28. Chemistry of transition elements

28.3 Colour of complexes

Paper 4

Question Paper

1 **(b)** The 3d orbitals in an isolated Ag^+ ion are degenerate.

(i) Define degenerate d orbitals.

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.... [1]

(ii) Sketch the shape of a $3d_{xy}$ orbital in Fig. 2.1.

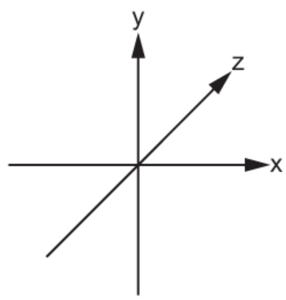

Fig. 2.1

[1]

2 **(c)** Potassium iron(III) ethanedioate, $K_3[Fe(C_2O_4)_3]$, dissolves in water to form a green solution.

Explain why transition elements can form coloured complexes.

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.... [3]

3 **(c)** Solutions containing the $[Ag(NH_3)_2]^+$ complex are colourless.

Explain why this complex is colourless.

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.... [2]

4 **(f)** A solution of Cr^{3+}(aq) and a solution of Fe^{3+}(aq) have different colours.

Explain why the two complexes have different colours.

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.... [2]

5 The structure of the polydentate ligand, $EDTA^{4-}$, is shown in Fig. 4.1.

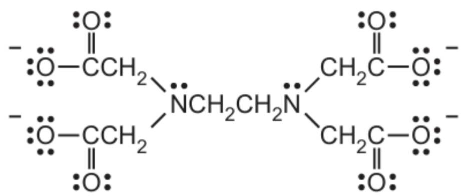

Fig. 4.1

The stability constants, at 298 K, of five octahedral complexes are given in Table 4.1.

Table 4.1

complex	K_{stab}
$[Cu(EDTA)]^{2-}$	6.31×10^{19}
$[Cr(EDTA)]^{2-}$	1.00×10^{13}
$[Cr(EDTA)]^{-}$	1.00×10^{24}
$[Fe(EDTA)]^{2-}$	2.00×10^{14}
$[Fe(EDTA)]^{-}$	1.26×10^{25}

(f) A solution of $[Cu(EDTA)]^{2-}$ ions is pale blue while a solution of $[Cu(NH_3)_4(H_2O)_2]^{2+}$ ions is deep blue.

Explain this difference in colour.

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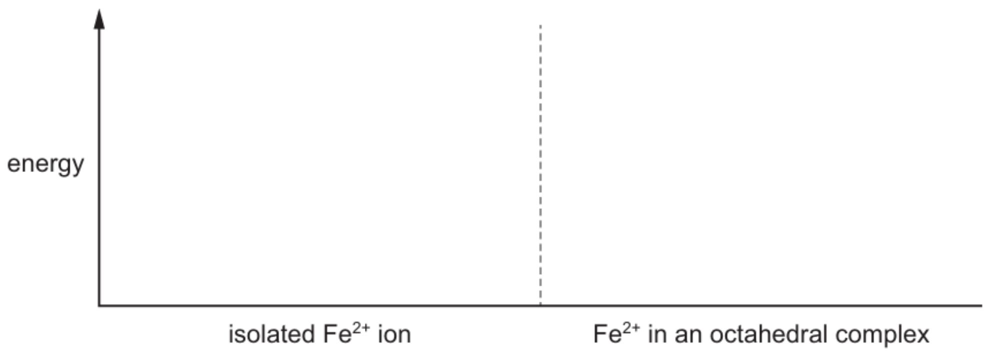
.... [2]

6 **(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]

7 **(c)** Explain why transition elements form coloured compounds.

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.... [3]

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

(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]

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

(a) Define transition element.

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.... [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.

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.... [1]

10 **(c)** $[Cr(H_2O)_6]^{2+}$ and $[Cr_2(O_2CCH_3)_4(H_2O)_2]$ are both complexes of chromium(II) and have different colours.

Explain why the colours of these complexes are different.

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.... [2]

11 An excess of sodium iodide is added to a solution of copper(II) sulfate. Iodine and a white precipitate of copper(I) iodide are formed.

(b) **(i)** Explain why the copper(II) sulfate solution is coloured.

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.... [4]

(ii) Suggest why the precipitate of copper(I) iodide is white.

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.... [1]

12 **(a)** Complete the electronic configuration of an isolated gaseous nickel(II) ion, Ni^{2+}.

	3d						4s
[Ar]	⇅						

[1]

(b) Explain the origin of colour in transition element complexes.

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.... [4]

13 A solution is made by dissolving $CuSO_4{\bullet}5H_2O$ in an excess of aqueous ammonia. This solution contains the copper complex $[Cu(NH_3)_4]^{2+}$.

(a) **(i)** Write an expression for the K_{stab} of $[Cu(NH_3)_4]^{2+}$.

K_{stab} =

[1]

(ii) State the colour of the solution of $[Cu(NH_3)_4]^{2+}$.

.... [1]

(e) Explain why complexes **Y** and **Z** are coloured and why their colours are different.

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.... [5]

14 **(c)** Cobalt(II) sulfate is added to water to form a pink solution containing complex ion **P**. An excess of concentrated hydrochloric acid is added to this solution to form a blue solution containing complex ion **Q**.

(iii) Explain why solutions that contain transition element ions are often coloured.

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.... [4]

(iv) Explain why the colours of **P** and **Q** are different.

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.... [2]

15 **(a)** **(i)** Complete the electronic configuration of the copper(II) ion.

$1s^2 2s^2 2p^6$ .... [1]

(ii) State the colour of the solutions containing the following ions.

- $[Cu(H_2O)_6]^{2+}(aq)$ ....
- $[CuCl_4]^{2-}(aq)$ ....

[1]

(iii) Octahedral complexes of Cu^{2+} with different ligands can have different colours.

Explain why.

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.... [2]

16 Many copper compounds, such as $CuSO_4$ and $Cu(NO_3)_2$ contain Cu^{2+} ions. Aqueous solutions of this ion contain the $[Cu(H_2O)_6]^{2+}$ complex ion, in which water behaves as a monodentate ligand.

(c) When water is added to concentrated aqueous cobalt(II) chloride the colour of the solution changes from blue to pink. Explain this observation.

No equation is needed, but you should include reference to electron movement between orbitals in your answer.

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.... [3]