

Unit

9

COORDINATION COMPOUNDS

I. Multiple Choice Questions (Type-I)

- Which of the following complexes formed by Cu^{2+} ions is most stable?
 - $\text{Cu}^{2+} + 4\text{NH}_3 \rightleftharpoons [\text{Cu}(\text{NH}_3)_4]^{2+}$, $\log K = 11.6$
 - $\text{Cu}^{2+} + 4\text{CN}^- \rightleftharpoons [\text{Cu}(\text{CN})_4]^{2-}$, $\log K = 27.3$
 - $\text{Cu}^{2+} + 2\text{en} \rightleftharpoons [\text{Cu}(\text{en})_2]^{2+}$, $\log K = 15.4$
 - $\text{Cu}^{2+} + 4\text{H}_2\text{O} \rightleftharpoons [\text{Cu}(\text{H}_2\text{O})_4]^{2+}$, $\log K = 8.9$
- The colour of the coordination compounds depends on the crystal field splitting. What will be the correct order of absorption of wavelength of light in the visible region, for the complexes, $[\text{Co}(\text{NH}_3)_6]^{3+}$, $[\text{Co}(\text{CN})_6]^{3-}$, $[\text{Co}(\text{H}_2\text{O})_6]^{3+}$
 - $[\text{Co}(\text{CN})_6]^{3-} > [\text{Co}(\text{NH}_3)_6]^{3+} > [\text{Co}(\text{H}_2\text{O})_6]^{3+}$
 - $[\text{Co}(\text{NH}_3)_6]^{3+} > [\text{Co}(\text{H}_2\text{O})_6]^{3+} > [\text{Co}(\text{CN})_6]^{3-}$
 - $[\text{Co}(\text{H}_2\text{O})_6]^{3+} > [\text{Co}(\text{NH}_3)_6]^{3+} > [\text{Co}(\text{CN})_6]^{3-}$
 - $[\text{Co}(\text{CN})_6]^{3-} > [\text{Co}(\text{NH}_3)_6]^{3+} > [\text{Co}(\text{H}_2\text{O})_6]^{3+}$
- When 0.1 mol $\text{CoCl}_3(\text{NH}_3)_5$ is treated with excess of AgNO_3 , 0.2 mol of AgCl are obtained. The conductivity of solution will correspond to
 - 1:3 electrolyte
 - 1:2 electrolyte
 - 1:1 electrolyte
 - 3:1 electrolyte

4. When 1 mol $\text{CrCl}_3 \cdot 6\text{H}_2\text{O}$ is treated with excess of AgNO_3 , 3 mol of AgCl are obtained. The formula of the complex is :
- $[\text{CrCl}_3(\text{H}_2\text{O})_3] \cdot 3\text{H}_2\text{O}$
 - $[\text{CrCl}_2(\text{H}_2\text{O})_4]\text{Cl} \cdot 2\text{H}_2\text{O}$
 - $[\text{CrCl}(\text{H}_2\text{O})_5]\text{Cl}_2 \cdot \text{H}_2\text{O}$
 - $[\text{Cr}(\text{H}_2\text{O})_6]\text{Cl}_3$
5. The correct IUPAC name of $[\text{Pt}(\text{NH}_3)_2\text{Cl}_2]$ is
- Diamminedichloridoplatinum (II)
 - Diamminedichloridoplatinum (IV)
 - Diamminedichloridoplatinum (0)
 - Dichloridodiammineplatinum (IV)
6. The stabilisation of coordination compounds due to chelation is called the chelate effect. Which of the following is the most stable complex species?
- $[\text{Fe}(\text{CO})_5]$
 - $[\text{Fe}(\text{CN})_6]^{3-}$
 - $[\text{Fe}(\text{C}_2\text{O}_4)_3]^{3-}$
 - $[\text{Fe}(\text{H}_2\text{O})_6]^{3+}$
7. Indicate the complex ion which shows geometrical isomerism.
- $[\text{Cr}(\text{H}_2\text{O})_4\text{Cl}_2]^+$
 - $[\text{Pt}(\text{NH}_3)_3\text{Cl}]$
 - $[\text{Co}(\text{NH}_3)_6]^{3+}$
 - $[\text{Co}(\text{CN})_5(\text{NC})]^{3-}$
8. The CFSE for octahedral $[\text{CoCl}_6]^{4-}$ is $18,000 \text{ cm}^{-1}$. The CFSE for tetrahedral $[\text{CoCl}_4]^{2-}$ will be
- $18,000 \text{ cm}^{-1}$
 - $16,000 \text{ cm}^{-1}$
 - $8,000 \text{ cm}^{-1}$
 - $20,000 \text{ cm}^{-1}$
9. Due to the presence of ambidentate ligands coordination compounds show isomerism. Palladium complexes of the type $[\text{Pd}(\text{C}_6\text{H}_5)_2(\text{SCN})_2]$ and $[\text{Pd}(\text{C}_6\text{H}_5)_2(\text{NCS})_2]$ are
- linkage isomers
 - coordination isomers
 - ionisation isomers
 - geometrical isomers
10. The compounds $[\text{Co}(\text{SO}_4)(\text{NH}_3)_5]\text{Br}$ and $[\text{Co}(\text{SO}_4)(\text{NH}_3)_5]\text{Cl}$ represent
- linkage isomerism
 - ionisation isomerism

- (iii) coordination isomerism
 - (iv) no isomerism
- 11.** A chelating agent has two or more than two donor atoms to bind to a single metal ion. Which of the following is **not** a chelating agent?
- (i) thiosulphato
 - (ii) oxalato
 - (iii) glycinato
 - (iv) ethane-1,2-diamine
- 12.** Which of the following species is **not** expected to be a ligand?
- (i) NO
 - (ii) NH_4^+
 - (iii) $\text{NH}_2\text{CH}_2\text{CH}_2\text{NH}_2$
 - (iv) CO
- 13.** What kind of isomerism exists between $[\text{Cr}(\text{H}_2\text{O})_6]\text{Cl}_3$ (violet) and $[\text{Cr}(\text{H}_2\text{O})_5\text{Cl}]\text{Cl}_2 \cdot \text{H}_2\text{O}$ (greyish-green)?
- (i) linkage isomerism
 - (ii) solvate isomerism
 - (iii) ionisation isomerism
 - (iv) coordination isomerism
- 14.** IUPAC name of $[\text{Pt}(\text{NH}_3)_2\text{Cl}(\text{NO}_2)]$ is :
- (i) Platinum diaminechloronitrite
 - (ii) Chloronitrito-N-ammineplatinum (II)
 - (iii) Diamminechloridonitrito-N-platinum (II)
 - (iv) Diamminechloronitrito-N-platinate (II)

II. Multiple Choice Questions (Type-II)

Note : In the following questions two or more options may be correct.

- 15.** Atomic number of Mn, Fe and Co are 25, 26 and 27 respectively. Which of the following inner orbital octahedral complex ions are diamagnetic?
- (i) $[\text{Co}(\text{NH}_3)_6]^{3+}$
 - (ii) $[\text{Mn}(\text{CN})_6]^{3-}$
 - (iii) $[\text{Fe}(\text{CN})_6]^{4-}$
 - (iv) $[\text{Fe}(\text{CN})_6]^{3-}$
- 16.** Atomic number of Mn, Fe, Co and Ni are 25, 26, 27 and 28 respectively. Which of the following outer orbital octahedral complexes have same number of unpaired electrons?

- (i) $[\text{MnCl}_6]^{3-}$
- (ii) $[\text{FeF}_6]^{3-}$
- (iii) $[\text{CoF}_6]^{3-}$
- (iv) $[\text{Ni}(\text{NH}_3)_6]^{2+}$

17. Which of the following options are correct for $[\text{Fe}(\text{CN})_6]^{3-}$ complex?

- (i) d^2sp^3 hybridisation
- (ii) sp^3d^2 hybridisation
- (iii) paramagnetic
- (iv) diamagnetic

18. An aqueous pink solution of cobalt(II) chloride changes to deep blue on addition of excess of HCl. This is because _____.

- (i) $[\text{Co}(\text{H}_2\text{O})_6]^{2+}$ is transformed into $[\text{CoCl}_6]^{4-}$
- (ii) $[\text{Co}(\text{H}_2\text{O})_6]^{2+}$ is transformed into $[\text{CoCl}_4]^{2-}$
- (iii) tetrahedral complexes have smaller crystal field splitting than octahedral complexes.
- (iv) tetrahedral complexes have larger crystal field splitting than octahedral complex.

19. Which of the following complexes are homoleptic?

- (i) $[\text{Co}(\text{NH}_3)_6]^{3+}$
- (ii) $[\text{Co}(\text{NH}_3)_4\text{Cl}_2]^+$
- (iii) $[\text{Ni}(\text{CN})_4]^{2-}$
- (iv) $[\text{Ni}(\text{NH}_3)_4\text{Cl}_2]$

20. Which of the following complexes are heteroleptic?

- (i) $[\text{Cr}(\text{NH}_3)_6]^{3+}$
- (ii) $[\text{Fe}(\text{NH}_3)_4\text{Cl}_2]^+$
- (iii) $[\text{Mn}(\text{CN})_6]^{4-}$
- (iv) $[\text{Co}(\text{NH}_3)_4\text{Cl}_2]$

21. Identify the optically active compounds from the following :

- (i) $[\text{Co}(\text{en})_3]^{3+}$
- (ii) *trans*- $[\text{Co}(\text{en})_2\text{Cl}_2]^+$
- (iii) *cis*- $[\text{Co}(\text{en})_2\text{Cl}_2]^+$
- (iv) $[\text{Cr}(\text{NH}_3)_5\text{Cl}]$

22. Identify the correct statements for the behaviour of ethane-1, 2-diamine as a ligand.

- (i) It is a neutral ligand.
- (ii) It is a didentate ligand.

- (iii) It is a chelating ligand.
 (iv) It is a unidentate ligand.
- 23.** Which of the following complexes show linkage isomerism?
- (i) $[\text{Co}(\text{NH}_3)_5(\text{NO}_2)]^{2+}$
 (ii) $[\text{Co}(\text{H}_2\text{O})_5\text{CO}]^{3+}$
 (iii) $[\text{Cr}(\text{NH}_3)_5\text{SCN}]^{2+}$
 (iv) $[\text{Fe}(\text{en})_2\text{Cl}_2]^+$

III. Short Answer Type

- 24.** Arrange the following complexes in the increasing order of conductivity of their solution: $[\text{Co}(\text{NH}_3)_3\text{Cl}_3]$, $[\text{Co}(\text{NH}_3)_4\text{Cl}_2]\text{Cl}$, $[\text{Co}(\text{NH}_3)_6]\text{Cl}_3$, $[\text{Cr}(\text{NH}_3)_5\text{Cl}]\text{Cl}_2$
- 25.** A coordination compound $\text{CrCl}_3 \cdot 4\text{H}_2\text{O}$ precipitates silver chloride when treated with silver nitrate. The molar conductance of its solution corresponds to a total of two ions. Write structural formula of the compound and name it.
- 26.** A complex of the type $[\text{M}(\text{AA})_2\text{X}_2]^{n+}$ is known to be optically active. What does this indicate about the structure of the complex? Give one example of such complex.
- 27.** Magnetic moment of $[\text{MnCl}_4]^{2-}$ is 5.92 BM. Explain giving reason.
- 28.** On the basis of crystal field theory explain why Co(III) forms paramagnetic octahedral complex with weak field ligands whereas it forms diamagnetic octahedral complex with strong field ligands.
- 29.** Why are low spin tetrahedral complexes not formed?
- 30.** Give the electronic configuration of the following complexes on the basis of Crystal Field Splitting theory.
 $[\text{CoF}_6]^{3-}$, $[\text{Fe}(\text{CN})_6]^{4-}$ and $[\text{Cu}(\text{NH}_3)_6]^{2+}$.
- 31.** Explain why $[\text{Fe}(\text{H}_2\text{O})_6]^{3+}$ has magnetic moment value of 5.92 BM whereas $[\text{Fe}(\text{CN})_6]^{3-}$ has a value of only 1.74 BM.
- 32.** Arrange following complex ions in increasing order of crystal field splitting energy (Δ_o):
 $[\text{Cr}(\text{Cl})_6]^{3-}$, $[\text{Cr}(\text{CN})_6]^{3-}$, $[\text{Cr}(\text{NH}_3)_6]^{3+}$.
- 33.** Why do compounds having similar geometry have different magnetic moment?
- 34.** $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ is blue in colour while CuSO_4 is colourless. Why?
- 35.** Name the type of isomerism when ambidentate ligands are attached to central metal ion. Give two examples of ambidentate ligands.

IV. Matching Type

Note : In the following questions match the items given in Columns I and II.

36. Match the complex ions given in Column I with the colours given in Column II and assign the correct code :

Column I (Complex ion)	Column II (Colour)
A. $[\text{Co}(\text{NH}_3)_6]^{3+}$	1. Violet
B. $[\text{Ti}(\text{H}_2\text{O})_6]^{3+}$	2. Green
C. $[\text{Ni}(\text{H}_2\text{O})_6]^{2+}$	3. Pale blue
D. $(\text{Ni}(\text{H}_2\text{O})_4(\text{en}))^{2+}(\text{aq})$	4. Yellowish orange
	5. Blue

Code :

(i)	A (1)	B (2)	C (4)	D (5)
(ii)	A (4)	B (3)	C (2)	D (1)
(iii)	A (3)	B (2)	C (4)	D (1)
(iv)	A (4)	B (1)	C (2)	D (3)

37. Match the coordination compounds given in Column I with the central metal atoms given in Column II and assign the correct code :

Column I (Coordination Compound)	Column II (Central metal atom)
A. Chlorophyll	1. rhodium
B. Blood pigment	2. cobalt
C. Wilkinson catalyst	3. calcium
D. Vitamin B ₁₂	4. iron
	5. magnesium

Code :

(i)	A (5)	B (4)	C (1)	D (2)
(ii)	A (3)	B (4)	C (5)	D (1)
(iii)	A (4)	B (3)	C (2)	D (1)
(iv)	A (3)	B (4)	C (1)	D (2)

38. Match the complex ions given in Column I with the hybridisation and number of unpaired electrons given in Column II and assign the correct code :

Column I (Complex ion)	Column II (Hybridisation, number of unpaired electrons)
A. $[\text{Cr}(\text{H}_2\text{O})_6]^{3+}$	1. dsp^2 , 1
B. $[\text{Co}(\text{CN})_4]^{2-}$	2. sp^3d^2 , 5
C. $[\text{Ni}(\text{NH}_3)_6]^{2+}$	3. d^2sp^3 , 3
D. $[\text{MnF}_6]^{4-}$	4. sp^3 , 4
	5. sp^3d^2 , 2

Code :

(i)	A (3)	B (1)	C (5)	D (2)
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- (ii) A (4) B (3) C (2) D (1)
 (iii) A (3) B (2) C (4) D (1)
 (iv) A (4) B (1) C (2) D (3)

39. Match the complex species given in Column I with the possible isomerism given in Column II and assign the correct code :

Column I (Complex species)

Column II (Isomerism)

- | | |
|---|-----------------|
| A. $[\text{Co}(\text{NH}_3)_4\text{Cl}_2]^+$ | 1. optical |
| B. <i>cis</i> - $[\text{Co}(\text{en})_2\text{Cl}_2]^+$ | 2. ionisation |
| C. $[\text{Co}(\text{NH}_3)_5(\text{NO}_2)]\text{Cl}_2$ | 3. coordination |
| D. $[\text{Co}(\text{NH}_3)_6][\text{Cr}(\text{CN})_6]$ | 4. geometrical |
| | 5. linkage |

Code :

- (i) A (1) B (2) C (4) D (5)
 (ii) A (4) B (3) C (2) D (1)
 (iii) A (4) B (1) C (5) D (3)
 (iv) A (4) B (1) C (2) D (3)

40. Match the compounds given in Column I with the oxidation state of cobalt present in it (given in Column II) and assign the correct code.

Column I (Compound)

Column II (Oxidation state of Co)

- | | |
|--|-------|
| A. $[\text{Co}(\text{NCS})(\text{NH}_3)_5](\text{SO}_3)$ | 1. +4 |
| B. $[\text{Co}(\text{NH}_3)_4\text{Cl}_2]\text{SO}_4$ | 2. 0 |
| C. $\text{Na}_4[\text{Co}(\text{S}_2\text{O}_3)_3]$ | 3. +1 |
| D. $[\text{Co}_2(\text{CO})_8]$ | 4. +2 |
| | 5. +3 |

Code :

- (i) A (1) B (2) C (4) D (5)
 (ii) A (4) B (3) C (2) D (1)
 (iii) A (5) B (1) C (4) D (2)
 (iv) A (4) B (1) C (2) D (3)

V. Assertion and Reason Type

Note : In the following questions a statement of assertion followed by a statement of reason is given. Choose the correct answer out of the following choices.

- (i) Assertion and reason both are true, reason is correct explanation of assertion.
 (ii) Assertion and reason both are true but reason is not the correct explanation of assertion.

- (iii) Assertion is true, reason is false.
 (iv) Assertion is false, reason is true.
- 41. Assertion** : Toxic metal ions are removed by the chelating ligands.
Reason : Chelate complexes tend to be more stable.
- 42. Assertion** : $[\text{Cr}(\text{H}_2\text{O})_6]\text{Cl}_2$ and $[\text{Fe}(\text{H}_2\text{O})_6]\text{Cl}_2$ are reducing in nature.
Reason : Unpaired electrons are present in their *d*-orbitals.
- 43. Assertion** : Linkage isomerism arises in coordination compounds containing ambidentate ligand.
Reason : Ambidentate ligand has two different donor atoms.
- 44. Assertion** : Complexes of MX_6 and MX_5L type (X and L are unidentate) do not show geometrical isomerism.
Reason : Geometrical isomerism is not shown by complexes of coordination number 6.
- 45. Assertion** : $[\text{Fe}(\text{CN})_6]^{3-}$ ion shows magnetic moment corresponding to two unpaired electrons.
Reason : Because it has d^2sp^3 type hybridisation.

VI. Long Answer Type

- 46.** Using crystal field theory, draw energy level diagram, write electronic configuration of the central metal atom/ion and determine the magnetic moment value in the following :
 (i) $[\text{CoF}_6]^{3-}$, $[\text{Co}(\text{H}_2\text{O})_6]^{2+}$, $[\text{Co}(\text{CN})_6]^{3-}$
 (ii) $[\text{FeF}_6]^{3-}$, $[\text{Fe}(\text{H}_2\text{O})_6]^{2+}$, $[\text{Fe}(\text{CN})_6]^{4-}$
- 47.** Using valence bond theory, explain the following in relation to the complexes given below:
 $[\text{Mn}(\text{CN})_6]^{3-}$, $[\text{Co}(\text{NH}_3)_6]^{3+}$, $[\text{Cr}(\text{H}_2\text{O})_6]^{3+}$, $[\text{FeCl}_6]^{4-}$
 (i) Type of hybridisation.
 (ii) Inner or outer orbital complex.
 (iii) Magnetic behaviour.
 (iv) Spin only magnetic moment value.
- 48.** $\text{CoSO}_4 \cdot 5\text{H}_2\text{O}$ exists in two isomeric forms 'A' and 'B'. Isomer 'A' reacts with AgNO_3 to give white precipitate, but does not react with BaCl_2 . Isomer 'B' gives white precipitate with BaCl_2 but does not react with AgNO_3 . Answer the following questions.
 (i) Identify 'A' and 'B' and write their structural formulas.
 (ii) Name the type of isomerism involved.
 (iii) Give the IUPAC name of 'A' and 'B'.
- 49.** What is the relationship between observed colour of the complex and the wavelength of light absorbed by the complex?
- 50.** Why are different colours observed in octahedral and tetrahedral complexes for the same metal and same ligands?