

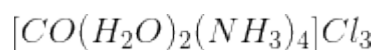
NCERT Solutions for Class 12 Chemistry Chapter 9 Coordination Compounds

Question 9.1(i) Write the formulas for the following coordination compounds:

(i) Tetraamminediaquacobalt(III) chloride

Answer :

The chemical formula for the coordination compound Tetraamminediaquacobalt(III) chloride is

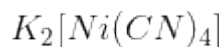


Question 9.1(ii) Write the formulas for the following coordination compounds:

(ii) Potassium tetracyanonickelate(II)

Answer :

The formula for the coordination compound Potassium tetracyanonickelate II is :

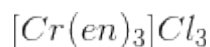


Question 9.1(iii) Write the formulas for the following coordination compounds:

(iii) Tris(ethane-1,2-diamine) chromium(III) chloride

Answer :

The formula for the coordination compound Tris(ethane-1,2-diamine) chromium(III) chloride is :

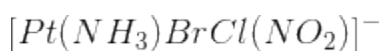


Question 9.1(iv) Write the formulas for the following coordination compounds:

(iv) Amminebromidochloridonitrito-N-platinate(II)

Answer :

The formula for the coordination compound Amminebromidochloridonitrito-N-platinate(II) :

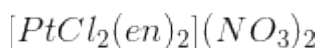


Question 9.1(v) Write the formulas for the following coordination compounds:

(v) Dichloridobis(ethane-1,2-diamine)platinum(IV) nitrate

Answer :

The chemical formula for the coordination compounds: Dichloridobis(ethane-1,2-diamine)platinum(IV) nitrate

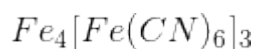


Question 9.1(vi) Write the formulas for the following coordination compounds:

(vi) Iron(III) hexacyanidoferrate(II)

Answer :

The formula for the coordination compound Iron(III) hexacyanidoferrate(II):



Question 9.2(i) Write the IUPAC names of the following coordination compounds:



Answer :

The IUPAC name of the coordination compound $[Co(NH_3)_6]Cl_3$ is :

Hexaamminecobalt(III) chloride

Question 9.2(ii) Write the IUPAC names of the following coordination compounds:

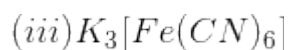


Answer :

The IUPAC name of the coordination compound $[Co(NH_3)_5Cl]Cl_2$ is

Pentaamminechloridocobalt(III) chloride

Question 9.2(iii) Write the IUPAC names of the following coordination compounds:

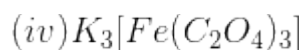


Answer :

The IUPAC name of the coordination compound $K_3[Fe(CN)_6]$ is

Potassium hexacyanoferrate(III).

Question 9.2(iv) Write the IUPAC names of the following coordination compounds:

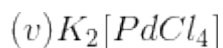


Answer :

The IUPAC name of the following coordination compound $K_3[Fe(C_2O_4)_3]$ is

Potassium trioxalatoferrate(III)

Question 9.2(v) Write the IUPAC names of the following coordination compounds:

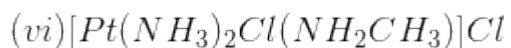


Answer :

The IUPAC names of the coordination compound $K_2[PdCl_4]$ is

Potassium tetrachloridopalladate(II).

Question 9.2(vi) Write the IUPAC names of the following coordination compounds:

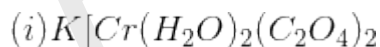


Answer :

The IUPAC name of the following coordination compound $[Pt(NH_3)_2Cl(NH_2CH_3)]Cl$ is :

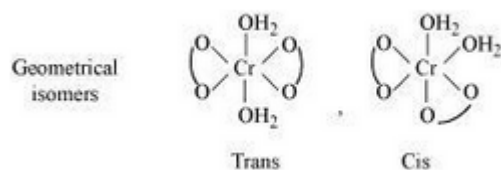
Diamminechlorido(methylamine)platinum(II) chloride.

Question 9.3(i) Indicate the types of isomerism exhibited by the following complexes and draw the structures for these isomers:

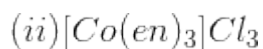


Answer :

Both geometrical (cis-, trans-) and optical isomers exists for the given compound.

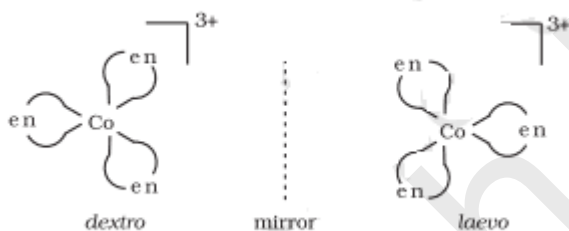


Question 9.3(ii) Indicate the types of isomerism exhibited by the following complexes and draw the structures for these isomers:

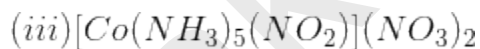


Answer :

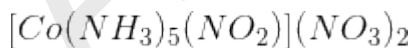
Two optical isomers can exist, Dextro and Laevo.



Question 9.3(iii) Indicate the types of isomerism exhibited by the following complexes and draw the structures for these isomers:

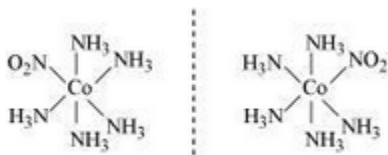


Answer :



There are 10 possible isomers. There are geometrical, ionisation and linkage isomers possible.

A pair of optical isomer



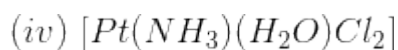
it also shows ionization isomerism



It can also show linkage isomerism

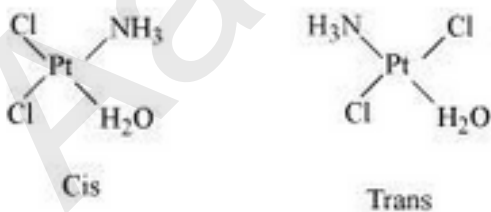


Question 9.3(iv) Indicate the types of isomerism exhibited by the following complexes and draw the structures for these isomers:

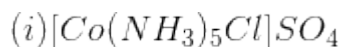


Answer :

Geometrical (cis-, trans-) isomers can exist for $[Pt(NH_3)(H_2O)Cl_2]$

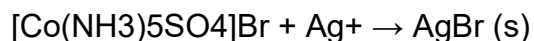
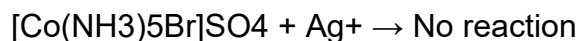
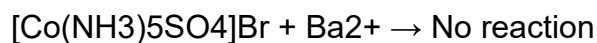
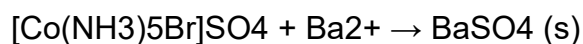


Question 9.4(i) Give evidence that following is ionisation isomer.

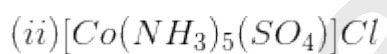


Answer :

The ionisation isomers dissolve in water to yield different ions and thus react differently to various reagents:

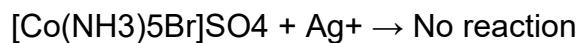
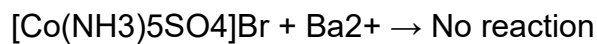
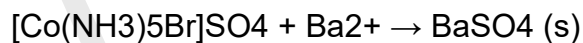


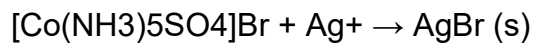
Question 9.4(ii) Give evidence that following is ionisation isomer.



Answer :

The ionisation isomers dissolve in water to yield different ions and thus react differently to various reagents:



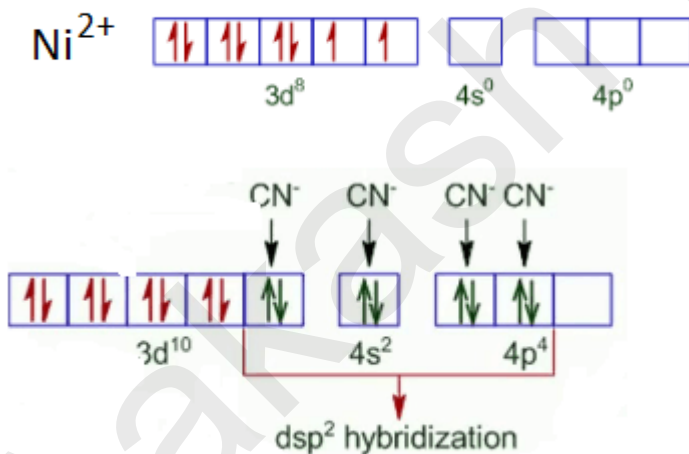


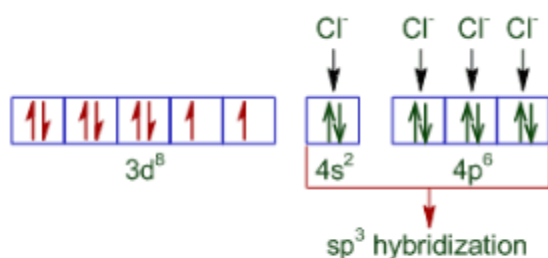
Question 9.5 Explain on the basis of valence bond theory that $[\text{Ni}(\text{CN})_4]^{2-}$ ion with square planar structure is diamagnetic and the $[\text{NiCl}_4]^{2-}$ ion with tetrahedral geometry is paramagnetic.

Answer :

In both the compounds, the oxidation state of Nickel is +2. So it has d^8 configuration.

Now, on the basis of ligand pairing of electrons will occur. Since CN^- is a strong ligand so pairing will occur but in case of Cl^- pairing will not be there as it is a weak ligand. So, the configuration of both the compounds looks like :-



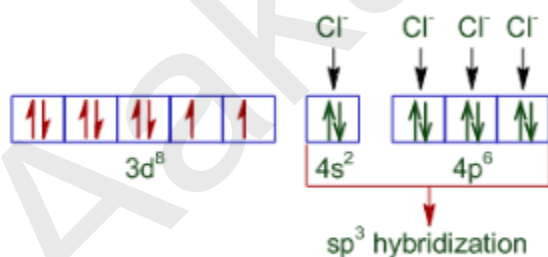


Thus $[Ni(CN)_4]^{2-}$ is a square planer and diamagnetic and $[NiCl_4]^{2-}$ has tetrahedral geometry and is paramagnetic.

Question 9.6 $[NiCl_4]^{2-}$ is paramagnetic while $[Ni(CO)_4]$ is diamagnetic though both are tetrahedral. Why?

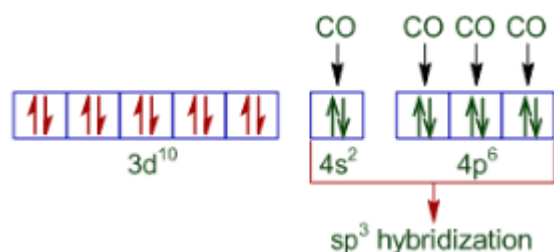
Answer :

The difference in the magnetic behaviour is due to the nature of ligands present. In case of $[NiCl_4]^{2-}$ the oxidation state of nickel is +2 and also Cl^- is a weak ligand. Thus its configuration becomes:-



So it is paramagnetic and tetrahedral in nature.

In the case of $[Ni(CO)_4]$, the oxidation state of nickel is 0. So its configuration is $3d^8 4s^2$. We also know that CO is a strong ligand, thus the configuration of nickel becomes:-



Hence the given compound is diamagnetic but tetrahedral in nature.

Question 9.7 $[Fe(H_2O)_6]^{3+}$ is strongly paramagnetic whereas $[Fe(CN)_6]^{3-}$ is weakly paramagnetic. Explain.

Answer :

In both the compounds Fe has +3 oxidation state i.e., d^5 configuration.



In the case of strong ligand (CN^-), the pairing of electron will occur. So number of electrons left unpaired will be 1.

In case of weak ligand (H_2O), pairing of electron will not there. Thus number of electrons unpaired will be 5.

We know that paramagnetic strength is directly proportional to the number of unpaired electrons.

Hence paramagnetism will be more in case of $[Fe(H_2O)_6]^{3+}$

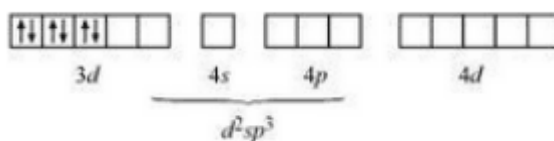
Question 9.8 Explain $[Co(NH_3)_6]^{3+}$ is an inner orbital complex whereas $[Ni(NH_3)_6]^{2+}$ is an outer orbital complex.

Answer :

Firstly consider $[Co(NH_3)_6]^{3+}$:-

The oxidation state of cobalt is +3. So the electronic configuration of it will be d^6 .

Since (NH_3) is a strong ligand so the pairing of electron will be there.

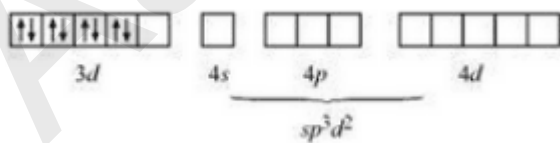


So, it has d^2sp^3 hybridisation and an inner orbital complex.

Now consider, $[Ni(NH_3)_6]^{2+}$

The oxidation state of nickel is +2. So its electronic configuration will be d^8 .

Also (NH_3) is a strong ligand so pairing of electrons will be seen.



Thus $[Ni(NH_3)_6]^{2+}$ is an outer orbital complex.

Question 9.9 Predict the number of unpaired electrons in the square planar $[Pt(CN)_4]^{2-}$ ion.

Answer :

The oxidation state of Pt in the given compound is +2. Also, it is given that the compound has square planar geometry i.e., it has dsp^2 hybridisation (d^8).

CN^- is a strong ligand so the pairing of electron will occur.

So there are no unpaired electrons in the given compound.

Question 9.10 The hexaqua manganese(II) ion contains five unpaired electrons, while the hexacyanoion contains only one unpaired electron. Explain using Crystal Field Theory.

Answer :

Consider **Hexaqua manganese (II)** :- In this compound, the oxidation state of Mn is +2 and its electronic configuration is d^5 .

H_2O is a weak ligand and crystal field is octahedral so the arrangement of electrons will be $t_{2g}^3 e_g^2$.

So the total number of unpaired electrons is 5.

Now consider hexacyanoion:- In this compound, the oxidation state of Mn is +2. It is surrounded by the strong ligands CN^- , so pairing will be there.

Its arrangement will be $t_{2g}^5 e_g^0$.

Thus the number of unpaired electrons will be 1.

NCERT Solutions for Class 12 Chemistry Chapter 9 Coordination Compounds- Exercise Questions

Question 9.1 Explain the bonding in coordination compounds in terms of Werner's postulates.

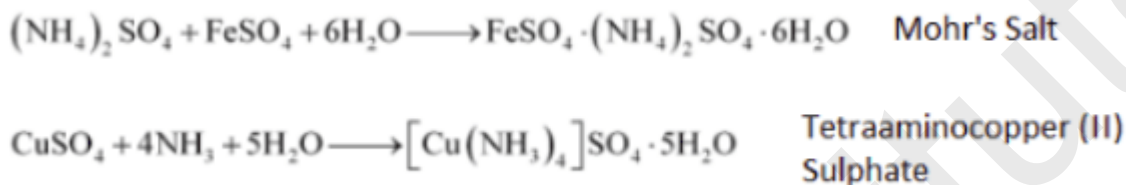
Answer :

Werner his theory of coordination compounds and gave some postulates. The main postulates are:

1. In coordination compounds metals show two types of linkages or valences namely primary valency and secondary valency.
2. The primary valences are generally ionisable and are satisfied or balanced by negative ions.
3. The secondary valences are non-ionisable. These are satisfied by either neutral molecules or by negative ions. The secondary valence is equal to the coordination number (No. of atoms surrounding the metal) and is constant for a metal.
4. According to different coordination numbers, the ions/groups bound by the secondary linkages to the metal have characteristic spatial arrangements.

Question 9.2 $FeSO_4$ solution mixed with $(NH_4)_2SO_4$ solution in 1:1 molar ratio gives the test of Fe^{2+} ion but $CuSO_4$ solution mixed with aqueous ammonia in 1:4 molar ratio does not give the test of Cu^{2+} ion. Explain why?

Answer :



The major difference between both the compounds is that the first compound is a salt and the other one is a coordination compound. In case of double salt compounds (Mohr's salt), the compound breaks into its constituent ions when dissolved in water, therefore it gives a positive test for the presence of Fe^{+2} . But in case of coordination compounds, they maintain their identity in both solid and dissolved state. Thus the individual property of each constituent is lost. And therefore it doesn't give a positive test for Cu^{+2} .

Question 9.3 Explain with two examples each of the following: coordination entity, ligand, coordination number, coordination polyhedron, homoleptic and heteroleptic.

Answer :

(i) Coordination entity:- It is an electrically charged species carrying either a positive charge or a negative charge. In a coordination entity, the central atom or ion is surrounded by some number of neutral molecules or negative ions (called ligands) accordingly.

E.g. $[PtCl_4]^{2-}$ and $[Ag(CN)_2]^-$

(ii) Ligand:- Ligands are the neutral molecules or negatively charged ions that surround the metal atom in a coordination entity according to the holding capacity of central metal ion are known as ligands. NH_3 and H_2O are two neutral ligands.

(iii) Coordination number:- The total number of metals that surrounds the central metal ion is known as coordination number.

For e.g., (a) In case of $[PtCl_6]^{2-}$ six chlorine atoms are attached to Pt, thus the coordination number of the given compound is 6.

(b) In case of $[Ni(NH_3)_4]^{2+}$ the central metal ion Ni is surrounded by 4 atoms of ligand so its coordination number is 4.

(iv) Coordination polyhedron:- It is defined as the spatial arrangement of the ligands which are directly attached to the central metal ion/atom.

E.g. square planar, tetrahedral.

(v) Homoleptic:- Homoleptic compounds are defined as the compounds in which the donor/ligand attached to central metal atom/ion is of one kind.

E.g. $[PtCl_6]^{2-}$ and $[Ni(NH_3)_4]^{2+}$

(vi) Heteroleptic:- These are the coordination compounds in which central atoms are attached with more than one type of ligand.

E.g. $[Co(NH_3)_5Cl]^{2+}$ and $[Co(NH_3)_4Cl_2]^{+1}$

Question 9.4 What is meant by unidentate, didentate and ambidentate ligands? Give two examples for each.

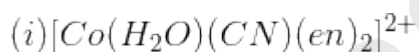
Answer :

Unidentate ligands:- The ligand which has only one donor site are known as unidentate ligands. E.g. Cl^- , NH_3

Bidentate(or didentate):- The ligands which have two donor sites are known as bidentate ligands. E.g. Ethane - 1,2 diamine, Oxalate ion

Ambidentate ligands:- The ligands which can attach themselves to the central metal through two different atoms. E.g NO_2 , SCN

Question 9.5 (i) Specify the oxidation numbers of the metals in the following coordination entities:



Answer :

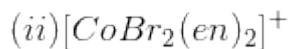
Let us assume that coordination number of cobalt is x .

$$x + 0 + (-1) + 2(0) = +2$$

Thus $x = 3$

Hence coordination number of cobalt is +3.

Question 9.5(ii) Specify the oxidation numbers of the metals in the following coordination entities:



Answer :

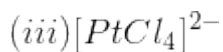
Let us assume that the coordination number of cobalt is x.

Then according to the question :

$$x + 2(-1) + 2(0) = 1$$

Hence the coordination number of cobalt is 3.

Question 9.5(iii) Specify the oxidation numbers of the metals in the following coordination entities:



Answer :

Let us assume the oxidation state of Pt to be x.

Then the equation becomes :-

$$\begin{aligned} x + 4(-1) &= -2 \\ x &= +2 \end{aligned}$$

Hence the oxidation state of Pt metal is 2.

Question 9.5(iv) Specify the oxidation numbers of the metals in the following coordination entities:



Answer :

Let the oxidation state of Fe be x.

Then the equation will be :-

$$\begin{aligned}x + 6(-1) &= -3 \\x &= +3\end{aligned}$$

Thus oxidation state of Fe in this coordination compound is 3.

Question 9.5(v) Specify the oxidation numbers of the metals in the following coordination entities:



Answer :

Let us assume the oxidation state of Cr to be x.

Then according to the question we get,

$$x + 3(0) + 3(-1) = 0$$

$$x = +3$$

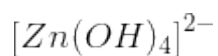
So the oxidation state of Cr will be 3.

Question 9.6(i) Using IUPAC norms write the formulas for the following:

(i) Tetrahydroxidozincate(II)

Answer :

Using the IUPAC rules :-

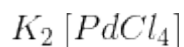


Question 9.6(ii) Using IUPAC norms write the formulas for the following:

(ii) Potassium tetrachloridopalladate(II)

Answer :

The required compound is :-



Question 9.6(iii) Using IUPAC norms write the formulas for the following:

(iii) Diamminedichloridoplatinum(II)

Answer :

The required chemical formula of compound is :-

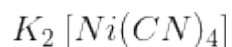


Question 9.6(iv) Using IUPAC norms write the formulas for the following:

(iv) Potassium tetracyanonickelate(II)

Answer :

The required compound is :-



Question 9.6(v) Using IUPAC norms write the formulas for the following:

(v) Pentaamminenitrito-O-cobalt(III)

Answer :

The compound is :-

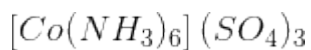


Question 9.6(vi) Using IUPAC norms write the formulas for the following:

(vi) Hexaamminecobalt(III) sulphate

Answer :

The required compound is :-

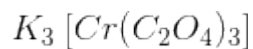


Question 9.6(vii) Using IUPAC norms write the formulas for the following:

(vii) Potassium tri(oxalato)chromate(III)

Answer :

The required compound is :-



Question 9.6(viii) Using IUPAC norms write the formulas for the following:

(viii) Hexaammineplatinum(IV)

Answer :

The required compound is :- $[Pt(NH_3)_6]^{4+}$

Question 9.6(ix) Using IUPAC norms write the formulas for the following:

(ix) Tetrabromidocuprate(II)

Answer :

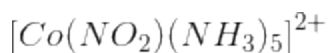
The required compound is $[Cu(Br)_4]^{2-}$

Question 9.6(x) Using IUPAC norms write the formulas for the following:

(x) Pentaamminenitrito-N-cobalt(III)

Answer :

The required compound is :-



Question 9.7(i) Using IUPAC norms write the systematic names of the following:

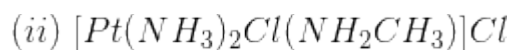


Answer :

Using IUPAC norms the name of the given compound is :-

Hexaamminecobalt(III) chloride

Question 9.7(ii) Using IUPAC norms write the systematic names of the following:

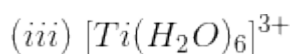


Answer :

According to the IUPAC norms :-

Diamminechlorido(methylamine) platinum(II) chloride

Question 9.7(iii) Using IUPAC norms write the systematic names of the following:

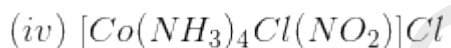


Answer :

Using the nomenclature rules, the required name of the compound

is:- **Hexaqua titanium(III) ion**

Question 9.7(iv) Using IUPAC norms write the systematic names of the following:

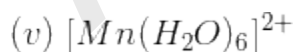


Answer :

Using IUPAC norms, the name of the given compound is :-

Tetraamminichloridonitrito-N-Cobalt(III) chloride

Question 9.7(v) Using IUPAC norms write the systematic names of the following:

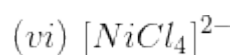


Answer :

The IUPAC name of the given compound is :-

Hexaquamanganese(II) ion

Question : 9.7(vi) Using IUPAC norms write the systematic names of the following:

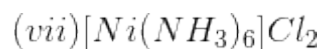


Answer :

According to the IUPAC norms, the systematic name of the given compound is:-

Tetrachloridonickelate(II) ion

Question 9.7(vii) Using IUPAC norms write the systematic names of the following:



Answer :

The IUPAC name of the given compound is :- **Hexaamminenickel(II) chloride**

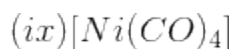
Question 9.7(viii) Using IUPAC norms write the systematic names of the following:



Answer :

The name of the given compound is :- **Tris(ethane-1, 2-diammine) cobalt(III) ion**

Question 9.7(ix) Using IUPAC norms write the systematic names of the following:



Answer :

The IUPAC name of the given compound is :- **Tetracarbonylnickel(0)**

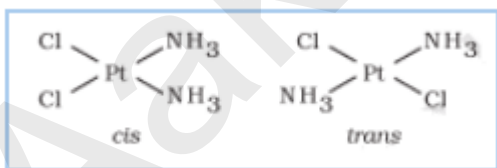
Question 9.8 List various types of isomerism possible for coordination compounds, giving an example of each.

Answer :

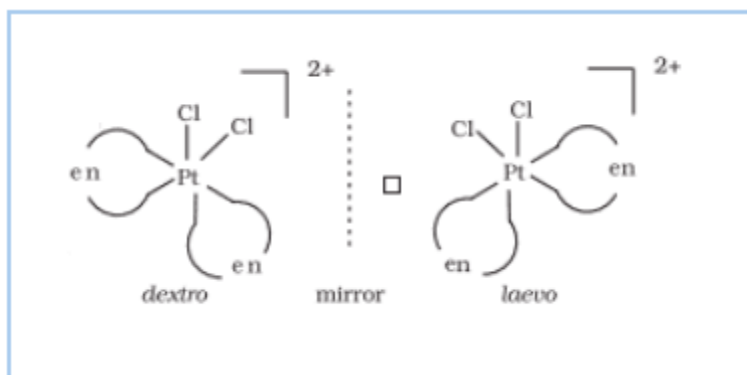
Two main types of isomerism are known in case of coordination compounds which can be further divided into subgroups:-

(a) *Stereoisomerism* :-

(i) Geometrical isomerism E.g



(ii) Optical isomerism



(b) *Structural isomerism :-*

(i) Linkage isomerism E.g $[Co(NH_3)_5(NO_2)] Cl_2$ and $[Co(NH_3)_5(ONO)] Cl_2$

(ii) Ionisation isomerism E.g $[Co(NH_3)_5SO_4] Br$ and $[Co(NH_3)_5Br] SO_4$

(iii) Coordination isomerism E.g $[Co(NH_3)_6] [Cr(CN)_6]$ and $[Cr(NH_3)_6] [Co(CN)_6]$

(iv) Solvate isomerism E.g $[Cr(H_2O)_6] Cl_3$ and $[Cr(H_2O)_5Cl] Cl_2 \cdot H_2O$

Question : 9.9(i) How many geometrical isomers are possible in the following coordination entities?

(i) $[Cr(C_2O_4)_3]^{3-}$

Answer:

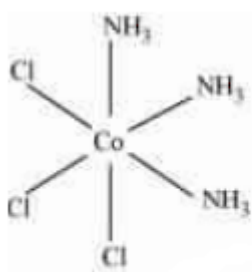
No geometrical isomers are possible since the given compound is a bidentate compound.

Question 9.9(ii) How many geometrical isomers are possible in the following coordination entities?

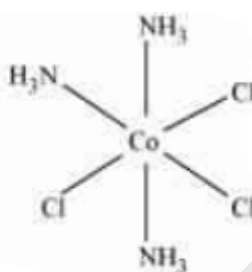


Answer :

The facial (fac) and meridional (mer) isomers are possible for the given compound.

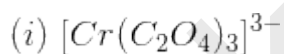


Facial



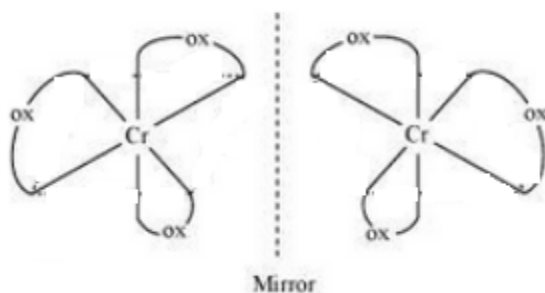
Meridional

Question 9.10(i) Draw the structures of optical isomers of:

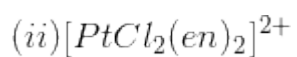


Answer :

The optical isomers of the given compound are:-

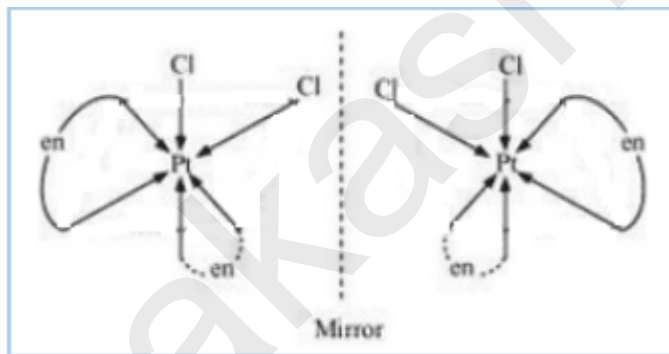


Question 9.10(ii) Draw the structures of optical isomers of:

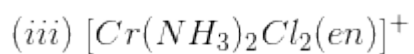


Answer :

The optical isomers of the given compound are given below :-

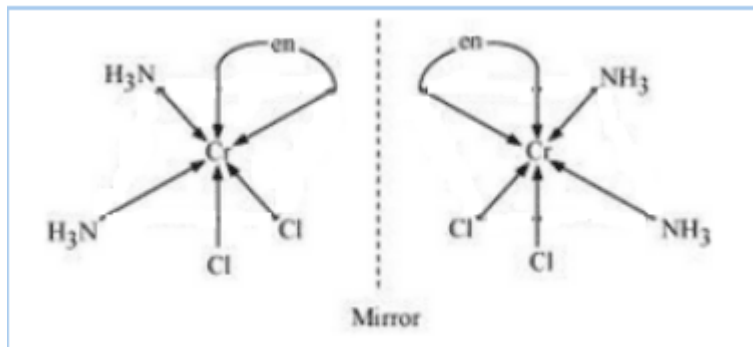


Question 9.10(iii) Draw the structures of optical isomers of:

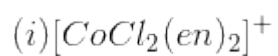


Answer :

The optical isomers of the given compound are:-

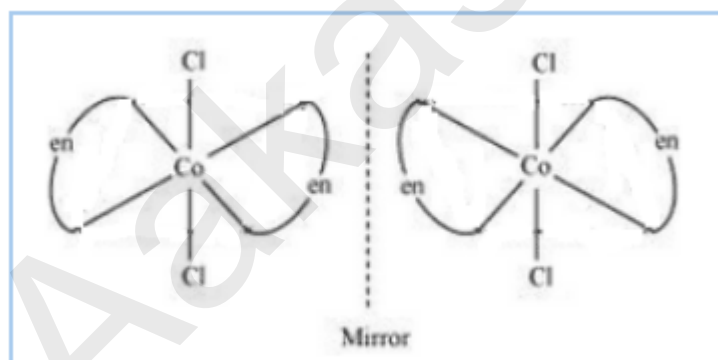


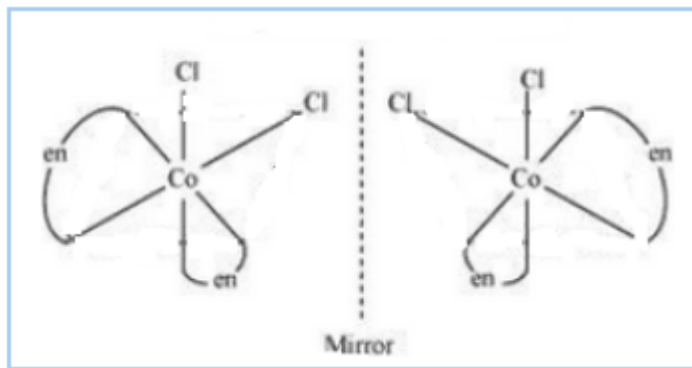
Question 9.11(i) Draw all the isomers (geometrical and optical) of:



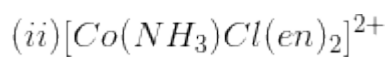
Answer :

The configurational isomers are:-



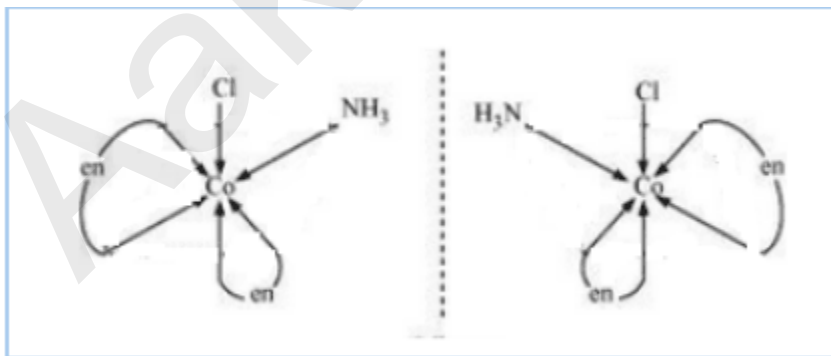
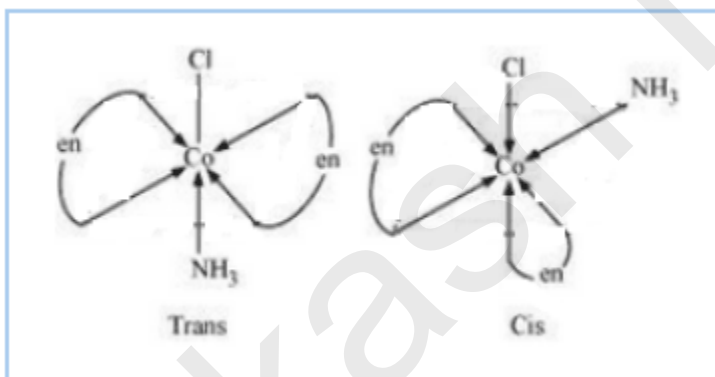


Question 9.11(ii) Draw all the isomers (geometrical and optical) of:

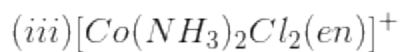


Answer :

The isomers of the given compound are :-

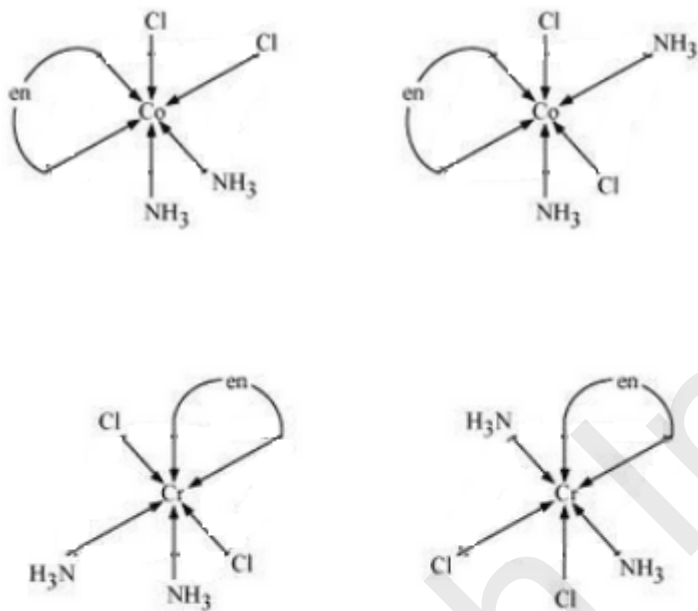


Question 9.11(iii) Draw all the isomers (geometrical and optical) of:



Answer :

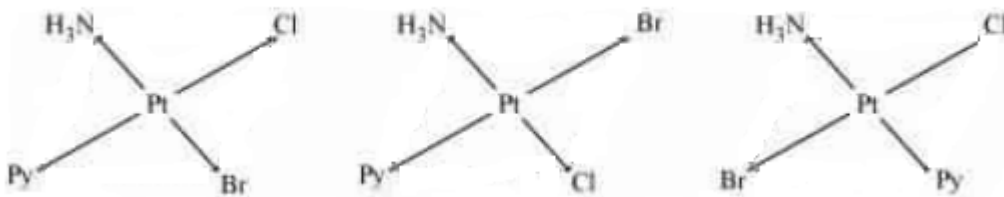
The possible isomers of the given compound are as follows :-



Question 9.12 Write all the geometrical isomers of $[Pt(NH_3)(Br)(Cl)(py)]$ and how many of these will exhibit optical isomers?

Answer :

The geometrical isomers of the compound are given below:-



We know that the given compound has tetrahedral geometry, so it can be optically active only when it has unsymmetric chelating agents. Hence the given compound doesn't have any optically active isomer.

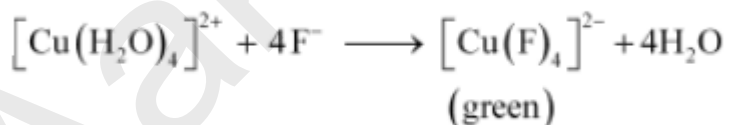
Question 9.13 Aqueous copper sulphate solution (blue in colour) gives:

- (i) a green precipitate with aqueous potassium fluoride and
- (ii) a bright green solution with aqueous potassium chloride. Explain these experimental results.

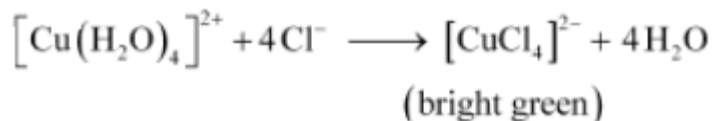
Answer :

We know that strong ligands can replace weak ligands from its solution.

- (i) In this case F^- ions can replace H_2O from aqueous copper sulphate solution.



(ii) In this compound, Cl^- being stronger ligand will replace H_2O and give a bright green



solution

Question 9.14 What is the coordination entity formed when excess of aqueous KCN is added to an aqueous solution of copper sulphate? Why is it that no precipitate of copper sulphide is obtained when $\text{H}_2\text{S}(\text{g})$ is passed through this solution?

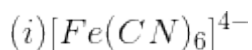
Answer :

When KCN is passed through an aqueous solution of copper sulphate, CN^- being a strong ligand, will replace water and form $\text{K}_2[\text{Cu}(\text{CN})_4]$.

It is known that in stable coordination compounds, the individual identity of each constituent is lost i.e., Cu^{+2} is not available freely.

Thus no precipitate of copper sulphide is obtained in the given conditions.

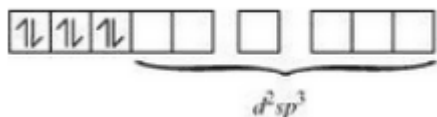
Question 9.15 Discuss the nature of bonding in the following coordination entities on the basis of valence bond theory:



Answer :

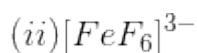
In the given compound oxidation state of Fe is +2. The electronic configuration of this compound is $3d^6$.

Also CN^- is a strong field ligand so it will cause the pairing of electrons.



Therefore the complex is diamagnetic and its geometry is octahedral.

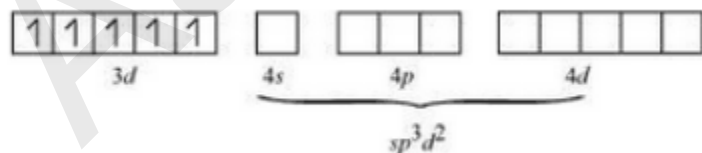
Question 9.15 Discuss the nature of bonding in the following coordination entities on the basis of valence bond theory:



Answer :

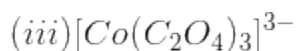
(ii) In the given complex the oxidation state of Fe is +3. Its electronic configuration is d^5 .

Also, the F^- ions are weak field ligands, therefore, the pairing of electrons will not occur.



Thus its geometry is octahedral and it is paramagnetic in nature.

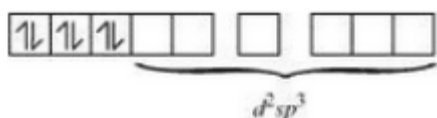
Question **9.15** Discuss the nature of bonding in the following coordination entities on the basis of valence bond theory:



Answer:

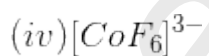
(iii) In the given compound, the oxidation state of Co is +3. Its electronic configuration thus becomes d^6 .

Also, oxalate is a weak field ligand therefore pairing of electrons will not occur.



Hence the complex is octahedral and paramagnetic in nature.

Question 9.15 Discuss the nature of bonding in the following coordination entities on the basis of valence bond theory:

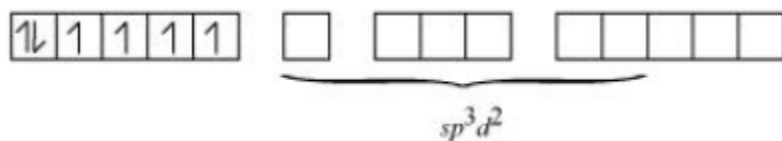


Answer :

(iv) The oxidation state of Co in the given compound is +3. The electronic configuration of the compound is d^6 .

Also, F^- is a weak field ligand so no pairing of electrons will occur.

nbsp;

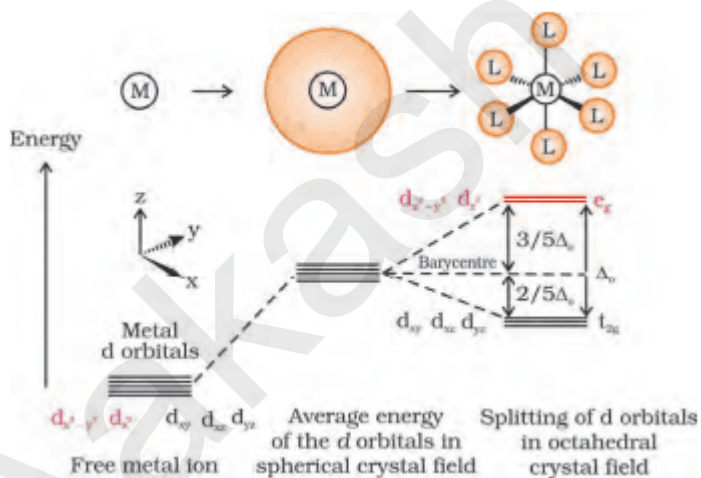


Hence the geometry of compound is octahedral and it is paramagnetic in nature.

Question 9.16 Draw figure to show the splitting of d orbitals in an octahedral crystal field.

Answer :

The splitting of d orbital is shown below:-

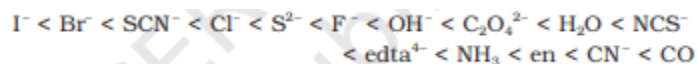


In this splitting $d_{x^2-y^2}$ and d_{z^2} experience a rise in energy and make the e_g level, while d_{xy} , d_{yz} and d_{zx} experience a fall in energy and generate the t_{2g} level.

Question 9.17 What is spectrochemical series? Explain the difference between a weak field ligand and a strong field ligand.

Answer :

The arrangement of ligands in the increasing order of their crystal-field splitting energy (CFSE) values is known as **spectrochemical series** .



The ligands on the right side of the series strong field ligands are present whereas on the left-hand side weak field ligands are present.

The strong field ligands are capable of splitting d orbitals to a higher extent as compared to weak field ligands.

Question 9.18 What is crystal field splitting energy? How does the magnitude of Δ_o decide the actual configuration of d orbitals in a coordination entity?

Answer :

It is known that the degenerated d-orbitals split into two levels - e_g and t_{2g} . The splitting of the degenerate levels due to the presence of ligands is called the crystal-field splitting and the energy difference between the two levels (e_g and t_{2g}) is called the crystal-field splitting energy (CFSE).

The CFSE is denoted by Δ_o .

After splitting of orbitals, the filling of the electrons starts. After 1 electron has been filled in each of the three t_{2g} orbitals, the fourth electron can enter the e_g orbital ($t_{2g}^3 e_g^1$ like electronic configuration) or the pairing of the electrons can take place in the t_{2g} orbitals ($t_{2g}^4 e_g^0$ like electronic configuration).

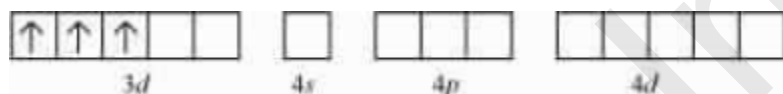
If the CFSE value or Δ_o value of a ligand is less than the pairing energy (P), then the electrons enter into the e_g orbital. And, if the Δ_o value of a ligand is more than the pairing energy (P), then the electrons will enter the t_{2g} orbital.

Question 9.19 $[Cr(NH_3)_6]^{3+}$ is paramagnetic while $[Ni(CN)_4]^{2-}$ is diamagnetic.

Explain why?

Answer :

In $[Cr(NH_3)_6]^{3+}$ the oxidation state of the compound is +3. Its electronic configuration is d^3 . Also, NH_3 is a weak field ligand so the pairing of electrons will not occur.



So this compound is paramagnetic in nature.

In $[Ni(CN)_4]^{2-}$ the oxidation state of the Ni is +2. Its electronic configuration is d^8 .

Also, CN^- is a strong field ligand so the pairing of electrons will occur.



Hence the above compound is diamagnetic in nature.

Question 9.20 A solution of $[Ni(H_2O)_6]^{2+}$ is green but a solution of $[Ni(CN)_4]^{2-}$ is colourless. Explain .

Answer :

In the case of $[Ni(CN)_4]^{2-}$, we have CN^- as a strong field ligand. So, the pairing of electrons will occur. The electronic configuration of Ni^{+2} is d^6 . Since all the electrons will be paired thus d-d electronic transition is not possible on this case. Whereas in case of $[Ni(H_2O)_6]^{2+}$ we have a weak field ligand (H_2O). The pairing of electrons will not occur. Thus electrons from a lower state of energy can transit to a higher state of energy and thus will give some colour.

Question 9.21 $[Fe(CN)_6]^{4-}$ and $[Fe(H_2O)_6]^{2+}$ are of different colours in dilute solutions. Why?

Answer :

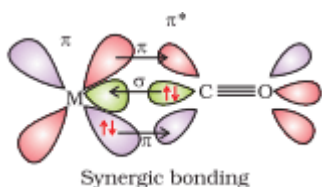
In both compounds, the oxidation state of Fe is +2. Also, in $[Fe(H_2O)_6]^{2+}$ we have weak field ligand whereas in $[Fe(CN)_6]^{4-}$ we have strong field ligand. So there is a difference in CFSE value in both the compounds. As a result, the colour shown by both compounds is different.

Question 9.22 Discuss the nature of bonding in metal carbonyls.

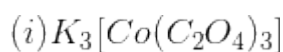
Answer :

The metal-carbon bond in metal carbonyls has both σ and π character. Basically the M–C σ bond is generated due to the donation of lone pair of electrons on the carbonyl carbon into a vacant orbital of the metal. Whereas the M–C π bond is formed due to the donation

of a pair of electrons from a filled d orbital of metal into the vacant/empty antibonding π^* orbital of carbon monoxide. As a result, this metal to ligand bonding leads to a synergic effect which strengthens the bond between CO and the metal.



Question 9.23 Give the oxidation state, d orbital occupation and coordination number of the central metal ion in the following complexes:



Answer :

The oxidation state of Co is +3 and its oxidation number is 6. The d orbital occupation of the given central metal ion is $t_{2g}^6 e_g^0$.

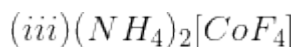
Question 9.23 Give the oxidation state, d orbital occupation and coordination number of the central metal ion in the following complexes:



Answer :

(ii) The oxidation state of Cr in the given complex is +3. The coordination number of Cr is 6. The d orbital occupation for central metal ion Cr^{3+} is t_{2g}^3 .

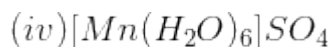
Question 9.23 Give the oxidation state, d orbital occupation and coordination number of the central metal ion in the following complexes:



Answer :

(iii) The oxidation state of Co in the given coordination compound is +2. Also, the coordination number of Co is 4. The d orbital occupation for the central metal ion Co^{2+} is $e_g^4 t_{2g}^3$.

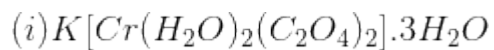
Question 9.23 Give the oxidation state, d orbital occupation and coordination number of the central metal ion in the following complexes:



Answer :

(iv) In the given complex compound the oxidation state of Mn is +2. Also, the coordination number of Mn is 6. The d orbital occupation for the central metal ion Mn^{+2} is $t_{2g}^3 e_g^2$.

Question 9.24 Write down the IUPAC name for the following complex and indicate the oxidation state, electronic configuration and coordination number. Also give stereochemistry and magnetic moment of the complex:



Answer :

The IUPAC name of the given compound is Potassium diaquadioxalatochromate (III) trihydrate.

The oxidation state of Cr in this compound is +3.

The electronic configuration is $3d^3$.

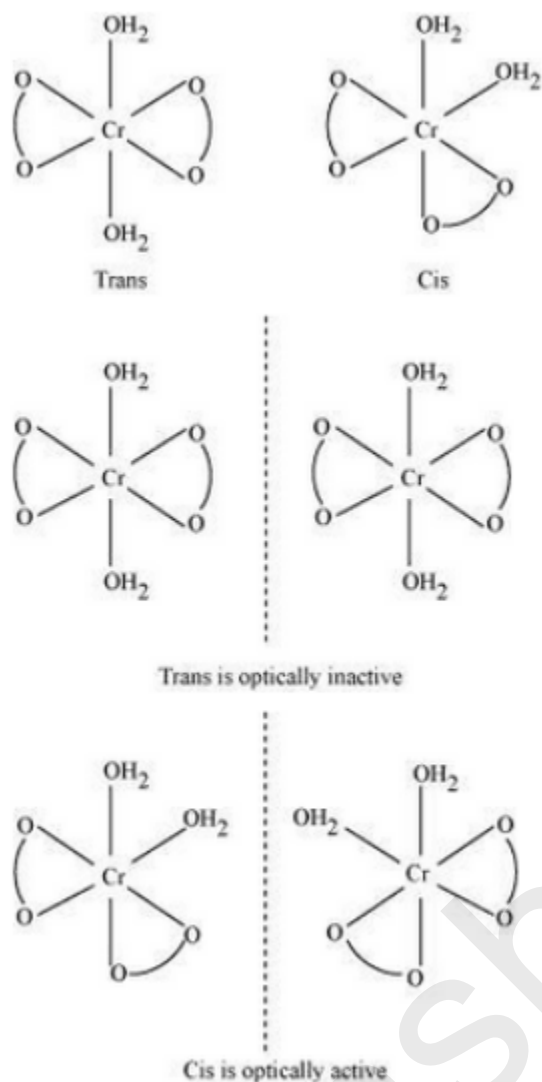
The coordination number of this compound is 6.

The magnetic moment of a compound is given by :

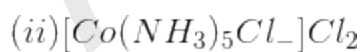
$$= \sqrt{n(n+2)} \text{ Here } n \text{ is the number of the unpaired electrons.}$$

$$\text{or } = \sqrt{3(3+2)} = \sqrt{15} BM$$

Stereochemistry:-



Question 9.24 Write down the IUPAC name for the following complex and indicate the oxidation state, electronic configuration and coordination number. Also give stereochemistry and magnetic moment of the complex:



Answer :

The IUPAC name of the given compound is Pentaamminechloridocobalt(III) chloride.

The oxidation state of Co in this compound is +3.

The electronic configuration is d^6 .

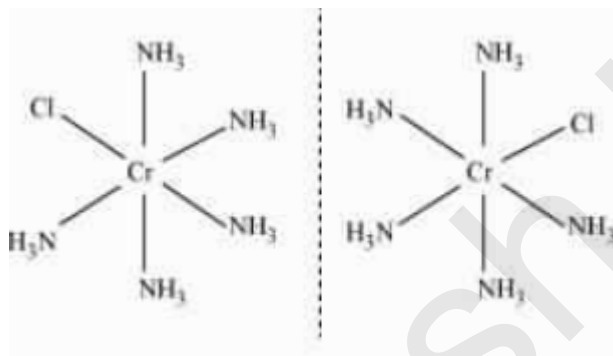
The coordination number of this compound is 6.

The magnetic moment of a compound is given by :

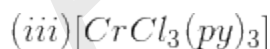
$$= \sqrt{n(n+2)} \text{ Here } n \text{ is the number of the unpaired electrons.}$$

$$\text{or } = \sqrt{0(0+2)} = 0BM$$

Stereochemistry:-



Question 9.24 Write down the IUPAC name for the following complex and indicate the oxidation state, electronic configuration and coordination number. Also give stereochemistry and magnetic moment of the complex:



Answer :

The IUPAC name of the given compound is Trichloridotripyridinechromium (III).

The oxidation state of Cr in this compound is +3.

The electronic configuration is d^3 .

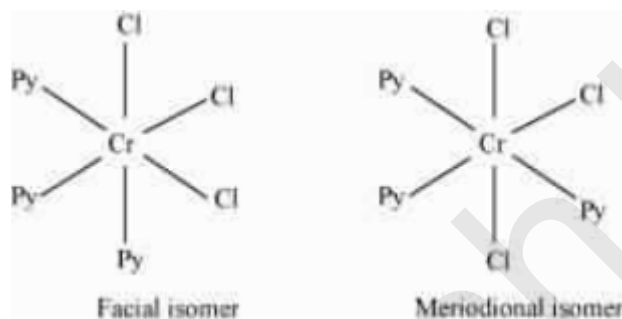
The coordination number of this compound is 6.

The magnetic moment of a compound is given by :

$$= \sqrt{n(n+2)} \text{ Here } n \text{ is the number of the unpaired electrons.}$$

$$\text{or } = \sqrt{3(3+2)} = \sqrt{15} BM$$

Stereochemistry:-



Question 9.24 Write down the IUPAC name for the following complex and indicate the oxidation state, electronic configuration and coordination number. Also give stereochemistry and magnetic moment of the complex:



Answer :

The IUPAC name of the given compound is Caesium tetrachloroferrate (III).

The oxidation state of Cs in this compound is +3.

The electronic configuration is d^5 .

The coordination number of this compound is 4.

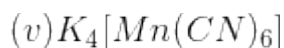
The magnetic moment of a compound is given by :

$$= \sqrt{n(n+2)} \text{ Here } n \text{ is the number of the unpaired electrons.}$$

$$\text{or } = \sqrt{5(5+2)} = \sqrt{35} BM = 5.92$$

Stereochemistry:- Optically inactive.

Question 9.24 Write down the IUPAC name for the following complex and indicate the oxidation state, electronic configuration and coordination number. Also give stereochemistry and magnetic moment of the complex:



Answer :

The IUPAC name of the given compound is Potassium hexacyanomanganate(II).

The oxidation state of Mn in this compound is +2.

The electronic configuration is d^5 .

The coordination number of this compound is 6.

The magnetic moment of a compound is given by :

$= \sqrt{n(n+2)}$ Here n is the number of the unpaired electrons.

$$= \sqrt{1(1+2)} = \sqrt{3}BM$$

or $= 1.72BM$

Stereochemistry:- Optically inactive.

Question 9.25 Explain the violet colour of the complex $[Ti(H_2O)_6]^{3+}$ on the basis of crystal field theory.

Answer :

In ground state, Ti has 23 electrons with electronic configuration $3d^3 4s^2$.

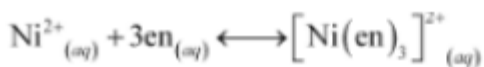
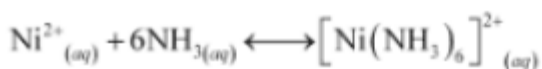
The oxidation state of Ti in the given compound is +3.

Hence it will now have the configuration $3d^2$. Since it has 2 unpaired electrons and has the ability to undergo d-d transition, the given complex gives violet colour.

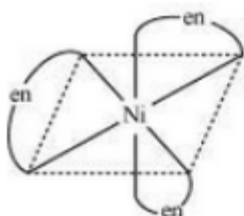
Question 9.26 What is meant by the chelate effect? Give an example .

Answer :

When a ligand is attached to the metal ion in such a manner that it forms a ring-like structure, then the metal-ligand bond is found to be more stable i.e., complexes containing chelate rings are more stable than complexes without rings. The formation of such rings is known as the chelate effect.



(more stable)



Question 9.27 Discuss briefly giving an example in each case the role of coordination compounds in:

(i) biological systems

Answer :

Coordination compounds play a great role in biological systems. The pigment which is responsible for photosynthesis, chlorophyll, is a coordination compound of magnesium. Haemoglobin (which acts as oxygen carrier) the red pigment of blood is a coordination compound of iron. Vitamin B₁₂, cyanocobalamin, the anti-pernicious anaemia factor, are few coordination compounds of cobalt which have biological importance.

Question 9.27 Discuss briefly giving an example in each case the role of coordination compounds in:

(ii) medicinal chemistry

Answer :

The role of coordination compounds in the medicine industry is very huge such as the use of chelate therapy in medicinal chemistry. The excess of copper and iron are removed by the chelating ligands D–penicillamine and desferrioxamine B via the formation of coordination compounds. Nowadays, some coordination compounds of platinum (such as cis–platin and related compounds) effectively inhibit the growth of tumours.

Question 9.27 Discuss briefly giving an example in each case the role of coordination compounds in:

(iii) analytical chemistry

Answer :

(iii) In analytical chemistry, the familiar colour reactions given by metal ions with a number of ligands generally chelating ligands. The formation of coordination entities gives the basis for their detection and estimation by classical and instrumental methods of analysis.

Question 9.27 Discuss briefly giving an example in each case the role of coordination compounds in:

(iv) extraction/metallurgy of metals

Answer :

In the metal extraction process of metals, like silver and gold, make use of complex formation. For example, gold combines with cyanide in the presence of oxygen and water to form the coordination entity $[\text{Au}(\text{CN})_2]$ in aqueous solution which can be further separated by addition of zinc.

9.27 Discuss briefly giving an example in each case the role of coordination compounds in: (iv) extraction/metallurgy of metal

Edit Q

Question 9.28 How many ions are produced from the complex $\text{Co}(\text{NH}_3)_6\text{Cl}_2$ in solution?

(i) 6 (ii) 4 (iii) 3 (iv) 2

Answer :

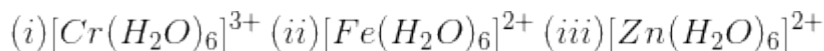
Total of 3 ions will be produced.

2 of Cl^- and one ion of $[\text{Co}(\text{NH}_3)_6]^+$ will be produced.

9.28 How many ions are produced from the complex in solution? (i) 6 (ii) 4 (iii) 3 (iv) 2

Edit Q

Question 9.29 Amongst the following ions which one has the highest magnetic moment value?



Answer :

(i) No. of unpaired electrons in $[Cr(H_2O)_6]^{3+}$ is 3.

The magnetic moment is given by :

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

$$\text{or} = \sqrt{3(3+2)} = \sqrt{15} BM$$

(ii) Similarly in $[Fe(H_2O)_6]^{2+}$ the number of unpaired electrons is 4.

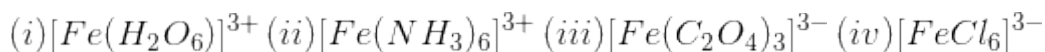
So the magnetic moment :

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

(iii) In the case of $[Zn(H_2O)_6]^{2+}$ the number of unpaired electrons is 0. So its magnetic moment is also zero.

Thus $[Fe(H_2O)_6]^{2+}$ has the highest dipole moment among all.

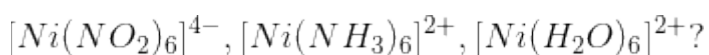
Question 9.31 Amongst the following, the most stable complex is



Answer :

We know that due to the chelation effect stability of the chelating compound is more than the simple compound. Thus it is easy to notice that $[Fe(C_2O_4)_3]^{3-}$ is most stable among all given compounds.

Question 9.32 What will be the correct order for the wavelengths of absorption in the visible region for the following:



Answer :

The order of the wavelength of absorption will be decided from the order of their CFSE values.

The CFSE values increase in the order :- $H_2O < NH_3 < NO_2^-$

Hence, the order of wavelengths of absorption in the visible region is : $[Ni(H_2O)_6]^{2+} > [Ni(NH_3)_6]^{2+} > [Ni(NO_2)_6]^{4-}$