

## 9



# Coordination Compounds

1. Which of the following complexes formed by  $\text{Cu}^{2+}$  ions is most stable?

- (i)  $\text{Cu}^{2+} + 4\text{NH}_3 \rightleftharpoons [\text{Cu}(\text{NH}_3)_4]^{2+}$ ,  $\log K = 11.6$   
 (ii)  $\text{Cu}^{2+} + 4\text{CN}^- \rightleftharpoons [\text{Cu}(\text{CN})_4]^{2-}$ ,  $\log K = 27.3$   
 (iii)  $\text{Cu}^{2+} + 2\text{en} \rightleftharpoons [\text{Cu}(\text{en})_2]^{2+}$ ,  $\log K = 15.4$   
 (iv)  $\text{Cu}^{2+} + 4\text{H}_2\text{O} \rightleftharpoons [\text{Cu}(\text{H}_2\text{O})_4]^{2+}$ ,  $\log K = 8.9$

Ans. (ii)

**Explanation:** Greater the value of  $\log K$  greater the stability of the complex compound.

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

- (i)  $[\text{Co}(\text{CN})_6]^{3-} > [\text{Co}(\text{NH}_3)_6]^{3+} > [\text{Co}(\text{H}_2\text{O})_6]^{3+}$   
 (ii)  $[\text{Co}(\text{NH}_3)_6]^{3+} > [\text{Co}(\text{H}_2\text{O})_6]^{3+} > [\text{Co}(\text{CN})_6]^{3-}$   
 (iii)  $[\text{Co}(\text{H}_2\text{O})_6]^{3+} > [\text{Co}(\text{NH}_3)_6]^{3+} > [\text{Co}(\text{CN})_6]^{3-}$   
 (iv)  $[\text{Co}(\text{CN})_6]^{3-} > [\text{Co}(\text{NH}_3)_6]^{3+} > [\text{Co}(\text{H}_2\text{O})_6]^{3+}$

Ans. (iii)

**Explanation:** In strong field ligand, there is more energy separation than weak field ligand it means that as the strength of ligand increases crystal field splitting energy increases.

$$\Delta E = hc/\lambda \text{ or } \Delta E \propto 1/\lambda$$

As  $\Delta E$  increases, wavelength of light absorbed decreases.

3. When 0.1 mol  $\text{CoCl}_3(\text{NH}_3)_5$  is treated with excess of  $\text{AgNO}_3$ , 0.2 mol of  $\text{AgCl}$  are obtained. The conductivity of solution will correspond to

- (i) 1:3 electrolyte (ii) 1:2 electrolyte  
 (iii) 1:1 electrolyte (iv) 3:1 electrolyte

Ans. (ii)

4. When 1 mol  $\text{CrCl}_3 \cdot 6\text{H}_2\text{O}$  is treated with excess of  $\text{AgNO}_3$ , 3 mol of  $\text{AgCl}$  are obtained. The formula of the complex is:

- (i)  $[\text{CrCl}_3(\text{H}_2\text{O})_3] \cdot 3\text{H}_2\text{O}$  (ii)  $[\text{CrCl}_2(\text{H}_2\text{O})_4]\text{Cl} \cdot 2\text{H}_2\text{O}$   
 (iii)  $[\text{CrCl}(\text{H}_2\text{O})_5]\text{Cl}_2 \cdot \text{H}_2\text{O}$  (iv)  $[\text{Cr}(\text{H}_2\text{O})_6]\text{Cl}_3$

Ans. (iv)

**Explanation:** 1 mol of  $\text{AgCl}$  is precipitated by one  $\text{Cl}^-$  ion.

3 mol of  $\text{AgCl}$  is precipitated by  $3\text{Cl}^-$  ions. So the formula of the complex is  $[\text{Cr}(\text{H}_2\text{O})_6]\text{Cl}_3$

5. The correct IUPAC name of  $[\text{Pt}(\text{NH}_3)_2\text{Cl}_2]$  is

- (i) Diamminedichloridoplatinum (II)

- (ii) Diamminedichloridoplatinum (IV)  
 (iii) Diamminedichloridoplatinum (0)  
 (iv) Dichlorodiammineplatinum (IV)

Ans. (i)

**Explanation:** The complex compound is  $[\text{Pt}(\text{NH}_3)_2\text{Cl}_2]$ .

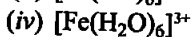
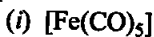
$\text{NH}_3$  is a neutral ligand and named as amine.

$\text{Cl}$  is anion ligand and named as chloride. Di or tri is prefixed to represent the number.

So the name of the compound is – Diamminedichloridoplatinum(II).

(II) represent the oxidation state of platinum.

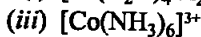
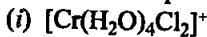
6. The stabilisation of coordination compounds due to chelation is called the chelate effect. Which of the following is the most stable complex species?



Ans. (iii)

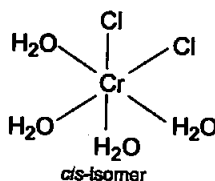
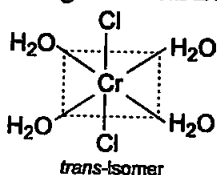
**Explanation:** When a di- or polydentate ligand uses its two or more donor atoms to bind a single metal ion, it is said to be a chelate ligand. The number of such ligating groups is called the denticity of the ligand. Such complexes, called chelate complexes tend to be more stable than similar complexes containing unidentate ligands.

7. Indicate the complex ion which shows geometrical isomerism.

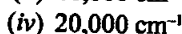
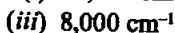
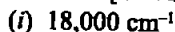


Ans. (i)

**Explanation:** Because it is a  $\text{MA}_4\text{B}_2$  type co-ordination compound. Possible geometrical isomers are



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



Ans. (iii)

**Explanation:** CFSE for octahedral and tetrahedral complex is related as

$$\Delta' = \frac{4}{9} \Delta_o$$

where  $\Delta_o$  = CFSE for octahedral complex

$\Delta_t$  = CFSE for tetrahedral complex

$$\Delta_o = 18000 \text{ cm}^{-1}$$

$$\Delta_t = \frac{4}{9} \times 18000 = 8,000 \text{ cm}^{-1}$$

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

- (i) linkage isomers                      (ii) coordination isomers  
(iii) ionisation isomers                (iv) geometrical isomers

Ans. (i)

**Explanation:** Linkage isomerism arises in a coordination compound containing ambidentate ligand. A simple example is provided by complexes containing the thiocyanate ligand, NCS—, which may bind through the nitrogen to give M—NCS or through sulphur to give M—SCN.

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

- (i) linkage isomerism                      (ii) ionisation isomerism  
(iii) coordination isomerism            (iv) no isomerism

Ans. (iv)

**Explanation:** Isomers means having same molecular formula but different structural formula but in the above question the molecular formula is different. Hence they are not isomers.

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

Ans. (i)

**Explanation:** Geometry of thiosulphato is not favourable to chelate a metal ion.

12. Which of the following species is **not** expected to be a ligand?

- (i) NO    (ii)  $\text{NH}_4^+$   
(iii)  $\text{NH}_2\text{CH}_2\text{CH}_2\text{NH}_2$                       (iv) CO

Ans. (ii)

**Explanation:** Ligand must have a lone pair electron to form M-L (metal-ligand bond)

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

Ans. (ii)

**Explanation:** This form of isomerism is known as 'hydrate isomerism' in case where water is involved as a solvent. This is similar to ionisation isomerism. Solvate isomers differ by whether or not a solvent molecule is directly bonded to the metal ion or merely present as free solvent molecules in the crystal lattice.

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)

Ans. (iii)

**Explanation:** The ligands are named in an alphabetical order before the name of the central atom/ion. (This procedure is reversed from writing formula). Names of the anionic ligands end in -o. State of the metal in cation, anion or neutral coordination entity is indicated by Roman numeral in parenthesis.

## II. MULTIPLE CHOICE QUESTIONS (TYPE-II)

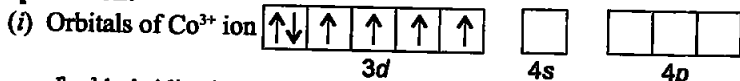
Note : In the following questions two or more options may be correct.

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?

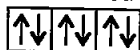
- (i)  $[\text{Co}(\text{NH}_3)_6]^{3+}$  (ii)  $[\text{Mn}(\text{CN})_6]^{3-}$   
 (iii)  $[\text{Fe}(\text{CN})_6]^{4-}$  (iv)  $[\text{Fe}(\text{CN})_6]^{3-}$

Ans. (i) and (iii)

**Explanation:**



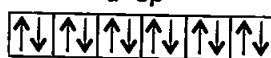
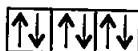
$d^2sp^3$  hybridised  
 orbitals of  $\text{Co}^{3+}$



$d^2sp^3$



(inner orbital or  
 low spin complex)

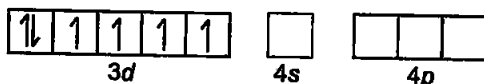


Six pairs of electrons  
 from six  $\text{NH}_3$  molecules

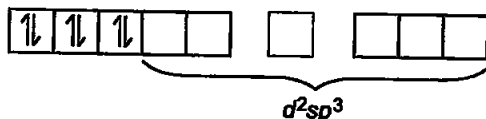
No. of unpaired electron = 0

Magnetic property = diamagnetic

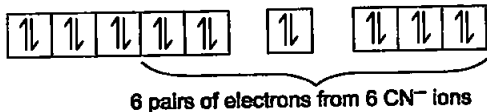
(ii) Electronic configuration is  $3d^6$  orbitals of  $\text{Fe}^{2+}$  ion:



As  $\text{CN}^-$  is a strong field ligand, it causes the pairing of the unpaired  $3d$  electrons. Since there are six ligands around the central metal ion, the most feasible hybridization  $d^2sp^3$ .  $d^2sp^3$  hybridized orbitals of  $\text{Fe}^{2+}$  are:



6 electron pairs from  $\text{CN}^-$  ions occupy the six hybrid  $d^2sp^3$  orbitals. Then,



Hence, the geometry of the complex is octahedral and the complex is diamagnetic (as there are no unpaired electrons).

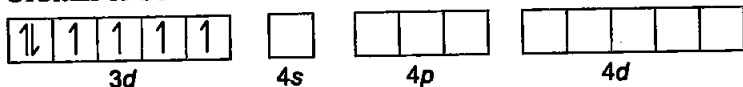
16. Atomic number of Mn, Fe, Co and Ni are 25, 26, 27 and 28 respectively. Which of the following outer orbital octahedral complexes have same number of unpaired electrons?

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

Ans. (i) and (iii)

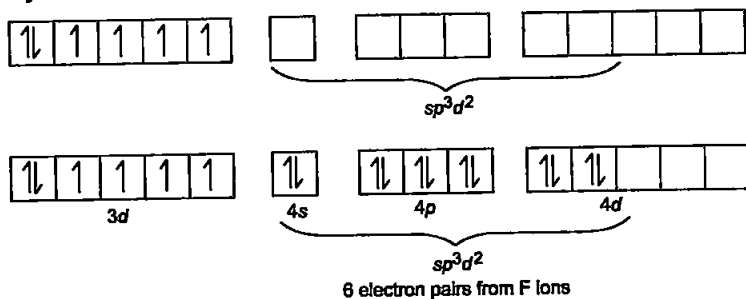
**Explanation:** Outer orbital complex or high spin complex

**Orbitals of  $\text{Co}^{3+}$  ion:**



Again, fluoride ion is a weak field ligand. It cannot cause the pairing of the 3d electrons. As a result, the  $\text{Co}^{3+}$  ion will undergo  $sp^3d^2$  hybridization  $sp^3d^2$ .

**Hybridized orbitals of  $\text{Co}^{3+}$  ion are:**



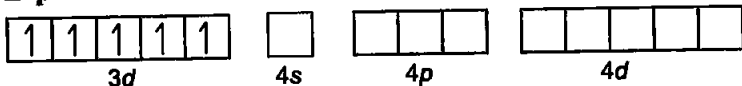
Similarly  $[\text{MnCl}_6]^{3-}$  is also outer orbital complex or high spin complex. Magnetic property-paramagnetic no. of unpaired electron = 4

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

Ans. (i) and (iii)

**Explanation:**



6 electron pairs from CN ions occupy the six hybrid  $d^2sp^3$  orbitals.

No. of unpaired electron = 1

Magnetic property = paramagnetic

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.

Ans. (ii) and (iii)

**Explanation:** Aqueous pink solution of cobalt (II) chloride is due to electric transition of electron from  $t_{2g}$  to  $e_g$  energy level of  $[\text{Co}(\text{H}_2\text{O})_6]^{2+}$  complex. When excess of HCl is added to this solution.

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)  $[\text{Ni}(\text{NH}_3)_4\text{Cl}_2]$

Ans. (i) and (iii)

**Explanation:** Complexes in which a metal is bound to only one kind of donor groups, e.g.,  $[\text{Co}(\text{NH}_3)_6]^{3+}$ , are known as homoleptic. Complexes in which a metal is bound to more than one kind of donor groups, e.g.,  $[\text{Co}(\text{NH}_3)_4\text{Cl}_2]^+$ , are known as heteroleptic.

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

Ans. (ii) and (iv)

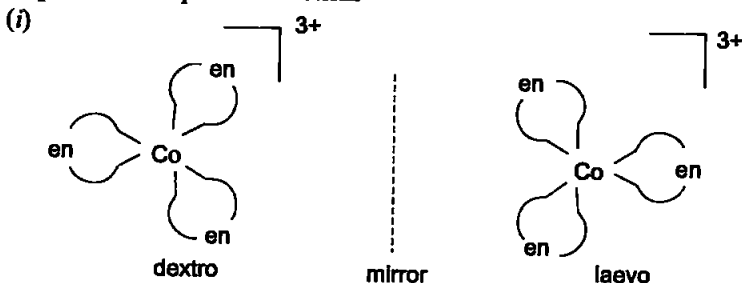
**Explanation:** Already explained in answer no.19.

21. Identify the optically active compounds from the following :

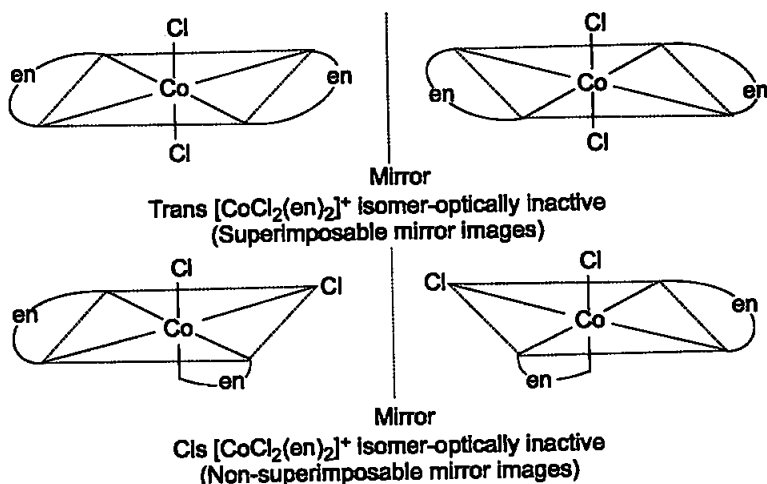
- (i)  $[\text{Co}(\text{en})_3]^{3+}$
- (ii)  $\text{trans-}[\text{Co}(\text{en})_2\text{Cl}_2]^+$
- (iii)  $\text{cis-}[\text{Co}(\text{en})_2\text{Cl}_2]^+$
- (iv)  $[\text{Cr}(\text{NH}_3)_5\text{Cl}]$

Ans. (i) and (iii)

**Explanation:** Optical Isomerism



*Optical isomers (d and l) of  $[\text{Co}(\text{en})_3]^{3+}$*



Optical isomers are mirror images that cannot be superimposed on one another. These are called as enantiomers. The molecules or ions that cannot be superimposed are called *chiral*. The two forms are called dextro (*d*) and laevo (*l*).

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.

Ans. (i), (ii) and (iii)

**Explanation:** When a ligand can bind through two donor atoms as in  $\text{H}_2\text{NCH}_2\text{CH}_2\text{NH}_2$  (ethane-1, 2-diamine) or  $\text{C}_2\text{O}_4^{2-}$  2-(oxalate), the ligand is said to be didentate and when several donor atoms are present in a single ligand as in  $\text{N}(\text{CH}_2\text{CH}_2\text{NH}_2)_3$ , the ligand is said to be polydentate. Ethylenediaminetetraacetate ion ( $\text{EDTA}^{4-}$ ) is an important hexadentate ligand. When a di- or polydentate ligand uses its two or more donor atoms to bind a single metal ion, it is said to be a chelate ligand. Ethane-1, 2-diamine is a neutral ligand.

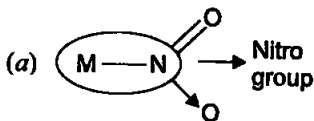
23. Which of the following complexes show linkage isomerism?

- (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)  $[\text{Fe}(\text{en})_2\text{Cl}_2]^+$

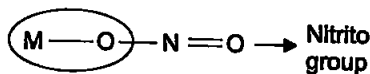
Ans. (i) and (iii)

**Explanation:** Linkage isomerism arises in a coordination compound containing ambidentate ligand. A simple example is provided by complexes containing the thiocyanate ligand.  $\text{NCS}^-$ , which may bind through the nitrogen to give  $\text{M-NCS}$  or through sulphur to give  $\text{M-SCN}$ . Jorgensen discovered such behaviour in the complex  $[\text{Co}(\text{NH}_3)_5\text{NO}_2\text{Cl}_2]$ , which is obtained as the red form, in which the nitrite ligand is bound

through oxygen ( $-\text{ONO}$ ), and as the yellow form, in which the nitrite ligand is bound through nitrogen ( $-\text{NO}_2$ ).



(The donor atom is N)

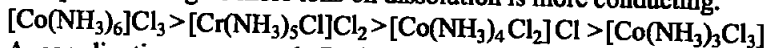


(The donor atom is oxygen)

### III. SHORT ANSWER TYPE

24. Arrange the following complexes in the increasing order of conductivity of their solution:  $[\text{Co}(\text{NH}_3)_3\text{Cl}_3]$ ,  $[\text{Co}(\text{NH}_3)_4\text{Cl}_2]\text{Cl}$ ,  $[\text{Co}(\text{NH}_3)_6]\text{Cl}_3$ ,  $[\text{Cr}(\text{NH}_3)_5\text{Cl}]\text{Cl}_2$ .

Ans. Complex which give more ions on dissolution is more conducting.

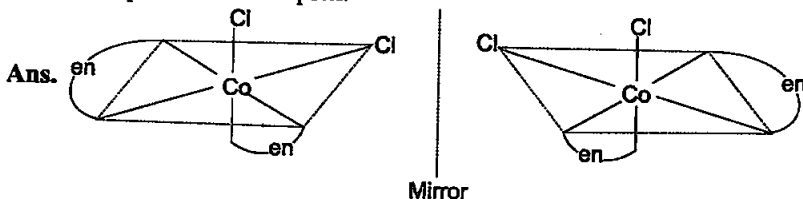


25. A coordination compound  $\text{CrCl}_3 \cdot 4\text{H}_2\text{O}$  precipitates silver chloride when treated with silver nitrate. The molar conductance of its solution corresponds to a total of two ions. Write structural formula of the compound and name it.

Ans. Since only two ions are present in the solution only one  $\text{Cl}^-$  is present outside the sphere.

The formula of the complex is  $[\text{Co}(\text{H}_2\text{O})_4\text{Cl}_2]\text{Cl}$  and its IUPAC name is Tetraaquadichloridocobalt (III) chloride.

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.



Cis  $[\text{CoCl}_2(\text{en})_2]^+$  isomer-optically active  
(Non-superimposable mirror images)

An optically active complex of the type  $[\text{M}(\text{AA})_2\text{X}_2]^{n+}$

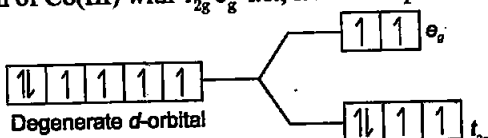
27. Magnetic moment of  $[\text{MnCl}_4]^{2-}$  is 5.92 BM. Explain giving reason.

Ans. Since the coordination number of  $\text{Mn}^{2+}$  ion in the complex ion is 4, it will be either tetrahedral ( $sp^3$  hybridisation) or square planar ( $dsp^2$  hybridisation). But the fact that the magnetic moment of the complex ion is 5.9 BM, it should be tetrahedral in shape rather than square planar because of the presence of five unpaired electrons in the  $d$  orbital.

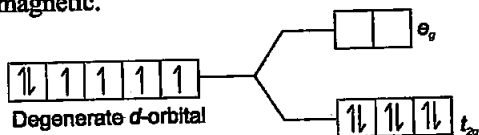
28. On the basis of crystal field theory explain why  $\text{Co}(\text{III})$  forms paramagnetic octahedral complex with weak field ligands whereas it forms diamagnetic octahedral complex with strong field ligands.



Ans. With weak field ligands  $\Delta_0 < P$  (pairing energy) so, the electronic configuration of Co(III) with  $t_{2g}^4 e_g^2$  i.e., it has 4 unpaired electrons



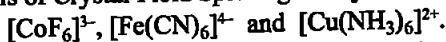
In strong field ligands  $\Delta_0 > P$  (pairing energy). So pairing occurs, thus, the electronic configuration will be  $t_{2g}^6 e_g^0$ . It has no unpaired electron and is diamagnetic.



29. Why are low spin tetrahedral complexes not formed?

Ans. In tetrahedral coordination entity formation, the d orbital splitting is inverted and is smaller as compared to the octahedral field splitting. For the same metal, the same ligands and metal-ligand distances, it can be shown that  $\Delta_t = (4/9) \Delta_0$ .

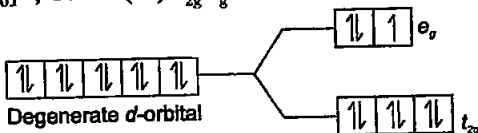
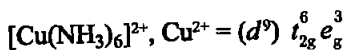
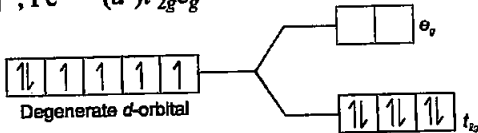
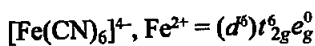
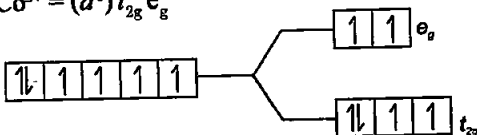
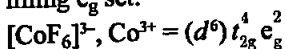
30. Give the electronic configuration of the following complexes on the basis of Crystal Field Splitting theory.



Ans. According to spectrochemical series ligands can be arranged in a series in the order of increasing field strength



Thus  $\text{CN}^-$  and  $\text{NH}_3$  are strong field ligand pair up the  $t_{2g}$  electrons before filling  $e_g$  set.



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.

Ans. Magnetic moment

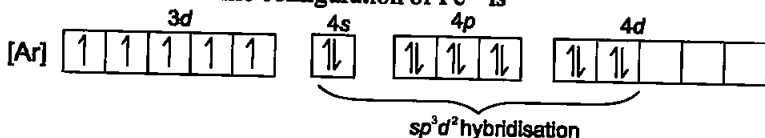
$$\mu = \sqrt{n(n+2)}$$

- (i)  $[\text{Fe}(\text{H}_2\text{O})_6]^{3+}$  has magnetic moment value = 5.92 BM

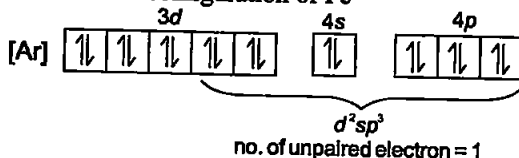
It means no. of unpaired electron = 5

For  $[\text{Fe}(\text{H}_2\text{O})_6]^{3+}$

The electronic configuration of  $\text{Fe}^{3+}$  is

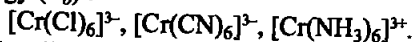


- (ii) This is an outer orbital complex  $\text{CN}^-$  is strong ligand  $\Delta_o > P$  for  $\text{CN}^-$  Electronic configuration of  $\text{Fe}^{3+}$



$$\therefore \mu = 1.74 \text{ BM}$$

32. Arrange following complex ions in increasing order of crystal field splitting energy ( $\Delta_o$ ) :

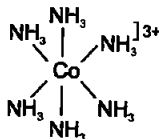
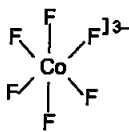


Ans. Crystal field splitting energy increases in the order  $[\text{Cr}(\text{Cl})_6]^{3-} < [\text{Cr}(\text{NH}_3)_6]^{3+} < [\text{Cr}(\text{CN})_6]^{3-}$

Because according to spectrochemical series the order of field strength  $\text{Cl}^- < \text{NH}_3 < \text{CN}^-$

33. Why do compounds having similar geometry have different magnetic moment?

Ans. It is due to the presence of weak and strong field ligands in complexes. If CFSE is high, the complex will show low value of magnetic moment and vice-versa, e.g.,  $[\text{CoF}_6]^{3-}$  and  $[\text{Co}(\text{NH}_3)_6]^{3+}$ , the former is paramagnetic, and the latter is diamagnetic because  $f^-$  is a strong field ligand while both have similar geometry.

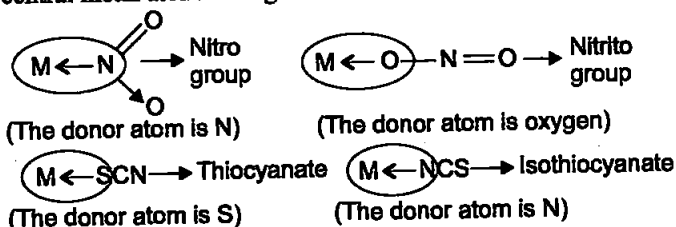


- 34  $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$  is blue in colour while  $\text{CuSO}_4$  is colourless. Why?

Ans. In  $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ , water acts as ligand as a result it causes crystal field splitting. Hence  $d-d$  transition is possible in  $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$  and shows colour. In the anhydrous  $\text{CuSO}_4$  due to the absence of water (ligand), crystal field splitting is not possible and hence no colour.

35. Name the type of isomerism when ambidentate ligands are attached to central metal ion. Give two examples of ambidentate ligands.

Ans. Ambidentate ligands are ligands that can attach themselves to the central metal atom through two different atoms. For example



#### IV. MATCHING TYPE

Note: In the following questions match the items given in Columns I and Column 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) |

Ans. (ii)

Explanation:

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

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 <sub>12</sub>	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)

Ans. (i)

Column I	Column II
A. Chlorophyll	Magnesium
B. Blood pigment	Iron
C. Wilkinson catalyst	Rhodium
D. Vitamin B <sub>12</sub>	Cobalt

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)  
 (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)

Ans. (ii)

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

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. $\text{cis-}[\text{Co}(\text{en})_2\text{Cl}_2]^+$	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) |

Ans. (iv)

Column I	Column II
A. $[\text{Co}(\text{NH}_3)_4\text{Cl}_2]^+$	geometrical
B. $\text{cis-}[\text{Co}(\text{en})_2\text{Cl}_2]^+$	optical
C. $[\text{Co}(\text{NH}_3)_5(\text{NO}_2)]\text{Cl}_2$	ionisation
D. $[\text{Co}(\text{NH}_3)_6][\text{Cr}(\text{CN})_6]$	coordination

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) |

Ans. (i)

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

- Assertion and reason both are true, reason is the correct explanation of assertion.
- Assertion and reason both are true but reason is not the correct explanation of assertion.
- Assertion is true but reason is false.
- 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.

Ans. (i)

**Explanation**: Toxic metal ions are removed by the chelating ligands. Metal ligand form stable complex compound with the toxic metal ions and remove them from the solution.

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.

Ans. (ii)

**Explanation**:  $[\text{Cr}(\text{H}_2\text{O})_6]\text{Cl}_2$  and  $[\text{Fe}(\text{H}_2\text{O})_6]\text{Cl}_2$  are reducing in nature. They form more stable complex after gaining electrons.

43. **Assertion** : Linkage isomerism arises in coordination compounds containing ambidentate ligand.

**Reason** : Ambidentate ligand has two different donor atoms.

Ans. (i)

**Explanation**: Linkage isomerism arises in coordination compounds containing ambidentate ligand because ambidentate ligand has two different donor atoms.

44. **Assertion** : Complexes of  $\text{MX}_6$  and  $\text{MX}_5\text{L}$  type (X and L are unidentate) do not show geometrical isomerism.

**Reason** : Geometrical isomerism is not shown by complexes of coordination number 6.

Ans. (ii)

**Explanation**: Complexes of  $\text{MX}_6$  and  $\text{MX}_5\text{L}$  type (X and L are unidentate) do not show geometrical isomerism due to plane of symmetry shown by them.

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.

Ans. (iv)

**Explanation**:  $[\text{Fe}(\text{CN})_6]^{3-}$  ion shows magnetic moment corresponding to not two for one  $[\text{Fe}(\text{CN})_6]^{3-}$  and  $[\text{Co}(\text{C}_2\text{O}_4)_3]^{3-}$  are inner orbital complexes involving  $d^2sp^3$  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)  $[\text{CoF}_6]^{3-}$ ,  $[\text{Co}(\text{H}_2\text{O})_6]^{2+}$ ,  $[\text{Co}(\text{CN})_6]^{3-}$

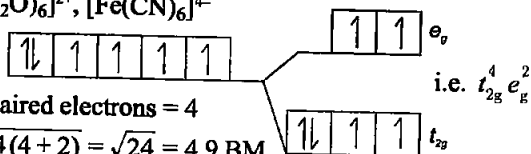
(ii)  $[\text{FeF}_6]^{3-}$ ,  $[\text{Fe}(\text{H}_2\text{O})_6]^{2+}$ ,  $[\text{Fe}(\text{CN})_6]^{4-}$

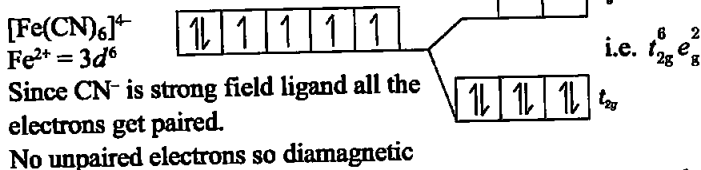
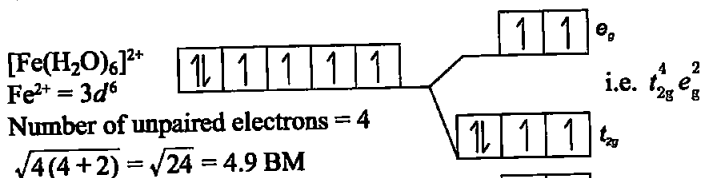
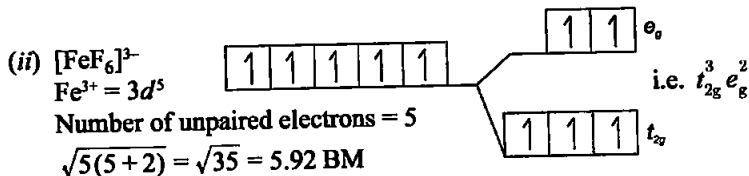
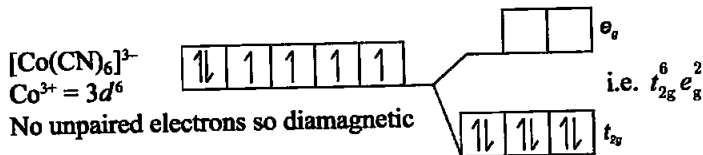
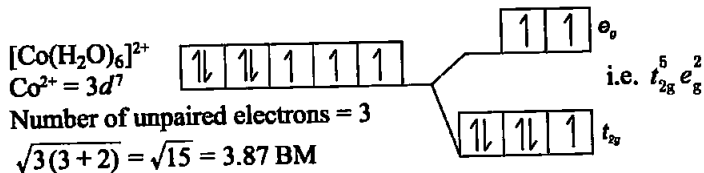
Ans. (i)  $[\text{CoF}_6]^{3-}$

$\text{Co}^{3+} = 3d^6$

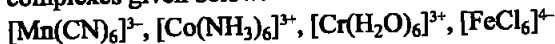
Number of unpaired electrons = 4

$\sqrt{n(n+2)} = \sqrt{4(4+2)} = \sqrt{24} = 4.9 \text{ BM}$



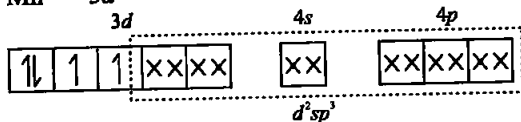
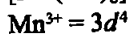


47. Using valence bond theory, explain the following in relation to the complexes given below:

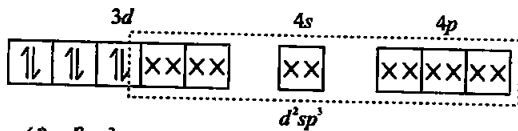
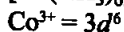


- (i) Type of hybridisation. (ii) Inner or outer orbital complex.  
 (iii) Magnetic behaviour. (iv) Spin only magnetic moment value.

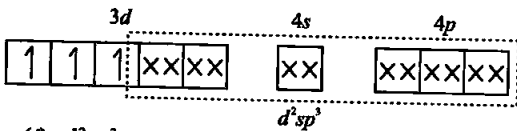
Ans.  $[\text{Mn}(\text{CN})_6]^{3-}$



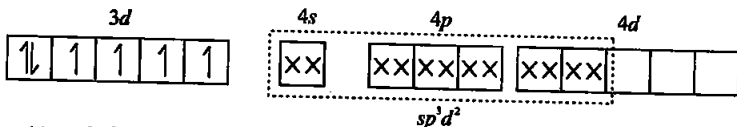
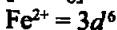
- (i)  $d^2sp^3$   
 (ii) Inner orbital complex  
 (iii) Paramagnetic  
 (iv)  $\sqrt{2(2+2)} = \sqrt{8} = 2.87 \text{ BM}$



- (i)  $d^2sp^3$
- (ii) Inner orbital complex
- (iii) Diamagnetic
- (iv) Zero



- (i)  $d^2sp^3$
- (ii) Inner orbital complex
- (iii) Paramagnetic
- (iv) 3.87 BM



- (i)  $sp^3d^2$
- (ii) Outer orbital complex
- (iii) Paramagnetic
- (iv) 4.9 BM

48.  $\text{CoSO}_4 \cdot 5\text{NH}_3$  exists in two isomeric forms 'A' and 'B'. Isomer 'A' reacts with  $\text{AgNO}_3$  to give white precipitate, but does not react with  $\text{BaCl}_2$ . Isomer 'B' gives white precipitate with  $\text{BaCl}_2$  but does not react with  $\text{AgNO}_3$ . 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'.

Ans. (i) A -  $[\text{Co}(\text{NH}_3)_5\text{SO}_4]\text{Cl}$

B -  $[\text{Co}(\text{NH}_3)_5\text{Cl}]\text{SO}_4$

- (ii) Ionisation isomerism.
- (iii) A. Pentaamminesulphatocobalt(III) chloride.  
B. Pentaamminechlorocobalt(III) sulphate.



49. What is the relationship between observed colour of the complex and the wavelength of light absorbed by the complex?

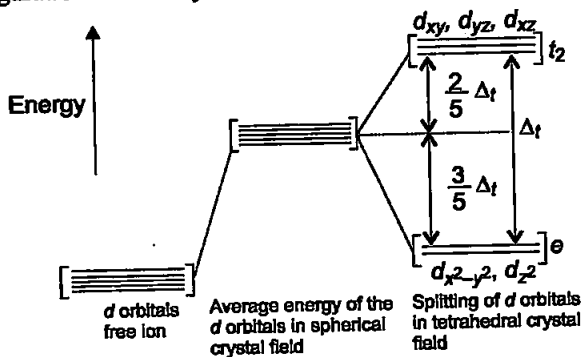
Ans. White light as it passes through the sample, so the light that emerges is no longer white. The colour of the complex is complementary to that which is absorbed. The complementary colour is the colour generated from the wavelength left over; if green light is absorbed by the complex, it appears red.

Coordination entity	Wavelength of light absorbed (nm)	Colour of light absorbed	Colour of coordination entity
$[\text{CoCl}(\text{NH}_3)_5]^{2+}$	535	Yellow	Violet
$[\text{Co}(\text{NH}_3)_5(\text{H}_2\text{O})]^{3+}$	500	Blue Green	Red
$[\text{Co}(\text{NH}_3)_6]^{3+}$	475	Blue	Yellow Orange
$[\text{Co}(\text{CN})_6]^{3-}$	310	Ultraviolet Not in visible region	Pale Yellow
$[\text{Cu}(\text{H}_2\text{O})_4]^{2+}$	600	Red	Blue
$[\text{Ti}(\text{H}_2\text{O})_6]^{3+}$	498	Blue Green	Violet

Above table gives the relationship of the different wavelength absorbed and the colour observed.

50. Why are different colours observed in octahedral and tetrahedral complexes for the same metal and same ligands?

Ans. In tetrahedral coordination entity formation, the  $d$  orbital splitting is inverted and is smaller as compared to the octahedral field splitting. For the same metal, the same ligands and metal-ligand distances, it can be shown that  $\Delta_t = (4/9) \Delta_o$ . Consequently, the orbital splitting energies are not sufficiently large for forcing pairing and, therefore, low spin configurations are rarely observed.



$d$  orbital splitting in a tetrahedral crystal field.

