Chemistry of Transition elements - 2022 June A2 Chemistry 9701

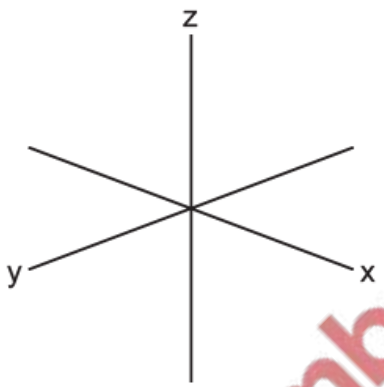
1. June/2022/Paper_41/No.2(a, b)

(a) Define transition element.

.....

..... [1]

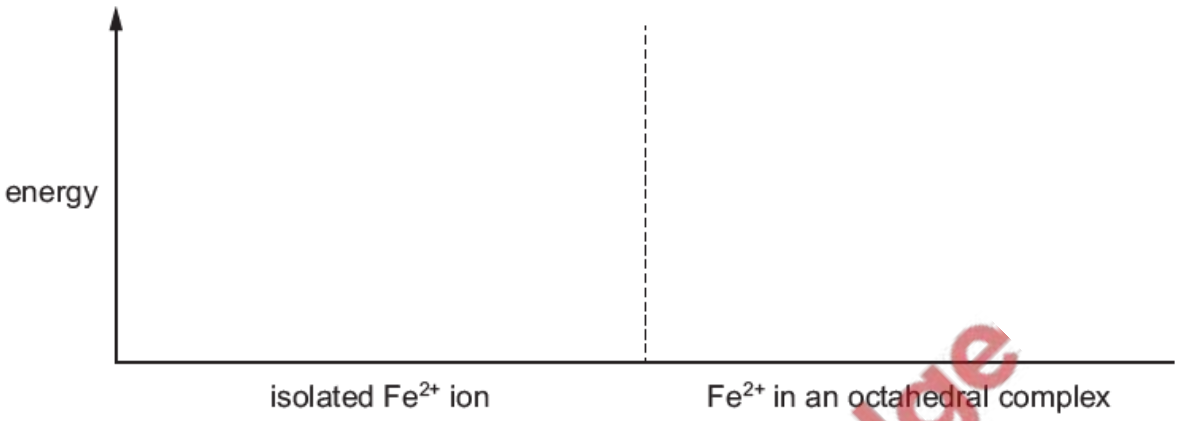
(b) Sketch the shape of a $3d_{z^2}$ orbital.



[1]

(a) The 3d orbitals in an isolated Fe^{2+} ion are degenerate.

Complete the diagram to show the splitting of the 3d orbital energy levels in an isolated Fe^{2+} ion and when Fe^{2+} forms an octahedral complex.



[2]

(b) (i) Bipyridine, bipy, is a bidentate ligand.

bipy

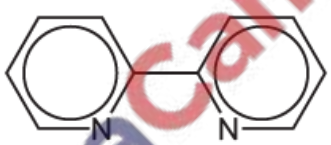


Fig. 4.1

Explain what is meant by bidentate ligand.

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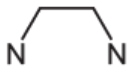
.....

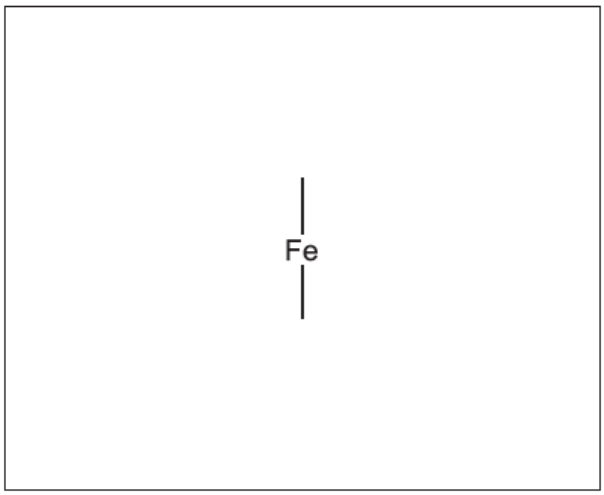
..... [2]

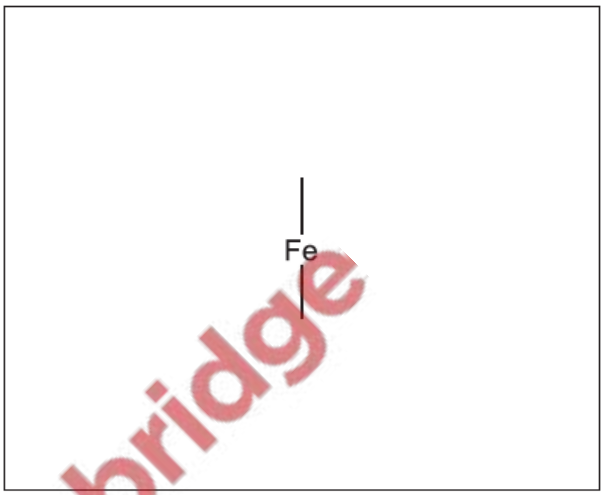
(ii) The complex $[Fe(bipy)_3]^{2+}$ exists as two stereoisomers.

Complete the three-dimensional diagrams to show the two stereoisomers of $[Fe(bipy)_3]^{2+}$.

State the type of stereoisomerism shown.

Use  to represent bipy in your diagrams.





type of stereoisomerism .....

[3]

(c) Standard electrode potentials can be used to compare the stability of different complex ions for a given transition element.

Table 4.1 lists electrode potentials for some electrode reactions for Fe^{3+}/Fe^{2+} systems.

Table 4.1

electrode reaction	$E^{\ominus}$/V
$[Fe(H_2O)_6]^{3+} + e^- \rightleftharpoons [Fe(H_2O)_6]^{2+}$	+0.77
$[Fe(CN)_6]^{3-} + e^- \rightleftharpoons [Fe(CN)_6]^{4-}$	+0.36
$[Fe(bipy)_3]^{3+} + e^- \rightleftharpoons [Fe(bipy)_3]^{2+}$	+0.96

Use relevant data from Table 4.1 to state which iron(III) complex is hardest to reduce. Explain your choice.

iron(III) complex .....

explanation .....

.....

[1]

3. June/2022/Paper_42/No.1(c _ e)

(c) $Be(OH)_2$ is soluble in aqueous solutions containing an excess of hydroxide ions and forms the complex ion $[Be(OH)_4]^{2-}$. This complex ion has a similar shape to that of $[CuCl_4]^{2-}$.

(i) Define the term complex ion.

.....

..... [1]

(ii) Draw a three-dimensional diagram to show the structure of the complex ion $[Be(OH)_4]^{2-}$. Name the shape of the $[Be(OH)_4]^{2-}$ complex ion.

(d) (i) Explain why transition elements can form complex ions.

.....

..... [1]

(ii) Complete Table 1.1 to show the coordination number of each metal ion, and the shapes and overall polarities of the complex ions listed.

Table 1.1

complex ion	shape	coordination number	polar or non-polar
cis-$[Pt(H_2NCH_2CH_2NH_2)Cl_2]$	square planar		
$[Ag(NH_3)_2]^+$			non-polar
$[Fe(C_2O_4)_3]^{3-}$		6	

[2]

(e) (i) Define stability constant, K_{stab}.

.....

..... [1]

(ii) Nickel can form complexes with the ligands *en*, $H_2NCH_2CH_2NH_2$, and *tn*, $H_2NCH_2CH_2CH_2NH_2$, as shown.

equilibrium **1** $[Ni(H_2O)_6]^{2+} + 3en \rightleftharpoons [Ni(en)_3]^{2+} + 6H_2O \quad K_{stab} = 6.76 \times 10^{17}$

equilibrium **2** $[Ni(H_2O)_6]^{2+} + 3tn \rightleftharpoons [Ni(tn)_3]^{2+} + 6H_2O \quad K_{stab} = 1.86 \times 10^{12}$

Construct an expression for the stability constant, K_{stab}, for equilibrium **1**.
State the units for K_{stab}.

K_{stab} =

units = ...
[2]

(iii) Describe what the K_{stab} values indicate about the position of equilibrium for equilibrium **1** and **2**. Use the K_{stab} values to deduce which complex, $[Ni(en)_3]^{2+}$ or $[Ni(tn)_3]^{2+}$, is more stable.

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..... [1]

4. June/2022/Paper_42/No.2

(a) Explain why transition elements have variable oxidation states.

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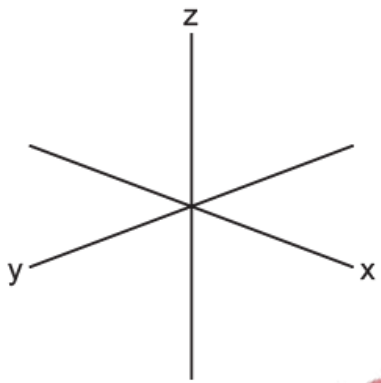
..... [1]

(b) Sketch the shape of a $3d_{xy}$ orbital.



[1]

(c) Explain why transition elements form coloured compounds.

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..... [3]

(d) Aqueous solutions of copper(II) salts contain $[Cu(H_2O)_6]^{2+}$ ions.

Equilibrium **3** and equilibrium **4** show two reactions of these ions.

equilibrium **3** $[Cu(H_2O)_6]^{2+}(aq) + 2OH^-(aq) \rightleftharpoons Cu(OH)_2(s) + 6H_2O(l)$

equilibrium **4** $[Cu(H_2O)_6]^{2+}(aq) + 4NH_3(aq) \rightleftharpoons [Cu(NH_3)_4(H_2O)_2]^{2+}(aq) + 4H_2O(l)$

(i) State the colour of $Cu(OH)_2(s)$ and $[Cu(NH_3)_4(H_2O)_2]^{2+}(aq)$.

colour of $Cu(OH)_2(s)$ .....

colour of $[Cu(NH_3)_4(H_2O)_2]^{2+}(aq)$ .....

[1]

(ii) Use Le Chatelier's principle to explain why a precipitate is formed when NaOH(aq) is added dropwise to $[Cu(H_2O)_6]^{2+}(aq)$.

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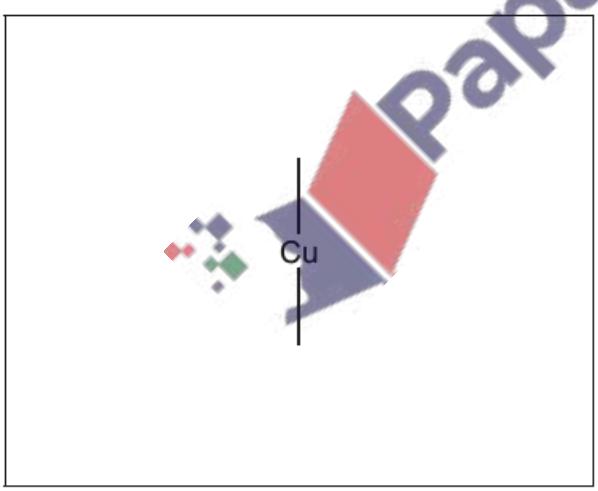
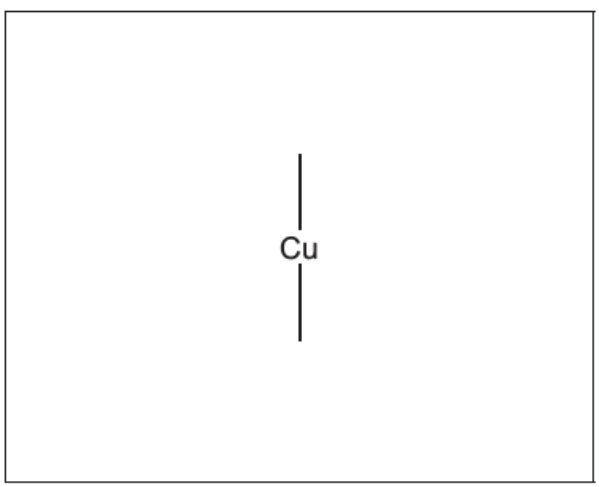
..... [1]

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

Draw three-dimensional diagrams to show the two stereoisomers.





[2]

[Total: 9]