Coordination Compounds

Previous Years' CBSE Board Questions

5.1 Werner's Theory of Coordination Compounds

MCQ

1. **Assertion :** $[Co(NH_3)_5SO_4]Cl$ gives a white precipitate with silver nitrate solution.

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

   (a) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).

   (b) Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of the Assertion (A).

   (c) Assertion (A) is true, but Reason (R) is false.

   (d) Assertion (A) is false, but Reason (R) is true. *(2023)*

2. One mole of $CrCl_3{\cdot}6H_2O$ compound reacts with excess $AgNO_3$ solution to yield two moles of $AgCl_{(s)}$. The structural formula of the compound is

   (a) $[Cr(H_2O)_5Cl]Cl_2{\cdot}H_2O$ (b) $[Cr(H_2O)_3Cl_3]{\cdot}3H_2O$

   (c) $[Cr(H_2O)_4Cl_2]Cl{\cdot}2H_2O$ (d) $[Cr(H_2O)_6Cl_3]$ *(2020)*

VSA (1 mark)

3. When a coordination compound $CrCl_3{\cdot}6H_2O$ is mixed with $AgNO_3$, 2 moles of AgCl are precipitated per mole of the compound. Write structural formula of the complex. *(AI 2019, 1/2, Delhi 2016)*

4. What is the difference between a complex and a double salt? *(AI 2019)* R

5. When a coordination compound $CoCl_3{\cdot}6NH_3$ is mixed with $AgNO_3$, 3 moles of AgCl are precipitated per mole of the compound. Write structural formula of the complex. *(1/2, AI 2016)*

5.2 Definition of Some Important Terms Pertaining to Coordination Compounds

MCQ

6. The oxidation number of Co in $[Co(en)_3]_2(SO_4)_3$ is

   (a) +2 (b) +3 (c) +4 (d) +6

   (2021C) Ap

7. Which of the following ligands form a 'chelate' complex with metal ion ?

   (a) H_2O (b) CN^- (c) $C_2O_4^{2-}$ (d) Cl^-

   (2021C)

8. The coordination number of Cr in $[CrCl_2(ox)_2]^{3-}$ is

   (a) 6 (b) 5 (c) 4 (d) 3

   (2021C)

9. The coordination number of 'Co' in the complex $[Co(en)_3]^{3+}$ is

   (a) 3 (b) 6 (c) 4 (d) 5

   (2020) R

10. **Assertion (A) :** $[Pt(en)_2Cl_2]^{2+}$ complex is less stable than $[Pt(NH_3)_4Cl_2]^{2+}$ complex.

    Reason (R) : $[Pt(en)_2Cl_2]^{2+}$ complex shows chelate effect.

    (a) Both Assertion (A) and Reason (R) are correct statements, and Reason (R) is the correct explanation of the Assertion (A).

    (b) Both Assertion (A) and Reason (R) are correct statements, but Reason (R) is not the correct explanation of the Assertion (A).

    (c) Assertion (A) is correct, but Reason (R) is incorrect statement.

    (d) Assertion (A) is incorrect, but Reason (R) is correct statement. *(2020)*

11. The oxidation state of Ni in $[Ni(CO)_4]$ is

    (a) 0 (b) 2

    (c) 3 (d) 4 *(2020)* An

VSA (1 mark)

12. Amongst $[Fe(C_2O_4)_3]^{3-}$ and $[Fe(NH_3)_6]^{3+}$, which is more stable and why? *(2019C)*

13. Write the coordination number and oxidation state of platinum in the complex $[Pt(en)_2Cl_2]$. *(2018)*

14. Which of the following is more stable complex and why?

    $[Co(NH_3)_6]^{3+}$ and $[Co(en)_3]^{3+}$ *(Delhi 2014)*

5.3 Nomenclature of Coordination Compounds

MCQ

15. The formula of the coordination compound tetraamminechloridonitrito-N-cobalt(III) chloride is :

    (a) $[Co(NH_3)_4Cl(ONO)]Cl_2$

    (b) $[Co(NH_3)_4Cl_2(NO_2)]Cl$

    (c) $[Co(NH_3)_4Cl(NO_2)]Cl$

    (d) $[Co(NH_3)_4(NO_2)]Cl_3$ *(2021C)*

VSA (1 mark)

16. Write the formula of the following coordination compound :

    Iron(III) hexacyanidoferrate(II) *(1/3, 2018)*

17. Write the IUPAC name of the following complex : $[Cr(NH_3)_3Cl_3]$. *(1/3, Delhi 2017)*

18. Write the IUPAC name of the following complex: $[Co(NH_3)_5(CO_3)]Cl$. *(1/3, Delhi 2017)*

19. When a coordination compound $CrCl_3{\cdot}6H_2O$ is mixed with $AgNO_3$, 2 moles of AgCl are precipitated per mole of the compound. Write IUPAC name of the complex. *(1/2, Delhi 2016)* An

SA I (2 marks)

20. Give the formulae of the following compounds :
   (a) Potassium tetrahydroxidozincate(II)
   (b) Hexaammineplatinum(IV) chloride *(2020)* Ap

21. Using IUPAC norms write the formulae for the following :
   (i) Pentaamminenitrito-O-cobalt(III) chloride
   (ii) Potassium tetracyanidonickelate(II)
(NCERT, Delhi 2019)

22. Using IUPAC norms write the formulae for the following :
   (a) Sodium dicyanidoaurate(I)
   (b) Tetraamminechloridonitrito-N-platinum(IV) sulphate *(AI 2017)*

23. Using IUPAC norms write the formulae for the following :
   (a) *Tris*(ethane-1,2,diamine)chromium(III) chloride
   (b) Potassium tetrahydroxozincate(II) *(AI 2017)*

24. Using IUPAC norms write the formulae for the following :
   (a) Potassium trioxalatoaluminate(III)
   (b) Dichlorido*bis*(ethane-1,2-diamine)cobalt(III)
(AI 2017) Ap

25. (i) Write down the IUPAC name of the following complex :
   $[Cr(NH_3)_2Cl_2(en)]Cl$ (*en* = ethylenediamine)
   (ii) Write the formula for the following complex :
   Pentaamminenitrito-O-cobalt (III). *(Delhi 2015)*

26. Using IUPAC norms write the formulae for the following coordination compounds :
   (i) Hexaamminecobalt(III) chloride
   (ii) Potassium tetrachloridonickelate(II) *(AI 2015)*

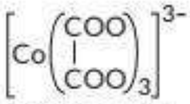
27. (i) Write down the IUPAC name of the following complex : $[Cr(en)_3]Cl_3$.
   (ii) Write the formula for the following complex : Potassium trioxalatochromate(III).
(Foreign 2015)

SA II (3 marks)

28. (i) Write the IUPAC name of the following complex : $[Co(NH_3)_4(H_2O)Cl]Cl_2$
   (ii) What is the difference between an Ambidentate ligand and a Bidentate ligand ?
   (iii) Out of $[Fe(NH_3)_6]^{3+}$ and $[Fe(C_2O_4)_3]^{3-}$, which complex is more stable and why?
(Term II, 2021-22) U

29. Write the IUPAC name of the following :
   (i) $[Co(NH_3)_6]Cl_3$ (ii) $[NiCl_4]^{2-}$
   (iii) $K_3[Fe(CN)_6]$ *(AI 2015C)* Ap

30. Write down the IUPAC name for each of the following complexes :
   (i) $[Co(NH_3)_5Cl]Cl_2$ (ii) $K_3[Fe(CN)_6]$
   (iii) $[NiCl_4]^{2-}$ *(Delhi 2014C)* U

31. Write the IUPAC name and draw the structure of each of the following complex entities :
   (i) 
   $\left[Co\begin{pmatrix}COO\\|\\COO\end{pmatrix}_3\right]^{3-}$ (ii) $[Cr(CO)_6]$
   (iii) $[PtCl_3(C_2H_4)]^-$
   (At. nos. Cr = 25, Co = 27, Pt = 78) *(AI 2014C)* Cr

5.4 Isomerism in Coordination Compounds

Structural Isomerism

MCQ

32. The compounds $[Co(SO_4)(NH_3)_5]Br$ and $[Co(Br)(NH_3)_5]SO_4$ represent
   (a) optical isomerism
   (b) linkage isomerism
   (c) ionisation isomerism
   (d) coordination isomerism. *(2023)*

33. The pair $[Co(NH_3)_4Cl_2]Br_2$ and $[Co(NH_3)_4Br_2]Cl_2$ will show
   (a) linkage isomerism
   (b) hydrate isomerism
   (c) ionization isomerism
   (d) coordinate isomerism *(2020)* U

34. **Assertion (A) :** Linkage isomerism arises in coordination compounds because of ambidentate ligand.
   Reason (R) : Ambidentate ligand like NO_2 has two different donor atoms *i.e.*, N and O.
   (a) Both Assertion (A) and Reason (R) are correct statements, and Reason (R) is the correct explanation of the Assertion (A).
   (b) Both Assertion (A) and Reason (R) are correct statements, but Reason (R) is not the correct explanation of the Assertion (A).
   (c) Assertion (A) is correct, but Reason (R) is incorrect statement.
   (d) Assertion (A) is incorrect, but Reason (R) is correct statement. *(2020)*

VSA (1 mark)

35. What type of isomerism is shown by the complex $[Co(NH_3)_5NO_2]Cl_2$? *(2020)*

36. What type of isomerism is exhibited by the complex $[Co(NH_3)_5Cl]SO_4$? *(1/3, 2018)*

OR

What type of isomerism is exhibited by the following complex : $[Co(NH_3)_5SO_4]Cl$ *(Foreign 2014)*

37. What type of isomerism is shown by the complex $[Co(NH_3)_6][Cr(CN)_6]$?
(1/3, Delhi 2017, Foreign 2014)

38. What type of isomerism is shown by the complex $[Co(NH_3)_5(SCN)]^{2+}$? *(1/3, AI 2017)*

39. What type of isomerism is exhibited by the complex $[Co(NH_3)_5NO_2]^{2+}$? *(Foreign 2014)*

SA I (2 marks)

40. (a) Which of the following species cannot act as a ligand? Give reason.
OH^-, NH_4^+, CH_3NH_2, H_2O
(b) The complex $[Co(NH_3)_5(NO_2)]Cl_2$ is red in colour. Give IUPAC name of its linkage isomer.
(2023)

Stereoisomerism

VSA (1 mark)

41. What type of isomerism is shown by the complex $[Co(en)_2Cl_2]^+$? Name the structure of an isomer of this complex which is optically active. *(1/2, 2020)* An

42. What type of isomerism is shown by the complex $[Co(en)_3]Cl_3$? *(NCERT Intext, 1/3, Delhi 2017)*

OR

What type of isomerism is exhibited by the complex $[Co(en)_3]^{3+}$? (*en* = ethane-1,2-diamine) *(1/3, AI 2014)*

43. Draw one of the geometrical isomers of the complex $[Pt(en)_2Cl_2]^{2+}$ which is optically active. *(1/3, Delhi 2016)*

44. Draw one of the geometrical isomers of the complex $[Pt(en)_2Cl_2]^{2+}$ which is optically inactive. *(AI 2016)*

45. Draw the geometrical isomers of complex $[Pt(NH_3)_2Cl_2]$. *(1/3, Delhi 2015)*

46. Write down the IUPAC name of the complex $[Pt(en)_2Cl_2]^{2+}$. What type of isomerism is shown by this complex? *(AI 2015)*

47. Draw the geometrical isomers of complex $[Pt(en)_2Cl_2]^{2+}$. *(1/3, Foreign 2015)* Cr

SA I (2 marks)

48. Write IUPAC name of the complex $[Pt(en)_2Cl_2]$. Draw structures of geometrical isomers for this complex. *(2019)*

49. Write IUPAC name of the complex $[Cr(NH_3)_4Cl_2]^+$. Draw structures of geometrical isomers for this complex. *(Delhi 2019)*

SA II (3 marks)

50. Indicate the types of isomerism exhibited by the following complexes :
(i) $[Co(NH_3)_5(NO_2)]^{2+}$
(ii) $[Co(en)_3]Cl_3$ (*en* = ethylene diamine)
(iii) $[Pt(NH_3)_2Cl_2]$ *(Delhi 2015C)* U

51. Write the IUPAC name of the complex $[Cr(NH_3)_4Cl_2]^+$. What type of isomerism does it exhibit? *(Delhi 2014)*

52. Draw the structures of optical isomers of each of the following complex ions :
$[Cr(C_2O_4)]^{3-}$, $[PtCl_2(en)_2]^{2+}$, $[Cr(NH_3)_2Cl_2(en)]^+$
(Delhi 2014C)

5.5 Bonding in Coordination Compounds

Valence Bond Theory

MCQ

53. The magnetic moment of $[NiCl_4]^{2-}$ is
(a) 1.82 B.M. (b) 2.82 B.M.
(c) 4.42 B.M. (d) 5.46 B.M.
[Atomic number : Ni = 28] *(2023)*

VSA (1 mark)

54. Write the IUPAC name and hybridisation of the complex, $[CoF_6]^{3-}$.
(Given : Atomic number of Co = 27) *(1/2, 2020)*

OR

Write the hybridisation and number of unpaired electrons in the complex $[CoF_6]^{3-}$. (Atomic no. of Co = 27) *(1/3, 2018)*

55. Predict the number of unpaired electrons in the square planar $[Pt(CN)_4]^{2-}$ ion. *(2019C)* An

56. Write the hybridisation and magnetic character of $[Co(C_2O_4)_3]^{3-}$.
(At. no. of Co = 27) *(1/3, Delhi 2017)*

57. Why is $[NiCl_4]^{2-}$ paramagnetic but $[Ni(CO)_4]$ is diamagnetic? (At. no. : Cr = 24, Co = 27, Ni = 28) *(NCERT Intext, 1/3, AI 2014)*

SA I (2 marks)

58. (i) Write the IUPAC name of $[Mn(H_2O)_6]SO_4$.
(ii) Why is $[Fe(CN)_6]^{4-}$ diamagnetic while $[FeF_6]^{3-}$ is paramagnetic ? [At. No. Fe= 26] *(2021C)*

59. Write IUPAC name and hybridization of the following complexes :
(i) $[Ni(CO)_4]$
(ii) $[CoF_6]^{3-}$
(Atomic number Ni = 28, Co = 27) *(2020)* Ap

60. (a) Write the IUPAC name and hybridisation of the complex $[Fe(CN)_6]^{3-}$.
(Given : Atomic number of Fe = 26)
(b) What is the difference between an ambidentate ligand and a chelating ligand ? *(2020)* Ap

61. Out of $[CoF_6]^{3-}$ and $[Co(en)_3]^{3+}$, which one complex is
(i) paramagnetic (ii) more stable
(iii) inner orbital complex and
(iv) high spin complex
(Atomic no. of Co = 27) *(2019)*

62. Out of $[CoF_6]^{3-}$ and $[Co(C_2O_4)_3]^{3-}$, which one complex is
(i) diamagnetic
(ii) more stable
(iii) outer orbital complex and
(iv) low spin complex ?
(Atomic no. of Co = 27) *(Delhi 2019)*

63. For the complex $[Fe(H_2O)_6]^{3+}$, write the hybridization, magnetic character and spin of the complex. (At. number Fe = 26) *(2/3,AI 2016)*

64. Write the hybridization and shape of the following complexes :
(i) $[CoF_6]^{3-}$
(ii) $[Ni(CN)_4]^{2-}$
(Atomic number : Co = 27, Ni = 28) *(AI 2015)*

65. Write the state of hybridization, shape and IUPAC name of the complex $[CoF_6]^{3-}$. (Atomic no. of Co = 27) *(Foreign 2014)*

66. Write the state of hybridization, shape and IUPAC name of the complex $[Ni(CN)_4]^{2-}$. (Atomic no. of Ni = 28) *(Foreign 2014)*

67. Write the state of hybridization, shape and IUPAC name of the complex $[Co(NH_3)_6]^{3+}$. (Atomic no. of Co = 27) *(Foreign 2014)*

SA II (3 marks)

68. (a) On the basis of crystal field theory, write the electronic configuration for d^4 with a strong field ligand for which $\Delta_o > P$.
(b) A solution of $[Ni(H_2O)_6]^{2+}$ is green but a solution of $[Ni(CO)_4]$ is colourless. Explain.
[Atomic number : Ni = 28] *(2023)*

69. (a) Write the hybridisation, shape and magnetic character of $[CoF_6]^{3-}$.
[Atomic number of Co = 27]
(b) Write the formula of pentaamminechloridocobalt(III) chloride. *(Term II, 2021-22)* Ev

70. (i) Calculate the spin only magnetic moment of the complex $[FeF_6]^{3-}$. (Atomic number of Fe = 26)
(ii) Write the IUPAC name of the given complex : $[Co(NH_3)_5Cl]Cl_2$
(iii) Why is the complex $[Co(en)_3]^{3+}$ more stable than $[CoF_6]^{3-}$? *(Term II, 2021-22)* Ev

71. (a) Using valence bond theory, predict the hybridization and magnetic character of the complex : $[Ni(CO)_4]$ (Atomic number : Ni = 28)
(b) Write IUPAC name of $[Pt(NH_3)_2Cl(NO_2)]$.
(c) Why $[Co(en)_3]^{3+}$ is a more stable complex than $[Co(NH_3)_6]^{3+}$? *(Term II, 2021-22)* Ev

72. Write the hybridisation and magnetic character of the following complexes :
(i) $[Fe(H_2O)_6]^{2+}$
(ii) $[Ni(CN)_4]^{2-}$
[Atomic number : Fe = 26, Ni = 28] *(AI 2019)*

LA (5 marks)

The following questions are case-based questions. Read the case carefully and answer the questions that follow.

73. In coordination compounds, metals show two types of linkages, primary and secondary. Primary valencies are ionisable and are satisfied by negatively charged ions. Secondary valencies are non-ionisable and are satisfied by neutral or negative ions having lone pair of electrons. Primary valencies are non-directional while secondary valencies decide the shape of the complexes.
(i) If $PtCl_2.2NH_3$ does not react with $AgNO_3$, what will be its formula?
(ii) What is the secondary valency of $[Co(en)_3]^{3+}$?
(iii) (1) Write the formula of Iron(III)hexacyanidoferrate(II)
(2) Write the IUPAC name of $[Co(NH_3)_5Cl]Cl_2$.

OR

(iii) Write the hybridization and magnetic behaviour of $[Ni(CN)_4]^{2-}$. *(2023)*

Crystal Field Theory

MCQ

74. **Assertion (A) :** Low spin tetrahedral complexes are rarely observed.
Reason (R) : Crystal field splitting energy is less than pairing energy for tetrahedral complexes.
(a) Both Assertion (A) and Reason (R) are correct statements, and Reason (R) is the correct explanation of the Assertion (A).
(b) Both Assertion (A) and Reason (R) are correct statements, but Reason (R) is not the correct explanation of the Assertion (A).
(c) Assertion (A) is correct, but Reason (R) is wrong statement.
(d) Assertion (A) is wrong, but Reason (R) is correct statement. *(2023, 2020)* R

75. The crystal field splitting energy for octahedral (Δ_o) and tetrahedral (Δ_t) complexes is related as
(a) $\Delta_t = \frac{2}{9}\Delta_o$ (b) $\Delta_t = \frac{5}{9}\Delta_o$
(c) $\Delta_t = \frac{4}{9}\Delta_o$ (d) $\Delta_t = 2\,\Delta_o$ *(2020)*

VSA (1 mark)

76. Why a solution of $[Ni(H_2O)_6]^{2+}$ is green while a solution of $[Ni(CN)_4]^{2-}$ is colourless?
(At. no. of Ni = 28) *(NCERT, 1/3, Delhi 2017)* Ev

SA I (2 marks)

77. (a) Why is $[NiCl_4]^{2-}$ paramagnetic while $[Ni(CN)_4]^{2-}$ is diamagnetic?
(Atomic number of Ni = 28)
(b) Why are low spin tetrahedral complexes rarely observed? *(2/3, AI 2017)* An

78. (i) On the basis of crystal field theory, write the electronic configuration of d^4 ion if $\Delta_o < P$.
(ii) Write the hybridization and magnetic behaviour of the complex $[Ni(CO)_4]$.
(At. no. of Ni = 28) *(2/3, Delhi 2015)* An

SA II (3 marks)

79. (i) On the basis of crystal field theory, write the electronic configuration for d^4 ion if $\Delta_o < P$.
(ii) Using valence bond theory, predict the hybridization and magnetic character of $[Ni(CN)_4]^{2-}$. (Atomic number of Ni = 28)

(iii) Write the formula of the following complex using IUPAC norms : Dichloridobis (ethane-1,2-diamine) cobalt (III) *(Term II, 2021-22)*

80. (i) Write the electronic configuration of d^4 on the basis of crystal field splitting theory, if $\Delta_o < P$.

(ii) $[Ni(CN)_4]^{2-}$ with square-planar structure is diamagnetic and $[NiCl_4]^{2-}$ with tetrahedral geometry is paramagnetic. Give reason to support the statement.
[Atomic number : Ni = 28]

(iii) Write the number of ions produced in the solution from the following complex :
$[PtCl_2(NH_3)_4]Cl_2$ *(Term II, 2021-22)* Ap

81. (a) Write the IUPAC name of the following complex : $K_3[Cr(C_2O_4)_3]$

(b) On the basis of crystal field theory, write the electronic configuration of d^5 ion if $\Delta_o < P$.

(c) What are ambidentate ligands? *(Term II, 2021-22)*

82. (i) Write the IUPAC name of the following complex : $K_2[PdCl_4]$

(ii) Using crystal field theory, write the electronic configuration of d^5 ion, if $\Delta_o > P$.

(iii) What are homoleptic complexes ? *(Term II, 2021-22)*

83. (i) Why chelate complexes are more stable than complexes with unidentate ligands?

(ii) What is "spectrochemical series"? What is the difference between a weak field ligand and a strong field ligand ? *(Term II, 2021-22)*

84. (a) Give the IUPAC name and electronic configuration of central metal atom in terms of t_{2g} and e_g of $K_4[Mn(CN)_6]$.

(b) What is meant by 'Chelate effect' ? Give an example. *(2020)* U

85. Define the following :
(a) Ambidentate ligands
(b) Spectrochemical series
(c) Heteroleptic complexes *(2019C)*

5.6 Bonding in Metal Carbonyls

VSA (1 mark)

86. Out of NH_3 and CO, which ligand forms a more stable complex with a transition metal and why? *(1/3, AI 2015)* U

5.7 Importance and Applications of Coordination Compounds

MCQ

87. **Assertion (A) :** EDTA is used to determine hardness of water.
Reason (R) : EDTA is a bidentate ligand.
(a) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).
(b) Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of the Assertion (A).
(c) Assertion (A) is true, but Reason (R) is false.
(d) Assertion (A) is false, but Reason (R) is true. *(2023)*

CBSE Sample Questions

5.1 Werner's Theory of Coordination Compounds

MCQ

1. The number of ions formed on dissolving one molecule of $FeSO_4.(NH_4)_2SO_4.6H_2O$ in water is
(a) 3 (b) 4
(c) 5 (d) 6 *(2022-23)*

5.2 Definition of Some Important Terms Pertaining to Coordination Compounds

MCQ

2. Ambidentate ligands like NO_2^- and SCN^- are
(a) unidentate
(b) didentate
(c) polydentate
(d) has variable denticity. *(2020-21)* R

5.3 Nomenclature of Coordination Compounds

MCQ

3. The formula of the coordination compound tetraammineaquachloridocobalt(III) chloride is
(a) $[Co(NH_3)_4(H_2O)Cl]Cl_2$
(b) $[Co(NH_3)_4(H_2O)Cl]Cl_3$
(c) $[Co(NH_3)_2(H_2O)Cl]Cl_2$
(d) $[Co(NH_3)_4(H_2O)Cl]Cl$ *(2020-21)*

5.4 Isomerism in Coordination Compounds

SA I (2 marks)

4. The formula $Co(NH_3)_5CO_3Cl$ could represent a carbonate or a chloride. Write the structures and names of possible isomers. *(2022-23)*

5.5 Bonding in Coordination Compounds

MCQ

5. The CFSE of $[CoCl_6]^{3-}$ is 18000 cm^{-1}, the CFSE for $[CoCl_4]^-$ will be
   (a) 18000 cm^{-1} (b) 8000 cm^{-1}
   (c) 2000 cm^{-1} (d) 16000 cm^{-1}
   (2022-23)

SA I (2 marks)

6. (i) Using Crystal Field Theory, write the electronic configuration of iron ion in the following complex ion. Also predict its magnetic behaviour : $[Fe(H_2O)_6]^{2+}$
   (ii) Write the IUPAC name of the coordination complex : $[CoCl_2(en)_2]NO_3$

   OR

   (i) Predict the geometry of $[Ni(CN)_4]^{2-}$.
   (ii) Calculate the spin only magnetic moment of $[Cu(NH_3)_4]^{2+}$ ion. *(2020-21)*

SA II (3 marks)

7. Using Valence bond theory, explain the following in relation to the paramagnetic complex $[Mn(CN)_6]^{3-}$
   (a) type of hybridisation
   (b) magnetic moment value
   (c) type of complex – inner, outer orbital complex
   (2022-23)

8. Answer the following questions :
   (a) $[Ni(H_2O)_6]^{2+}_{(aq)}$ is green in colour whereas $[Ni(H_2O)_4(en)]^{2+}_{(aq)}$ is blue in colour, give reason in support of your answer.
   (b) Write the formula and hybridisation of the following compound :
   tris(ethane-1,2-diamine)cobalt(III) sulphate U

   OR

   In a coordination entity, the electronic configuration of the central metal ion is $t_{2g}^3 e_g^1$.
   (a) Is the coordination compound a high spin or low spin complex?
   (b) Draw the crystal field splitting diagram for the above complex. *(Term II, 2021-22)*

Detailed SOLUTIONS

Previous Years' CBSE Board Questions

1. (c) : $[Co(NH_3)_5SO_4]Cl \xrightarrow{AgNO_3} \underset{\text{(white ppt)}}{AgCl\downarrow}$

Only Cl^- ion gets ionise, SO_4^{2-} will not ionise since it is present inside coordination sphere.

2. (a) : For one mole of the compound, two moles of AgCl are precipitated which indicates two ionisable chloride ions in the complex. Hence, its structural formula is $[CrCl(H_2O)_5]Cl_2{\cdot}H_2O$

3. For one mole of the compound, two moles of AgCl are precipitated which indicates two ionisable chloride ions in the complex. Hence, its structural formula is $[CrCl(H_2O)_5]Cl_2{\cdot}H_2O$

Commonly Made Mistake

- Student must know the difference between primary and secondary valency.
- Primary valency - Normally ionisable and are satisfied by negative ions.
- Secondary valency - Non-ionisable and are satisfied by neutral molecules or negative ions.

4. Double salts dissociate into ions completely when dissolved in water. On the other hand, in complexes, the complex ion does not dissociate.

5. Structural formula : $[Co(NH_3)_6]Cl_3$

6. (b) : $[Co(en)_3]_2(SO_4)_3$

Let oxidation number of Co be *x*.

$2(+x + 3(0)) = +6$
$2x = +6$
$x = +3$

7. (c) : $C_2O_4^{2-}$ is a chelating ligand, it forms a chelate complex with metal ion.

8. (a) : The coordination number of Cr in $[CrCl_2(ox)_2]^{3-}$ is 6 as Cl is monodentate ligand and oxalate is bidentate ligand.

9. (b) : Ethane-1, 2-diamine (*en*) is a bidentate ligand.

Key Points

- The secondary valency is equal to the coordination number.

10. (d) : Formation of chelate rings increases the stability of the complex.

11. (a) : As CO is a neutral ligand, its oxidation state is zero. The oxidation state of Ni in $Ni(CO)_4$ is calculated as follows :
$x + 4(0) = 0, x = 0$

12. $[Fe(C_2O_4)_3]^{3-}$ is more stable than $[Fe(NH_3)_6]^{3+}$ due to chelate effect, as it forms rings.

13. Coordination number and oxidation state of Pt in the complex $[Pt(en)_2Cl_2]$ are 6 and +2 because *en* is a bidentate and neutral ligand.

14. $[Co(en)_3]^{3+}$ is more stable complex than $[Co(NH_3)_6]^{3+}$ due to chelate effect as it forms rings.

15. (c) : $[Co(NH_3)_4Cl(NO_2)]Cl$
Tetraamminechloridonitrito-N-cobalt(III) chloride

16. $Fe_4[Fe(CN)_6]_3$

17. IUPAC name of the complex $[Cr(NH_3)_3Cl_3]$ is triamminetrichloridochromium(III).

18. Pentaamminecarbonatocobalt(III) chloride

19. IUPAC name of the complex
For one mole of the compound, two moles of AgCl are precipitated which indicates two ionisable chloride ions in the complex. Hence, its structural formula is

$[CrCl(H_2O)_5]Cl_2 \cdot H_2O$
$[CrCl(H_2O)_5]Cl_2 \cdot H_2O$ is :
Pentaaquachloridochromium(III) chloride.

20. (a) $K_2[Zn(OH)_4]$

Potassium tetrahydroxidozincate(II)

(b) $[Pt(NH_3)_6]Cl_4$

Hexaammineplatinum(IV) chloride

Key Points

- If the complex provides anionic complex ion then the name of the metal ends with the suffix *ate*.

21. (i) $[Co(NH_3)_5(ONO)]Cl_2$ (ii) $K_2[Ni(CN)_4]$

22. (a) $Na[Au(CN)_2]$

Sodium dicyanidoaurate(I)

(b) $[Pt(NH_3)_4(Cl)(NO_2)]SO_4$

Tetraamminechloridonitrito-N-platinum(IV) sulphate

23. (a) $[Cr(en)_3]Cl_3$

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

(b) $K_2[Zn(OH)_4]$

Potassium tetrahydroxidozincate(II)

24. (a) $K_3[Al(C_2O_4)_3]$

Potassium trioxalatoaluminate(III)

(b) $[CoCl_2(en)_2]^+$

Dichlorido*bis*(ethane-1,2-diamine)cobalt(III) ion

25. (i) Diamminedichlorido(ethane-1,2-diamine) chromium(III) chloride.

(ii) $[Co(NH_3)_5(ONO)]^{2+}$

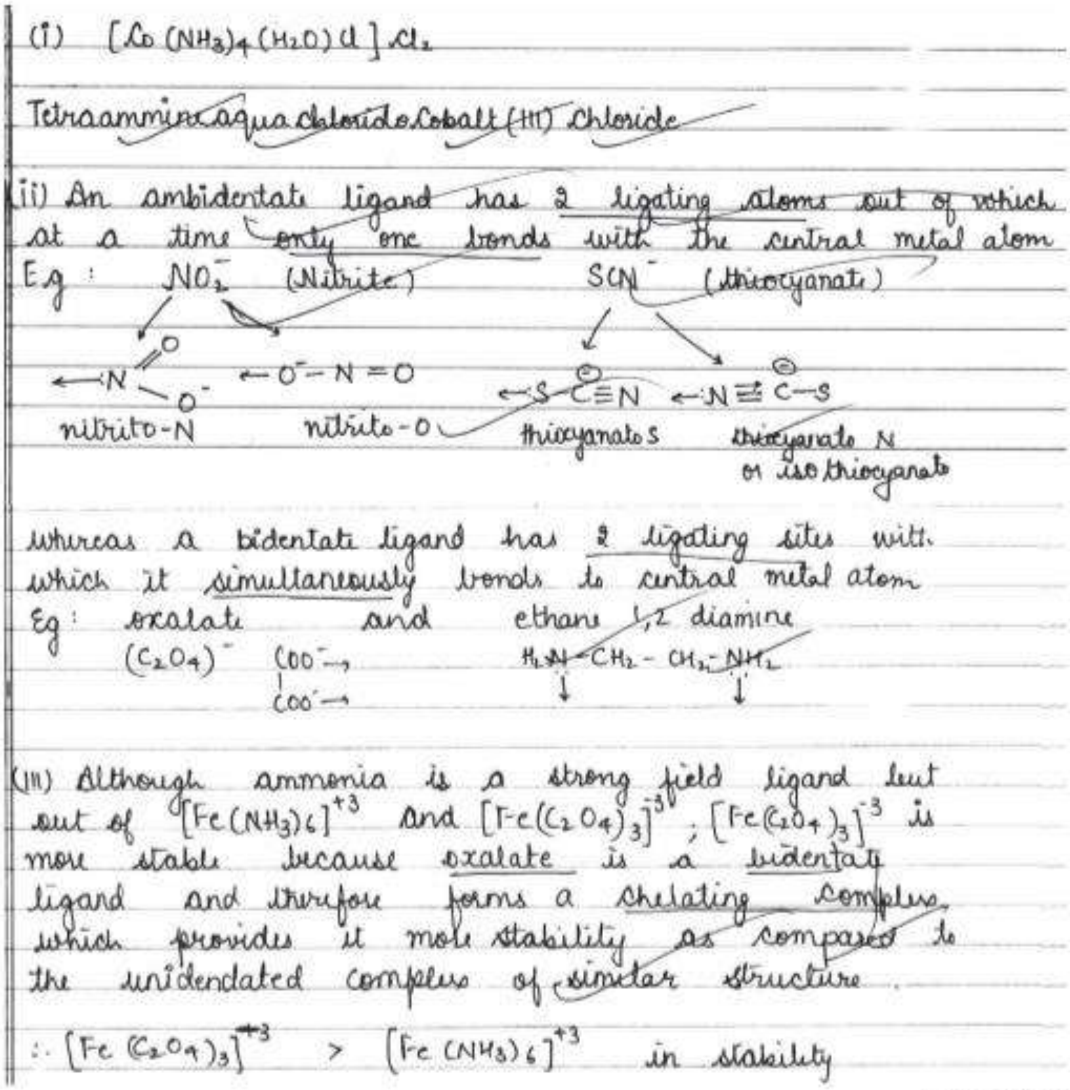
26. (i) $[Co(NH_3)_6]Cl_3$

(ii) $K_2[NiCl_4]$

27. (i) *Tris*(ethylenediammine)chromium(III) chloride

(ii) $K_3[Cr(ox)_3]$

28.



(i) $[Co(NH_3)_4(H_2O)Cl]Cl_2$

Tetraammineaquachloridocobalt(III) Chloride

(ii) An ambidentate ligand has 2 ligating atoms out of which at a time only one bonds with the central metal atom

Eg : NO_2^- (Nitrite) SCN^- (thiocyanate)

$\leftarrow N \langle {}^{O}_{O^-}$ $\leftarrow O^- - N = O$ $\leftarrow S - \overset{\ominus}{C} \equiv N$ $\leftarrow N \equiv \overset{\ominus}{C} - S$

nitrito-N nitrito-O thiocyanato S thiocyanato N or isothiocyanato

whereas a bidentate ligand has 2 ligating sites with which it simultaneously bonds to central metal atom

Eg : oxalate $(C_2O_4)^-$ $COO^- \rightarrow$ / $COO^- \rightarrow$ and ethane 1,2 diamine $H_2\overset{\downarrow}{N} - CH_2 - CH_2 - \overset{\downarrow}{N}H_2$

(III) Although ammonia is a strong field ligand but out of $[Fe(NH_3)_6]^{+3}$ and $[Fe(C_2O_4)_3]^{-3}$; $[Fe(C_2O_4)_3]^{-3}$ is more stable because oxalate is a bidentate ligand and therefore forms a chelating complex which provides it more stability as compared to the unidentated complex of similar structure.

$\therefore [Fe(C_2O_4)_3]^{+3} > [Fe(NH_3)_6]^{+3}$ in stability

[Topper's Answer, 2022]

29. (i) Hexaamminecobalt(III) chloride

(ii) Tetrachloridonickelate(II) ion

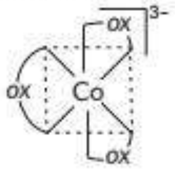
(iii) Potassium hexacyanidoferrate(III)

30. (i) Pentaamminechloridocobalt(III) chloride

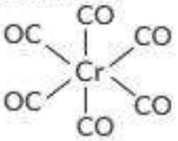
(ii) Potassium hexacyanidoferrate(III)

(iii) Tetrachloridonickelate(II) ion

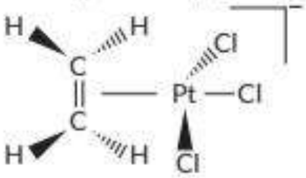
31. (i) Trioxalatocobaltate(III)



(ii) Hexacarbonylchromium(0)



(iii) Trichloridoetheneplatinate(II) ion



32. (c): Compounds, which give different ions in solution due to the exchange of ions in coordination sphere and counter ions are called ionisation isomers.
Therefore, $[Co(Br)(NH_3)_5]SO_4$ and $[Co(SO_4)(NH_3)_5]Br$ are ionisation isomers.

33. (c): The pair $[Co(NH_3)_4Cl_2]Br_2$ and $[Co(NH_3)_4Br_2]Cl_2$ will show ionisation isomerism.

34. (a)

35. Linkage isomerism is shown by the given complex as NO_2 is an ambidentate ligand. The resultant linkage isomers are $[Co(NH_3)_5(NO_2)]Cl_2$ and $[Co(NH_3)_5(ONO)]Cl_2$. Ionisation isomerism is also shown by the given complex as $[Co(NH_3)_5(NO_2)]Cl_2$ and $[Co(NH_3)_5Cl]NO_2Cl$

36. Ionisation isomerism : $[Co(NH_3)_5Cl]SO_4$ and $[Co(NH_3)_5SO_4]Cl$

37. Coordination isomerism

38. The complex $[Co(NH_3)_5(SCN)]^{2+}$ shows linkage isomerism as SCN^- is an ambidentate ligand.

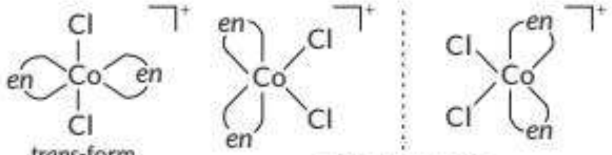
39. Linkage isomerism : $[Co(NH_3)_5NO_2]^{2+}$ and $[Co(ONO)(NH_3)_5]^{2+}$

Concept Applied

- Linkage isomerism arises in a coordination compound containing ambidentate ligand.

40. (a) An atom, molecule or ion which is linked to central metal atom or ion through coordinate bond by donating lone pair of electrons present on its donor atom is known as ligand.
Here, NH_4^+ cannot act as a ligand since there is no lone pair of electrons on its donor atom.
(b) Linkage isomer of $[Co(NH_3)_5(NO_2)]Cl_2$ is $[Co(NH_3)_5(ONO)]Cl_2$
IUPAC name : Pentaamminenitrito-O-cobalt(III) chloride.

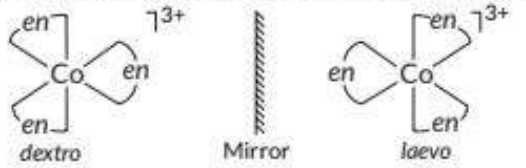
41. $[CoCl_2(en)_2]^+$: Dichloridobis(ethane-1,2-diamine) cobalt(III) ion
This complex exhibit both optical and geometrical isomerism and *cis* isomer is optically active.



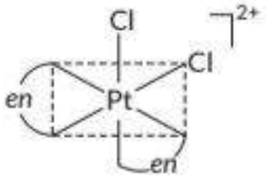
trans-form

cis-form exists in two enantiomeric forms (*d* and *l*)

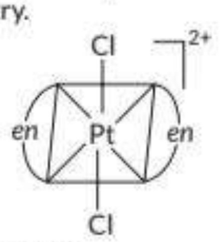
42. The complex, $[Co(en)_3]Cl_3$ shows optical isomerism.



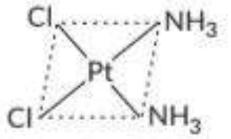
43. *Cis*-isomer of the complex $[Pt(en)_2Cl_2]^{2+}$ is optically active.



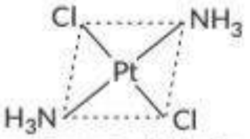
44. *Trans*-isomer is optically inactive due to the presence of plane of symmetry.



45. Geometrical isomers

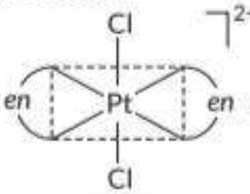


cis-Diamminedichlorido platinum(II)

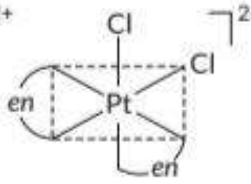


trans-Diamminedichlorido platinum(II)

46. IUPAC name - Dichlorido*bis*(ethane-1,2-diamine) platinum(IV) ion. This complex shows geometrical and optical isomerism.

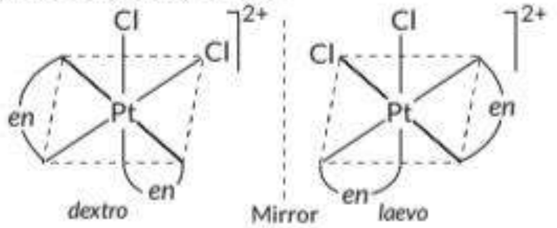


trans

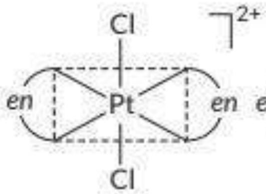


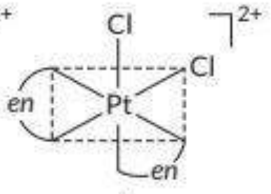
cis

Cis-isomer is optically active.

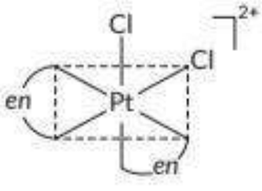


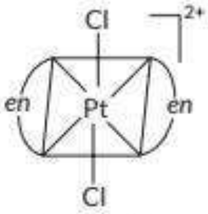
47. This complex shows geometrical and optical isomerism. Geometrical isomers are *cis*-*trans* isomers.


trans

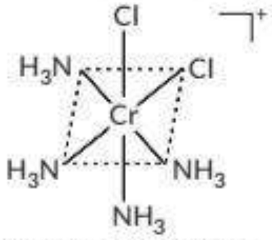

cis

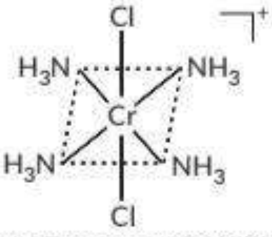
48. $[Pt(en)_2Cl_2]$
Dichloridodiethylenediamine platinum(II)
Geometrical isomers of $[Pt(en)_2Cl_2]$ are


cis-form


trans-form

49. Tetraamminedichloridochromium(III) ion
Geometrical isomers of $[Cr(NH_3)_4Cl_2]^+$;


cis-Tetraamminedichlorido chromium(III) ion

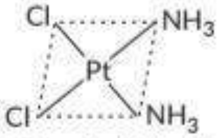

trans-Tetraamminedichlorido chromium(III) ion

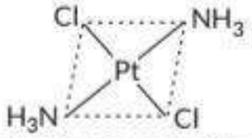
50. (i) Linkage isomerism : $[Co(NH_3)_5NO_2]^{2+}$ and $[Co(NH_3)_5(ONO)]^{2+}$

(ii) Optical isomerism : $[Co(en)_3]Cl_3$

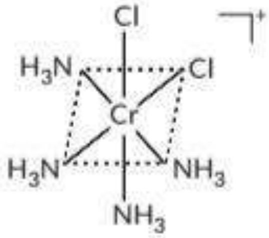

dextro Mirror laevo

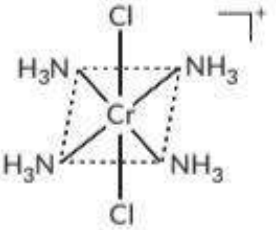
(iii) Geometrical isomerism : $[Pt(NH_3)_2Cl_2]$


cis-Diamminedichlorido platinum (II)

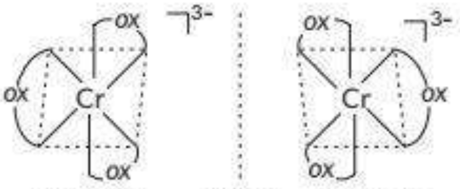

trans-Diamminedichlorido platinum (II)

51. Tetraamminedichloridochromium(III) ion $[Cr(NH_3)_4Cl_2]^+$ shows geometrical isomerism.

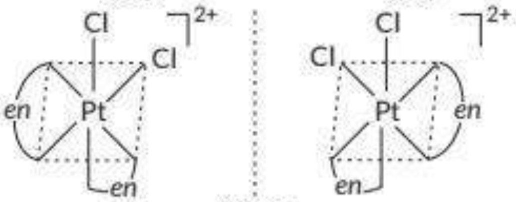

cis-Tetraamminedichlorido chromium(III) ion


trans-Tetraamminedichlorido chromium(III) ion

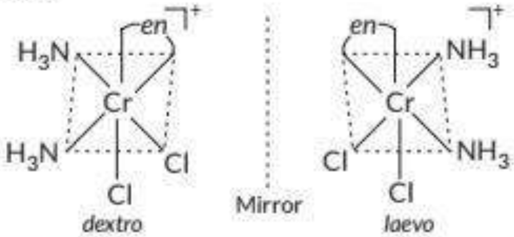
52. $[Cr(C_2O_4)]^{3-}$:


$[Cr(ox)_3]^{3-}$ dextro Mirror $[Cr(ox)_3]^{3-}$ laevo

$[PtCl_2(en)_2]^{2+}$:


dextro Mirror laevo

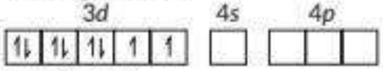
$[Cr(NH_3)_2Cl_2(en)]^+$:


dextro Mirror laevo

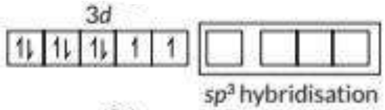
Key Points

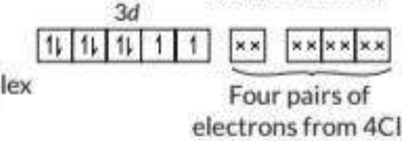
- Optical isomers are mirror images that cannot be superimposed on one another.

53. (b): In $[NiCl_4]^{2-}$, Ni is in +2 oxidation state and has $3d^8$ outer electronic configuration.

Orbital of Ni^{2+} ion


Since, Cl^- is a weak field ligand.

sp^3 hybridised orbital of Ni^{2+}


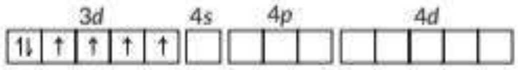
$[NiCl_4]^{2-}$ high spin complex


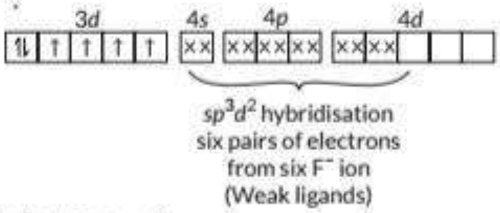
It is sp^3 hybridised high spin paramagnetic complex.

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

$$= \sqrt{2(2+2)} = \sqrt{2 \times 4} = \sqrt{8} = 2.82\,\text{B.M.}$$

54. The IUPAC name of $[CoF_6]^{3-}$ is hexafluoridocobaltate(III).
Oxidation state of Co ion in $[CoF_6]^{3-}$ is +3.

Co^{3+} :


Co^{3+} in $[CoF_6]^{3-}$:


No. of unpaired electrons = 4

Key Points

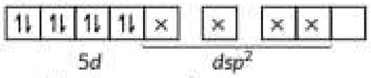
- Weak field ligands give, outer orbital or high spin or spin free complex.

55. $[Pt(CN)_4]^{2-}$ has square planar structure.

Pt : $[Xe]\,4f^{14}\,5d^9\,6s^1$

Pt^{2+} : $[Xe]\,4f^{14}\,5d^8\,6s^0$

$[Pt(CN)_4]^{2-}$:

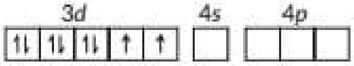


No. of unpaired electrons = 0.

56. The complex $[Co(C_2O_4)_3]^{3-}$ has d^2sp^3-hybridisation and it is diamagnetic in nature due to the absence of unpaired electrons.

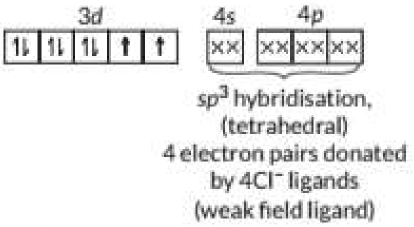
57. $[NiCl_4]^{2-}$ contains Ni^{2+} ion with $3d^8$ configuration.

Ni^{2+} : Ground state



Cl^- is a weak field ligand thus no pairing will occur. Hence, outer 4s and 4p-orbitals are used in hybridisation.

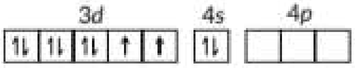
$[NiCl_4]^{2-}$: with $4Cl^-$ ligands



It has two unpaired electrons hence, it is paramagnetic.

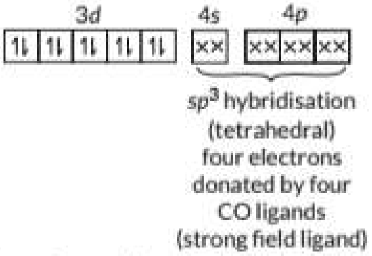
$[Ni(CO)_4]$ contains Ni(0) – $3d^84s^2$ configuration.

Ni(0) : Ground state



CO is a strong field ligand hence, 4s-electrons will shift to 3d-orbital making 4s-orbital vacant.

$[Ni(CO)_4]$:



The complex has all paired electrons hence, it is diamagnetic.

Key Points

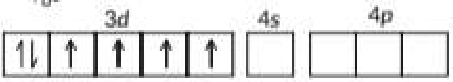
- Strong field ligands give, inner orbital or low spin or spin paired complex. Weak field ligands give, outer orbital or high spin or spin free complex.

58. (i) $[Mn(H_2O)_6]SO_4$

Hexaaquamanganese(II) sulphate

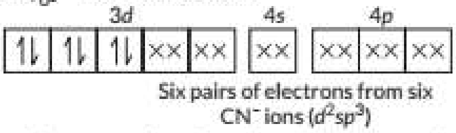
(ii) $[Fe(CN)_6]^{4-}$ ion :

Fe^{2+} ion :



Fe^{2+} ion hybridised (under the influence of strong field ligand).

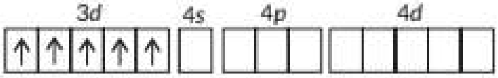
$[Fe(CN)_6]^{4-}$ ion formation :



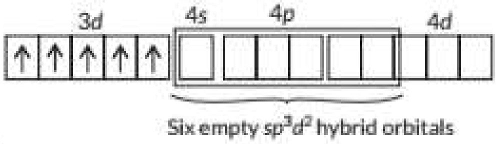
Since, the complex ion does not contain any unpaired electron, so it is diamagnetic.

$[FeF_6]^{3-}$ ion :

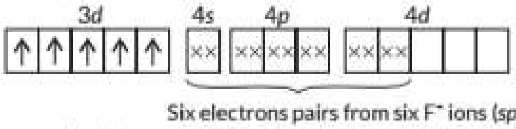
Fe^{3+} ion :



Fe^{3+} ion hybridised (under the influence of weak field ligand).



$[FeF_6]^{3-}$ ion formation :



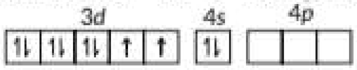
As the complex ion contains five unpaired electrons, it is highly paramagnetic in nature.

$\mu_s = \sqrt{5(5+2)} = \sqrt{35} = 5.9$ B.M.

59. (i) IUPAC name; Tetracarbonylnickel(0)

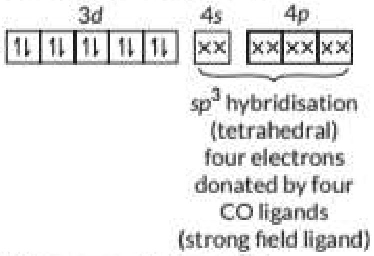
$[Ni(CO)_4]$ contains Ni(0) – $3d^84s^2$ configuration.

Ni(0) : Ground state



CO is a strong field ligand hence, 4s-electrons will shift to 3d-orbital making 4s-orbital vacant.

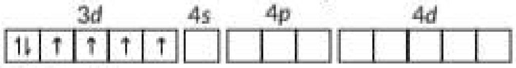
$[Ni(CO)_4]$:



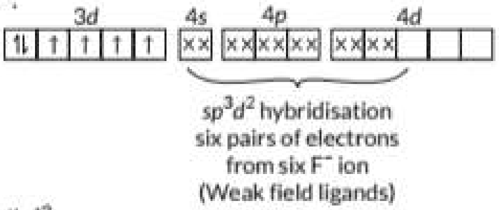
(ii) The IUPAC name of $[CoF_6]^{3-}$ is hexafluoridocobaltate(III).

Oxidation state of Co ion in $[CoF_6]^{3-}$ is +3.

Co^{3+} :



Co^{3+} in $[CoF_6]^{3-}$:



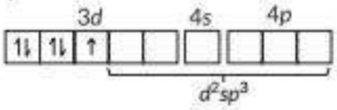
60. (a) $[Fe(CN)_6]^{3-}$

IUPAC name : Hexacyanidoferrate (III) ion

Fe is present as Fe^{3+} in $[Fe(CN)_6]^{3-}$

Fe^{3+} : [Ar] $3d^5 4s^0$

As CN$^-$ is a strong field ligand, hence, electrons in $3d$ get paired up.

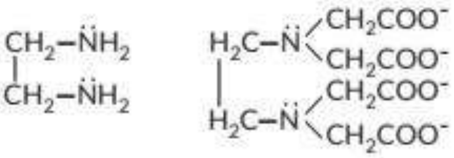


Hybridisation is d^2sp^3.

(b) Ambidentate ligands : These are the unidentate ligands containing more than one coordinating atoms are called ambidentate ligands.

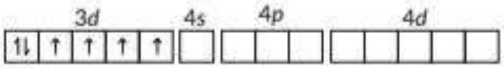
For example NO$_2$; it can donate through –N or –O both.

Chelating ligands : Bidentate or polydentate ligands which contain two or more donor atoms and these are positioned in such a way that a five or six membered ring is formed with metal ion. for example ethylenediamine and EDTA$^-$.



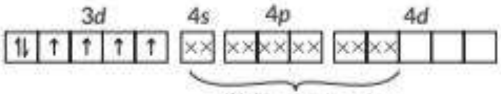
61. Oxidation state of Co ion in [CoF$_6$]$^{3-}$ is +3.

Co^{3+} :



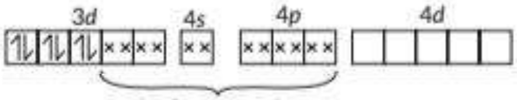
(In ground state)

[CoF$_6$]$^{3-}$:



sp^3d^2 hybridisation
six pairs of electrons
from six F$^-$ ion
(Weak field ligands)

[Co(en)$_3$]$^{3+}$:



six electron pairs
donated by three en
(d^2sp^3 hybridization)

(i) [CoF$_6$]$^{3-}$ is paramagnetic in nature.

(ii) Chelating ligands form more stable cyclic/ring complexes than unidentate or non-chelating ligands. Since, [Co(en)$_3$]$^{3+}$ contains en which is a bidentate chelating ligand, it is more stable than [CoF$_6$]$^{3-}$.

(iii) [Co(en)$_3$]$^{3+}$ is an inner orbital complex as its hybridisation is d^2sp^3 hybridisation.

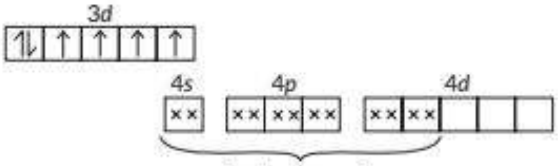
(iv) [CoF$_6$]$^{3-}$ is a high spin complex.

Concept Applied

- Strong field ligand forms low spin, inner orbital complexes and weak field ligands from high spin outer orbital complex.

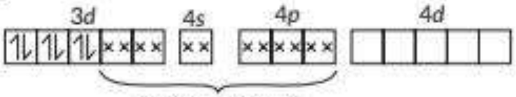
62. Formation of [CoF$_6$]$^{3-}$ and [Co(C$_2$O$_4$)$_3$]$^{3-}$ can be represented as :

[CoF$_6$]$^{3-}$:



six electron pairs
donated by F$^-$ ions
(sp^3d^2 hybridization)

[Co(C$_2$O$_4$)$_3$]$^{3-}$:



six electron pairs
donated by en
(d^2sp^3 hybridization)

(i) [Co(C$_2$O$_4$)$_3$]$^{3-}$ is diamagnetic as all electrons are paired.

(ii) [Co(C$_2$O$_4$)$_3$]$^{3-}$ is more stable as C$_2$O$_4^{2-}$ is a chelating ligand and forms chelate rings.

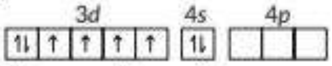
(iii) [CoF$_6$]$^{3-}$ is outer orbital complex as it undergoes sp^3d^2 hybridization using the outer $4d$-orbital.

(iv) [Co(C$_2$O$_4$)$_3$]$^{3-}$ is low spin complex due to absence of any unpaired electron.

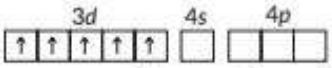
63. [Fe(H$_2$O)$_6$]$^{3+}$:

Fe atom (Z = 26)

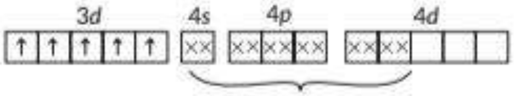
Ground state :



Fe^{3+}ion :



[Fe(H$_2$O)$_6$]$^{3+}$:

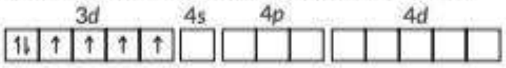


sp^3d^2 hybridisation
six pairs of electrons
from six H$_2$O ligands
(weak field ligand)

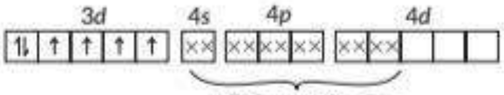
The complex ion has outer orbital octahedral geometry (high spin) and is paramagnetic due to the presence of five unpaired electrons.

64. (i) Oxidation state of Co ion in [CoF$_6$]$^{3-}$ is +3.

Co^{3+} :

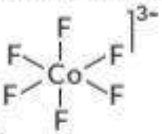


[CoF$_6$]$^{3-}$:



sp^3d^2 hybridisation
six pairs of electrons
from six F$^-$ ion
(Weak field ligands)

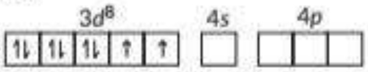
Structure – Outer orbital octahedral complex



Nature – Paramagnetic

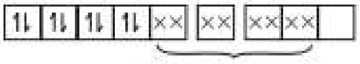
(ii) In [Ni(CN)$_4$]$^{2-}$: Ni is present as Ni(II) with $3d^8$ configuration.

Ni^{2+} :



(In ground state)

[Ni(CN)$_4$]$^{2-}$:

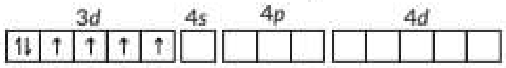


dsp^2 hybridisation
four electrons pairs
donated by four
CN$^-$ ions
(Strong field ligand)

The complex ion has square planar geometry and is diamagnetic in nature.

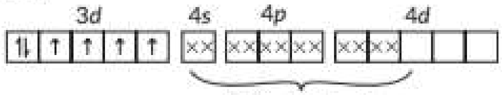
65. Oxidation state of Co ion in [CoF$_6$]$^{3-}$ is +3.

Co^{3+} :



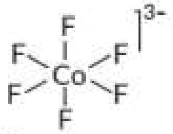
(In ground state)

[CoF$_6$]$^{3-}$:



sp^3d^2 hybridisation
six pairs of electrons
from six F$^-$ ion
(Weak field ligands)

Structure – Outer orbital octahedral complex



Nature – Paramagnetic

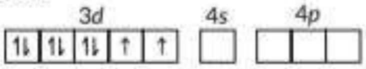
IUPAC Name : Hexafluoridocobaltate(III) ion

Key Points

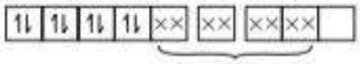
- F$^-$ is a weak field ligands.

66. In [Ni(CN)$_4$]$^{2-}$: Ni is present as Ni(II) with 3d^8 configuration.

Ni^{2+} :



[Ni(CN)$_4$]$^{2-}$:



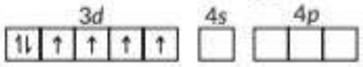
dsp^2 hybridisation
four electrons pairs
donated by four
CN$^-$ ions
(Strong field ligand)

The complex ion has square planar geometry and is diamagnetic in nature.

IUPAC name : Tetracyanidonickelate(II) ion

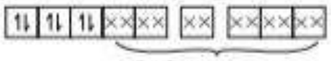
67. Oxidation of cobalt in [Co(NH$_3$)$_6$]$^{3+}$ is +3.

Co^{3+} :



Ground State

[Co(NH$_3$)$_6$]$^{3+}$ ion :



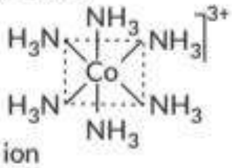
d^2sp^3 hybridisation
six pairs of electrons
from six NH$_3$ ligand
(Strong field ligand)

Hybridisation – d^2sp^3

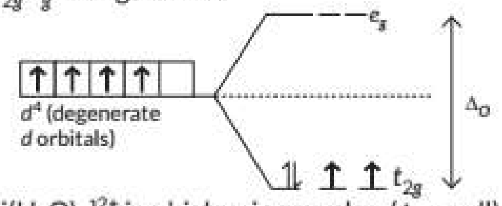
Structure – Octahedral
(low spin)

Nature – Diamagnetic

IUPAC name : Hexaamminecobalt(III) ion



68. (a) On the basis of CFT, if strong field ligand is present for d^4 orbit with $\Delta_o > P$, the energy gap between t_{2g} and e_g will be more and thus the electron will pair up giving $t_{2g}^4 e_g^0$ configuration.

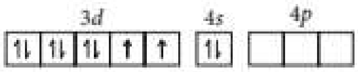


(b) [Ni(H$_2$O)$_6$]$^{2+}$ is a high spin complex (Δ_o small).

In [Ni(H$_2$O)$_6$]$^{2+}$, d-d transitions are taking place on absorbing low energy radiation (red component of spectrum) from visible region showing green as the complementary colour.

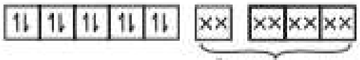
[Ni(CO)$_4$] contains Ni(0) – 3$d^8$4s^2 configuration.

Ni(0) :
Ground state



CO is a strong field ligand hence, 4s-electrons will shift to 3d-orbital making 4s-orbital vacant.

[Ni(CO)$_4$] :

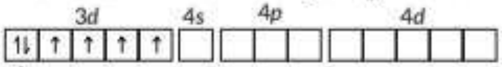


sp^3 hybridisation
(tetrahedral)
four electrons
denoted by four
CO ligands
(strong ligand)

The complex has all paired electrons hence, it is colourless.

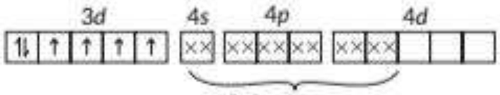
69. (a) Oxidation state of Co ion in [CoF$_6$]$^{3-}$ is +3.

Co^{3+} :



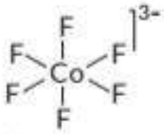
(In ground state)

[CoF$_6$]$^{3-}$:



sp^3d^2 hybridisation
six pairs of electrons
from six F$^-$ ion
(Weak field ligands)

Structure – Outer orbital octahedral complex



Nature – Paramagnetic

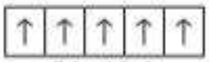
(b) [Co(NH$_3$)$_5$Cl]Cl

Pentaamminechloridocobalt(III) chloride

70. (i) [FeF$_6$]$^{3-}$

Oxidation state of Fe = +3

Fe^{3+} : 3d^5,



3d-orbitals

$\mu_{spin} = \sqrt{n(n+2)}$ B.M. $= \sqrt{5(5+2)}$ B.M $= 5.91$ B.M.

(ii) Pentaamminechloridocobalt(III) chloride

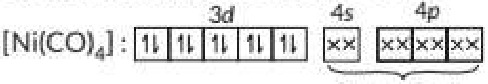
(iii) Chelating ligands form more stable cyclic/ring complexes than unidentate or non-chelating ligands.

Since, $[Co(en)_3]^{3+}$ contains *en* which is a bidentate chelating ligand, it is more stable than $[CoF_6]^{3-}$.

71. (a) $[Ni(CO)_4]$ contains Ni(0) – $3d^8 4s^2$ configuration.

Ground state

CO is a strong field ligand hence, 4*s*-electrons will shift to 3*d*-orbital making 4*s*-orbital vacant.

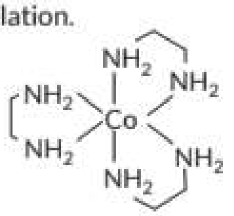


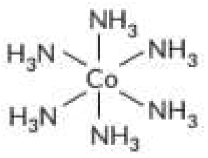
sp^3 hybridisation
(tetrahedral)
four electrons
donated by four
CO ligands
(strong field ligand)

The complex has all paired electrons hence, it is diamagnetic.

(b) Diamminechloridonitrito-N-platinum(II)

(c) $[Co(en)_3]^{3+}$ is a complex having bidentate ligand (*en*) that form a five - membered ring around Co metal that results in chelation. While no such ring is formed in $[Co(NH_3)_6]^{3+}$ complex. So, $[Co(en)_3]^{3+}$ is more stable due to chelation.



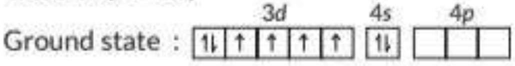


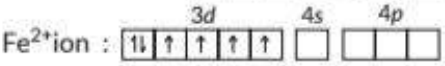
(*en* = ethylenediamine)

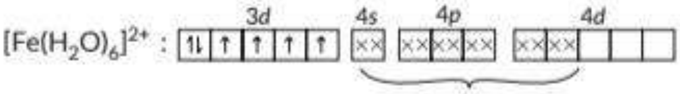
Key Points

- Chelating ligands form more stable complexes.

72. (i) $[Fe(H_2O)_6]^{2+}$:
Fe atom (*Z* = 26)



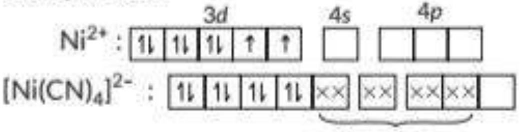




sp^3d^2 hybridisation
six pairs of electrons
from six H_2O ligands
(weak field ligand)

The complex ion has outer orbital octahedral geometry (high spin) and is paramagnetic due to the presence of four unpaired electrons.

(ii) In $[Ni(CN)_4]^{2-}$: Ni is present as Ni(II) with $3d^8$ configuration.



dsp^2 hybridisation
four electrons pairs
donated by four
CN^- ions
(Strong field ligand)

The complex ion has square planar geometry and is diamagnetic in nature.

73. (i) Its formula will be $[Pt(NH_3)_2Cl_2]$.

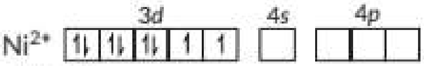
(ii) *en* is a bidentate ligand. Hence in $[Co(en)_3]^{3+}$, its secondary valency is 6.

(iii) (1) $Fe_4[Fe(CN)_6]_3$ is Iron (III) hexacyanidoferrate(II).

(2) IUPAC name of $[Co(NH_3)_5Cl]Cl_2$ is pentaammine chloridocobalt(III) chloride.

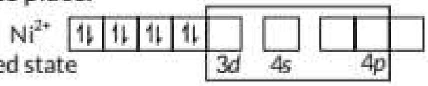
OR

(iii) In $[Ni(CN)_4]^{2-}$, Ni is present as Ni(II) with $3d^8$-configuration.



(In ground state)

CN^- is a strong field ligand. Hence pairing of electrons in 3*d*-orbital takes place.



In excited state

with $4CN^-$ ligands

dsp^2 hybridisation
4 electron pairs donated
by $4CN^-$ ions.

It has all paired electrons, hence it is diamagnetic.

74. (a): If $\Delta_o < P$ (*i.e.*, Δ_o small, weak field ligand) → electrons spread out among all *d*-orbitals before pairing up → forms high spin complex.

For tetrahedral crystal field, the order of splitting is reversed and is related to Δ_o as

$$\Delta_t = \frac{4}{9}\Delta_o$$

Consequently the orbital splitting energies are not sufficiently large for forcing pairing and therefore, low spin configurations are rarely observed in tetrahedral coordination entities.

75. (c)

76. $[Ni(H_2O)_6]^{2+}$ is a high spin complex (Δ_o small) while $[Ni(CN)_4]^{2-}$ is a low spin square planar complex.

In $[Ni(H_2O)_6]^{2+}$ complex, *d-d* transitions are taking place on absorbing low energy radiation (red component of spectrum) from visible region showing green as the complementary colour.

In $[Ni(CN)_4]^{2-}$ complex, *d-d* transitions do not take place because there is no unpaired electron present hence, complex is colourless.

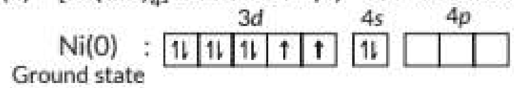
77. (a) Due to the presence of weak field ligand, *i.e.*, Cl^- in the complex $[NiCl_4]^{2-}$ two unpaired electrons are present in 3*d*-orbitals of Ni-atom hence, this complex is paramagnetic in nature. On the other hand, due to the presence of strong field ligand *i.e.*, CN^- in the complex $[Ni(CN)_4]^{2-}$, no unpaired electron is present in 3*d*-orbitals of Ni-atom (as strong field ligand causes pairing of electrons), hence, it is diamagnetic in nature.

(b) In tetrahedral coordination entity formation, the *d*-orbital splitting is smaller. Consequently, the orbital splitting energies are not sufficiently large to force pairing and therefore, low spin configurations are rarely observed.

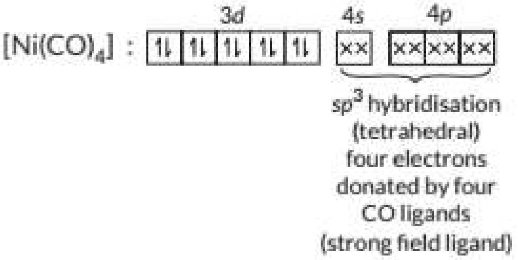
78. (i) For d^4 ion, if $\Delta_o < P$, the fourth electron enters one of the e_g orbitals giving the configuration $t_{2g}^3\, e_g^1$.

Ligands for which $\Delta_o < P$ are known as weak field ligands and form high spin complexes.

(ii) $[Ni(CO)_4]$ contains Ni(0) – $3d^8 4s^2$ configuration.



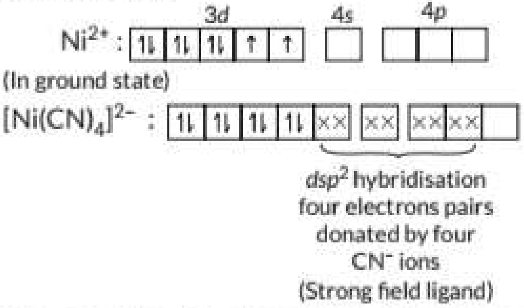
CO is a strong field ligand hence, 4s-electrons will shift to 3d-orbital making 4s-orbital vacant.



The complex has all paired electrons hence, it is diamagnetic.

79. (i) When $\Delta_o < P$, $t_{2g}^3\, e_g^1$

(ii) In $[Ni(CN)_4]^{2-}$: Ni is present as Ni(II) with $3d^8$ configuration.



The complex ion has square planar geometry and is diamagnetic in nature.

(iii) $[Co(en)_2Cl_2]^+$

Dichloridobis(ethane-1,2-diamine)cobalt(III) ion

80. (i) For d^4 ion, if $\Delta_o < P$, the fourth electron enters one of the e_g orbitals giving the configuration $t_{2g}^3\, e_g^1$. Ligands for which $\Delta_o < P$ are known as weak field ligands and form high spin complexes.

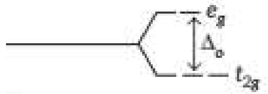
(ii) Due to the presence of weak field ligand, *i.e.*, Cl^- in the complex $[NiCl_4]^{2-}$ two unpaired electrons are present in 3*d*-orbitals of Ni-atom hence, this complex is paramagnetic in nature. On the other hand, due to the presence of strong field ligand *i.e.*, CN^- in the complex $[Ni(CN)_4]^{2-}$, no unpaired electron is present in 3*d*-orbitals of Ni-atom (as strong field ligand causes pairing of electrons), hence, it is diamagnetic in nature.

(iii) $[PtCl_2(NH_3)_4]Cl_2 \rightarrow [PtCl_2(NH_3)_4]^{2+}_{(aq)} + 2Cl^-_{(aq)}$

Hence, the total number of ions produced is three.

81. (a) $K_3[Cr(C_2O_4)_3]$: Potassium trioxalatochromate(III)

(b) According to crystal field theory, five *d*-orbitals, split into two different energy levels termed as t_{2g} and e_g as shown below :



Degenerated *d*-orbitals

For d^5 ion with $\Delta_o < P$, electronic configuration will be $t_{2g}^3\, e_g^2$.

Concept Applied

- Weak field ligands causes less splitting, for these $\Delta_o < P$, hence before pairing electron goes to higher e_g level, causing formation of high spin complexes.

(c) Ambidentate ligand : A unidentate ligand which can coordinate to central metal atom through two different atoms is called ambidentate ligand. For example, NO_2^- ion can coordinate either through nitrogen or through oxygen to the central metal atom/ion.

82. (i) $K_2[PdCl_4]$: Potassium tetrachloridopalladate(II)

(ii) If $\Delta_o > P$, it becomes energetically favourable for the fourth and fifth electron to occupy in t_{2g} orbital with the resultant configuration $t_{2g}^5\, e_g^0$. Such an effect is produced by strong field ligand and such a complex formed is referred to as low spin complex.

(iii) Homoleptic complexes : Complexes in which a metal is bond to only one kind of ligand are called homoleptic complexes.

e.g., $[Co(NH_3)_6]^{3+}$, $[Cu(CN)_6]^{3-}$, $[Ti(H_2O)_6]^{3+}$

83. (i) The complexes formed by chelating ligand are more stable than that formed by unidentate ligand because of multiple points of attachment of the ligand with the central atom/ion and formation of stable cyclic closed ring structures.

(ii) A spectrochemical series is an experimentally determined series based on the absorption of light by complexes with different ligands. It contains an arrangement of ligands in increasing order of their field strength. The series can be listed as :

$I^- < Br^- < SCN^- < Cl^- < S^{2-} < F^- < OH^- < C_2O_4^{2-} < H_2O < NCS^- < edta^{4-} < NH_3 < en < CN^- < CO$

A strong field ligand produces a stronger field and causes greater splitting of the *d*-orbitals. In this case, pairing of electrons occurs. For example : CO, CN^-, etc. On the other hand, a weak field ligand produces a weak field and causes lesser splitting of *d*-orbitals. In such case, pairing of electrons does not occur. For example : Cl^-, Br^-, I^-, etc.

84. (a) $K_4[Mn(CN)_6]$

Potassium Hexacyanomanganate(II)

In $K_4[Mn(CN)_6]$, Mn is present in +2 oxidation state.

Mn^{2+} : d^5 configuration

In presence of strong ligand, $\Delta_o < P$

Hence : $t_{2g}^5\, e_g^0$

(b) A ligand which forms two or more bonds with central atom or ion and results in the formation of stable cyclic complex is called chelating ligand and the effect is called chelating effect. For example, oxalate, ethylene diamine, dimethyl glyoxime, etc.

85. (a) Ambidentate ligand : Ligands having two different atoms through which it can act as a ligand

For example,

CN^- CN^- : $\leftarrow {}^{-}C\equiv N$ or $\ddot{C}\equiv\dot{N}:\rightarrow$

Cyanido-C Cyanido-N

(b) A spectrochemical series is an experimentally determined series based on the absorption of light by complexes with different ligands. It contains an arrangement of ligands in increasing order of their field strength. The series can be listed as :

$I^- < Br^- < SCN^- < Cl^- < S^{2-} < F^- < OH^- < C_2O_4^{2-} < H_2O < NCS^- < edta^{4-} < NH_3 < en < CN^- < CO$

(c) Heteroleptic complexes : Complexes in which the central atom is bound to different type of ligands are called *heteroleptic complexes.*

e.g., $[Co(NH_3)_4Cl_2]$, $K_2[Fe(CN)_5NO]$, $[Fe(H_2O)_5NO]SO_4$

86. In CO, both lone pair of electrons and vacant π^* orbitals are present. Hence, it acts as electron pair σ donor as well as π acceptor by back bonding. Hence, M—CO bond is stronger.

$$M \overset{\pi}{\underset{\sigma}{\rightleftarrows}} CO$$

NH_3 is electron pair donor only. Accumulation of negative charge on the metal ion takes place, hence $M—NH_3$ bond is weaker.

$M \leftarrow NH_3$

87. (c) : Hardness of water is estimated by titration with EDTA. EDTA is a hexadentate ligand.

CBSE Sample Questions

1. (c) : 1 mole of Mohr's salt gives 1 Fe^{2+}, $2SO_4^{2-}$ and $2NH_4^+$ ions on dissolving in water. The total number of ions is 5. (1)

2. (a) : Ambidentate ligands such as NO_2^-, SCN^- are unidentate ligands. (1)

3. (a) : Tetraammineaquachloridocobalt(III) chloride : $[Co(NH_3)_4(H_2O)Cl]Cl_2$ (1)

4. $[Co(NH_3)_5CO_3]Cl$ and $[Co(NH_3)_5Cl]CO_3$

Pentaamminecarbonatocobalt(III) chloride

Pentaamminechloridocobalt(III) carbonate (2)

5. (b) : Using equation, $\Delta_t = \frac{4}{9}\Delta_o$

$\Delta_t = (4/9) \times 18000\ cm^{-1} = 8000\ cm^{-1}$ (1)

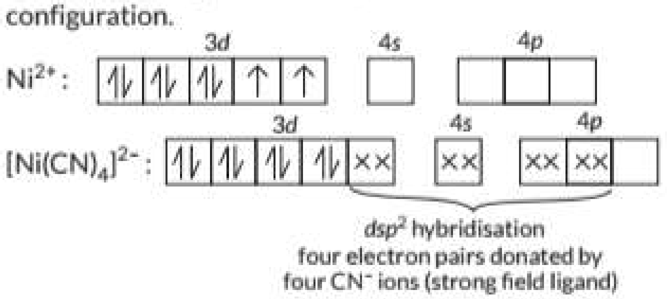
6. (i) Electronic configuration : $t_{2g}^4 e_g^2$ (1/2)

This complex is paramagnetic due to the presence of four unpaired electrons. (1/2)

(ii) Dichloridobis(ethane-1,2-diamine)cobalt(III) nitrate (1)

OR

(i) In $[Ni(CN)_4]^{2-}$: Ni is present as Ni(II) with $3d^8$ configuration.



∴ The complex ion has a square planar geometry. (1)

(ii) $Cu(Z = 29) : [Ar]\ 3d^{10}4s^1$

$Cu^{2+} : 3d^9$

Number of unpaired electron = 1

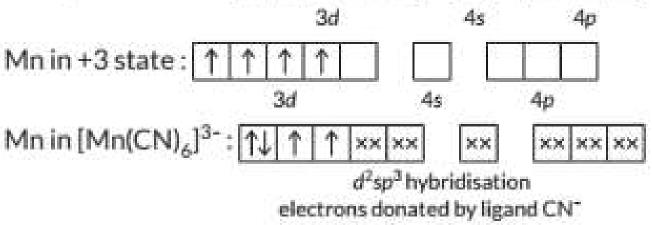
Magnetic moment, $\mu_B = \sqrt{n(n+2)}$

$= \sqrt{1(1+2)} = 1.73$ B.M. (1)

7. $[Mn(CN)_6]^{3-}$

Mn : $[Ar]\ 3d^5 4s^2$

$Mn^{3+} : [Ar]\ 3d^4$



(a) Type of hybridisation – d^2sp^3 (1)

(b) Magnetic moment value =

$\sqrt{n(n+2)} = \sqrt{(2(2+2))} = 2.83$ B.M.

(n = no. of unpaired electrons) (1)

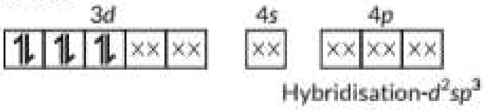
(c) Type of complex – inner orbital complex. (1)

8. (a) The colour of coordination compounds depends upon the type of ligands and *d-d* transition taking place. H_2O is weak field ligand, which causes small splitting, leading to the *d-d* transition corresponding green colour, however due to the presence of ethane-1,2-diamine (*en*) which is a strong field ligand, the splitting is increased. Due to the change in $t_{2g} - e_g$ splitting the colouration of the compound changes from green to blue. (1)

(b) Formula of the compound is $[Co(H_2NCH_2CH_2NH_2)_3]_2(SO_4)_3$. (1)

The hybridisation of the compound is d^2sp^3.

Cobalt in this complex has an oxidation number of +3. The electronic configuration of $Co^{3+} : 3d^6\ 4s^0$ and *en* is a strong field ligand that will cause pairing of electrons in *d*-orbital of Co^{3+}.

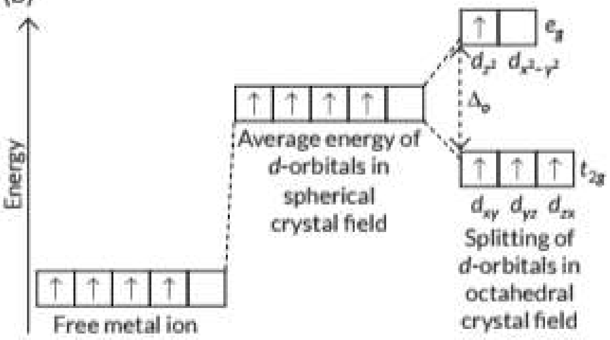


(1)

OR

(a) As the fourth electron enters one of the e_g orbitals giving the configuration $t_{2g}^3 e_g^1$, *i.e.*, no pairing of electrons which indicates $\Delta_o < P$ hence, it is a high spin complex. (1)

(b)



(2)