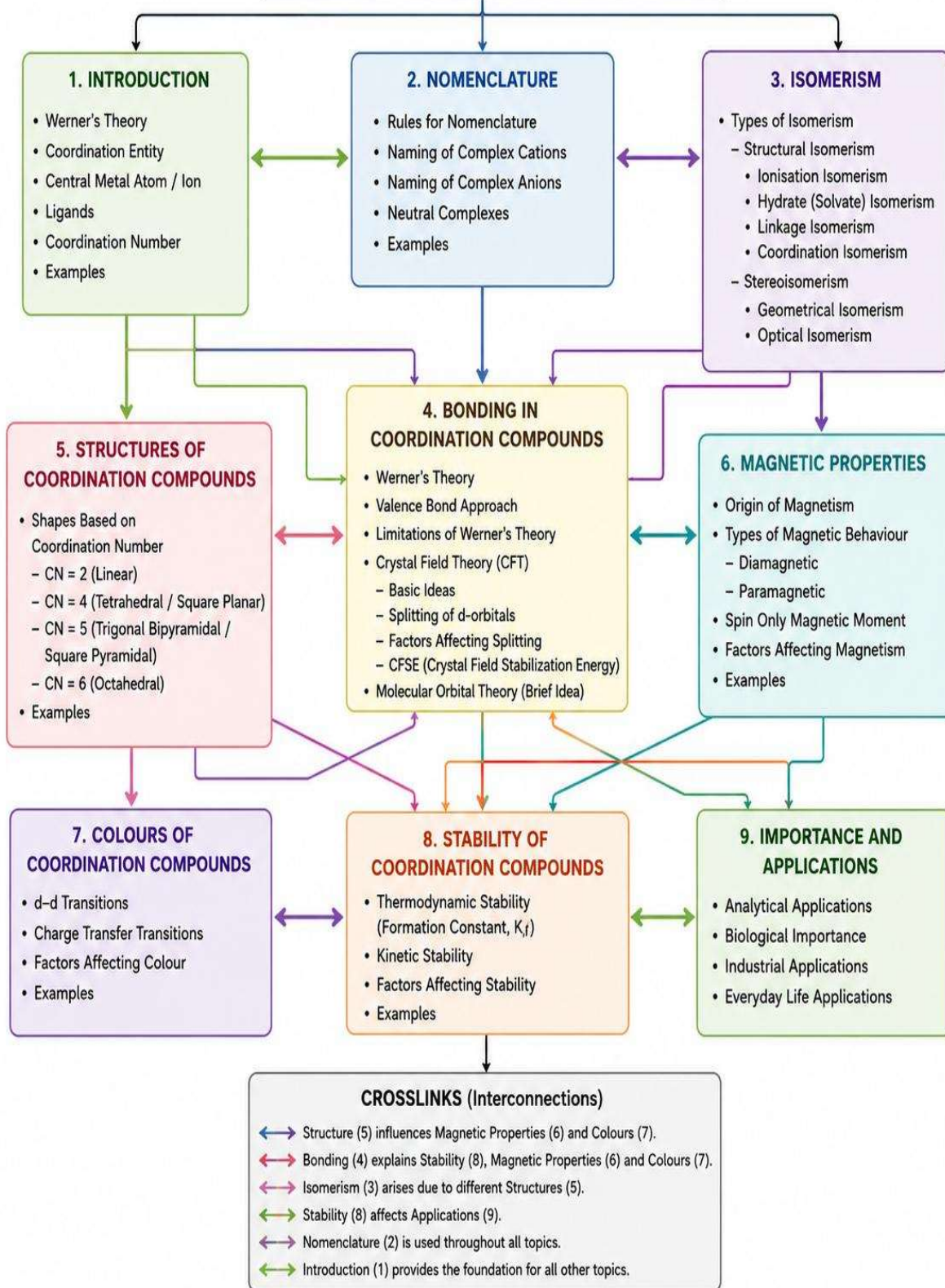


COORDINATION COMPOUNDS



QUESTION BANK

SECTION –A (1 MARK EACH)

1. One mole of the complex compound $\text{Co}(\text{NH}_3)_5\text{Cl}_3$, gives 3 moles of ions on dissolution in water. One mole of the same complex reacts with two moles of AgNO_3 solution to yield two moles of AgCl (s). The structure of the complex is

- (a) $[\text{Co}(\text{NH}_3)_3\text{Cl}_3] \cdot 2\text{NH}_3$ (b) $[\text{Co}(\text{NH}_3)_4\text{Cl}_2] \text{Cl} \cdot \text{NH}_3$
 (c) $[\text{Co}(\text{NH}_3)_4\text{Cl}] \text{Cl}_2 \cdot \text{NH}_3$ (d) $[\text{Co}(\text{NH}_3)_5\text{Cl}] \text{Cl}_2$

2. In the coordination compound, $\text{K}_2[\text{Ni}(\text{CN})_4]$, the oxidation state of nickel is

- (a) 0 (b) +1 (c) +2 (d) –1

3. $[\text{EDTA}]^{4-}$ is a :

- (a) monodentate ligand (b) bidentate ligand
 (c) quadridentate ligand (d) hexadentate ligand

4. The total number of possible isomers for the complex $[\text{Co}(\text{C}_2\text{O}_4)_2(\text{NH}_3)_2]$ are:

- (a) 1 (b) 2 (c) 3 (d) 4

5. The stabilisation of coordination compounds due to chelation is called the chelate effect. Which of the following is the most stable complex species?

- (a) $[\text{Fe}(\text{CO})_5]$ (b) $[\text{Fe}(\text{CN})_6]^{3-}$ (c) $[\text{Fe}(\text{C}_2\text{O}_4)_3]^{3-}$ (d) $[\text{Fe}(\text{H}_2\text{O})_6]^{3+}$

6. 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, $[\text{Co}(\text{NH}_3)_6]^{3+}$, $[\text{Co}(\text{CN})_6]^{3-}$, $[\text{Co}(\text{H}_2\text{O})_6]^{3+}$?

- (a) $[\text{Co}(\text{CN})_6]^{3-} > [\text{Co}(\text{NH}_3)_6]^{3+} > [\text{Co}(\text{H}_2\text{O})_6]^{3+}$
 (b) $[\text{Co}(\text{NH}_3)_6]^{3+} > [\text{Co}(\text{H}_2\text{O})_6]^{3+} > [\text{Co}(\text{CN})_6]^{3-}$
 (c) $[\text{Co}(\text{H}_2\text{O})_6]^{3+} > [\text{Co}(\text{NH}_3)_6]^{3+} > [\text{Co}(\text{CN})_6]^{3-}$
 (d) None of the above

(Hint: Greater the crystal field splitting energy (Δ_0), smaller will be the wavelength absorbed. Use the spectrochemical series)

7. On the basis of CFT what will be the electronic configuration of d^5 in terms of t_{2g} and e_g Orbitals when $\Delta_0 > P$.

- a) $t_{2g}^4 e_g^1$ b) $t_{2g}^5 e_g^0$ c) $t_{2g}^0 e_g^5$ d) $t_{2g}^3 e_g^2$

8. Match the coordination compounds given in Column I with their corresponding properties or applications given in Column II and choose the correct option.

Column I	Column II
(A) $[\text{Co}(\text{NH}_3)_6]\text{Cl}_3$	(1) Anticancer drug
(B) $\text{K}_4[\text{Fe}(\text{CN})_6]$	(2) Paramagnetic complex
(C) cis- $[\text{Pt}(\text{NH}_3)_2\text{Cl}_2]$	(3) Coordination number = 6
(D) $[\text{Cr}(\text{H}_2\text{O})_6]\text{Cl}_3$	(4) Strong field ligand complex

- (a) A–3, B–4, C–1, D–2 (b) A–4, B–3, C–2, D–1
 (c) A–2, B–1, C–4, D–3 (d) A–1, B–2, C–3, D–4

9. Which of the following statements is correct ? (Atomic number of Ni = 28)

- (a) $\text{Ni}(\text{CO})_4$ is diamagnetic and $[\text{NiCl}_4]^{2-}$ and $[\text{Ni}(\text{CN})_4]^{2-}$ are paramagnetic
 (b) $\text{Ni}(\text{CO})_4$ and $[\text{Ni}(\text{CN})_4]^{2-}$ are diamagnetic and $[\text{NiCl}_4]^{2-}$ is paramagnetic
 (c) $\text{Ni}(\text{CO})_4$ and $[\text{NiCl}_4]^{2-}$ are diamagnetic and $[\text{Ni}(\text{CN})_4]^{2-}$ is paramagnetic
 (d) $[\text{NiCl}_4]^{2-}$ and $[\text{Ni}(\text{CN})_4]^{2-}$ are diamagnetic and $\text{Ni}(\text{CO})_4$ is paramagnetic

10. Which of the following pairs represent linkage isomers?

- (a) $[\text{Pd}(\text{PPh}_3)_2(\text{NCS})_2]$ and $[\text{Pd}(\text{PPh}_3)_2(\text{SCN})_2]$

- (b) $[\text{Co}(\text{NH}_3)_5\text{NO}_3]\text{SO}_4$ and $[\text{Co}(\text{NH}_3)_5\text{SO}_4]\text{NO}_3$
 (c) $[\text{PtCl}_2(\text{NH}_3)_4]\text{Br}_2$ and $[\text{PtBr}_2(\text{NH}_3)_4]\text{Cl}_2$
 (d) $[\text{Cu}(\text{NH}_3)_4][\text{PtCl}_4]$ and $[\text{Pt}(\text{NH}_3)_4][\text{CuCl}_4]$

ASSERTION- REASON TYPE QUESTIONS (1 MARK EACH)

In the following questions a statement of Assertion (A) followed by a statement of Reason (R) is given. Choose the correct option out of the choices given below each question.

- a) Both A and R are true and R is correct explanation of A.
 b) Both A and R are true but R is not correct explanation of A.
 c) A is true but R is false. d) A is False but R is true.

11. Assertion : A chelating ligand must possess two or more lone pairs at such a distance that it may form suitable strain free rings at the metal ion.

Reason : $\text{H}_2\text{N} - \text{NH}_2$ is a chelating ligand.

12. Assertion(A): $[\text{Fe}(\text{CN})_6]^{3-}$ is weakly paramagnetic while $[\text{Fe}(\text{CN})_6]^{4-}$ is diamagnetic.

Reason(R) : $[\text{Fe}(\text{CN})_6]^{3-}$ has +3 oxidation state while $[\text{Fe}(\text{CN})_6]^{4-}$ has +2 oxidation state.

13. Assertion (A): $[\text{Ti}(\text{H}_2\text{O})_6]^{3+}$ is coloured while $[\text{Sc}(\text{H}_2\text{O})_6]^{3+}$ is colourless.

Reason (R): $d-d$ transition is not possible in $[\text{Sc}(\text{H}_2\text{O})_6]^{3+}$.

14. Assertion (A): Optical isomerism is not shown by square planar complexes .

Reason (R): Square planar complexes do not possess chiral structures.

15. Assertion : $[\text{Co}(\text{NH}_3)_5\text{SO}_4]\text{Cl}$ gives a white precipitate with silver nitrate solution.

Reason : The complex dissociate to give Cl^- and SO_4^{2-} ions.

ANSWERS

ANSWERS KEY :

Q	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
A	d	a	d	d	c	c	b	a	b	a	c	b	a	a	c

SECTION –B (TWO MARKS EACH)

1. A cationic complex has two isomers A & B. Each has one Co^{3+} , five NH_3 , one Br and one SO_4^{2-} . A gives a white precipitate with BaCl_2 solution while B gives a yellow precipitate with AgNO_3 solution.

(a) What are the possible structures of the complexes A and B ?

(b) Will the two complexes have same colour ?

(HINT: (a) $[\text{Co}(\text{NH}_3)_5\text{Br}]\text{SO}_4$ and $[\text{Co}(\text{NH}_3)_5\text{SO}_4]\text{Br}$; (b) No

2. A, B and C are three complexes of Chromium with the empirical formula $\text{H}_{12}\text{O}_6\text{Cl}_3\text{Cr}$. All the three complexes have Cl and H_2O molecules as the ligands. Complex A does not react with conc. H_2SO_4 . Complexes B and C lose 6.75% and 13.5% of their original weight respectively on heating with conc.

H_2SO_4 . Identify A, B and C.

(HINT- Data suggests that the complexes are hydrate isomers. As complex A does not lose any molecule of H_2O on heating which shows that no water molecule of H_2O is outside the co-ordination sphere. A =

$[\text{Cr}(\text{H}_2\text{O})_6]\text{Cl}_3$. As B loses 6.75% actual loss in wt. = $\frac{18}{266.5} \times 100 = 6.75\%$, B = $[\text{Cr}(\text{H}_2\text{O})_5\text{Cl}]\text{Cl}_2 \cdot \text{H}_2\text{O}$. As C loses 13.5% of wt. on heating which is twice the loss in the first case. C isomer exists as a dihydrate :

$[\text{Cr}(\text{H}_2\text{O})_4\text{Cl}_2]\text{Cl} \cdot 2\text{H}_2\text{O}$.)

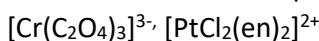
3. How t_{2g} and e_g orbitals are formed in an octahedral complex?

(**HINT**-In an octahedral complex, the metal ion is at the center and ligands at the corners. The $d_{x^2-y^2}$ and d_{z^2} orbitals point along the axes (toward ligands), causing greater repulsion and higher energy. The other d orbitals lie between the axes, facing less repulsion and have lower energy.)

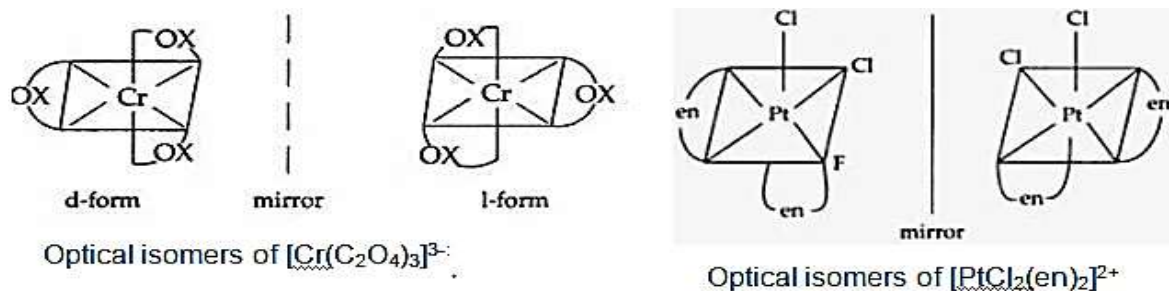
4. A solution of $[\text{Ni}(\text{H}_2\text{O})_6]^{2+}$ is green but a solution of $[\text{Ni}(\text{CN})_4]^{2-}$ is colourless. Explain.

HINT- In $[\text{Ni}(\text{H}_2\text{O})_6]^{2+}$, H_2O is a weak field ligand. Therefore, there are unpaired electrons in Ni^{2+} . In this complex, the d electrons from the lower energy level can be excited to the higher energy level i.e., the possibility of $d-d$ transition is present. Hence, $[\text{Ni}(\text{H}_2\text{O})_6]^{2+}$ is coloured. In $[\text{Ni}(\text{CN})_4]^{2-}$, the electrons are all paired as CN^- is a strong field ligand. Therefore, $d-d$ transition is not possible in $[\text{Ni}(\text{CN})_4]^{2-}$. Hence, it is colourless. As there are no unpaired electrons, it is diamagnetic.

5. Draw the structures of optical isomers of each of the following complex ions:



HINT-



SECTION - C (3 MARKS EACH)

1. A student prepared three co-ordination complexes containing chromium having the following characteristics:

Sr. No.	Formula	colour	Cl- ions present in solution per formula unit
(A)	$\text{CrCl}_3 \cdot 6\text{H}_2\text{O}$	violet	3
(B)	$\text{CrCl}_3 \cdot 6\text{H}_2\text{O}$	Light green	2
(C)	$\text{CrCl}_3 \cdot 6\text{H}_2\text{O}$	Dark green	1

(a) Write the structures of the three complexes.

(b) Give IUPAC name of the complex

HINT- According to Werner's Coordination theory.

2. On the basis of valence bond theory explain geometry, nature of hybridisation, magnetic property & optical isomerism of $[\text{Co}(\text{OX})_3]^{3-}$ and $[\text{CoF}_6]^{3-}$

HINT- According to Valance bond theory.

3. Calculate the magnetic moment of the following complexes;

(i) $[\text{Cr}(\text{NH}_3)_6]^{3+}$ (ii) $[\text{CoF}_6]^{3-}$ (iii) $[\text{Fe}(\text{CN})_6]^{3-}$

HINT- Use formula $\mu = \sqrt{n(n+2)} \text{ BM}$

4. What will be the correct order for the wavelengths of absorption in the Visible region for the following: $[\text{Ni}(\text{NO}_2)_6]^{4-}$, $[\text{Ni}(\text{NH}_3)_6]^{2+}$, $[\text{Ni}(\text{H}_2\text{O})_6]^{2+}$?

HINT:- Stronger field $\rightarrow$ larger $\Delta o \rightarrow$ absorbs higher energy (shorter wavelength)

Weaker field $\rightarrow$ smaller $\Delta o \rightarrow$ absorbs lower energy (longer wavelength)

ligand strength increases roughly in this order: $\text{H}_2\text{O} < \text{NH}_3 < \text{NO}_2^-$

Hence, order of the wave length of absorption is as follows



5. (a) On the basis of crystal field theory, write the electronic configuration of d^6 in terms of t_{2g} and e_g in an octahedral field when $\Delta_o < P$ and $\Delta_o > P$

b. Low spin configuration are rarely observed in tetrahedral coordination entity formation. Explain.

HINT-1.a)

Weak field ligands	Strong field ligands
$\Delta_o < P$	$\Delta_o > P$
t_{2g}^4, e_g^2	t_{2g}^6, e_g^0

b). The orbital splitting energies, Δ_t are not sufficiently large for forcing pairing of electrons in the tetrahedral coordination entity formation.

SECTION –D Case Study Based question (Four marks)

1. Read the passage carefully and answer the questions that follows.

Alfred Werner, a Swiss chemist was the first to formulate his idea about the structure of coordination compounds. He proposed the concept of primary and secondary valences for a metal ion. The primary valences are normally ionisable and satisfied by negative ions. The secondary valences are non-ionisable and it is equal to coordination number and is fixed for a metal. The groups bound by the secondary linkages to metal have spatial arrangements corresponding to different coordination numbers. Octahedral, tetrahedral and square planar geometrical shapes are more common in coordination compounds of transition metals. Double salts and coordination complexes are formed by the combination of two or more stable compounds in stoichiometric ratio. Double salts are dissociated into simple ions completely when dissolved in water whereas complexes do not dissociate completely into ions. Werner was the first to discover optical activity in certain coordination compounds.

(i) What is the oxidation number of cobalt in coordination entity: $[\text{Co}(\text{H}_2\text{O})(\text{CN})(\text{en})_2]^{2+}$?

(ii) What is the coordination number of chromium in $\text{K}[\text{Cr}(\text{H}_2\text{O})_2(\text{C}_2\text{O}_4)_2]$?

(iii) Arrange the following complexes in increasing order of conductivity of their solution. Give reason.

$[\text{Co}(\text{NH}_3)_3\text{Cl}_3]$, $[\text{Co}(\text{NH}_3)_4\text{Cl}_2]\text{Cl}$, $[\text{Co}(\text{NH}_3)_6]\text{Cl}_3$, $[\text{Co}(\text{NH}_3)_5\text{Cl}]\text{Cl}_2$

OR

How many ions are produced from the complex $[\text{Co}(\text{NH}_3)_6]\text{Cl}_3$ in solution?

HINT- (i) O.N. of Co is +3 (ii) Coordination number = 6

(iii) Increasing order $[\text{Co}(\text{NH}_3)_3\text{Cl}_3] < [\text{Co}(\text{NH}_3)_4\text{Cl}_2]\text{Cl} < [\text{Co}(\text{NH}_3)_5\text{Cl}]\text{Cl}_2 < [\text{Co}(\text{NH}_3)_6]\text{Cl}_3$

As no. of ions in solution increases their conductivity also increases.

OR

(iii) 4

2. Read the passage carefully and answer the questions that follow

Valence bond theory considers the bonding between metal ion and ligands

as purely covalent. On the other hand, crystal field theory considers the metal-ligand bond to be ionic arising from electrostatic interaction between the metal ion and the ligands. In coordination compounds, the interaction between the ligand and the metal ion causes the five d-orbitals to split-up. This is called crystal field splitting and the energy difference between the two sets of energy levels is called crystal field splitting energy. The crystal field splitting (Δ_o) depends upon the nature of the ligand and the charge of the metal ion. The electronic configuration of the metal ion in the complexes depends on the relative values of Δ_o and P (pairing energy). If $\Delta_o < P$, then complex will be high spin. If $\Delta_o > P$, then complex will be low spin.

(i) Calculate the magnetic moment of the metal ion in the complex $\text{K}_4[(\text{Fe}(\text{CN})_6)]$.

- (ii) On the basis of crystal field theory, write the electronic configuration of d^4 in terms of t_{2g} and e_g in an octahedral field when $\Delta_o > P$.
- (iii) Explain the violet colour of $[\text{Ti}(\text{H}_2\text{O})_6]^{3+}$ complex on the basis of the crystal field theory. (Atomic number of Ti = 22)

OR

(iii) State the magnetic property of each of the following complexes.

- a) Hexaamminechromium (III) ion (At no of Chromium = 24)
 b) Tetraamminezinc(II) ion (At number of Zinc = 30)
HINT: (i) Magnetic moment = $\sqrt{n(n+2)}$; Answer: $\mu = \sqrt{24} \text{ BM}$
 (ii) As per the summary (iii) As per the summary

OR

- (iii) a) Paramagnetic. b) Diamagnetic

SECTION - E (5 MARKS):

1. (a) Draw the geometrical isomers of $[\text{Co}(\text{en})_2\text{Cl}_2]^{2+}$. Which geometrical isomer of $[\text{Co}(\text{en})_2\text{Cl}_2]^{2+}$ is not optically active and why?
 (b) Write the hybridisation and magnetic behaviour of $[\text{CoF}_6]^{3-}$.
 [Given: Atomic number of Co = 27]

2.A) (i) Write the IUPAC name of the following complexes:

- (a) $[\text{Cr}(\text{H}_2\text{O})_6]\text{Cl}_3$ (b) $[\text{Pt}(\text{NH}_3)_2\text{Cl}_4]$ (c) $[\text{Fe}(\text{CN})_6]^{3-}$

(ii) Give the formula for the following complexes:

- (a) Tetraamminecopper(II) sulphate (b) Potassium trioxalatochromate(III)
 (c) Hexaamminecobalt(III) chloride

B). Discuss the nature of bonding in the following coordination entities on the basis of valence bond theory:

- (i) $[\text{Fe}(\text{CN})_6]^{4-}$ (ii) $[\text{FeF}_6]^{3-}$

HINT-A) (i) (a) Hexaaquachromium (III) chloride. (b) Diamminetetra-chloroplatinum (II) (c) Hexacyanoferrate(II) ion

- ii) (a) $[\text{Cu}(\text{NH}_3)_4]\text{SO}_4$ (b) $\text{K}_3[\text{Cr}(\text{C}_2\text{O}_4)_3]$ (c) $[\text{Co}(\text{NH}_3)_6]\text{Cl}_3$

B) (i). $[\text{Fe}(\text{CN})_6]^{4-}$ CN^- is a strong field ligand, hence pairing of 3d orbital takes place ; d^2sp^3
 (ii) $[\text{FeF}_6]^{3-}$, F^- is a weak field ligand hence pairing doesn't occur; Answer: sp^3d^2