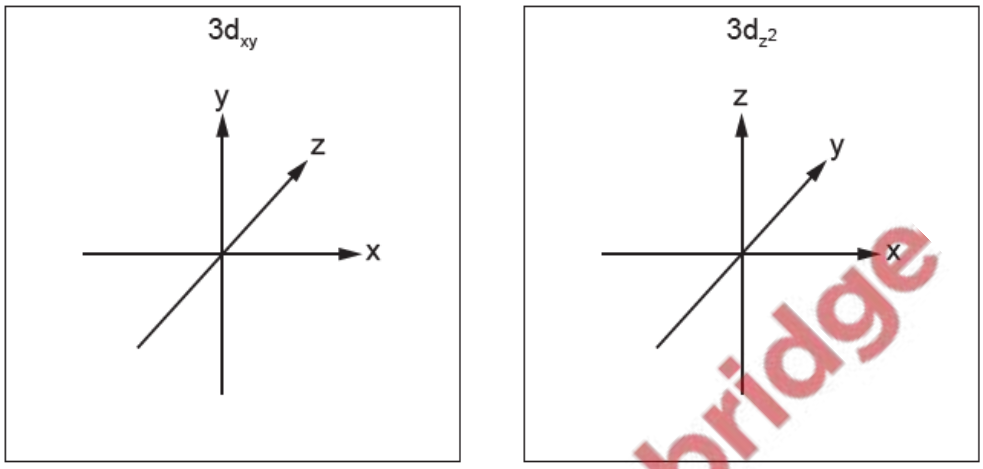
Chemistry of Transition elements - 2022 Nov A2 Chemistry 9701

1. Nov/2022/Paper_41/No.5

A transition element is a d-block element which forms one or more stable ions with incomplete d-orbitals.

(a) Two of the 3d orbitals are the $3d_{xy}$ orbital and the $3d_{z^2}$ orbital.

Sketch the shapes of these two orbitals.



[1]

(b) The Ni^{2+} ion forms many different complexes. A solution containing the $[Ni(H_2O)_6]^{2+}$ complex ion is green. When an excess of 1,2-diaminoethane, *en*, $H_2NCH_2CH_2NH_2$, is added, the colour of the solution changes to blue. This is due to the formation of the $[Ni(en)_3]^{2+}$ complex ion.

(i) Explain why the two solutions are coloured, and why the colours are different.

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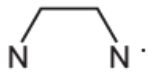
.....

..... [4]

(ii) The $[Ni(en)_3]^{2+}$ complex can exist as a mixture of two stereoisomers.

Complete the three-dimensional diagram to show one of the stereoisomers.

Each *en* ligand can be represented using 

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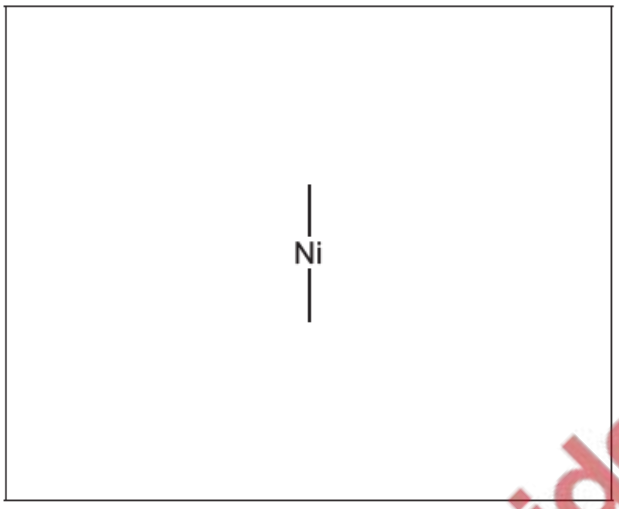

[1]

(iii) Name the geometry of the complex ion drawn in **(b)(ii)** and the type of stereoisomerism shown by $[Ni(en)_3]^{2+}$.

geometry .....

stereoisomerism shown .....

[1]

(c) Iron(II) carbonate, $FeCO_3$, and nickel(II) carbonate, $NiCO_3$, both decompose when heated.

$FeCO_3$ decomposes at a lower temperature than $NiCO_3$.

Suggest a possible reason for this difference. Explain your answer.

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.....

..... [2]

(d) **A** is a pale green salt containing Fe^{2+} ions. A sample of 2.62 g of **A** is dissolved in water and the solution is made up to exactly 100 cm^3 with water. 25.0 cm^3 samples of this solution are placed in conical flasks and titrated against 0.0100 mol dm^{-3} acidified potassium manganate(VII).

The equation for the only reaction that occurs is shown.

$$5Fe^{2+} + MnO_4^- + 8H^+ \rightarrow 5Fe^{3+} + Mn^{2+} + 4H_2O$$

The average titre value is 35.0 cm^3 of 0.0100 mol dm^{-3} acidified potassium manganate(VII).

(i) Describe the colour change that is seen in the conical flask at the end-point of this titration.

The colour changes from ..... to ..... . [1]

(ii) Calculate the percentage by mass of iron in **A**.

[A_r: Fe, 55.8]

percentage by mass of iron = ... % [2]

[Total: 12]

2. Nov/2022/Paper_41/No.6

An aqueous solution of copper(II) sulfate is a blue colour due to the presence of $[Cu(H_2O)_6]^{2+}$ complex ions.

(a) (i) Write an equation for the reaction between $[Cu(H_2O)_6]^{2+}$ ions and NaOH(aq).

..... [1]

(ii) Write an equation for the reaction between $[Cu(H_2O)_6]^{2+}$ ions and an excess of conc. HCl.

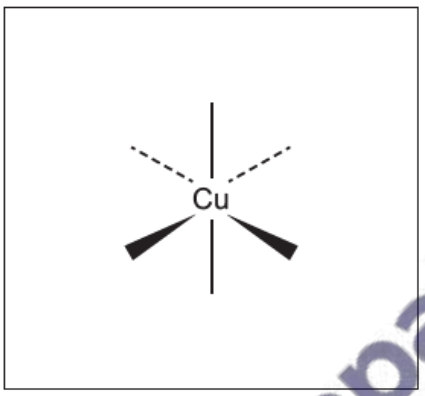
..... [1]

(b) If an excess of ammonia is added to a solution of $[Cu(H_2O)_6]^{2+}$ a deep blue solution containing $[Cu(NH_3)_4(H_2O)_2]^{2+}$ complex ions is formed.

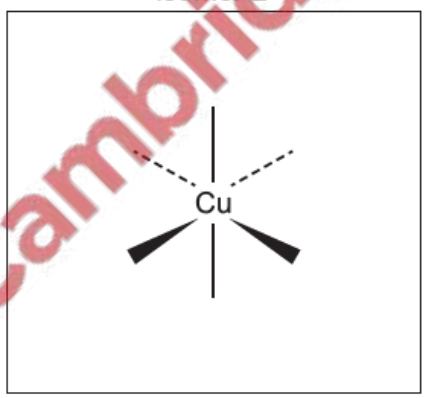
(i) There are two possible stereoisomers with the formula $[Cu(NH_3)_4(H_2O)_2]^{2+}$.

Complete the diagrams to show the two stereoisomers in the boxes below.

isomer 1



isomer 2



[1]

(ii) Use your answer in **(b)(i)** to deduce whether each of these isomers is polar or non-polar.

polarity of isomer 1 .....

polarity of isomer 2 .....

[1]

(c) The numerical value of the stability constant, K_{stab}, of the $[Cu(NH_3)_4(H_2O)_2]^{2+}$ complex ion is 1.40×10^{13}.

(i) Define stability constant.

.....

..... [1]

(ii) Compare the stabilities of the $[Cu(H_2O)_6]^{2+}$ and $[Cu(NH_3)_4(H_2O)_2]^{2+}$ complex ions. Explain your answer.

.....

..... [1]

(iii) Write an expression for the stability constant, K_{stab}, of the $[Cu(NH_3)_4(H_2O)_2]^{2+}$ complex ion. State the units of the stability constant.

K_{stab} =

units = ...
[2]

(iv) In a particular solution the concentration of the $[Cu(NH_3)_4(H_2O)_2]^{2+}$ complex ion is 0.0074 mol dm^{-3} and the concentration of NH_3 is 0.57 mol dm^{-3}.

Use your expression in **(c)(iii)** and the K_{stab} value of 1.40×10^{13} to calculate the concentration of the $[Cu(H_2O)_6]^{2+}$ complex ion in this solution.

concentration of $[Cu(H_2O)_6]^{2+}$ = ... mol dm^{-3} [1]

(d) Phenanthroline, $C_{12}H_8N_2$, and ethanedioate ions, $C_2O_4^{2-}$, are bidentate ligands.

Ruthenium(III) ions, Ru^{3+}, form an octahedral complex with phenanthroline and chloride ions. The complex ion contains two phenanthroline molecules.

Iron(III) ions, Fe^{3+}, form an octahedral complex with ethanedioate ions only.

Deduce the formula and charge of each of these complex ions.

Ru^{3+} complex .....

Fe^{3+} complex .....
[2]

[Total: 11]

3. Nov/2022/Paper_42/No.5

Copper is a transition element. It forms a wide variety of compounds.

(a) Define transition element.

.....

..... [1]

(b) An aqueous solution of copper(II) sulfate, $CuSO_4$, contains $[Cu(H_2O)_6]^{2+}$ complex ions. If an excess of concentrated hydrochloric acid is added to this solution a ligand exchange reaction occurs and $[CuCl_4]^{2-}$ complex ions are formed.

(i) Complete Table 5.1 to state the geometry, the coordination number of copper, and one bond angle in each of the two complex ions.

Table 5.1

complex ion	geometry	coordination number	bond angle
$[Cu(H_2O)_6]^{2+}$			
$[CuCl_4]^{2-}$			

[3]

(ii) In an isolated Cu^{2+} ion the d-orbitals are all degenerate. In a complex ion such as $[Cu(H_2O)_6]^{2+}$ the d-orbitals are non-degenerate.

Define degenerate and non-degenerate in this context.

degenerate .....

non-degenerate .....

[1]

(iii) Explain why the solutions of the two complex ions in Table 5.1 are **different** colours.

.....

..... [1]

(c) Cu^{2+} forms a complex ion containing water molecules and ethanedioate ions, $C_2O_4^{2-}$, as ligands. The formula of the complex is $[Cu(C_2O_4)_2(H_2O)_2]^{2-}$. The ethanedioate ion is a bidentate ligand.

(i) Explain what is meant by bidentate.

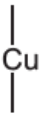
.....

..... [1]

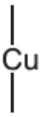
(ii) There are three stereoisomers with the formula $[Cu(C_2O_4)_2(H_2O)_2]^{2-}$.

Complete the three-dimensional diagrams to show these three stereoisomers.

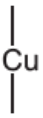
stereoisomer 1



stereoisomer 2



stereoisomer 3



[2]

(iii) Use your answer to **(c)(ii)** to answer this question.

Stereoisomers 1, 2 and 3 show two different types of isomerism.

Name these two types of isomerism.

For each type of isomerism identify the pair of stereoisomers that demonstrate this isomerism.

type of isomerism	pair of stereoisomers
	and
	and

[2]

(d) A solution contains 3.70 g of $Na_2[Cu(C_2O_4)_2(H_2O)_2]$ dissolved in 100 cm^3 of solution. A 25.0 cm^3 sample of this solution is warmed and then oxidised by 0.0100 mol dm^{-3} acidified potassium manganate(VII).

The equation for the redox reaction is shown.

$$5C_2O_4^{2-} + 2MnO_4^- + 16H^+ \rightarrow 10CO_2 + 2Mn^{2+} + 8H_2O$$

Calculate the minimum volume of 0.0100 mol dm^{-3} acidified potassium manganate(VII) needed to oxidise all of the ethanedioate ions, $C_2O_4^{2-}$, in the 25.0 cm^3 sample. Show all your working.

[M_r: $Na_2[Cu(C_2O_4)_2(H_2O)_2]$, 321.5]

minimum volume = ... cm^3 [3]

(e) Copper(II) nitrate, $Cu(NO_3)_2$, and barium nitrate, $Ba(NO_3)_2$, both decompose when heated.

Copper(II) nitrate decomposes at a lower temperature than barium nitrate.

Suggest a reason for this difference. Explain your answer.

.....

.....

.....

..... [2]

[Total: 16]

4. Nov/2022/Paper_42/No.6

An aqueous solution of cobalt(II) chloride is a pink colour due to the presence of $[Co(H_2O)_6]^{2+}$ complex ions.

(a) (i) Complete Table 6.1 to describe what is observed when the named reagent is added to an aqueous solution of cobalt(II) chloride.

Table 6.1

reagent	colour of cobalt-containing product	state of cobalt-containing product
NaOH(aq)		
an excess of conc. HC*l*		

[2]

(ii) Write an equation for the reaction between $[Co(H_2O)_6]^{2+}$ ions and NaOH(aq).

..... [1]

(iii) Write an equation for the reaction between $[Co(H_2O)_6]^{2+}$ ions and an excess of conc. HC*l*.

..... [1]

(b) (i) Define stability constant.

.....

..... [1]

(ii) Write an expression for the stability constant, K_{stab}, of the $[Co(NH_3)_6]^{2+}$ complex ion.

K_{stab} =

[1]

(iii) Give the units of the stability constant, K_{stab}, of the $[Co(NH_3)_6]^{2+}$ complex ion.

units = ... [1]

(iv) The numerical value of the stability constant, K_{stab}, of the $[Co(NH_3)_6]^{2+}$ complex ion is 7.7×10^4.

In an aqueous solution the concentration of the $[Co(NH_3)_6]^{2+}$ complex ion is $0.0740\,mol\,dm^{-3}$ and the concentration of NH_3 is $0.480\,mol\,dm^{-3}$ at equilibrium.

Calculate the concentration of $[Co(H_2O)_6]^{2+}$ in this solution.

concentration = ... $mol\,dm^{-3}$ [1]

[Total: 8]