

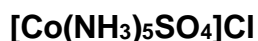
## Very Short Answer Questions

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### Very Short Answer Questions (PYQ)

**Q.1. What type of isomerism is exhibited by the following complex:**

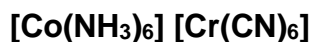
[CBSE (F) 2014]



**Ans.** Ionisation isomerism

**Q.2. What type of isomerism is shown by the following complex:**

[CBSE (F) 2014]



**Ans.** Coordination isomerism

**Q.3. Which of the following is more stable complex and why?  $[\text{Co}(\text{NH}_3)_6]^{3+}$  and  $[\text{Co}(\text{en})_3]^{3+}$**

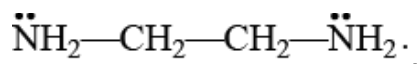
[CBSE Delhi 2014]

**Ans.**  $[\text{Co}(\text{en})_3]^{3+}$  is more stable complex because of chelation.

**Q.4. Why is the complex  $[\text{Co}(\text{en})_3]^{3+}$  more stable than the complex  $[\text{CoF}_6]^{3-}$ ?**

[CBSE East 2016]

**Ans.** Due to chelate effect as the complex  $[\text{Co}(\text{en})_3]^{3+}$  contains chelating ligand



**Q.5. Why is CO a stronger ligand than  $\text{Cl}^-$ ?**

[CBSE (F) 2011]

**Ans.** CO is a stronger ligand than  $\text{Cl}^-$  as it is a  $\pi$ -acceptor ligand.

**Q.6. Give an example of linkage isomerism.**

[CBSE Delhi 2010]

**Ans.** The example of linkage isomerism:  $[\text{Co}(\text{NH}_3)_5\text{NO}_2]^{2+}$  and  $[\text{Co}(\text{NH}_3)_5\text{ONO}]^{2+}$ .

**Q.7. What do you understand by 'denticity of a ligand'?**

[CBSE (F) 2011]

**Ans.** The number of coordinating groups present in ligand is called the denticity of ligand. For example, denticity of ethane-1, 2-diamine is 2, as it has two donor nitrogen atoms which can link to central metal atom.

**Q.8. Define crystal field splitting energy.**

[CBSE (F) 2016]

**Ans.** When ligand approach a transition metal ion, the *d*-orbitals split into two sets, one with lower energy and the other with higher energy. The difference of energy between the two sets of orbitals is known as crystal field splitting energy.

### Very Short Answer Questions (OIQ)

**Q.1. What are crystal fields?**

**Ans.** The ligands especially anionic (or polar neutral ligands) has around them negatively charged field because of which they are called crystal fields.

**Q.2. Square planar complexes with coordination number of four exhibit geometrical isomerism whereas tetrahedral complexes do not. Why?**

**Ans.** Tetrahedral complexes do not show geometrical isomerism because the relative positions of the ligands attached to the central metal atom are same with respect to each other.

**Q.3. Do we call metal carbonyls as organometallics? Why?**

**Ans.** Yes, metal carbonyls are called organometallics because C atom of CO is linked to the metal atom. In fact, the metal-carbon bonds have both  $\sigma$  and  $\pi$  character.

**Q.4. What is spectrochemical series?**

**Ans.** The series in which ligands are arranged in the order of increasing field strength is called spectrochemical series. The order is

$\text{I}^- < \text{Br}^- < \text{SCN}^- < \text{Cl}^- < \text{S}^{2-} < \text{F}^- < \text{OH}^- < \text{C}_2\text{O}_4^{2-} < \text{H}_2\text{O} < \text{NCS}^- < \text{EDTA}^{4-} < \text{NH}_3 < \text{en} < \text{CN}^- < \text{CO}$

**Q.5. Why are low spin tetrahedral complexes not formed?**

[NCERT Exemplar]

**Ans.** Because for tetrahedral complexes, the crystal field stabilisation energy is lower than pairing energy.

**Q.6. Which isomer of  $[\text{CoCl}_2(\text{en})_2]^+$  does not show optical isomerism?**

**Ans.** *Trans* isomer does not show optical isomerism.

**Q.7. How many isomers are there for octahedral complex  $[\text{CoCl}_2(\text{en})(\text{NH}_3)_2]^+$ ?**

[NCERT Exemplar]

**Ans.** There will be three isomers: *cis* and *trans* isomers. *Cis* will also show optical isomerism.

**Q.8. Which compound is used to estimate the hardness of water volumetrically?**

**Ans.** EDTA.

**Q.9. A coordination compound with the molecular formula  $\text{CrCl}_3 \cdot 4\text{H}_2\text{O}$  precipitates  $\text{AgCl}$  with  $\text{AgNO}_3$  solution. Its molar conductivity is found to be equivalent to two ions. What is the structural formula and name of the compound?**

[HOTS]

**Ans.**  $[\text{Cr}(\text{H}_2\text{O})_4\text{Cl}_2]\text{Cl}$ ; Tetraaquadichloridochromium(III) chloride

**Q.10. Arrange the following complexes in the order of increasing electrical conductivity:**

[HOTS]

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

**Ans.**  $[\text{Co}(\text{NH}_3)_3\text{Cl}_3] < [\text{Co}(\text{NH}_3)_4\text{Cl}_2]\text{Cl} < [\text{Co}(\text{NH}_3)_5\text{Cl}]\text{Cl}_2 < [\text{Co}(\text{NH}_3)_6]\text{Cl}_3$

**Q.11. Give IUPAC name of linkage isomer of  $[\text{Co}(\text{NH}_3)_5(\text{NO}_2)]^{2+}$ .**

[HOTS]

**Ans.** The linkage isomer is  $[\text{Co}(\text{NH}_3)_5(\text{ONO})]^{2+}$ . Its IUPAC name is Pentaaminenitrito-O-cobalt (III).

**Q.12. Write IUPAC name of coordination isomer of  $[\text{Co}(\text{NH}_3)_6] [\text{Cr}(\text{CN})_6]$ .**

[HOTS]

**Ans.** The coordination isomer is  $[\text{Cr}(\text{NH}_3)_6] [\text{Co}(\text{CN})_6]$ , Hexaamminechromium(III) hexacyanidocobaltate(III).

**Q.13.** A complex of the type  $[M(AA)_2X_2]^{n+}$  is known to be optically active. What does this indicate about the structure of the complex? Give one example of such complex.

**[NCERT Exemplar] [HOTS]**

**Ans.** An optically active complex of the type  $[M(AA)_2X_2]^{n+}$  indicates *cis*-octahedral structure, e.g., *cis*- $[Pt(en)_2Cl_2]^{2+}$  or *cis*- $Cr(en)_2Cl_2^+$ .

**Q.14.** Name a complex used in treatment of cancer.

**Ans.** Cisplatin  $\{cis-[Pt(NH_3)_2Cl_2]\}$  is used in the treatment of cancer.

## Short Answer Questions-I

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### Short Answer Questions-I (PYQ)

**Q.1. Give the formula of each of the following coordination entities:**

- i.  $\text{Co}^{3+}$  ion is bound to one  $\text{Cl}^-$ , one  $\text{NH}_3$  molecule and two bidentate ethylene diamine (en) molecules.
- ii.  $\text{Ni}^{2+}$  ion is bound to two water molecules and two oxalate ions.

Write the name and magnetic behaviour of each of the above coordination entities.

(At. nos. Co = 27, Ni = 28)

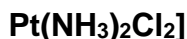
[CBSE Delhi 2012]

**Ans. (i).**  $[\text{Co}(\text{NH}_3)\text{Cl}(\text{en})_2]^{2+}$  : Amminechloridobis (ethane-1, 2-diamine)-cobalt(III) ion  
Magnetic behaviour : Diamagnetic

**(ii).**  $[\text{Ni}(\text{H}_2\text{O})_2(\text{ox})_2]^{2-}$  : Diaquadioxalatonickelate (II) ion  
Magnetic behaviour : Paramagnetic

**Q.2. Answer the following questions:**

**Q. Write the IUPAC name of the isomer of the following complex:**



**Ans.** *cis*-Diamminedichloridoplatinum (II) and *trans*-Diamminedichloridoplatinum (II)

**Q. Write the formula for the following:**

Tetraammineaquachloridocobalt (III) nitrate

[CBSE (F) 2017]

**Ans.**  $[\text{Co}(\text{NH}_3)_4(\text{H}_2\text{O})\text{Cl}](\text{NO}_3)_2$

**Q.3. Using IUPAC norms write the formulae for the following:**

- i. Tris(ethane-1, 2-diamine) chromium (III) chloride
- ii. Potassium tetrahydroxozincate(II)

[CBSE (AI) 2017]

Ans.

- i.  $[\text{Cr}(\text{en})_3]\text{Cl}_3$
- ii.  $\text{K}_2[\text{Zn}(\text{OH})_4]$

**Q.4. When a coordination compound  $\text{CrCl}_3 \cdot 6\text{H}_2\text{O}$  is mixed with  $\text{AgNO}_3$ , 2 moles of  $\text{AgCl}$  are precipitated per mole of the compound. Write**

- i. structural formula of the complex.
- ii. IUPAC name of the complex.

[CBSE Delhi 2016] [HOTS]

Ans. (i).  $[\text{Cr}(\text{H}_2\text{O})_5\text{Cl}]\text{Cl}_2 \cdot \text{H}_2\text{O}$

(ii). Pentaquachloridochromium (III) Chloride monohydrate.

**Q.5. When a coordination compound  $\text{PtCl}_4 \cdot 6\text{NH}_3$  is mixed with  $\text{AgNO}_3$ , 4 moles of  $\text{AgCl}$  are precipitated per mole of the compound. Write**

**Q. structural formula of the complex.**

Ans.  $[\text{Pt}(\text{NH}_3)_6]\text{Cl}_4$

**Q. IUPAC name of the complex.**

[CBSE East 2016] [HOTS]

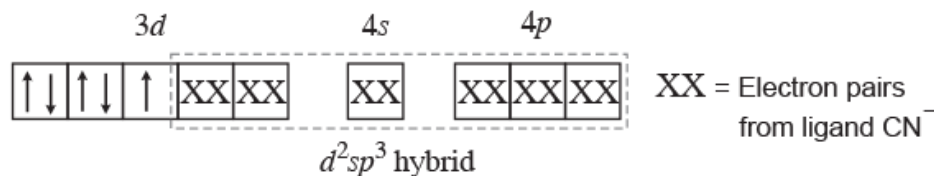
Ans. Hexaammineplatinum (IV) chloride

**Q.6. For the complex  $[\text{Fe}(\text{CN})_6]^{3-}$ , write the hybridisation type, magnetic character and spin nature of the complex. (At. Number : Fe = 26).**

[CBSE Delhi 2016]

Ans.

$[\text{Fe}(\text{CN})_6]^{3-}$ ,  $\text{Fe}^{3+}(3d^5)$



- $d^2sp^3$  hybridisation
- Paramagnetic in nature and low spin complex.

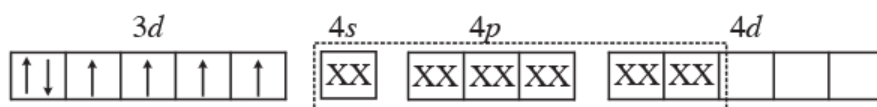
**Q.7. Write the state of hybridisation, shape and IUPAC name of the complex  $[\text{CoF}_6]^{3-}$ .**

(Atomic no. of Co = 27)

[CBSE (F) 2014]

**Ans.**

$[\text{CoF}_6]^{3-}$ : Hexafluoridocobaltate (III) ion;  $\text{Co}^{3+} = [\text{Ar}]3d^6$



XX = Electron pair from ligand  $\text{F}^-$

Hybridisation =  $sp^3d^2$ , Shape = Octahedral

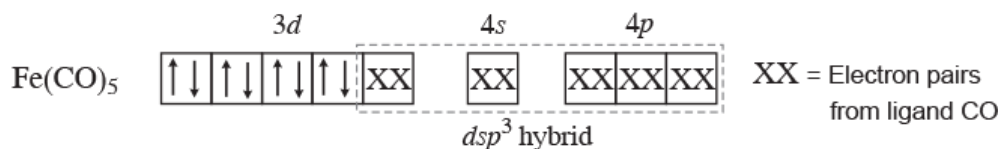
**Q.8. For the complex  $[\text{Fe}(\text{CO})_5]$ , write the hybridization, magnetic character and spin of the complex.**

(At. number: Fe = 26)

[CBSE (F) 2016]

**Ans.**

$\text{Fe}([\text{Ar}] 3d^6 4s^2)$



Hybridisation	$dsp^3$
Magnetic character	Diamagnetic
Spin of the complex	Low spin complex or inner orbital complex

**Q.9. What is meant by crystal field splitting energy? 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**

- $\Delta_0 > P$

ii.  $\Delta_0 < P$

[CBSE (AI) 2013]

**Ans.** The difference of energy between two sets of degenerate orbitals after crystal field splitting is known as crystal field splitting energy.

i.  $t_{2g}^4 e_g^0$

ii.  $t_{2g}^3 e_g^1$

### Short Answer Questions-I (OIQ)

**Q.1. What is the relationship between observed colour of the complex and the wavelength of light absorbed by the complex?**

[NCERT Exemplar]

**Ans.** When white light falls on the complex, some part of it is absorbed. Higher the crystal field splitting, lower will be the wavelength absorbed by the complex. The observed colour of complex is the colour generated from the wavelength left over.

**Q.2. Why do compounds having similar geometry have different magnetic moment?**

[NCERT Exemplar]

**Ans.** It is due to the presence of weak and strong 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.

**Q.3.  $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$  is blue in colour while  $\text{CuSO}_4$  is colourless. Why?**

[NCERT Exemplar]

**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 it is colourless.

**Q.4. 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.**

[NCERT Exemplar]



**Ans.**  $[\text{Fe}(\text{CN})_6]^{3-}$  involves  $d^2sp^3$  hybridisation with one unpaired electron and  $[\text{Fe}(\text{H}_2\text{O})_6]^{3+}$  involves  $sp^3d^2$  hybridisation with five unpaired electrons. This difference is due to the presence of strong  $\text{CN}^-$  and weak ligand  $\text{H}_2\text{O}$  in these complexes.

**Q.5. Write the formulae of the following coordination compounds:**

- i. Tetraamminediaquacobalt(III) chloride
- ii. Tris (ethane-1, 2-diamine) chromium(III) chloride

**Ans.**

- i.  $[\text{Co}(\text{NH}_3)_4(\text{H}_2\text{O})_2]\text{Cl}_3$
- ii.  $[\text{Cr}(\text{en})_3]\text{Cl}_3$

**Q.6. The  $\pi$ -complexes are known for transition metals only. Why?**

**Ans.** Transition metals have vacant  $d$ -orbitals in their atoms or ions into which the electron pairs can be donated by ligands containing  $\pi$ -electrons, e.g.,  $\text{C}_6\text{H}_6$ ,  $\text{CH}_2=\text{CH}_2$ , etc. Thus,  $d\pi - p\pi$  bonding is possible.

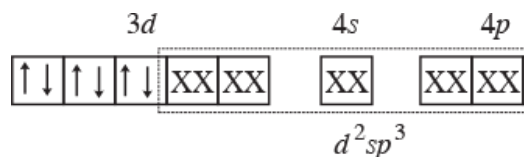
**Q.7. Using valence bond theory explain the  $[\text{Co}(\text{NH}_3)_6]^{3+}$  in relation to the terms given below:**

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

[NCERT Exemplar]

**Ans.**  $[\text{Co}(\text{NH}_3)_6]^{3+}$

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



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

**Q.8. 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.**

[NCERT Exemplar]

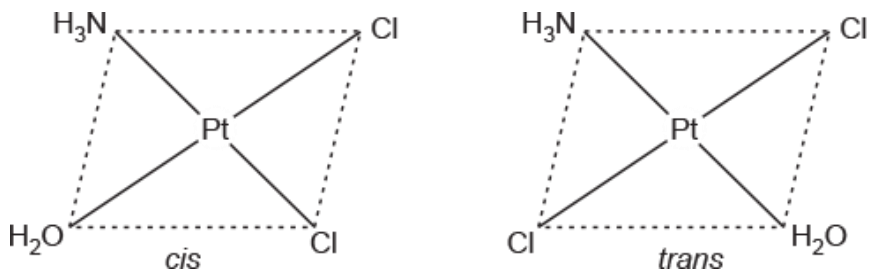
**Ans.**

With weak field ligands,  $\Delta_0 < P$ , the electronic configuration of Co(III) will be  $t_{2g}^4 e_g^2$  and it has 4 unpaired electrons and is paramagnetic. With strong field ligands,  $\Delta_0 > P$  the electronic configuration will be  $t_{2g}^6 e_g^0$ . It has no unpaired electrons and is diamagnetic.

**Q.9. Indicate the types of isomerism exhibited by the following complexes and draw the structures for these isomers:**

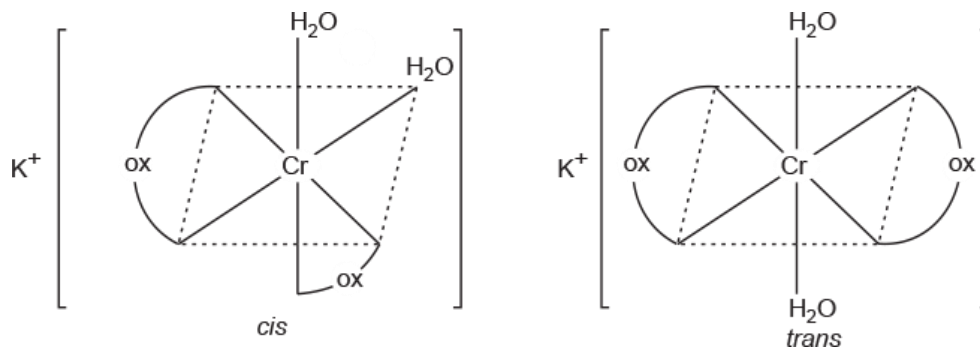
- i.  $[\text{Pt}(\text{NH}_3)(\text{H}_2\text{O})\text{Cl}_2]$
- ii.  $\text{K}[\text{Cr}(\text{H}_2\text{O})_2(\text{C}_2\text{O}_4)_2]$

**Ans. (i).** Geometrical isomers can exist.

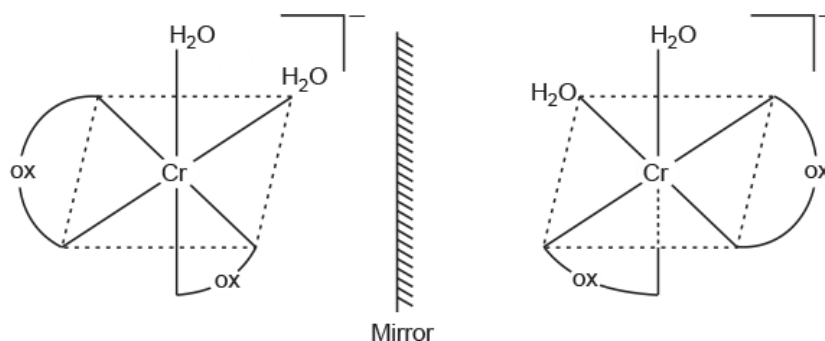


**(ii).** Both geometrical (*cis-trans*) and optical isomers for *cis* can exist.

**a.** Geometrical isomers of  $\text{K}[\text{Cr}(\text{H}_2\text{O})_2(\text{C}_2\text{O}_4)_2]$ :



b. Optical isomers (*d*- and *l*-) of *cis*-K[Cr(H<sub>2</sub>O)<sub>2</sub>(C<sub>2</sub>O<sub>4</sub>)<sub>2</sub>]:



**Q.10. Answer the following questions:**

**Q. Write the IUPAC name of Fe<sub>4</sub> [Fe(CN)<sub>6</sub>]<sub>3</sub>.**

**Ans.** Iron (III) hexacyanoferrate (II).

**Q. Write all the possible isomers of [Co(NH<sub>3</sub>)<sub>5</sub>(SCN)]Cl.**

**Ans.** [Co(NH<sub>3</sub>)<sub>5</sub>(SCN)]Cl, [Co(NH<sub>3</sub>)<sub>5</sub>(NCS)]Cl, [Co(NH<sub>3</sub>)<sub>5</sub>Cl]SCN, [Co(NH<sub>3</sub>)<sub>5</sub>Cl]NCS.

MA<sub>5</sub>B type complexes do not show geometrical or optical isomerism.

**Q.11. An octahedral complex is prepared by mixing CoCl<sub>3</sub> and NH<sub>3</sub> in the molar ratio 1 : 4, 0.1 m solution of this complex was found to freeze at 0.372°C. What is the formula of the complex? Given that molal depression constant (*K<sub>f</sub>*) for water = 1.86°C/m.**

[HOTS]

**Ans.** Theoretical value of

$$\Delta T_f = K_f \times m = 1.86^\circ\text{C}/\text{m} \times 0.1\text{m} = 0.186^\circ\text{C}$$

Observed value of  $\Delta T_f = 0.372^\circ\text{C}$ .

As observed  $\Delta T_f$  is twice the theoretical value, this shows that each molecule of the complex dissociate to form two ions. This can be possible only if the formula of the complex is [Co(NH<sub>3</sub>)<sub>4</sub>Cl<sub>2</sub>]Cl.

**Q.12. Write the IUPAC name of the ionisation isomer of the coordination compound [Co(NH<sub>3</sub>)<sub>5</sub>Br]SO<sub>4</sub>. Give one chemical test to distinguish between the two compounds.**

[CBSE Sample Paper 2016] [HOTS]

**Ans.** Ionisation isomer is  $[\text{Co}(\text{NH}_3)_5\text{SO}_4]\text{Br}$ .

The IUPAC name is Pentaamminesulphatocobalt(III)bromide.

The isomer  $[\text{Co}(\text{NH}_3)_5\text{Br}]\text{SO}_4$  will give  $\text{SO}_4^{2-}$  ions in the solution which gives white precipitate with  $\text{BaCl}_2$  solution. The isomer  $[\text{Co}(\text{NH}_3)_5\text{SO}_4]\text{Br}$  will give  $\text{Br}^-$  ions in the solution which gives yellow precipitate with  $\text{AgNO}_3$  solution.

**Q.13.** A chloride of fourth group cation in qualitative analysis gives a green coloured complex [A] in aqueous solution which when treated with ethane-1, 2-diamine (en) gives pale-yellow solution [B] which on subsequent addition of ethane-1, 2-diamine turns to blue/purple [C] and finally to violet [D]. Write the structures of complexes [A], [B], [C] and [D].

[CBSE Sample Paper 2017]

**Ans.**  $A = [\text{Ni}(\text{H}_2\text{O})_6]^{2+}$

$B = [\text{Ni}(\text{H}_2\text{O})_4(\text{en})]^{2+}$

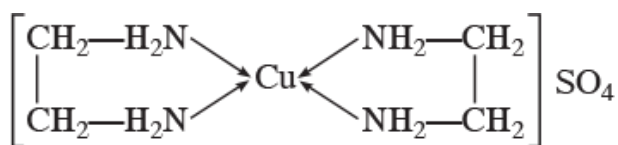
$C = [\text{Ni}(\text{H}_2\text{O})_2(\text{en})_2]^{2+}$

$D = [\text{Ni}(\text{en})_3]^{2+}$

**Q.14.** Answer the following questions:

**Q.** Write formula of a chelate complex and give its IUPAC name.

**Ans.**



Bis-(ethane-1,2-diamine) copper(II) sulphate  
(Chelate complex)

**Q.** Name two complexes which are used in medicines.

**Ans.**

- The platinum complex, *cis*- $[\text{Pt}(\text{NH}_3)_2\text{Cl}_2]$  known as cisplatin is used in the treatment of cancer.
- $\text{Ca-EDTA}$  complex is used in the treatment of lead poisoning.

**Q.15.** Answer the following questions:

**Q. What is meant by chelate effect?**

**Ans.** When a bidentate or polydentate ligand is bonded through two or more donor sites to a metal ion and forms a ring structure then it is said to be chelating ligand. Chelating ligands form more stable complexes than monodentate analogs. This is called chelating effect.

**Q. Square complexes of  $MX_2A_2$  type with coordination number of 4 exhibit geometrical isomerism whereas tetrahedral complexes with similar composition do not. Why?**

**Ans.** Square planar complexes of  $MA_2X_2$  type with coordination number 4 exhibit geometrical isomerism because any of the two ligand may be arranged adjacent to each other in a *cis*- form or opposite to each other in a *trans*- form. Tetrahedral complexes of this type do not show geometrical isomerism because the relative positions of the monodentate ligands attached to the central metal atom are same with respect to each other.

**Q.16. Write IUPAC names of the following coordination compounds:**

- i.  $K_3[Fe(C_2O_4)_3]$
- ii.  $K_2[PdCl_4]$

**Ans.**

- i. Potassium trioxalatoferrate(III)
- ii. Potassium tetrachloridopalladate(II)

## Short Answer Questions-II

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### Short Answer Questions-II (PYQ)

**Q.1. Giving a suitable example for each, explain the following:**

**Q. Crystal field splitting**

**Ans. Crystal field splitting:** When the ligands approach the central metal ion, the electrons in the  $d$ -orbitals of central metal ion will be repelled by the lone pairs of the ligands. Because of these interactions the degeneracy of  $d$ -orbitals of the metal ion is lost and these split into two sets of orbitals having different energies. This is known as

crystal field splitting, e.g., for  $d^4$ , configuration is  $t_{2g}^3 e_g^1$ , in the presence of weak field ligand.

**Q. Linkage isomerism**

**Ans. Linkage isomerism:** The isomers which have same molecular formula but differ in the linkage of ligand atom to the central metal atom are called linkage isomers, e.g.,



**Q. Ambidentate ligand**

[CBSE (AI) 2009]

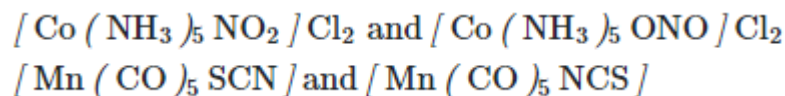
**Ans. Ambidentate ligand:** A unidentate ligand which can bind to the central metal atom through any of the two donor atoms present in it is called ambidentate ligand, e.g.,

$\text{NO}_2$  can bind to metal either through nitro-N ( $\leftarrow \text{N} \begin{matrix} \text{O} \\ \parallel \\ \text{O} \end{matrix}$ ) or through oxygen atom, i.e., as nitrito-O ( $\leftarrow \text{O}-\text{N}=\text{O}$ )

**Q.2. Explain the following giving an example in each case:**

**Q. Linkage isomerism**

**Ans. Linkage isomerism:** This type of isomerism arises due to the presence of an ambidentate ligand in a coordination compound. Some examples of linkage isomers are:

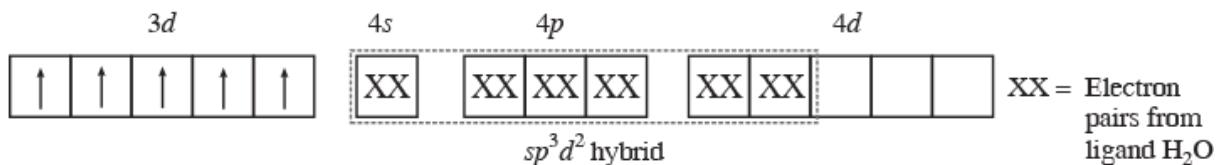




Q.4. Answer the following questions:

Q. For the complex  $[\text{Fe}(\text{H}_2\text{O})_6]^{3+}$ , write the hybridisation, magnetic character and spin of the complex. (At. number: Fe = 26)

Ans.

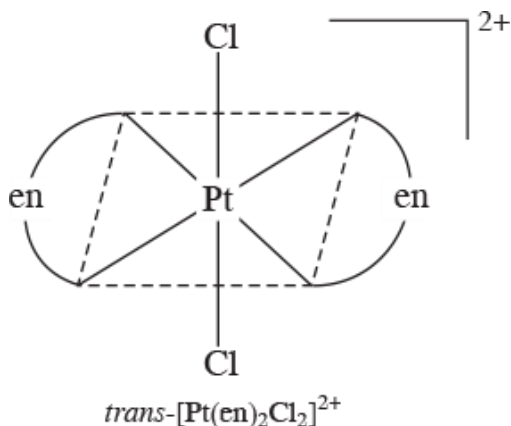


Hybridisation	$sp^3d^2$
Magnetic character	Paramagnetic
Spin of the complex	High spin complex

Q. Draw one of the geometrical isomers of the complex  $[\text{Pt}(\text{en})_2\text{Cl}_2]^{2+}$  which is optically inactive.

[CBSE Central 2016]

Ans. (ii).



Q.5. Write the name, stereochemistry and magnetic behaviour of the following:

(At. nos. Mn = 25, Co = 27, Ni = 28)

- i.  $\text{K}_4[\text{Mn}(\text{CN})_6]$
- ii.  $[\text{Co}(\text{NH}_3)_5\text{Cl}]\text{Cl}_2$
- iii.  $\text{K}_2[\text{Ni}(\text{CN})_4]$



[CBSE Delhi 2011]

Ans.

S. No.	Name of the complex	Hybridisation of metal ion involved	Geometry of complex	Magnetic behaviour
(i)	Potassium hexacyano manganate (II)	$d^2sp^3$	Octahedral	Paramagnetic
(ii)	Pentaamminechloridocobalt (III) chloride	$d^2sp^3$	Octahedral	Diamagnetic
(iii)	Potassium tetra cyanonickelate (II)	$dsp^2$	Square planar	Diamagnetic

Q.6. Write the name, the structure and the magnetic behaviour of each one of the following complexes:

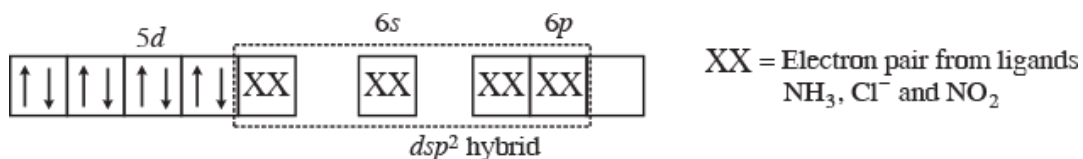
- $[\text{Pt}(\text{NH}_3)_2\text{Cl}(\text{NO}_2)]$
- $[\text{Co}(\text{NH}_3)_4\text{Cl}_2]\text{Cl}$
- $[\text{Ni}(\text{CO})_4]$

(At. nos. Co = 27, Ni = 28, Pt = 78)

[CBSE Delhi 2012]

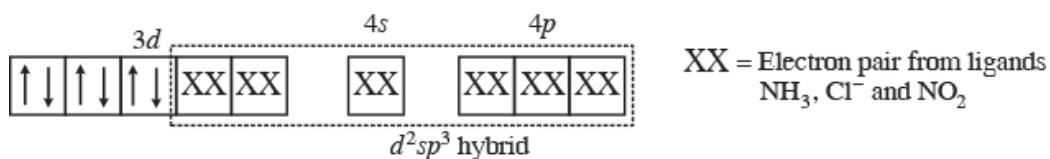
Ans.

- $[\text{Pt}(\text{NH}_3)_2\text{ClNO}_2]$ : Diamminechloridonitrito-N-platinum (II);  $\text{Pt}^{2+} = 5d^8$



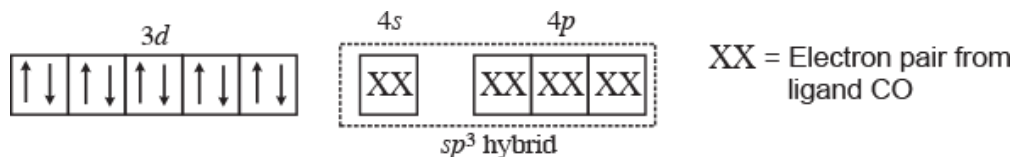
Structure = Square planar; Magnetic behaviour : Diamagnetic

- $[\text{Co}(\text{NH}_3)_4\text{Cl}_2]\text{Cl}$ : Tetraamminedichloridocobalt (III) chloride;  $\text{Co}^{3+} = 3d^6$



Structure = Octahedral; Magnetic behaviour : Diamagnetic

iii.  $[\text{Ni}(\text{CO})_4]$  : Tetracarbonyl nickel(0);  $\text{Ni} = 3d^8 4s^2$



Structure = Tetrahedral; Magnetic behaviour : Diamagnetic

**Q.7. Name the following coordination entities and describe their structures:**

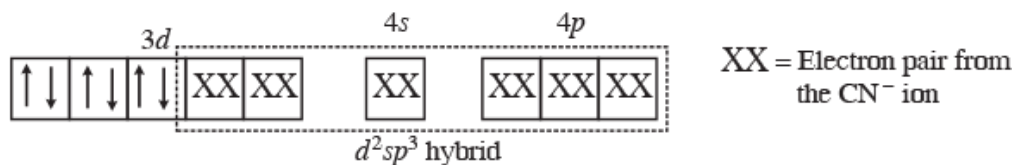
- i.  $[\text{Fe}(\text{CN})_6]^{4-}$
- ii.  $[\text{Cr}(\text{NH}_3)_4\text{Cl}_2]^+$
- iii.  $[\text{Ni}(\text{CN})_4]^{2-}$

(Atomic Numbers: Fe = 26, Cr = 24, Ni = 28)

[CBSE (AI) 2012]

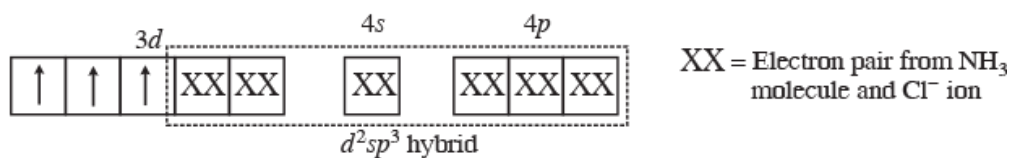
Ans.

i.  $[\text{Fe}(\text{CN})_6]^{4-}$  = Hexacyanoferrate (II) ion;  $\text{Fe}^{2+}(3d^6)$



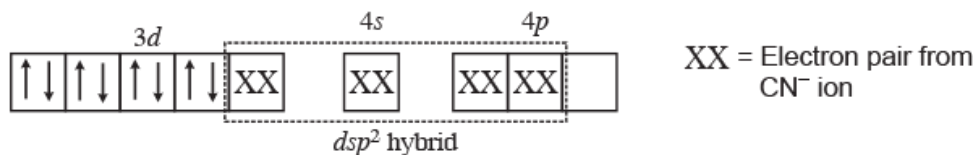
$d^2sp^3$  hybridisation in  $[\text{Fe}(\text{CN})_6]^{4-}$  leads to octahedral structure.

ii.  $[\text{Cr}(\text{NH}_3)_4\text{Cl}_2]^+$  = Tetraamminedichloridochromium (III) ion;  $\text{Cr}^{3+}(3d^3)$



$d^2sp^3$  hybridisation in  $[\text{Cr}(\text{NH}_3)_4\text{Cl}_2]^+$  leads to octahedral structure.

iii.  $[\text{Ni}(\text{CN})_4]^{2-}$  = Tetracyanonickelate(II)ion;  $\text{Ni}^{2+}(\text{II}) (3d^8)$



$dsp^2$  hybridisation in  $[\text{Ni}(\text{CN})_4]^{2-}$  leads to square planar structure.

**Q.8. Give the name, the stereochemistry and the magnetic behaviour of the following complexes:**

- i.  $[\text{Co}(\text{NH}_3)_5\text{Cl}]\text{Cl}_2$
- ii.  $\text{K}_2[\text{Ni}(\text{CN})_4]$

[CBSE (F) 2011]

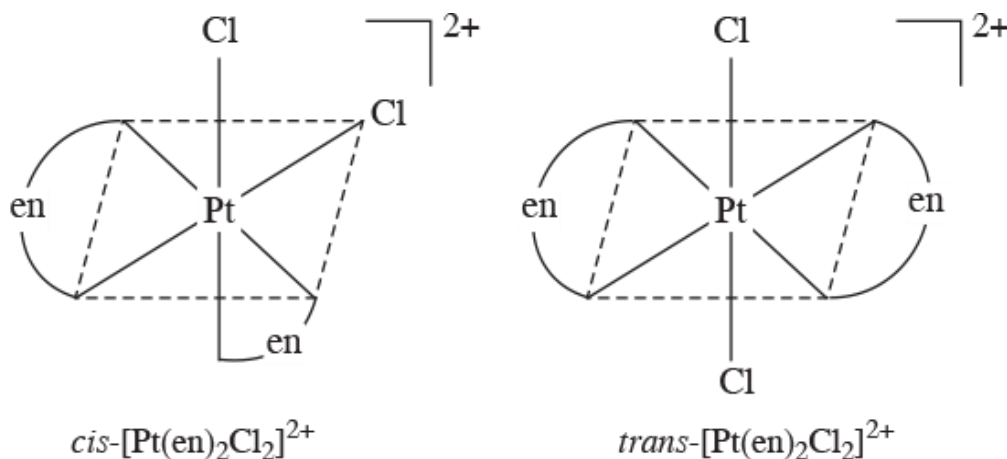
**Ans. (i).**  $[\text{Co}(\text{NH}_3)_5\text{Cl}]\text{Cl}_2$ : Pentaamminechloridocobalt(III) chloride  
 Co(III):  $[\text{Ar}] 3d^6 4s^0$ — $d^2sp^3$  hybridisation leads to octahedral shape.  
 Magnetic behaviour: Diamagnetic.

**(ii).**  $\text{K}_2[\text{Ni}(\text{CN})_4]$ : Potassium tetracyanonickelate (II)  
 Ni(II):  $[\text{Ar}] 3d^8 4s^0$ — $dsp^2$  hybridisation leads to square planar shape.  
 Magnetic behaviour: Diamagnetic.

**Q.9. Answer the following questions:**

**Q. Draw the geometrical isomers of complex  $[\text{Pt}(\text{en})_2\text{Cl}_2]^{2+}$ .**

**Ans.**



**Q. On the basis of crystal field theory, write the electronic configuration for  $d^4$  ion, if  $\Delta_0 > P$**

**Ans.**

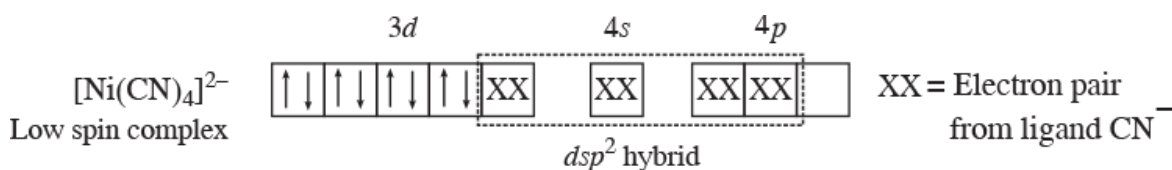


**Q. Write the hybridization type and magnetic behaviour of the complex  $[\text{Ni}(\text{CN})_4]^{2-}$ .**

(Atomic number of Ni = 28).

[CBSE (AI) 2015]

Ans.  $\text{Ni}^{2+} : 3d^8 4s^0$



Hybridisation =  $dsp^2$

Magnetic behaviour = Diamagnetic

**Q.10. Answer the following questions:**

**Q. What type of isomerism is shown by the complex  $[\text{Co}(\text{NH}_3)_6][\text{Cr}(\text{CN})_6]$ ?**

Ans. Coordination isomerism.

**Q. Why a solution of  $[\text{Ni}(\text{H}_2\text{O})_6]^{2+}$  is green while a solution of  $[\text{Ni}(\text{CN})_4]^{2-}$  is colourless?**

(At no. of Ni = 28)

Ans. In  $[\text{Ni}(\text{H}_2\text{O})_6]^{2+}$ , Ni is in + 2 oxidation state with the configuration  $3d^8 4s^0$ , i.e., it has two unpaired electrons which do not pair up in the presence of weak  $\text{H}_2\text{O}$  ligand. The  $d-d$  transition absorbs red light and the complementary green light is emitted.

On the other hand, in  $[\text{Ni}(\text{CN})_4]^{2-}$ , Ni is again in +2 oxidation state with the electronic configuration  $3d^8$ . In the presence of strong  $\text{CN}^-$  ligand the two unpaired electrons in the  $3d$  orbitals pair up. As there is no unpaired electron in  $[\text{Ni}(\text{CN})_4]^{2-}$  therefore the complex is colourless.

**Q. Write the IUPAC name of the following complex:  $[\text{Co}(\text{NH}_3)_5(\text{CO}_3)]\text{Cl}$ .**

[CBSE Delhi 2017]

Ans. Pentaamminecarbonatocobalt(III)chloride

**Q.11. Answer the following questions:**

**Q. What type of isomerism is shown by  $[\text{Co}(\text{NH}_3)_5\text{ONO}]\text{Cl}_2$ ?**

Ans. Linkage isomerism and the linkage isomer is  $[\text{Co}(\text{NH}_3)_5\text{NO}_2]\text{Cl}_2$ .

**Q. On the basis of crystal field theory, write the electronic configuration for  $d^4$  ion, if  $\Delta_0 < P$ .**

**Ans.**

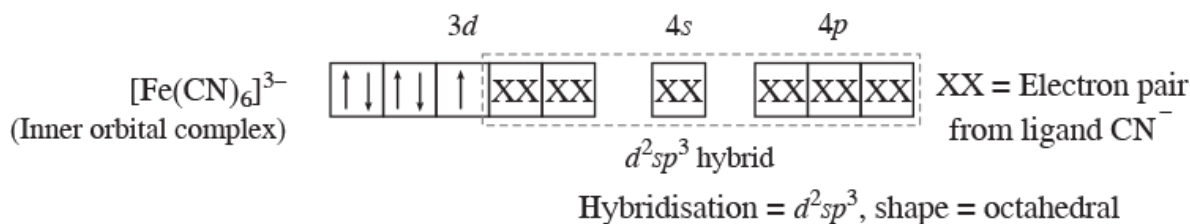
If  $\Delta_0 < P$ , the fourth electron enters one of two  $e_g$  orbitals giving the configuration  $t_{2g}^3 e_g^1$ .

**Q. Write the hybridisation and shape of  $[\text{Fe}(\text{CN})_6]^{3-}$ .**

**(Atomic number of Fe = 26)**

**[CBSE Ajmer 2015]**

**Ans.**  $\text{Fe}^{3+} : 3d^5 4s^0$



**Q.12. Answer the following questions:**

**Q. What type of isomerism is shown by the complex  $[\text{Co}(\text{NH}_3)_5(\text{SCN})]^{2+}$ ?**

**Ans.** Linkage isomerism.

**Q. Why is  $[\text{NiCl}_4]^{2-}$  paramagnetic while  $[\text{Ni}(\text{CN})_4]^{2-}$  is diamagnetic?**

**(Atomic number of Ni = 28)**

**Ans.** In both  $[\text{NiCl}_4]^{2-}$  and  $[\text{Ni}(\text{CN})_4]^{2-}$ , Ni is in +2 oxidation state with configuration  $3d^8$  and it contains two unpaired electrons. In  $[\text{NiCl}_4]^{2-}$  due to presence of weak ligand  $\text{Cl}^-$  no pairing takes place and hence paramagnetic whereas in  $[\text{Ni}(\text{CN})_4]^{2-}$ ,  $\text{CN}^-$  is a strong field ligand and pairing occurs and hence diamagnetic.

**Q. Why are low spin tetrahedral complexes rarely observed?**

**[CBSE (AI) 2017]**

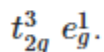
**Ans.** This is due to very low CFSE which is not able to pair up the electrons.

**Q.13. Answer the following questions:**

**Q. Define crystal field splitting energy. On the basis of crystal field theory, write the electronic configuration for  $d^4$  ion if  $\Delta_0 < P$ .**

**Ans.** When ligand approach a transition metal ion, the  $d$ -orbitals split into two sets, one with lower energy and the other with higher energy. The difference of energy between the two sets of orbitals is called crystal field splitting energy.

If  $\Delta_0 < P$ , the fourth electron enters one of the  $e_g$  orbitals giving the configuration



**Q.  $[\text{Ni}(\text{CN})_4]^{2-}$  is colourless whereas  $[\text{Ni}(\text{H}_2\text{O})_6]^{2+}$  is green. Why?**

**(At. no. of Ni = 28)**

**[CBSE (F) 2017]**

**Ans.** In  $[\text{Ni}(\text{H}_2\text{O})_6]^{2+}$ , Ni is in + 2 oxidation state with the configuration  $3d^8 4s^0$ , *i.e.*, it has two unpaired electrons which do not pair up in the presence of weak  $\text{H}_2\text{O}$  ligand. The  $d-d$  transition absorbs red light and the complementary green light is emitted.

On the other hand, in  $[\text{Ni}(\text{CN})_4]^{2-}$ , Ni is again in +2 oxidation state with the electronic configuration  $3d^8$ . In the presence of strong  $\text{CN}^-$  ligand the two unpaired electrons in the  $3d$  orbitals pair up. As there is no unpaired electron in  $[\text{Ni}(\text{CN})_4]^{2-}$  therefore the complex is colourless.

### Short Answer Questions-II (OIQ)

**Q.1. Explain with two examples each of the following:**

**Q. Coordination entity**

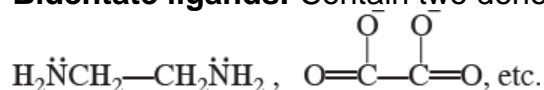
**Ans. Coordination Entity:** A coordination entity constitutes a central metal atom or ion bonded to a fixed number of molecules or ions (ligands), *e.g.*,  $[\text{Co}(\text{NH}_3)_3\text{Cl}_3]$ ,  $[\text{Fe}(\text{CN})_6]^{4-}$ ,  $[\text{Cu}(\text{NH}_3)_4]^{2+}$ , etc.

**Q. Ligand**

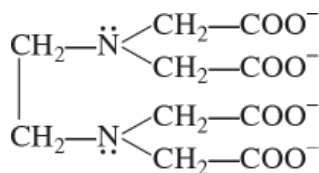
**Ans. Ligands:** Ligands are the atoms, molecules or ions which donate a pair of electrons to central metal atom or ion and form a coordinate bond with it. Depending upon the number of donor atoms available for coordination, the ligands may be classified as:

- **Unidentate ligands:** Contain one donor atom, *e.g.*,  $\text{NH}_3$ ,  $:\ddot{\text{Cl}}:$ , etc.

- **Bidentate ligands:** Contain two donor atoms, e.g.,

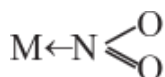


- **Polydentate ligands:** Contain several donor atoms, e.g.,

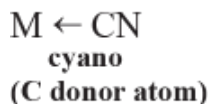
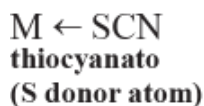


Ethylenediaminetetraacetate ion (EDTA<sup>4-</sup>) (Hexadentate)

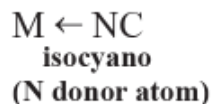
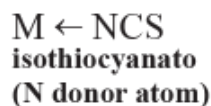
- **Ambidentate ligand:** A ligand which contains two donor atoms but only one of them forms a coordinate bond at a time with central metal atom/ion is called an ambidentate ligand. Some common examples are given below:



**nitrito—N**  
(N donor atom)



**nitrito—O**  
(O donor atom)



- **Chelating ligand:** When a bidentate or a polydentate ligand uses its two or more donor atoms to bind a single metal ion, then a ring-like structure is obtained. It is called chelate and the ligand is known as chelating ligand. The chelating ligands form more stable complexes than the unidentate ligands. This is because when chelation occurs entropy increases and the process becomes more favourable.

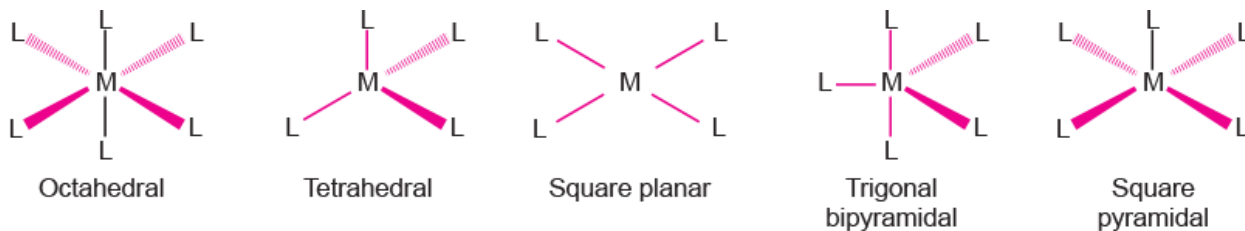
## Q. Coordination number

**Ans. Coordination Number (CN):** The coordination number of a metal ion in a complex may be defined as the total number of ligand donor atoms to which the metal ion is directly bonded. For example, in the complex ions, [Co(NH<sub>3</sub>)<sub>6</sub>]<sup>3+</sup> and [Fe(C<sub>2</sub>O<sub>4</sub>)<sub>3</sub>]<sup>3-</sup>, the coordination numbers of both Co and Fe is 6.

## Q.2. Explain with two examples each of the following:

### Q. Coordination polyhedron

**Ans. Coordination Polyhedron:** The spatial arrangement of the ligand atoms which are directly attached to the central atom/ion is known as the coordination polyhedron around the central atom/ion. Tetrahedral, square planar, octahedral, square pyramidal and trigonal bipyramidal are common shapes of coordination polyhedra.



**Fig. 9.1:** Shapes of different coordination polyhedra.  
M represents the central atom/ion and L, a unidentate ligand

### Q. Homoleptic complex

**Ans. Homoleptic Complex:** The complex in which metal atom is bound to only one kind of donor groups, e.g.,  $[\text{Cu}(\text{CN})_4]^{3-}$ .

### Q. Heteroleptic complex

**Ans. Heteroleptic Complex:** The complex in which metal atom is bound to more than one kind of donor groups, e.g.,  $[\text{Co}(\text{NH}_3)_4\text{Cl}_2]^+$ .

### Q.3. Differentiate between weak field and strong field coordination entity.

**Ans.**

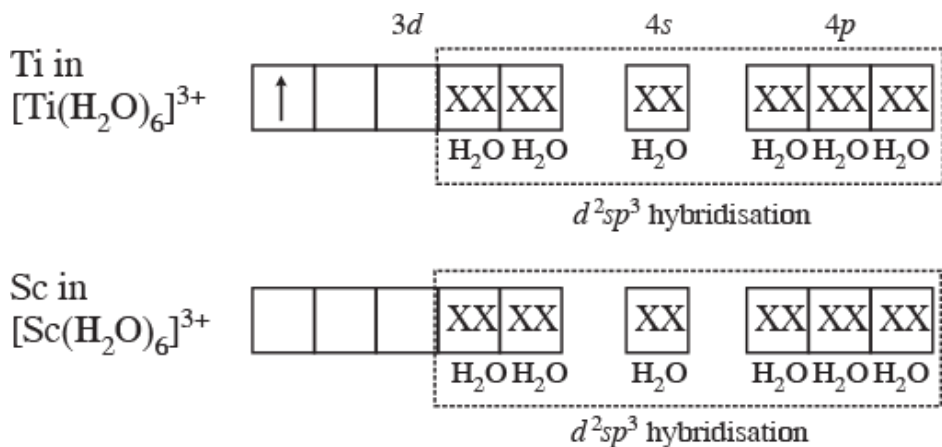
S.No.	Weak field coordination entity	Strong field coordination entity
(i)	They are formed when the crystal field stabilisation energy ( $\Delta_o$ ) in octahedral complexes is less than the energy required for an electron pairing in a single orbital (P).	They are formed when the crystal field stabilisation energy ( $\Delta_o$ ) is greater than the P.
(ii)	They are also called high spin complexes.	They are called low spin complexes.
(iii)	They are mostly paramagnetic in nature.	They are mostly diamagnetic or less paramagnetic than weak field.
(iv)	Never formed by $\text{CN}^-$ ligands.	Formed by $\text{CN}^-$ like ligands.

### Q.4. How would you account for the following?

**Q.  $[\text{Ti}(\text{H}_2\text{O})_6]^{3+}$  is coloured while  $[\text{Sc}(\text{H}_2\text{O})_6]^{3+}$  is colourless.**



**Ans.** The outer electronic structure of  $[\text{Ti}(\text{H}_2\text{O})_6]^{3+}$  and  $[\text{Sc}(\text{H}_2\text{O})_6]^{3+}$  are given below:

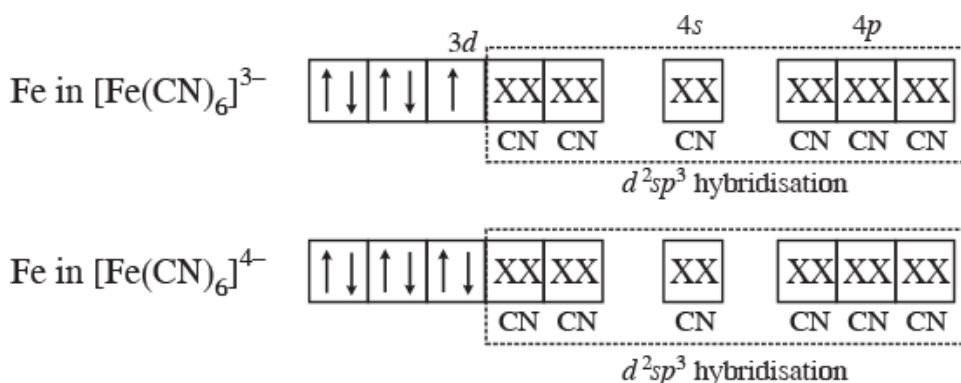


Due to the presence of one electron in  $3d$ -subshell in  $[\text{Ti}(\text{H}_2\text{O})_6]^{3+}$  complex  $d-d$  transition takes place by the absorption of visible light. Hence, the complex appears coloured.

On the other hand,  $[\text{Sc}(\text{H}_2\text{O})_6]^{3+}$  does not possess any unpaired electron. Hence,  $d-d$  transition (which is responsible for colour) in this complex is not possible. Therefore, it is colourless.

**Q.  $[\text{Fe}(\text{CN})_6]^{3-}$  is weakly paramagnetic while  $[\text{Fe}(\text{CN})_6]^{4-}$  is diamagnetic.**

**Ans.** Paramagnetism is attributed to the presence of unpaired electrons. Greater the number of unpaired electrons, greater is the paramagnetism.

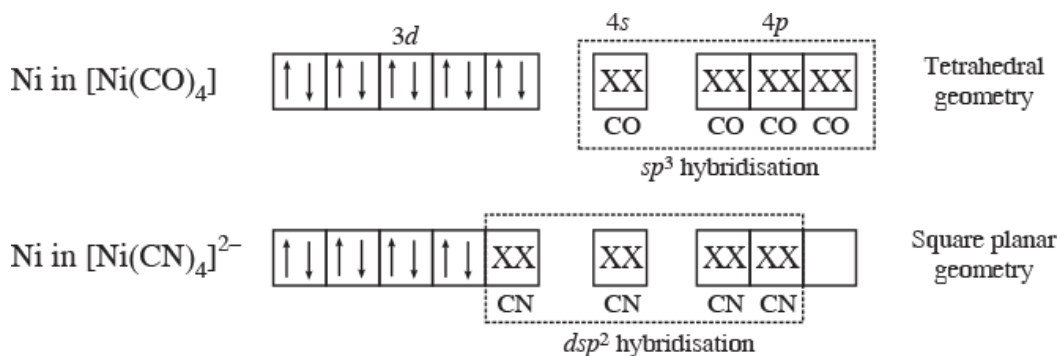


Due to the presence of one unpaired electron in the  $3d$  subshell in  $[\text{Fe}(\text{CN})_6]^{3-}$ , it is weakly paramagnetic. On the other hand,  $[\text{Fe}(\text{CN})_6]^{4-}$  is diamagnetic because all the electrons are paired.

**Q.  $[\text{Ni}(\text{CO})_4]$  possesses tetrahedral geometry while  $[\text{Ni}(\text{CN})_4]^{2-}$  is square planar.**

**Ans.** Ni in  $[\text{Ni}(\text{CO})_4]$  is  $sp^3$  hybridised. Hence, it is tetrahedral.

In  $[\text{Ni}(\text{CN})_4]^{2-}$ , the  $\text{Ni}^{2+}$  is  $dsp^2$  hybridised. Hence, it has square planar geometry.

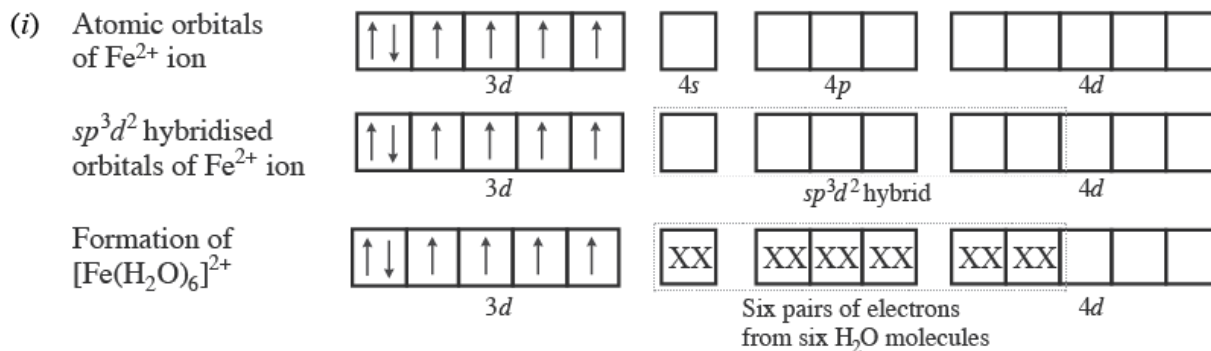


**Q.5. Describe for any two of the following complex ions, the type of hybridisation, shape and magnetic property:**

- i.  $[\text{Fe}(\text{H}_2\text{O})_6]^{2+}$
- ii.  $[\text{Co}(\text{NH}_3)_6]^{3+}$
- iii.  $[\text{NiCl}_4]^{2-}$

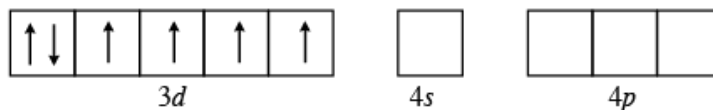
(At. Nos. Fe = 26, Co = 27, Ni = 28)

**Ans.**

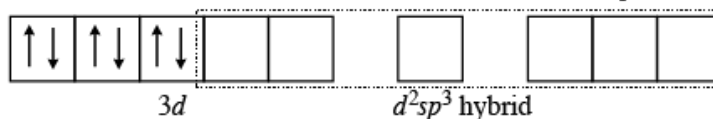


Octahedral because of  $sp^3d^2$  hybridisation. Paramagnetic, as there are four unpaired electrons present in the complex ion.

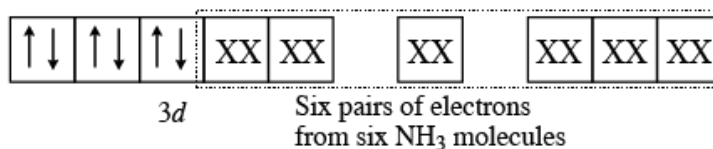
(ii) Atomic orbitals of Co (III) ion



$d^2sp^3$  hybridised orbitals of Co (III) ion

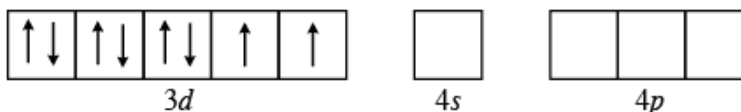


Formation of  $[\text{Co}(\text{NH}_3)_6]^{3+}$

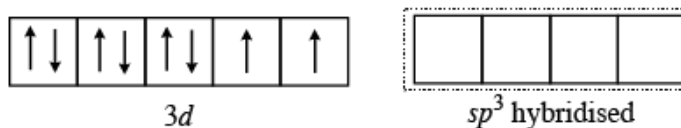


$d^2sp^3$  hybridisation leads to octahedral geometry. Diamagnetic, as there is no unpaired electron present in the complex.

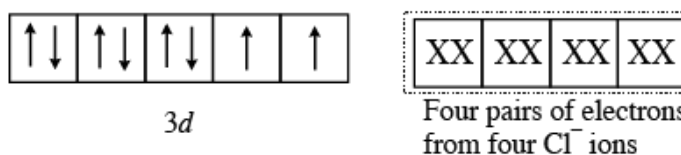
(iii) Atomic orbitals of Ni (II) ion



$sp^3$  hybridised orbitals of Ni (II)



Formation of  $[\text{NiCl}_4]^{2-}$



$sp^3$  hybridisation leads to tetrahedral geometry. Paramagnetic, as there are two unpaired electrons.

(any two)

**Q.6. Write IUPAC names of the following coordination compounds:**

- i.  $[\text{Co}(\text{NH}_3)_6]\text{Cl}_3$
- ii.  $[\text{Co}(\text{NH}_3)_5\text{Cl}]\text{Cl}_2$
- iii.  $\text{K}_3[\text{Fe}(\text{CN})_6]$

**Ans.**

- i. Hexaamminecobalt(III) chloride
- ii. Pentaamminechloridocobalt(III) chloride
- iii. Potassium hexacyanoferrate(III)

**Q.7. Answer the following questions:**

**Q. Write the formulae for the following coordination compounds:**

- a. Tetraammineaquachloridocobalt (III) chloride
- b. Potassiumtetracyanonickelate (II)

**Ans.**

- a.  $[\text{Co}(\text{NH}_3)_4(\text{H}_2\text{O})\text{Cl}]\text{Cl}_2$
- b.  $\text{K}_2[\text{Ni}(\text{CN})_4]$

**Q. Write the hybridisation of the complex  $[\text{NiCl}_4]^{2-}$ .**

**(Atomic number of Ni = 28)**

**Ans.**  $sp^3$  hybridisation.

**Q.8. Write the formulae of the following coordination compounds:**

- i. Amminebromidochloridonitrito-N-platinate(II)
- ii. Dichloridobis(ethane-1, 2-diamine)platinum(IV) nitrate
- iii. Iron(III)hexacyanoferrate(II)

**Ans.**

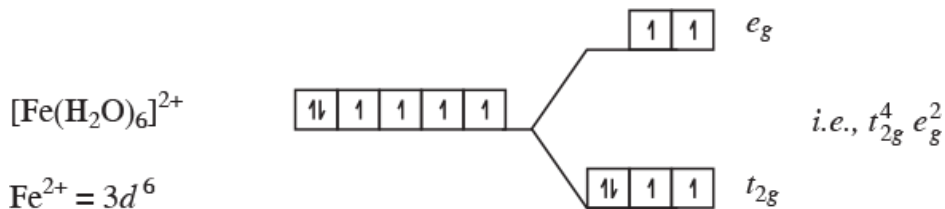
- i.  $[\text{Pt}(\text{NH}_3)\text{BrCl}(\text{NO}_2)]^-$
- ii.  $[\text{PtCl}_2(\text{en})_2](\text{NO}_3)_2$
- iii.  $\text{Fe}_4[\text{Fe}(\text{CN})_6]_3$

**Q.9. 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;**

$[\text{Fe}(\text{H}_2\text{O})_6]^{2+}$ ,

**[NCERT Exemplar]**

**Ans.**



Number of unpaired electrons ( $n$ ) = 4

$$\text{Magnetic moment } (\mu) = \sqrt{4(4+2)} = \sqrt{24} = 4.9 \text{ BM}$$

**Q.10. Answer the following questions:**

**Q. What is the coordination number of central metal ion in  $[\text{Fe}(\text{C}_2\text{O}_4)_3]^{3-}$ ?**

**Ans.** Six

**Q. Write the formula of Pentamminechloridoplatinum (IV).**

**Ans.**  $[\text{Pt}(\text{NH}_3)_5\text{Cl}]\text{Cl}_3$

**Q.10. Arrange following complex ions in increasing order of crystal field splitting energy ( $\Delta_0$ ):**

$[\text{Cr}(\text{Cl})_6]^{3-}$ ,  $[\text{Cr}(\text{CN})_6]^{3-}$ ,  $[\text{Cr}(\text{NH}_3)_6]^{3+}$

**[NCERT Exemplar]**

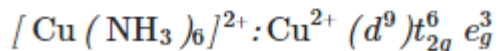
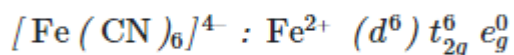
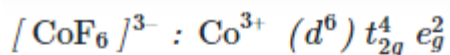
**Ans.** Crystal field splitting energy increases in the order  $[\text{Cr}(\text{Cl})_6]^{3-} < [\text{Cr}(\text{NH}_3)_6]^{3+} < [\text{Cr}(\text{CN})_6]^{3-}$ .

**Q.11. Give the electronic configuration of the following complexes on the basis of crystal field splitting theory.**

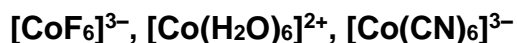
$[\text{CoF}_6]^{3-}$ ,  $[\text{Fe}(\text{CN})_6]^{4-}$  and  $[\text{Cu}(\text{NH}_3)_6]^{2+}$ .

**[NCERT Exemplar]**

**Ans.**



**Q.12. 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:**

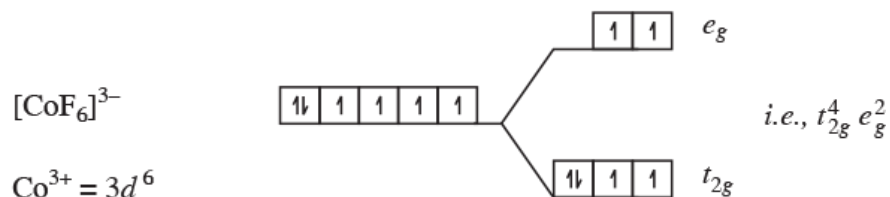


**[NCERT Exemplar]**

**Ans.**

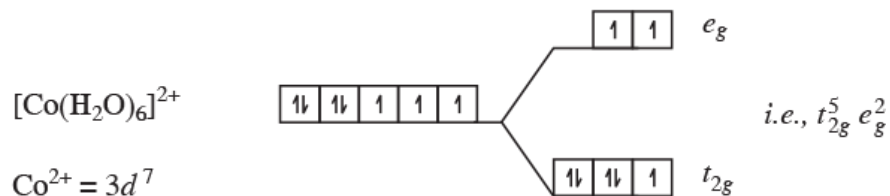
Magnetic moment,  $\mu = \sqrt{n(n+2)}$

where,  $n$  = Number of unpaired electrons



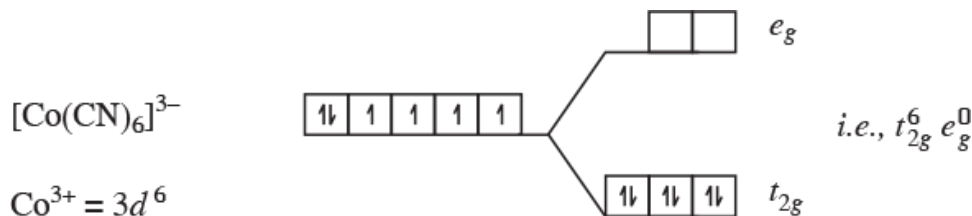
Number of unpaired electrons ( $n$ ) = 4

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



Number of unpaired electrons ( $n$ ) = 3

Magnetic moment =  $\sqrt{n(n+2)} = \sqrt{3(3+2)} = \sqrt{15} = 3.87$  BM



No unpaired electrons, so it is diamagnetic.

**Q.13. Give the number of unpaired electrons in the following complex ions:**

**$[\text{FeF}_6]^{4-}$  and  $[\text{Fe}(\text{CN})_6]^{4-}$**

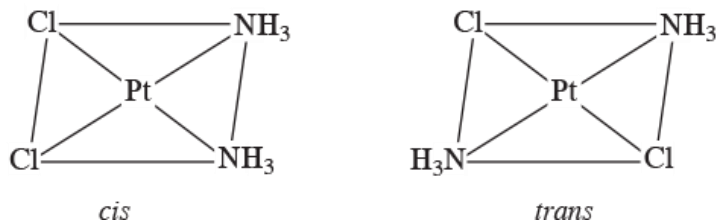
**Ans.**  $[\text{FeF}_6]^{4-}$  has 4 unpaired electrons as  $\text{F}^-$  is a weak field ligand.

$[\text{Fe}(\text{CN})_6]^{4-}$  has no unpaired electrons as  $\text{CN}^-$  is a strong field ligand.

**Q.14. Answer the following questions:**

**Q. Draw the geometrical isomers of complex  $[\text{Pt}(\text{NH}_3)_2\text{Cl}_2]$ .**

**Ans.**



Geometrical isomers of  $[\text{Pt}(\text{NH}_3)_2\text{Cl}_2]$

**Q. On the basis of crystal field theory, write the electronic configuration for  $d^4$  ion if  $\Delta_0 < P$ .**

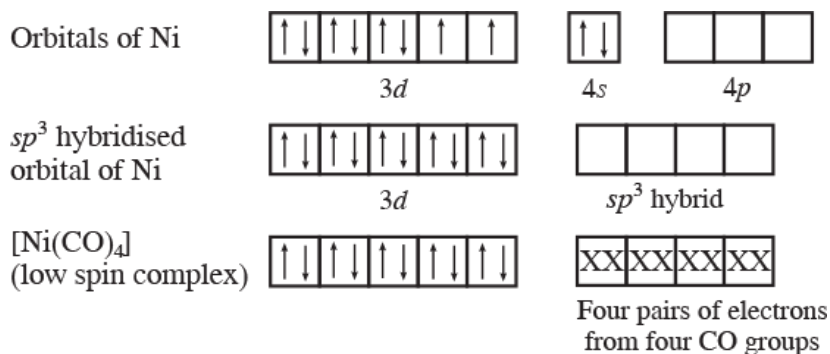
**Ans.**

If  $\Delta_0 < P$  then fourth electron enters one of the  $e_g$  orbitals giving the configuration  $t_{2g}^3 e_g^1$ .

**Q. Write the hybridisation and magnetic behaviour of the complex  $[\text{Ni}(\text{CO})_4]$ .**

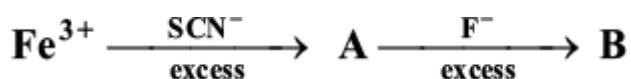
**(At. no. of Ni = 28)**

**Ans.** The complex  $[\text{Ni}(\text{CO})_4]$  involves  $sp^3$  hybridisation.



The complex is diamagnetic as evident from the absence of unpaired electrons.

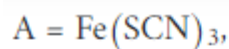
Q.15.



What are A and B? Give IUPAC names of A and B. Find spin only magnetic moment of B.

[HOTS]

Ans.



Trithiocyanato iron(III)

Hexafluoridoferrate(III) ion

EC of Fe(III) =  $d^5$ ,

unpaired electrons ( $n$ ) = 5

Spin only magnetic moment of B =  $\sqrt{n(n+2)}$

$$= \sqrt{5(5+2)}$$

$$= 5.916 \text{ BM}$$

Q.16. Explain the following:

[HOTS]

Q. Low spin octahedral complexes of nickel are not known.

Ans.



Orbitals of  $\text{Ni}^{2+}$



For the formation of low spin complex, electrons present in  $3d$  electrons of  $\text{Ni}^{2+}$  should pair up. This will produce only one empty  $d$  orbital. Hence,  $d^2sp^3$  hybridisation in nickel is not possible to form low spin octahedral complex.

**Q.  $\text{Co}^{2+}$  is easily oxidised to  $\text{Co}^{3+}$  in the presence of a strong ligand.**

**Ans.** With the electronic configuration  $3d^7 4s^0$ ,  $\text{Co}^{2+}$  has three unpaired electrons.  $\text{H}_2\text{O}$  being a weak ligand, the unpaired electrons present in  $3d$  orbitals of  $\text{Co}(\text{II})$  do not pair up. In the presence of strong ligands, two unpaired electrons in  $3d$  orbitals pair up and the third unpaired electron shifts to higher energy orbital from where it can be easily lost and hence shows an oxidation state of III.

**Q. CO is a stronger complexing reagent than  $\text{NH}_3$ .**

**Ans.** CO has empty  $\pi$ -orbitals which overlap with filled  $d$ -orbitals ( $t_{2g}$  orbitals) of transition metals and form  $\pi$ -bonds by back bonding. These  $\pi$ -interactions increase the value of crystal field stabilisation energy ( $\Delta_0$ ).

As  $\text{NH}_3$  cannot form  $\pi$  bonds by back bonding, therefore, CO is stronger ligand than  $\text{NH}_3$ .

**Q.17. Answer the following questions:**

**[HOTS]**

**Q. Give the electronic configuration of the  $d$ -orbitals of Ti in  $[\text{Ti}(\text{H}_2\text{O})_6]^{3+}$  ion in an octahedral crystal field.**

**Ans.**

In  $[\text{Ti}(\text{H}_2\text{O})_6]^{3+}$  ion, Ti is in +3 oxidation state. There is one electron in  $d$ -orbital and the electronic configuration is  $t_{2g}^1 e_g^0$ .

**Q. Why is this complex coloured? Explain on the basis of distribution of electrons in the  $d$ -orbitals.**

**Ans.** Due to  $d-d$  transition, the electron present in  $t_{2g}$  absorbs green and yellow radiation of white light for excitation to  $e_g$  and the configuration becomes  $t_{2g}^0 e_g^1$ . The complementary colour is purple.

**Q. How does the colour change on heating  $[\text{Ti}(\text{H}_2\text{O})_6]^{3+}$  ion?**

**Ans.** On heating, H<sub>2</sub>O is lost. In the absence of ligand, crystal field splitting does not occur hence the substance becomes colourless.

**Q.18.** A metal ion M<sup>n+</sup> having d<sup>4</sup> valence electronic configuration combines with three bidentate ligands to form a complex compound. Assuming  $\Delta_0 > P$ :

[HOTS]

**Q.** Explain orbital splitting during this complex formation.

**Ans.** As  $\Delta_0 > P$  pairing will occur in the t<sub>2g</sub> orbitals and e<sub>g</sub> orbitals will remain vacant.

**Q.** Write the electronic configuration of the valence electrons of the metal M<sup>n+</sup> ion in terms of t<sub>2g</sub> and e<sub>g</sub>.

**Ans.**



**Q.** What type of hybridisation will M<sup>n+</sup> ion have?

**Ans.** As there are three bidentate ligands to combine therefore hybridisation will be d<sup>2</sup>sp<sup>3</sup>.

**Q.** Name the type of isomerism exhibited by this complex.

**Ans.** Optical isomerism.

**Q.19.** Write the correct formulae for the following coordination compounds:

- i. CrCl<sub>3</sub>.6H<sub>2</sub>O (violet with 3 chloride ions precipitated as AgCl)
- ii. CrCl<sub>3</sub>.6H<sub>2</sub>O (light green colour, with 2 chloride ions precipitated as AgCl )
- iii. CrCl<sub>3</sub>.6H<sub>2</sub>O (dark green colour, with 1 chloride ion precipitated as AgCl )

[CBSE Sample Paper 2017]

**Ans.**

- i. [Cr(H<sub>2</sub>O)<sub>6</sub>]Cl<sub>3</sub>
- ii. [Cr(H<sub>2</sub>O)<sub>5</sub>Cl]Cl<sub>2</sub>.H<sub>2</sub>O
- iii. [Cr(H<sub>2</sub>O)<sub>4</sub>Cl<sub>2</sub>]Cl.2H<sub>2</sub>O

**Q.20.** CoSO<sub>4</sub>Cl.5NH<sub>3</sub> exists in two isomeric forms 'A' and 'B'. Isomer 'A' reacts with AgNO<sub>3</sub> to give white precipitate, but does not react with BaCl<sub>2</sub>. Isomer 'B' gives

white precipitate with  $\text{BaCl}_2$  but does not react with  $\text{AgNO}_3$ . Answer the following questions:

**Q. Identify 'A' and 'B' and write their structural formulae.**

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

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

**Q. Name the type of isomerism involved.**

**Ans.** Ionisation isomerism

**Q. Give the IUPAC name of 'A' and 'B'.**

**[NCERT Exemplar]**

**Ans.**

**A.** – Pentaamminesulphatocobalt(III) chloride

**B.** – Pentaamminechloridocobalt(III) sulphate