Class 12 Chemistry Chapter 9 - Coordination Compounds Important Questions with Answers

Short Answer Type Questions

Q1. Arrange the following complexes in the increasing order of conductivity of their solution:

$[Co(NH_3)_3Cl_3]$, $[Co(NH_3)_4Cl_2]Cl$, $[Co(NH_3)_6]Cl_3$, $[Cr(NH_3)_5Cl]Cl_2$

Answer:

Ionisable ions or molecules exist outside the coordination sphere. When a complex dissolves, it releases more ions, making it more conductive.

$[Co(NH_3)_3Cl_3]$ (1 ion) < $[Co(NH_3)_4Cl_2]Cl$ (2 ions) < $[Cr(NH_3)_5Cl]Cl_2$ (3 ions) < $[Co(NH_3)_6]Cl_3$ (4 ions)

Here, the number of ions increases and conductivity increases.

Q2. A coordination compound CrCl, $4H_2O$ precipitates silver chloride when treated with silver nitrate. The molar conductance of its solution corresponds to a total of two ions. Write the structural formula of the compound and name it.

Answer:

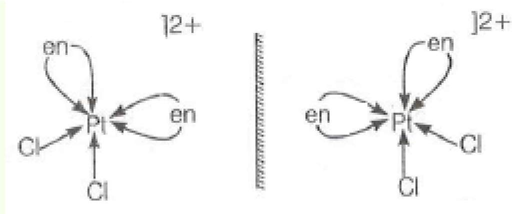
There is chloride ion outside the complex because silver chloride precipitates when treated with silver nitrate. There is only one chloride ion outside the complex since only two ions are generated. As a result, the compound's structural formula and nomenclature are:

$[Co(H_2O)_4Cl_2]Cl$ - Tetraaquadichloridocobalt(III) chloride.

Q3. 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 a complex.

Answer:

In case the given complex is to be optically active, it must be octahedral in nature. This means that 'A' must be a bidentate ligand. The complex can have the structure $[Pt(en)_2Cl_2]^{2+}$. Only its cis isomer can show optical isomerism.



Non-superimosable isomers of $[Pt(en)_2Cl_2]^{2+}$

Q4. Magnetic moment of $[MnCl_4]^{2-}$ is 5.92 BM. Explain why

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Answer:

The existence of five unpaired electrons in the d-orbitals of the Mn^{2+} ion corresponds to a magnetic moment of 5.92 BM. As a result, rather than dsp^2, sp^3 hybridisation is used. As a result, the tetrahedral structure of the $[MnCl_4]^{2-}$ complex will have a magnetic moment of 5.92 BM.

Explanation:

Because the total charge on the coordination sphere is -2 and the charge of the four Cl ligands is -4 in the complex, the oxidation number of the central metal atom Mn will be +2.
Mn ion now has a +2 charge, which means it can only be used once.
These five electrons are all going to be unpaired.
Currently, Magnetic Moment = $\sqrt{n(n+2)}$
where n is the number of unpaired electrons.
n=5 in this case.
So,
$= \sqrt{5(5+2)}$
$= \sqrt{35}$
= 5.916
Magnetic moment = 5.92 BM.

Q5. On the basis of crystal field theory explains why Co (III) forms a paramagnetic octahedral complex with weak field ligands whereas it forms a diamagnetic octahedral complex with strong field ligands.

Answer:

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

Q6. Why are low spin tetrahedral complexes not formed?

Answer:

In a tetrahedral complex, the d-orbital is split too small as compared to octahedral. For the same metal and same ligand $\Delta t = 4/9\Delta_o$.
Hence, the orbital energies are not enough to force pairing. As a result, low spin configurations are rarely observed in tetrahedral complexes.

Q7. Give the electronic configuration of the following complexes on the basis of Crystal Field Splitting theory.
$[CoF_6]^{3-}$, $[Fe(CN)_6]^{4-}$ and $[Cu(NH_3)_6]^{2+}$.

Answer:

$[CoF_6]^{3-} = Co^{3+} = (d)^6 = t_{2g}{}^4e_g{}^2$
$[Fe(CN)_6]^{4-} = Fe^{2+} = (d)^6 = t_{2g}{}^6e_g{}^0$
$[Cu(NH_3)_6]^{2+} = Cu^{2+} = (d)^9 = t_{2g}{}^6e_g{}^3$

Q8. Explain why $[Fe(HO)_6]^{3+}$ has a magnetic moment value of 5.92 BM whereas $[Fe(CN)_6]^{3-}$ has a value of only 1.74 BM.

Answer:

$[Fe(CN)_6]^{3–}$ involves d^2sp^3 hybridisation with one unpaired electron and $[Fe(H_2O)_6]^{3+}$ involves sp^3d^2 hybridisation with five unpaired electrons. This difference is due to the presence of strong ligand $CN^–$ and weak ligand H_2O in these complexes.

Q9. Arrange the following complex ions in increasing order of crystal field splitting energy (Δ_o) :
$[Cr(Cl)_6]^{3–}$, $[Cr(CN)_6]^{3–}$, $[Cr(NH_3)_6]^{3+}$.

Answer:

The order of increasing Δ_o value for the complex ions is:

$[Cr(Cl)_6]^{3–} < [Cr(CN)_6]^{3–} < [Cr(NH_3)_6]^{3+}$

This is because of increasing order of the Δ_o values of the ligands in the spectrochemical series.

Q10. Why do compounds having similar geometry have different magnetic moments?

Answer:

The presence of weak and strong field ligands in complexes is the reason for this. For example, $[CoF_6]^{3-}$ and $[Co(NH_3)_6]^{3+}$ are paramagnetic and diamagnetic respectively, because F is a weak field ligand and NH_3 is a strong field ligand while both have similar geometry. Because F is a weak field ligand and NH_3 is a strong field ligand, the complex will have a low magnetic moment if CFSE is high, and vice versa.

Q11. $CuSO_4.5H_2O$ is blue in colour while $CuSO_4$ is colourless. Why?

Answer:

Water acts as a ligand in $CuSO_4.5H_2O$, causing crystal field splitting. As a result, in $CuSO_4.5H_2O$, a d—d transition is possible and coloured. Crystal field splitting is impossible in anhydrous $CuSO_4$ due to the lack of water (ligand), hence there is no colour.

Q12. Name the type of isomerism when ambidentate ligands are attached to a central metal ion. Give two examples of ambidentate ligands.

Answer:

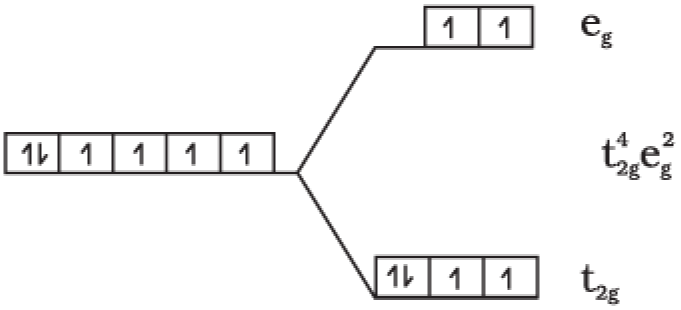
Ligands having more than one different binding position are known as ambidentate ligands. For example, SCN has two different binding positions S and N. Coordination compounds containing ambidentate ligands are considered to show linkage isomerism due to the presence of two different binding positions.
e.g., (i) $[CO(NH_3)_5SCN]^{3+}$ and (ii) $[Fe(NH_3)_5(NO_2)]^{3+}$

Long Answer Type Questions

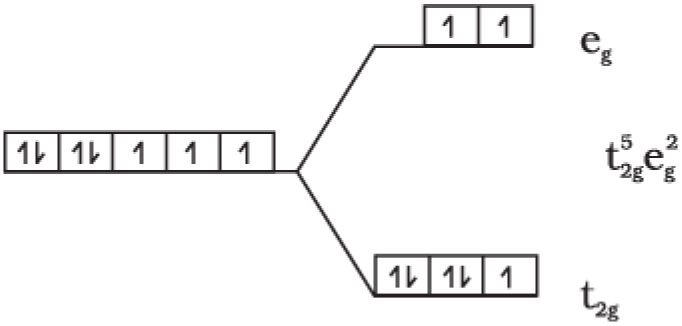
Q1. Using crystal field theory, draw an energy level diagram, write electronic configuration of the central metal atom/ion and determine the magnetic moment value in the following:
(i) $[CoF_6]^{3-}$, $[Co(H_2O)_6]^{2+}$, $[Co(CN)_6]^{3-}$
(ii) $[FeF_6]^{3-}$, $[Fe(H_2O)_6]^{2+}$, $[Fe(CN)_6]^{4-}$

Answer:

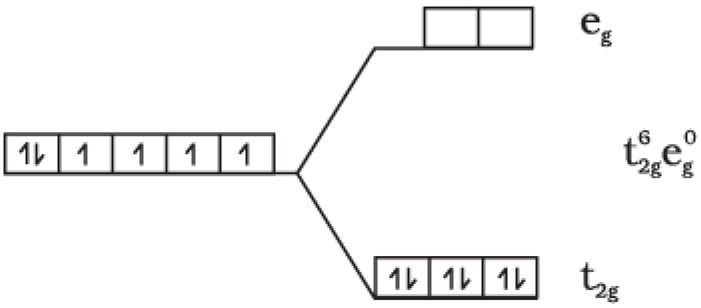
$[CoF_6]^{3-}$
$Co^{3+} = 3d^6$
F^- ion is a weak field ligand. The value of Δ_0 is small ($P>\Delta_0$). Electron pairing is not possible.
Number of unpaired electrons = 4
Magnetic moment = $\sqrt{n(n+2)} = \sqrt{4(4+2)} = \sqrt{24} = 4.9$BM



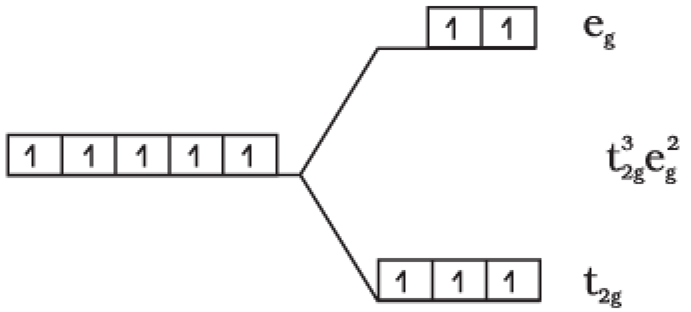
$[Co(H_2O)_6]^{2+}$
$Co^{2+} = 3d^7$
H_2O is a weak field ligand. The value of Δ_0 is small. Electron pairing is not possible.
Number of electrons = 3
$\sqrt{n(n+2)} = \sqrt{3(3+2)} = \sqrt{15} = 3.87BM$



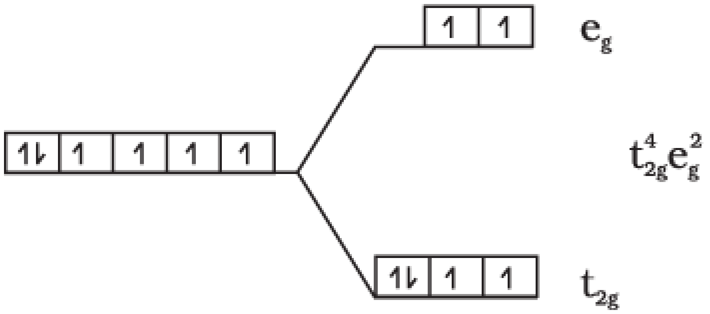
$[Co(CN)_6]^{3-}$
$Co^{3+} = 3d^6$
CN^- is a strong field ligand. The value of Δ_0 is large. Electron pairing is not possible.
Number of unpaired electrons = Zero.
Since there are no unpaired electrons present, the complex is diamagnetic in nature.



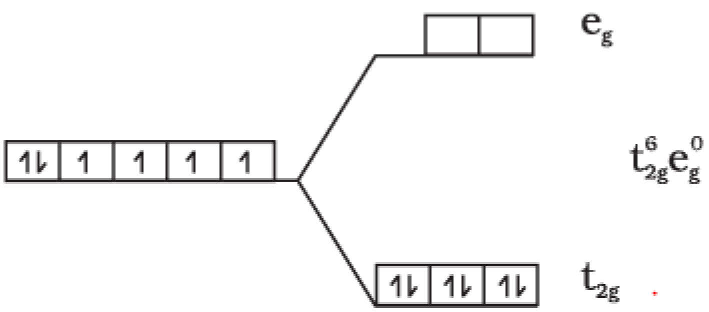
$[FeF_6]^{3-}$
$Fe^{3+} = 3d^5$
F^- ion is a weak ligand. The value of Δ_0 is small ($P>\Delta_0$). Electron pairing is not possible.
Number of unpaired electrons = 5
$\sqrt{n(n+2)} = \sqrt{5(5+2)} = \sqrt{3} = 5.92$BM



$[Fe(H_2O)_6]^{2+}$
$Fe^{2+} = 3d^6$
H_2O is a weak field ligand. The value of Δ_0 is small ($P>\Delta_0$). Electron pairing is not possible.
Number of unpaired electrons = 4
Magnetic moment = $\sqrt{n(n+2)} = \sqrt{4(4+2)} = \sqrt{24} = 4.9$BM



$[Fe(CN)_6]^{4-}$
$Fe^{2+} = 3d^6$
CN^- ion is a strong field ligand. The value of Δ_0 is large ($P< \Delta_0$). Electron pairing is possible.
Number of unpaired electrons= zero.
Since there are no unpaired electrons present, the complex is diamagnetic in nature.

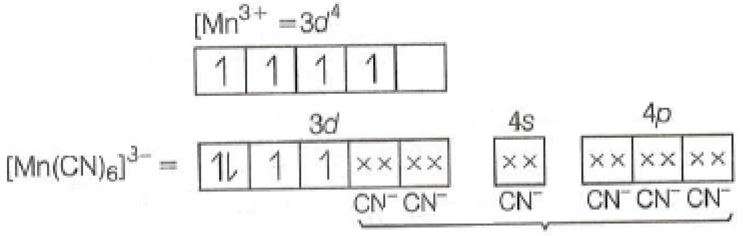


Q2. Using valence bond theory, explain the following in relation to the complexes given below:
$[Mn(CN)_6]^{3-}$, $[Co(NH_3)_6]^{3+}$, $[Cr(H_2O)_6]^{3+}$, $[FeCl_6]^{4-}$

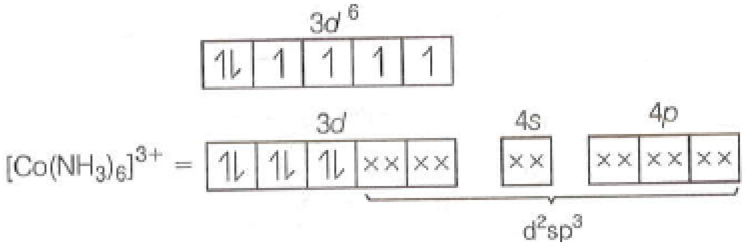
(i) Type of hybridisation.
(ii) Inner or outer orbital complex.
(iii) Magnetic behaviour.
(iv) Spin only magnetic moment value.

Answer:

$[Mn(CN)_6]^{3-}$
(i) Type of hybridisation = d^2sp^3 hybridisation
(ii) Inner or outer orbital complex = Inner orbital complex because (n-1)d - orbitals are used.
(iii) Magnetic behaviour = Paramagnetic, as two unpaired electrons are present.
(iv) Spin only magnetic moment value = Spin only magnetic moment (μ) = √2(2+2) = √8 = 2.82BM.



$[Co(NH_3)_6]^{3+}$
(i) Type of hybridisation = d^2sp^3 hybridisation
(ii) Inner or outer orbital complex = Inner orbital complex as(n-1)d-orbitals take part.)
(iii) Magnetic behaviour = Diamagnetic (as three paired electrons are present.)
(iv) Spin only magnetic moment value = Spin only magnetic moment (μ) = √0(0+2) = √0 = 0



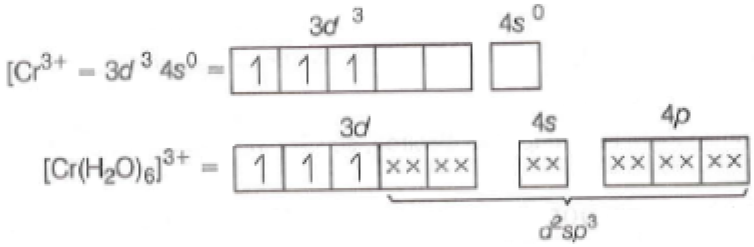
[$Cr(H_2O)_6]^{3+}$

(i) Type of hybridisation = d^2sp^3 hybridisation

(ii) Inner or outer orbital complex = Inner orbital complex as(n-1)d-orbitals take part.)

(iii) Magnetic behaviour = Paramagnetic (as three unpaired electrons are present.)

(iv) Spin only magnetic moment value = Spin only magnetic moment (μ) = √3(3+2) = √15 = 3.87BM.



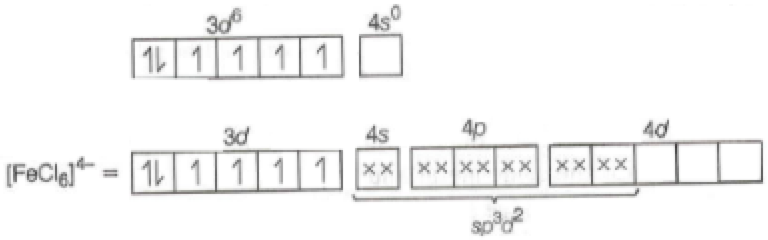
$[FeCl_6]^{4-}$

(i) Type of hybridisation = sp^3d^2 hybridisation

(ii) Inner or outer orbital complex = Outer orbital complex because nd-orbitals are involved in hybridisation.

(iii) Magnetic behaviour = Paramagnetic (because of the presence of four unpaired electrons).

(iv) Spin only magnetic moment value = Spin only magnetic moment (μ) = √4(4+2) = √24 = 4.9BM



Q3. $CoSO_4Cl.5NH_3$ exists in two isomeric forms 'A' and 'B'. Isomer 'A' reacts with $AgNO_3$ to give white precipitate, but does not react with $BaCl_2$. Isomer 'B' gives white precipitate with $BaCl_2$ but does not react with $AgNO_3$. Answer the following questions.

(i) Identify 'A' and 'B' and write their structural formulas.

(ii) Name the type of isomerism involved.

(iii) Give the IUPAC name of 'A' and 'B'.

Answer:

(i) As isomer A reacts with $AgNO_3$ to give a white precipitate, Cl must be present in the ionisation sphere.

As it does not react with $BaCl_2$, SO_4^{2-} must be present in the coordination sphere.

Therefore the formula of A = $[Co(NH_3)_5SO_4]Cl$ (coordination no. of Co = 6)

As reactions are reversed for isomer B, formula B = $[Co(NH_3)_5Cl]SO_4$

(ii) The type of isomerism involved is Ionisation isomerism

(iii) The IUPAC name of

A = Pentaamminesulphatocobalt (III) chloride ,

B = Pentaamminechloridocobalt (III) sulphate.

Q4. What is the relationship between the observed colour of the complex and the wavelength of light absorbed by the complex?

Answer:

Some of the white light that falls on the complex is absorbed. The lower the wavelength absorbed by the complex, the higher the crystal field splitting energy. The wavelength from the wavelength left behind is used to generate the observed colour of the complex.

When green light is absorbed, for example, the complex appears red. The lower the wavelength absorbed by the complex, the higher the crystal field splitting. The complex's observed colour is the colour created by the wavelength that was left over.

Assume an octahedral complex with an empty e_g level and unpaired electrons in the t_{2g} level in the ground level, according to crystal field theory. If an unpaired electron absorbs light in the blue-green area, it will excite to the e_g level, causing the complex to become violet. Crystal field splitting does not occur in the absence of a ligand, and the material is colourless. $CuSO_4.5H_2O$ is blue in colour, however anhydrous $CuSO_4$ is white.

Q5. Why are different colours observed in octahedral and tetrahedral complexes for the same metal and same ligands?

Answer:

In the octahedral and tetrahedral fields, the extent of d-orbital splitting differs. In the octahedral and tetra federal fields, the crystal field stabilisation energy is strongly related.

$\Delta_t = (4/9)\Delta_o$

Where,
Δ_t = crystal field splitting energy in tetrahedral field
Δ_o= crystal field splitting energy in octahedral field

Wavelength of light and CFSE (crystal field stabilisation energy) are related to each other by formula
$\Delta_o = E = hc/\lambda$
$E \propto 1\lambda$

For the same metal and ligands, higher wavelengths of light are absorbed in octahedral complexes than in tetrahedral complexes. As a result, many colours can be seen.