CHAPTER
9

Coordination Compounds

9.1 Werner's Theory of Coordination Compounds

1. The correct order of the stoichiometries of AgCl formed when $AgNO_3$ in excess is treated with the complexes : $CoCl_3.6NH_3$, $CoCl_3.5NH_3$, $CoCl_3.4NH_3$ respectively is
(a) 3AgCl, 1AgCl, 2AgCl
(b) 3AgCl, 2AgCl, 1AgCl
(c) 2AgCl, 3AgCl, 2AgCl
(d) 1AgCl, 3AgCl, 2AgCl *(NEET 2017)*

2. Cobalt(III) chloride forms several octahedral complexes with ammonia. Which of the following will not give test for chloride ions with silver nitrate at 25°C?
(a) $CoCl_3 \cdot 5NH_3$ (b) $CoCl_3 \cdot 6NH_3$
(c) $CoCl_3 \cdot 3NH_3$ (d) $CoCl_3 \cdot 4NH_3$
(2015, Cancelled)

3. An excess of $AgNO_3$ is added to 100 mL of a 0.01 M solution of dichlorotetraaquachromium(III) chloride. The number of moles of AgCl precipitated would be
(a) 0.003 (b) 0.01
(c) 0.001 (d) 0.002 *(NEET 2013)*

4. Which of the following will exhibit maximum ionic conductivity?
(a) $K_4[Fe(CN)_6]$ (b) $[Co(NH_3)_6]Cl_3$
(c) $[Cu(NH_3)_4]Cl_2$ (d) $[Ni(CO)_4]$ *(2001)*

5. A coordination complex compound of cobalt has the molecular formula containing five ammonia molecules, one nitro group and two chlorine atoms for one cobalt atom. One mole of this compound produces three mole ions in an aqueous solution. On reacting this solution with excess of $AgNO_3$ solution, we get two moles of AgCl precipitate. The ionic formula for this complex would be
(a) $[Co(NH_3)_5(NO_2)]Cl_2$
(b) $[Co(NH_3)_5Cl][Cl(NO_2)]$
(c) $[Co(NH_3)_4(NO_2)Cl][(NH_3)Cl]$
(d) $(Co(NH_3)_5][(NO_2)_2Cl_2]$ *(1998)*

9.2 Definitions of Some Important Terms Pertaining to Coordination Compounds

6. The correct increasing order of *trans*-effect of the following species is
(a) $NH_3 > CN^- > Br^- > C_6H_5^-$
(b) $CN^- > C_6H_5^- > Br^- > NH_3$
(c) $Br^- > CN^- > NH_3 > C_6H_5^-$
(d) $CN^- > Br^- > C_6H_5^- > NH_3$ *(NEET-II 2016)*

7. The sum of coordination number and oxidation number of the metal *M* in the complex $[M(en)_2(C_2O_4)]Cl$ (where *en* is ethylenediamine) is
(a) 6 (b) 7
(c) 8 (d) 9 *(2015)*

8. The anion of acetylacetone (*acac*) forms Co(*acac*)$_3$ chelate with Co^{3+}. The rings of the chelate are
(a) five membered (b) four membered
(c) six membered (d) three membered.
(Karnataka NEET 2013)

9. Which of the following statements is true?
(a) Silicon exhibits 4 coordination number in its compound.
(b) Bond energy of F_2 is less than Cl_2.
(c) Mn(III) oxidation state is more stable than Mn(II) in aqueous state.
(d) Elements of 15th gp shows only +3 and +5 oxidation states. *(2002)*

10. Coordination number of Ni in $[Ni(C_2O_4)_3]^{4-}$ is
(a) 3 (b) 6
(c) 4 (d) 2 *(2001)*

11. The coordination number and oxidation state of Cr in $K_3[Cr(C_2O_4)_3]$ are respectively
(a) 3 and + 3 (b) 3 and 0
(c) 6 and + 3 (d) 4 and + 2 *(1995)*

12. Which of the following ligands is expected to be bidentate?
(a) CH_3NH_2 (b) $CH_3C\equiv N$
(c) Br (d) $C_2O_4^{2-}$ *(1994)*

9.3 Nomenclature of Coordination Compounds

13. The name of complex ion, $[Fe(CN)_6]^{3-}$ is
(a) hexacyanitoferrate(III) ion
(b) tricyanoferrate(III) ion
(c) hexacyanidoferrate(III) ion
(d) hexacyanoiron(III) ion. *(2015)*

14. The correct IUPAC name for $[CrF_2(en)_2]Cl$ is
(a) chlorodifluoridoethylenediaminechromium (III) chloride
(b) difluoridobis(ethylene diamine)chromium (III) chloride
(c) difluorobis-(ethylene diamine)chromium (III) chloride
(d) chlorodifluoridobis(ethylene diamine) chromium (III). *(Karnataka NEET 2013)*

15. The hypothetical complex chlorodiaquatriammine cobalt(III) chloride can be represented as
(a) $[CoCl(NH_3)_3(H_2O)_2]Cl_2$
(b) $[Co(NH_3)_3(H_2O)Cl_3]$
(c) $[Co(NH_2)_3(H_2O)_2Cl]$
(d) $[Co(NH_3)_3(H_2O)_3]Cl_3$ *(2002)*

16. IUPAC name of $[Pt(NH_3)_3(Br)(NO_2)Cl]Cl$ is
(a) triamminebromochloronitroplatinum(IV) chloride
(b) triamminebromonitrochloroplatinum(IV) chloride
(c) triamminechlorobromonitroplatinum(IV) chloride
(d) triamminenitrochlorobromoplatinum(IV) chloride. *(1998)*

17. The formula of dichlorobis(urea)copper(II) is
(a) $[Cu\{O=C(NH_2)_2\}Cl]Cl$
(b) $[CuCl_2]\{O=C(NH_2)_2\}$
(c) $[Cu\{O=C(NH_2)_2\}Cl_2$
(d) $[CuCl_2\{O=C(NH_2)_2\}_2]$ *(1997)*

9.4 Isomerism in Coordination Compounds

18. The type of isomerism shown by the complex $[CoCl_2(en)_2]$ is
(a) geometrical isomerism
(b) coordination isomerism
(c) ionization isomerism
(d) linkage isomerism. *(NEET 2018)*

19. Number of possible isomers for the complex $[Co(en)_2Cl_2]Cl$ will be (en = ethylenediamine)
(a) 1 (b) 3
(c) 4 (d) 2 *(2015)*

20. The complexes $[Co(NH_3)_6][Cr(CN)_6]$ and $[Cr(NH_3)_6][Co(CN)_6]$ are the examples of which type of isomerism?
(a) Linkage isomerism
(b) Ionization isomerism
(c) Coordination isomerism
(d) Geometrical isomerism *(2011)*

21. The complex, $[Pt(py)(NH_3)BrCl]$ will have how many geometrical isomers?
(a) 3 (b) 4
(c) 0 (d) 2 *(2011)*

22. The existence of two different coloured complexes with the composition of $[Co(NH_3)_4Cl_2]^+$ is due to
(a) linkage isomerism
(b) geometrical isomerism
(c) coordination isomerism
(d) ionization isomerism. *(2010)*

23. Which one of the following complexes is not expected to exhibit isomerism?
(a) $[Ni(NH_3)_4(H_2O)_2]^{2+}$ (b) $[Pt(NH_3)_2Cl_2]$
(c) $[Ni(NH_3)_2Cl_2]$ (d) $[Ni(en)_3]^{2+}$ *(2010)*

24. Which of the following does not show optical isomerism?
(a) $[Co(NH_3)_3Cl_3]^0$
(b) $[Co(en)Cl_2(NH_3)_2]^+$
(c) $[Co(en)_3]^{3+}$
(d) $[Co(en)_2Cl_2]^+$ (en = ethylenediamine) *(2009)*

25. Which of the following will give a pair of enantiomorphs?
(a) $[Cr(NH_3)_6][Co(CN)_6]$
(b) $[Co(en)_2Cl_2]Cl$
(c) $[Pt(NH_3)_4][PtCl_6]$
(d) $[Co(NH_3)_4Cl_2]NO_2$
(en = $NH_2CH_2CH_2NH_2$) *(2007)*

26. $[Co(NH_3)_4(NO_2)_2]Cl$ exhibits
(a) linkage isomerism, geometrical isomerism and optical isomerism
(b) linkage isomerism, ionization isomerism and optical isomerism
(c) linkage isomerism, ionization isomerism and geometrical isomerism
(d) ionization isomerism, geometrical isomerism and optical isomerism. *(2006)*

27. Which one of the following is expected to exhibit optical isomerism? (en = ethylenediamine)
(a) *cis*-$[Pt(NH_3)_2Cl_2]$
(b) *trans*-$[Pt(NH_3)_2Cl_2]$
(c) *cis*-$[Co(en)_2Cl_2]^+$
(d) *trans*-$[Co(en)_2Cl_2]^+$ *(2005)*

28. Which of the following coordination compounds would exhibit optical isomerism?
(a) Pentaamminenitrocobalt(III) iodide
(b) Diamminedichloroplatinum(II)
(c) *trans*-Dicyanobis(ethylenediamine) chromium(III) chloride
(d) *tris*-(Ethylenediamine)cobalt(III) bromide
(2004)

29. Which of the following will give maximum number of isomers?
(a) $[Co(NH_3)_4Cl_2]$ (b) $[Ni(en)(NH_3)_4]^{2+}$
(c) $[Ni(C_2O_4)(en)_2]^{2-}$ (d) $[Cr(SCN)_2(NH_3)_4]^+$
(2001)

30. Which complex compound will give four isomers?
(a) $[Fe(en)_3]Cl_3$
(b) $[Co(en)_2Cl_2]Cl$
(c) $[Fe(PPh_3)_3NH_3ClBr]Cl$
(d) $[Co(PPh_3)_3Cl]Cl_3$ *(2000)*

31. The total number of possible isomers for the complex compound $[Cu^{II}(NH_3)_4][Pt^{II}Cl_4]$ are
(a) 5 (b) 6
(c) 3 (d) 4 *(1998)*

32. The number of geometrical isomers of the complex $[Co(NO_2)_3(NH_3)_3]$ is
(a) 4 (b) 0
(c) 2 (d) 3 *(1997)*

33. The number of geometrical isomers for $[Pt(NH_3)_2Cl_2]$ is
(a) 3 (b) 4
(c) 1 (d) 2 *(1995)*

9.5 Bonding in Coordination Compounds

34. Which of the following is the correct order of increasing field strength of ligands to form coordination compounds?
(a) $SCN^- < F^- < C_2O_4^{2-} < CN^-$
(a) $SCN^- < F^- < CN^- < C_2O_4^{2-}$
(b) $F^- < SCN^- < C_2O_4^{2-} < CN^-$
(c) $CN^- < C_2O_4^{2-} < SCN^- < F^-$ *(NEET 2020)*

35. What is the correct electronic configuration of the central atom in $K_4[Fe(CN)_6]$ based on crystal field theory?
(a) $e^4 t_2^2$ (b) $t_{2g}^4 e_g^2$
(c) $t_{2g}^6 e_g^0$ (d) $e^3 t_2^3$ *(NEET 2019)*

36. Aluminium chloride in acidified aqueous solution forms a complex '*A*', in which hybridisation state of Al is '*B*'. What are '*A*' and '*B*', respectively?
(a) $[Al(H_2O)_6]^{3+}$, sp^3d^2
(b) $[Al(H_2O)_4]^{3+}$, sp^3
(c) $[Al(H_2O)_4]^{3+}$, dsp^2
(d) $[Al(H_2O)_6]^{3+}$, d^2sp^3 *(Odisha NEET 2019)*

37. The crystal field stabilisation energy (CFSE) for $[CoCl_6]^{4-}$ is 18000 cm^{-1}. The CFSE for $[CoCl_4]^{2-}$ will be
(a) 6000 cm^{-1} (b) 16000 cm^{-1}
(c) 18000 cm^{-1} (d) 8000 cm^{-1}
(Odisha NEET 2019)

38. The geometry and magnetic behaviour of the complex $[Ni(CO)_4]$ are
(a) square planar geometry and diamagnetic
(b) tetrahedral geometry and diamagnetic
(c) square planar geometry and paramagnetic
(d) tetrahedral geometry and paramagnetic.
(NEET 2018)

39. Correct increasing order for the wavelengths of absorption in the visible region for the complexes of Co^{3+} is
(a) $[Co(H_2O)_6]^{3+}$, $[Co(en)_3]^{3+}$, $[Co(NH_3)_6]^{3+}$
(b) $[Co(H_2O)_6]^{3+}$, $[Co(NH_3)_6]^{3+}$, $[Co(en)_3]^{3+}$
(c) $[Co(NH_3)_6]^{3+}$, $[Co(en)_3]^{3+}$, $[Co(H_2O)_6]^{3+}$
(d) $[Co(en)_3]^{3+}$, $[Co(NH_3)_6]^{3+}$, $[Co(H_2O)_6]^{3+}$
(NEET 2017)

40. Pick out the correct statement with respect to $[Mn(CN)_6]^{3-}$.
(a) It is sp^3d^2 hybridised and tetrahedral.
(b) It is d^2sp^3 hybridised and octahedral.
(c) It is dsp^2 hybridised and square planar.
(d) It is sp^3d^2 hybridised and octahedral.
(NEET 2017)

41. Jahn–Teller effect is not observed in high spin complexes of
(a) d^7 (b) d^8
(c) d^4 (d) d^9 *(NEET-II 2016)*

42. The hybridization involved in complex $[Ni(CN)_4]^{2-}$ is (At. No. Ni = 28)
(a) sp^3 (b) d^2sp^2
(c) d^2sp^3 (d) dsp^2 *(2015)*

43. Among the following complexes the one which shows zero crystal field stabilization energy (CFSE) is
(a) $[Mn(H_2O)_6]^{3+}$ (b) $[Fe(H_2O)_6]^{3+}$
(c) $[Co(H_2O)_6]^{2+}$ (d) $[Co(H_2O)_6]^{3+}$ *(2014)*

44. A magnetic moment at 1.73 BM will be shown by one among of the following
(a) $TiCl_4$ (b) $[CoCl_6]^{4-}$
(c) $[Cu(NH_3)_4]^{2+}$ (d) $[Ni(CN)_4]^{2-}$
(NEET 2013)

45. Crystal field splitting energy for high spin d^4 octahedral complex is

(a) $-1.2\ \Delta_o$ (b) $-0.6\ \Delta_o$

(c) $-0.8\ \Delta_o$ (d) $-1.6\ \Delta_o$

(Karnataka NEET 2013)

46. Which among the following is a paramagnetic complex?

(a) $[Co(NH_3)_6]^{3+}$ (b) $[Pt(en)Cl_2]$

(c) $[CoBr_4]^{2-}$ (d) $Mo(CO)_6$

(At. No. Mo = 42, Pt = 78)

(Karnataka NEET 2013)

47. Which is diamagnetic?

(a) $[CoF_6]^{3-}$ (b) $[Ni(CN)_4]^{2-}$

(c) $[NiCl_4]^{2-}$ (d) $[Fe(CN)_6]^{3-}$

(Karnataka NEET 2013)

48. Which one of the following is an outer orbital complex and exhibits paramagnetic behaviour?

(a) $[Ni(NH_3)_6]^{2+}$ (b) $[Zn(NH_3)_6]^{2+}$

(c) $[Cr(NH_3)_6]^{3+}$ (d) $[Co(NH_3)_6]^{3+}$ *(2012)*

49. Low spin complex of d^6-cation in an octahedral field will have the following energy

(a) $\frac{-12}{5}\Delta_o + P$ (b) $\frac{-12}{5}\Delta_o + 3P$

(c) $\frac{-2}{5}\Delta_o + 2P$ (d) $\frac{-2}{5}\Delta_o + P$

(Δ_o = crystal field splitting energy in an octahedral field, P = Electron pairing energy) *(2012)*

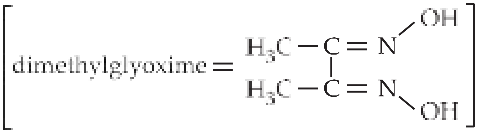
50. Red precipitate is obtained when ethanol solution of dimethylglyoxime is added to ammoniacal Ni(II). Which of the following statements is not true?

(a) Red complex has a square planar geometry.

(b) Complex has symmetrical H-bonding.

(c) Red complex has a tetrahedral geometry.

(d) Dimethylglyoxime functions as bidentate ligand.



(Mains 2012)

51. Of the following complex ions, which is diamagnetic in nature?

(a) $[NiCl_4]^{2-}$ (b) $[Ni(CN)_4]^{2-}$

(c) $[CuCl_4]^{2-}$ (d) $[CoF_6]^{3-}$ *(2011)*

52. The d-electron configurations of Cr^{2+}, Mn^{2+}, Fe^{2+} and Co^{2+} are d^4, d^5, d^6 and d^7 respectively. Which one of the following will exhibit minimum paramagnetic behaviour?

(a) $[Mn(H_2O)_6]^{2+}$ (b) $[Fe(H_2O)_6]^{2+}$

(c) $[Co(H_2O)_6]^{2+}$ (d) $[Cr(H_2O)_6]^{2+}$

(At. nos. Cr = 24, Mn = 25, Fe = 26, Co = 27) *(2011)*

53. Which of the following complex compounds will exhibit highest paramagnetic behaviour?

(a) $[Ti(NH_3)_6]^{3+}$ (b) $[Cr(NH_3)_6]^{3+}$

(c) $[Co(NH_3)_6]^{3+}$ (d) $[Zn(NH_3)_6]^{2+}$

(At. No. Ti = 22, Cr = 24, Co = 27, Zn = 30) *(2011)*

54. Which of the following complex ions is not expected to absorb visible light?

(a) $[Ni(CN)_4]^{2-}$ (b) $[Cr(NH_3)_6]^{3+}$

(c) $[Fe(H_2O)_6]^{2+}$ (d) $[Ni(H_2O)_6]^{2+}$ *(2010)*

55. Crystal field stabilization energy for high spin d^4 octahedral complex is

(a) $-1.8\ \Delta_o$ (b) $-1.6\ \Delta_o + P$

(c) $-1.2\ \Delta_o$ (d) $-0.6\ \Delta_o$ *(2010)*

56. Out of TiF_6^{2-}, CoF_6^{3-}, Cu_2Cl_2 and $NiCl_4^{2-}$ (Z of Ti = 22, Co = 27, Cu = 29, Ni = 28) the colourless species are

(a) Cu_2Cl_2 and $NiCl_4^{2-}$ (b) TiF_6^{2-} and Cu_2Cl_2

(c) CoF_6^{3-} and $NiCl_4^{2-}$ (d) TiF_6^{2-} and CoF_6^{3-}.

(2009)

57. Which of the following complex ions is expected to absorb visible light?

(a) $[Ti(en)_2(NH_3)_2]^{4+}$ (b) $[Cr(NH_3)_6]^{3+}$

(c) $[Zn(NH_3)_6]^{2+}$ (d) $[Sc(H_2O)_3(NH_3)_3]^{3+}$

[At. nos. Zn = 30, Sc = 21, Ti = 22, Cr = 24] *(2009)*

58. Which of the following complexes exhibits the highest paramagnetic behaviour?

(a) $[Co(ox)_2(OH)_2]^-$ (b) $[Ti(NH_3)_6]^{3+}$

(c) $[V(gly)_2(OH)_2(NH_3)_2]^+$

(d) $[Fe(en)(bpy)(NH_3)_2]^{2+}$

where *gly* = glycine, *en* = ethylenediamine and *bpy* = bipyridyl moities. (At. nos. Ti = 22, V = 23, Fe = 26, Co = 27) *(2008)*

59. In which of the following coordination entities the magnitude of Δ_o (CFSE in octahedral field) will be maximum?

(a) $[Co(CN)_6]^{3-}$ (b) $[Co(C_2O_4)_3]^{3-}$

(c) $[Co(H_2O)_6]^{3+}$ (d) $[Co(NH_3)_6]^{3+}$

(At. No. Co = 27) *(2008)*

60. The d electron configurations of Cr^{2+}, Mn^{2+}, Fe^{2+} and Ni^{2+} are $3d^4$, $3d^5$, $3d^6$ and $3d^8$ respectively. Which one of the following aqua complexes will exhibit the minimum paramagnetic behaviour?

(a) $[Fe(H_2O)_6]^{2+}$ (b) $[Ni(H_2O)_6]^{2+}$

(c) $[Cr(H_2O)_6]^{2+}$ (d) $[Mn(H_2O)_6]^{2+}$.

(At. No. Cr = 24, Mn = 25, Fe = 26, Ni = 28)

(2007)

61. $[Cr(H_2O)_6]Cl_3$ (At. no. of Cr = 24) has a magnetic moment of 3.83 B.M. The correct distribution of 3*d* electrons in the chromium of the complex is

(a) $3d^1_{xy}, 3d^1_{yz}, 3d^1_{z^2}$

(b) $3d^1_{(x^2-y^2)}, 3d^1_{z^2}, 3d^1_{xz}$

(c) $3d^1_{xy}, 3d^1_{(x^2-y^2)}, 3d^1_{yz}$

(d) $3d^1_{xy}, 3d^1_{yz}, 3d^1_{xz}$ *(2006)*

62. Which one of the following is an inner orbital complex as well as diamagnetic in behaviour?

(a) $[Zn(NH_3)_6]^{2+}$ (b) $[Cr(NH_3)_6]^{3+}$

(c) $[Co(NH_3)_6]^{3+}$ (d) $[Ni(NH_3)_6]^{2+}$

(Atomic number : Zn = 30, Cr = 24, Co = 27, Ni = 28) *(2005)*

63. Among $[Ni(CO)_4]$, $[Ni(CN)_4]^{2-}$, $[NiCl_4]^{2-}$ species, the hybridisation states at the Ni atom are, respectively

(a) sp^3, dsp^2, dsp^2 (b) sp^3, dsp^2, sp^3

(c) sp^3, sp^3, dsp^2 (d) dsp^2, sp^3, sp^3.

[Atomic number of Ni = 28] *(2004)*

64. CN^- is a strong field ligand. This is due to the fact that

(a) it carries negative charge

(b) it is a pseudohalide

(c) it can accept electrons from metal species

(d) it forms high spin complexes with metal species. *(2004)*

65. Considering H_2O as a weak field ligand, the number of unpaired electrons in $[Mn(H_2O)_6]^{2+}$ will be (atomic number of Mn = 25)

(a) three (b) five

(c) two (d) four. *(2004)*

66. In an octahedral structure, the pair of *d* orbitals involved in d^2sp^3 hybridisation is

(a) $d_{x^2-y^2}, d_{z^2}$ (b) $d_{xz}, d_{x^2-y^2}$

(c) d_{z^2}, d_{xz} (d) d_{xy}, d_{yz}. *(2004)*

67. The number of unpaired electrons in the complex ion $[CoF_6]^{3-}$ is

(a) 2 (b) 3

(c) 4 (d) zero

(Atomic no. : Co = 27) *(2003)*

68. Atomic number of Cr and Fe are respectively 24 and 26, which of the following is paramagnetic with the spin of electron?

(a) $[Cr(CO)_6]$ (b) $[Fe(CO)_5]$

(c) $[Fe(CN)_6]^{4-}$ (d) $[Cr(NH_3)_6]^{3+}$ *(2002)*

69. Which statement is incorrect?

(a) $Ni(CO)_4$ - tetrahedral, paramagnetic

(b) $[Ni(CN)_4]^{2-}$ - square planar, diamagnetic

(c) $Ni(CO)_4$ - tetrahedral, diamagnetic

(d) $[NiCl_4]^{2-}$ - tetrahedral, paramagnetic *(2001)*

9.6 Bonding in Metal Carbonyls

70. Iron carbonyl, $Fe(CO)_5$ is

(a) tetranuclear (b) mononuclear

(c) trinuclear (d) dinuclear.

(NEET 2018)

71. An example of a sigma bonded organometallic compound is

(a) Grignard's reagent (b) ferrocene

(c) cobaltocene (d) ruthenocene.

(NEET 2017)

72. Which of the following has longest C—O bond length? (Free C—O bond length in CO is 1.128 Å.)

(a) $[Fe(CO)_4]^{2-}$ (b) $[Mn(CO)_6]^+$

(c) $Ni(CO)_4$ (d) $[Co(CO)_4]^-$

(NEET-I 2016)

73. Which of the following carbonyls will have the strongest C – O bond?

(a) $Mn(CO)_6^+$ (b) $Cr(CO)_6$

(c) $V(CO)_6^-$ (d) $Fe(CO)_5$ *(2011)*

74. Which of the following does not have a metal - carbon bond?

(a) $Al(OC_2H_5)_3$ (b) C_2H_5MgBr

(c) $K[Pt(C_2H_4)Cl_3]$ (d) $Ni(CO)_4$ *(2004)*

75. Among the following which is not the π-bonded organometallic compound?

(a) $K[PtCl_3(\eta^2 - C_2H_4)]$

(b) $Fe(\eta^5 - C_5H_5)_2$

(c) $Cr(\eta^6 - C_6H_6)_2$

(d) $(CH_3)_4Sn$ *(2003)*

76. Which of the following organometallic compounds is σ and π-bonded?

(a) $[Fe(\eta^5 - C_5H_5)_2]$

(b) $K[PtCl_3(\eta^2 - C_2H_4)]$

(c) $[Co(CO)_5NH_3]^{2+}$

(d) $Fe(CH_3)_3$ *(2001)*

77. Shape of $Fe(CO)_5$ is

(a) octahedral (b) square planar

(c) trigonal bipyramidal (d) square pyramidal.

(2000)

78. In metal carbonyl having general formula $M(CO)_x$ where M = metal, x = 4 and the metal is bonded to

(a) carbon and oxygen (b) C O═

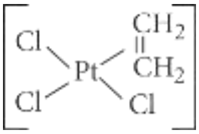
(c) oxygen (d) carbon. *(1995)*

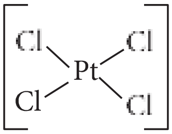
9.7 Importance and Applications of Coordination Compounds

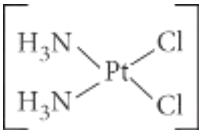
79. Which of the following complexes is used to be as an anticancer agent?
(a) *mer*-$[Co(NH_3)_3Cl_3]$ (b) *cis*-$[PtCl_2(NH_3)_2]$
(c) *cis*-$K_2[PtCl_2Br_2]$ (d) Na_2CoCl_4 *(2014)*

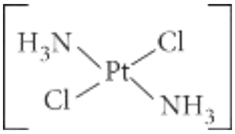
80. Copper sulphate dissolves in excess of KCN to give
(a) $Cu(CN)_2$ (b) CuCN
(c) $[Cu(CN)_4]^{3-}$ (d) $[Cu(CN)_4]^{2-}$ *(2006)*

81. Which of the following is considered to be an anticancer species?

(a)


(b)


(c)


(d)


(2004)

82. In the silver plating of copper, $K[Ag(CN)_2]$ is used instead of $AgNO_3$. The reason is
(a) a thin layer of Ag is formed on Cu
(b) more voltage is required
(c) Ag^+ ions are completely removed from solution
(d) less availability of Ag^+ ions, as Cu cannot displace Ag from $[Ag(CN)_2]^-$ ion. *(2002)*

83. $CuSO_4$ when reacts with KCN forms CuCN, which is insoluble in water. It is soluble in excess of KCN, due to formation of the following complex
(a) $K_2[Cu(CN)_4]$
(b) $K_3[Cu(CN)_4]$
(c) $CuCN_2$
(d) $Cu[KCu(CN)_4]$ *(2002)*

84. Hypo is used in photography to
(a) reduce AgBr grains to metallic silver
(b) convert metallic silver to silver salt
(c) remove undecomposed silver bromide as a soluble complex
(d) remove reduced silver. *(1988)*

ANSWER KEY

1.	(b)	**2.**	(c)	**3.**	(c)	**4.**	(a)	**5.**	(a)	**6.**	(b)	**7.**	(d)	**8.**	(c)	**9.**	(b)	**10.**	(b)
11.	(c)	**12.**	(d)	**13.**	(c)	**14.**	(b)	**15.**	(a)	**16.**	(a)	**17.**	(d)	**18.**	(a)	**19.**	(b)	**20.**	(c)
21.	(a)	**22.**	(b)	**23.**	(c)	**24.**	(a)	**25.**	(b)	**26.**	(c)	**27.**	(c)	**28.**	(d)	**29.**	(d)	**30.**	(c)
31.	(d)	**32.**	(c)	**33.**	(d)	**34.**	(a)	**35.**	(c)	**36.**	(a)	**37.**	(d)	**38.**	(b)	**39.**	(d)	**40.**	(b)
41.	(b)	**42.**	(d)	**43.**	(b)	**44.**	(c)	**45.**	(b)	**46.**	(c)	**47.**	(b)	**48.**	(a)	**49.**	(b)	**50.**	(c)
51.	(b)	**52.**	(c)	**53.**	(b)	**54.**	(a)	**55.**	(d)	**56.**	(b)	**57.**	(b)	**58.**	(a)	**59.**	(a)	**60.**	(b)
61.	(d)	**62.**	(c)	**63.**	(b)	**64.**	(b)	**65.**	(b)	**66.**	(a)	**67.**	(c)	**68.**	(d)	**69.**	(a)	**70.**	(b)
71.	(a)	**72.**	(a)	**73.**	(a)	**74.**	(a)	**75.**	(d)	**76.**	(c)	**77.**	(c)	**78.**	(d)	**79.**	(b)	**80.**	(c)
81.	(c)	**82.**	(d)	**83.**	(b)	**84.**	(c)												

Hints & Explanations

1. (b) : $[Co(NH_3)_6]Cl_3 + 3AgNO_3 \rightarrow 3AgCl\downarrow + [Co(NH_3)_6](NO_3)_3$

$[Co(NH_3)_5Cl]Cl_2 + 2AgNO_3 \rightarrow 2AgCl\downarrow + [Co(NH_3)_5Cl](NO_3)_2$

$[Co(NH_3)_4Cl_2]Cl + AgNO_3 \rightarrow AgCl\downarrow + [Co(NH_3)_4Cl_2]NO_3$

2. (c) : For octahedral complexes, coordination number is 6. Hence, $CoCl_3 \cdot 3NH_3$ *i.e.*, $[Co(NH_3)_3Cl_3]$ will not ionise and will not give test for Cl^- ion with silver nitrate.

3. (c) : $[Cr(H_2O)_4Cl_2]Cl + AgNO_3 \rightarrow [Cr(H_2O)_4Cl_2]NO_3 + \underset{ppt.}{AgCl}$

No. of millimoles of solution = 100 mL × 0.01 M
= 1 millimole
= 10^{-3} mole

So, mole of AgCl = 0.001

4. (a) : Ionic conductance increases with increasing the number of ions, produced after decomposition.

Compound	No. of ions produced
$K_4[Fe(CN)_6]$	5
$[Co(NH_3)_6]Cl_3$	4
$[Cu(NH_3)_4]Cl_2$	3
$[Ni(CO)_4]$	0

5. (a) : As the complex gives two moles of AgCl ppt. with $AgNO_3$ solution, so the complex must have two ionisable Cl atoms. Hence, the probable complex, which gives three mole ions may be $[Co(NH_3)_5NO_2]Cl_2$.

$[Co(NH_3)_5NO_2]Cl_2 \rightarrow [Co(NH_3)_5NO_2]^{2+} + 2Cl^-$

one mole → 3 mole ions

6. (b) : The intensity of the *trans*-effect (as measured by the increase in rate of substitution of the *trans* ligand) follows the sequence : $CN^- > C_6H_5^- > Br^- > NH_3$

7. (d) : $[M(en)_2(C_2O_4)]Cl$:

Oxidation number of metal = +3

Coordination number of metal = 6

∴ Sum of oxidation number and coordination number $= 3 + 6 = 9$

8. (c) : The ligand acetylacetone forms six membered chelate ring in the complex $[Co(acac)_3]$.

9. (b) : Bond energy of F_2 is less than Cl_2 due to inter-electronic repulsions in small sized F-atoms.

Silicon exhibits coordination number 6.

In aqueous state, Mn(II) is more stable.

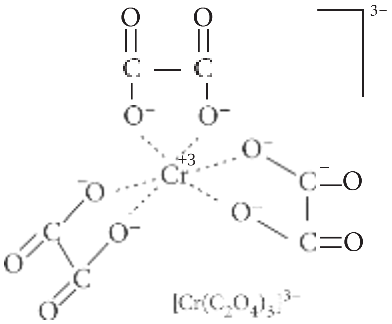
$$Mn\ Mn^{2+} + 2e^-$$

The common oxidation states of 15th group elements are –3, +3 and +5.

10. (b) : $C_2O_4^{2-} \rightarrow$ bidentate ligand.

3 molecules attached from two sides with Ni makes coordination number 6.

11. (c) :

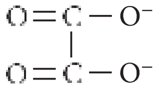


As the number of atoms of the ligands that are directly bound to the central metal is known as coordination number. It is six here (see in figure).

Oxidation state : Let oxidation state of Cr be x.

$\Rightarrow 3(+1) + x + 3(-2) = 0 \Rightarrow 3 + x - 6 = 0 \Rightarrow x = +3$

12. (d) : When a ligand has two groups that are capable of bonding to the central atom, it is said to be bidentate. Thus, the only ligand, which is expected to be bidentate is $C_2O_4^{2-}$ as



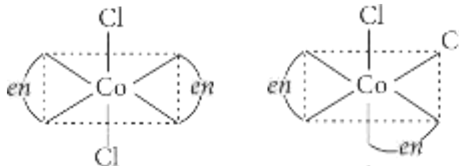
13. (c) **14. (b)**

15. (a) : Chlorodiaquatriamminecobalt(III) chloride can be represented as $[CoCl(NH_3)_3(H_2O)_2]Cl_2$.

16. (a) : The ligands are named in the alphabetic order according to latest IUPAC system. So, the name of $[Pt(NH_3)_3Br(NO_2)Cl]Cl$ is triamminebromochloronitro platinum(IV) chloride. (The oxidation no. of 'Pt' is +4).

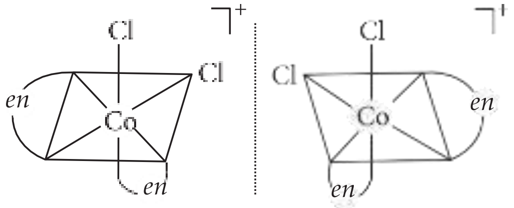
17. (d) : The formula of dichlorobis(urea)copper(II) is $[CuCl_2\{(NH_2)_2CO\}_2]$.

18. (a) : $[CoCl_2(en)_2]$, exhibits geometrical isomerism, as the coordination number of Co is 6 and this compound has octahedral geometry.

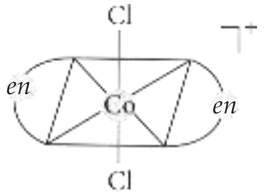


trans-form (optically inactive) *cis*-form (optically active)

19. (b) : Possible isomers of $[Co(en)_2Cl_2]Cl$:



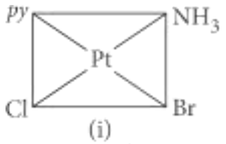
cis-isomer
(*d* and *l* forms)



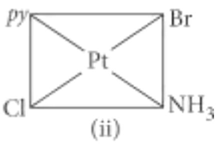
trans-isomer

20. (c) : Coordination isomerism arises from the interchange of ligands between cationic and anionic entities of different metal ions present in the complex. *e.g.*, $[Co(NH_3)_6][Cr(CN)_6]$ and $[Cr(NH_3)_6][Co(CN)_6]$

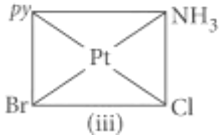
21. (a) : $[Pt(py)(NH_3)BrCl]$ can have three isomers.



(i)

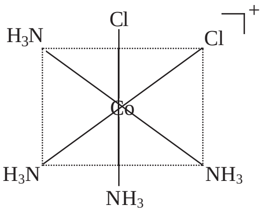


(ii)

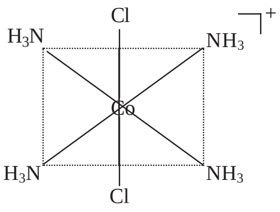


(iii)

22. (b) :



cis-form
(violet in colour)



trans-form
(green in colour)

23. (c) : Compounds having tetrahedral geometry does not exhibit isomerism due to presence of symmetry elements. Here, $[Ni(NH_3)_2Cl_2]$ has tetrahedral geometry.

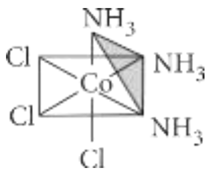
24. (a) : Optical isomerism is shown by :

(i) Complexes of the type $[M(AA)_2Y_2]$, containing one symmetrical bidentate ligand *i.e.*, $[Co(en)Cl_2(NH_3)_2]^+$.

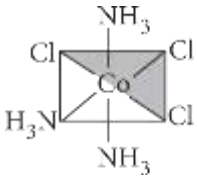
(ii) Complexes of the type $[M(AA)_3]$, containing a symmetrical bidentate ligand *i.e.*, $[Co(en)_3]^{3+}$.

(iii) Complexes of the type $[M(AA)_2X_2]$, *i.e.*, $[Co(en)_2Cl_2]^+$.
However complexes of the type $[MA_3B_3]$ show geometrical isomerism, known as *fac*-*mer* isomerism.

$\therefore$ $[Co(NH_3)_3Cl_3]$ exhibits *fac*-*mer* isomerism.

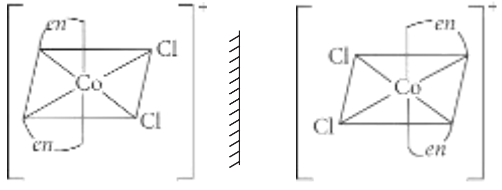


fac-isomer



mer-isomer

25. (b) : Either a pair of crystals, molecules or compounds that are mirror images of each other but are not identical, and that rotate the plane of polarised light equally, but in opposite directions are called as enantiomorphs.



cis-*d*-isomer *cis*-*l*-isomer

26. (c) : Ionization isomerism arises when the coordination compounds give different ions in solution.

$[Co(NH_3)_4(NO_2)_2]Cl \square [Co(NH_3)_4(NO_2)_2]^+ + Cl^-$

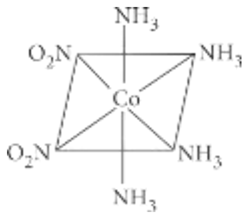
$[Co(NH_3)_4(NO_2)Cl]NO_2 \square [Co(NH_3)_4(NO_2)Cl]^+ + NO_2^-$

Linkage isomerism occurs in complex compounds which contain ambidentate ligands like NO_2^-, SCN^-, CN^-, $S_2O_3^{2-}$ and CO.

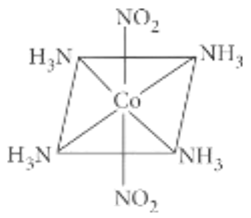
$[Co(NH_3)_4(NO_2)_2]Cl$ and $[Co(NH_3)_4(ONO)_2]Cl$

are linkage isomers as NO_2^- is linked through N or through O.

Octahedral complexes of the type Ma_4b_2 exhibit geometrical isomerism.



cis-form

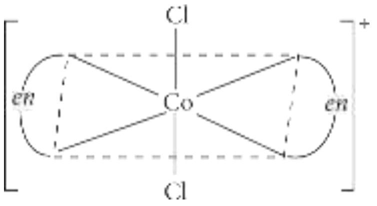


trans-form

27. (c) : Optical isomerism is not shown by square planar complexes.

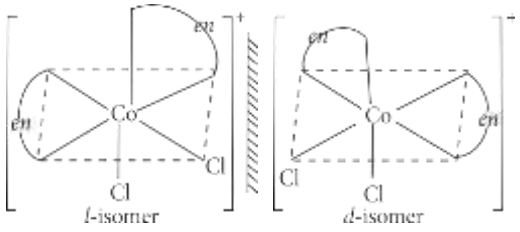
Octahedral complexes of general formulae, $[Ma_2b_2c_2]^{n\pm}$, $[Mabcdef]$, $[M(AA)_3]^{n\pm}$, $[M(AA)_2a_2]^{n\pm}$ (where AA = symmetrical bidentate ligand), $[M(AA)_2ab]^{n\pm}$ and $[M(AB)_3]^{n\pm}$

(where AB = unsymmetrical ligands) show optical isomerism.



trans-$[Co(en)_2Cl_2]^+$

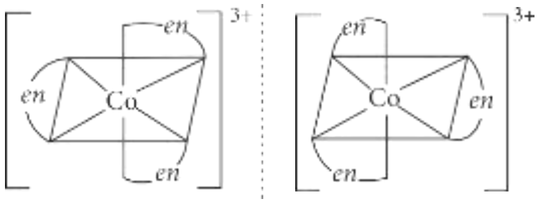
does not show optical isomerism (superimposable mirror image). But *cis*-form shows optical isomerism.



l-isomer *d*-isomer

cis-$[Co(en)_2Cl_2]^+$

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



d-form mirror *l*-form

29. (d) : $[Cr(SCN)_2(NH_3)_4]^+$ shows linkage, geometrical and optical isomerism.

30. (c) : $[Fe(PPh_3)_3NH_3ClBr]Cl$ can give two optical and two geometrical isomers. While other complexes do not form geometrical isomers.

31. (d) : The isomers of the complex compound $[Cu^{II}(NH_3)_4][Pt^{II}Cl_4]$ are :

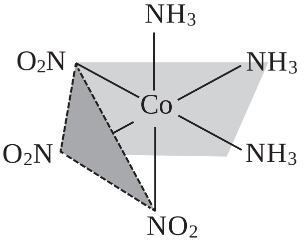
(i) $[Cu(NH_3)_3Cl]\ [Pt(NH_3)Cl_3]$

(ii) $[Pt(NH_3)_3Cl][Cu(NH_3)Cl_3]$

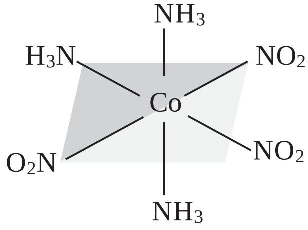
(iii) $[Pt(NH_3)_4][CuCl_4]$

So, the total no. of isomers are = 4

32. (c) : Possible geometrical isomers are :

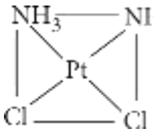


fac-



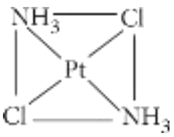
mer–

33. (d) :



cis-form

and



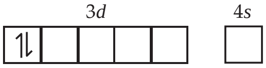
trans-form

34. (a) : According to spectrochemical series, order of increasing field strength is :

$SCN^- < F^- < C_2O_4^{2-} < CN^-$

35. (c) : In $K_4[Fe(CN)_6]$ complex, Fe is in +2 oxidation state.

Fe^{2+} :



As CN^- is a strong field ligand, it causes pairing of electrons therefore, electronic configuration of Fe^{2+} in $K_4[Fe(CN)_6]$ is $t_{2g}^6 e_g^0$.

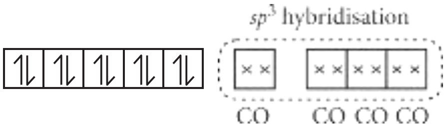
36. (a)

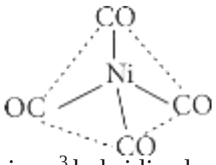
37. (d) : $\Delta_t = \frac{4}{9}\Delta_o = \frac{4}{9} \times 18000 = 8000\ \text{cm}^{-1}$

38. (b) : Ni(28) : $[Ar]3d^8 4s^2$

∵ CO is a strong field ligand, so, unpaired electrons get paired.

In $[Ni(CO)_4]$:





Thus, the complex is sp^3 hybridised with tetrahedral geometry and diamagnetic in nature.

39. (d) : Increasing order of crystal field splitting energy is : $H_2O < NH_3 < en$

Thus, increasing order of crystal field splitting energy for the given complexes is :

$[Co(H_2O)_6]^{3+} < [Co(NH_3)_6]^{3+} < [Co(en)_3]^{3+}$

As, $E = \frac{hc}{\lambda}$

Thus, increasing order of wavelength of absorption is :

$[Co(en)_3]^{3+} < [Co(NH_3)_6]^{3+} < [Co(H_2O)_6]^{3+}$

40. (b) : $[Mn(CN)_6]^{3-}$: Let oxidation state of Mn be x.

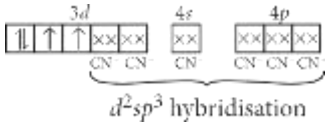
$x + 6 \times (-1) = -3 \Rightarrow x = +3$

Electronic configuration of Mn : $[Ar]4s^2 3d^5$

Electronic configuration of Mn^{3+} : $[Ar]3d^4$

CN^- is a strong field ligand thus, it causes pairing of electrons in $3d$-orbital.

$[Mn(CN)_6]^{3-}$: [Ar]

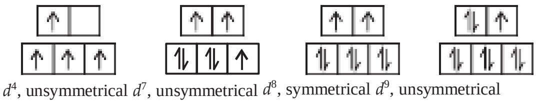


Thus, $[Mn(CN)_6]^{3-}$ has d^2sp^3 hybridisation and has octahedral geometry.

41. (b) : Jahn–Teller distortion is usually significant for asymmetrically occupied e_g orbitals since they are directed towards the ligands and the energy gain is considerably more.

In case of unevenly occupied t_{2g} orbitals, the Jahn–Teller distortion is very weak since the t_{2g} set does not point directly at the ligands and therefore, the energy gain is much less.

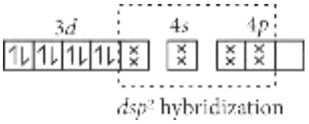
High spin complexes :



42. (d) : $[Ni(CN)_4]^{2-}$: Oxidation number of Ni = +2

Electronic configuration of Ni^{2+} : $3d^8 4s^0$

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



Pairing of electrons in d-orbital takes place due to the presence of strong field ligand (CN^-).

43. (b) : H_2O is a weak field ligand, hence Δ_o < pairing energy.

CFSE = $(-0.4x + 0.6y)\Delta_o$

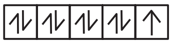
where, x and y are no. of electrons occupying t_{2g} and e_g orbitals respectively.

For $[Fe(H_2O)_6]^{3+}$ complex ion,

$Fe^{3+}(3d^5) = t_{2g}^3 e_g^2 = -0.4 \times 3 + 0.6 \times 2 = 0.0$ or $0\ \Delta_o$

44. (c) : Oxidation state of Cu in $[Cu(NH_3)_4]^{2+}$ is + 2

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



It has one unpaired electron (n = 1).

$\mu = \sqrt{n(n+2)} = \sqrt{1(1+2)} = \sqrt{3} = 1.73\ \text{BM}$

45. (b) : CFSE = $(-0.4\,x + 0.6\,y)\,\Delta_o$

where, x = No. of electrons occupying t_{2g} orbitals

y = no. of electrons occupying e_g orbitals

$= (-0.4 \times 3 + 0.6 \times 1)\Delta_o$ [∵ High spin $d^4 = t_{2g}^3 e_g^1$]

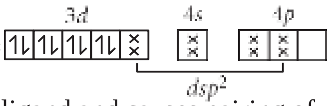
$= (-1.2 + 0.6)\Delta_o = -0.6\ \Delta_o$

46. (c) : Co^{2+} in $[CoBr_4]^{2-}$ has $3d^7 4s^0$ configuration and Br^- is a weak field ligand. Thus, it has 3 unpaired electrons and hence, paramagnetic.

47. (b) : In $[Ni(CN)_4]^{2-}$ all orbitals are doubly occupied, hence, it is diamagnetic.

$Ni^{2+} = 3d^8$

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



CN^- is a strong field ligand and causes pairing of $3d$-electrons of Ni^{2+}.

48. (a) : $[Ni(NH_3)_6]^{2+}$: sp^3d^2 (outer), octahedral, paramagnetic

$[Zn(NH_3)_6]^{2+}$: sp^3d^2 (outer), octahedral, diamagnetic

$[Cr(NH_3)_6]^{3+}$: d^2sp^3 (inner), octahedral, paramagnetic

$[Co(NH_3)_6]^{3+}$: d^2sp^3 (inner), octahedral, diamagnetic

49. (b) : CFSE = $(-0.4x + 0.6y)\Delta_o + zP$

where x = number of electrons occupying t_{2g} orbital

y = number of electrons occupying e_g orbital

z = number of pairs of electrons

For low spin d^6 complex electronic configuration

$= t_{2g}^6 e_g^0$ or $t_{2g}^{2,2,2} e_g^0$

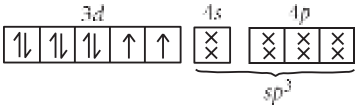
$\therefore \quad x = 6, y = 0, z = 3$

CFSE = $(-0.4 \times 6 + 0 \times 0.6)\Delta_o + 3P$

$$= \frac{-12}{5}\Delta_o + 3P$$

50. (c) : $[Ni(dmg)_2]$ is square planar in structure not tetrahedral.

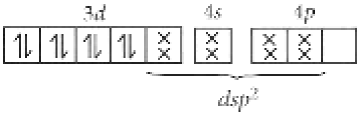
51. (b) : $[NiCl_4]^{2-}$:



Number of unpaired electrons = 2

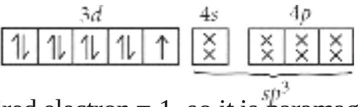
Hence, $[NiCl_4]^{2-}$ is paramagnetic.

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



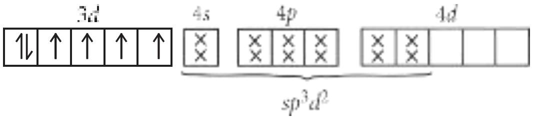
Number of unpaired electrons = 0, so it is diamagnetic in nature.

$[CuCl_4]^{2-}$:



No. of unpaired electron = 1, so it is paramagnetic.

$[CoF_6]^{3-}$:



No. of unpaired electrons = 4, so it is paramagnetic.

52. (c) : $[Mn(H_2O)_6]^{2+}$: $Mn^{2+} = 3d^5$

$\therefore$ Number of unpaired electrons = 5

$[Fe(H_2O)_6]^{2+}$: $Fe^{2+} = 3d^6$

$\therefore$ Number of unpaired electrons = 4

$[Co(H_2O)_6]^{2+}$: $Co^{2+} = 3d^7$

$\therefore$ Number of unpaired electrons = 3

$[Cr(H_2O)_6]^{2+}$: $Cr^{2+} = 3d^4$

$\therefore$ Number of unpaired electrons = 4

Minimum paramagnetic behaviour is shown by $[Co(H_2O)_6]^{2+}$.

53. (b) : Ti : [Ar] $3d^2 4s^2$, Ti^{3+} : [Ar] $3d^1 4s^0$

(1 unpaired electron)

Cr : [Ar] $3d^4 4s^2$, Cr^{3+} : [Ar] $3d^3 4s^0$

(3 unpaired electrons)

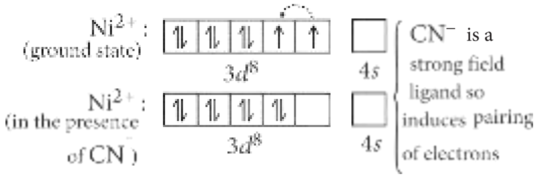
Co : [Ar] $3d^7 4s^2$, Co^{3+} : [Ar] $3d^6 4s^0$

Zn : [Ar] $3d^{10} 4s^2$, Zn^{2+} : [Ar] $3d^{10}$ (No unpaired electrons because of pairing)

(No unpaired electrons)

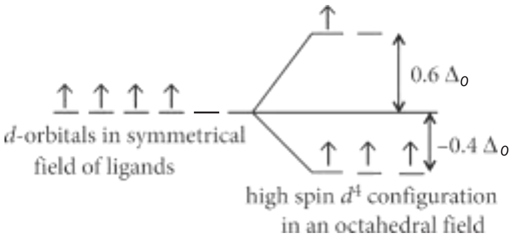
$[Cr(NH_3)_6]^{3+}$ exhibits highest paramagnetic behaviour as it contains 3 unpaired electrons.

54. (a) : A transition metal complex absorbs visible light only if it has unpaired electrons.



No unpaired electron so does not absorb visible light.

55. (d) :



CFSE = $3(-0.4)\Delta_o + 0.6\Delta_o = -1.2\Delta_o + 0.6\Delta_o = -0.6\Delta_o$

56. (b) : A species is coloured when it contains unpaired d-electrons which are capable of undergoing d-d transition on adsorption of light of a particular wavelength.

In TiF_6^{2-}, Ti^{4+} : $3d^0$, colourless

In CoF_6^{3-}, Co^{3+} : $3d^6$, coloured

In Cu_2Cl_2, Cu^+ : $3d^{10}$, colourless

In $NiCl_4^{2-}$, Ni^{2+} : $3d^8$, coloured

Thus, TiF_6^{2-} ($3d^0$) and Cu_2Cl_2 ($3d^{10}$) with empty and fully filled d-orbitals appear colourless as they are not capable of undergoing d-d transition.

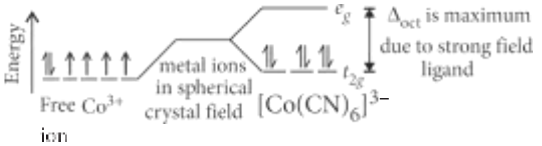
57. (b) : $Ti^{4+} \rightarrow 3d^0$, $Cr^{3+} \rightarrow 3d^3$

$Zn^{2+} \rightarrow 3d^{10}$, $Sc^{3+} \rightarrow 3d^0$

Transition metal ions containing completely filled d-orbitals or empty d-orbitals are colourless species. Thus, only $[Cr(NH_3)_6]^{3+}$ having unpaired electron absorb visible light and is coloured.

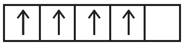
58. (a) : O.S. of Ti in the complex $[Ti(NH_3)_6]^{3+}$ is +3.
$Ti^{3+}: 1s^2 2s^2 2p^6 3s^2 3p^6 3d^1$
No. of unpaired electrons in *d* orbital is one.
Let O.S. of V in complex $[V(gly)_2(OH)_2(NH_3)_2]^+$ is *x*.
$x + 2 \times 0 + 2 \times (-1) + 2 \times 0 = +1$
$\therefore \quad x = +3$
$V^{3+}: 1s^2 2s^2 2p^6 3s^2 3p^6 3d^2$
No. of unpaired electrons in *d* orbital is two.
O.S. of Fe in complex $[Fe(en)(bpy)(NH_3)_2]^{2+}$ is +2.
$\therefore \quad Fe^{2+}: 1s^2 2s^2 2p^6 3s^2 3p^6 3d^6$
As all are strong ligands so, pairing of electrons takes place.
No. of unpaired electron in *d* orbital is zero.
Let O.S. of Co in the given complex $[Co(ox)_2(OH)_2]^-$ is *x*.
$x + 2 \times (-2) + 2 \times (-1) = -1 \Rightarrow x - 4 - 2 = -1$
$\therefore \quad x = +5$
$Co^{5+}: 1s^2 2s^2 2p^6 3s^2 3p^6 3d^4$
As *ox* and OH^- are weak field ligands so no pairing of electrons takes place, $t_{2g}^3 e_g^1$ so, it has 4 unpaired electrons and has highest paramagnetic behaviour.

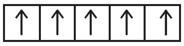
59. (a) : When the ligands are arranged in order of the magnitude of crystal field splitting, the arrangement, thus, obtained is called spectrochemical series.
Arranged in increasing field strength as
$I^- < Br^- < Cl^- < NO_3^- < F^- < OH^- < C_2O_4^{2-} < H_2O < NH_3 < en < NO_2^- < CN^- < CO$
It has been observed that ligands before H_2O are weak field ligands while ligands after H_2O are strong field ligands.

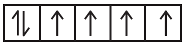


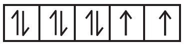
CFSE in octahedral field depends upon the nature of ligands. Stronger the ligands larger will be the value of Δ_{oct}.

60. (b) : 3*d*

$Cr^{2+} \Rightarrow$

4 unpaired electrons

$Mn^{2+} \Rightarrow$

5 unpaired electrons

$Fe^{2+} \Rightarrow$

4 unpaired electrons

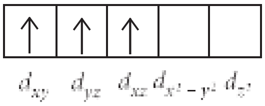
$Ni^{2+} \Rightarrow$

2 unpaired electrons

Greater the number of unpaired electrons, higher is the paramagnetism. Hence, $[Ni(H_2O)_6]^{2+}$ will exhibit the minimum paramagnetic behaviour.

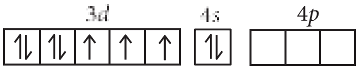
61. (d) : Magnetic moment = $\sqrt{n(n+2)}$

$3.83 = \sqrt{n(n+2)} \Rightarrow (3.83)^2 = n(n+2)$

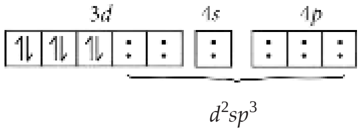
$\Rightarrow 14.6689 = n^2 + 2n$
On solving the equation, $n = 3$
$Cr^{3+}: [Ar]3d^3$



62. (c) : $[Co(NH_3)_6]^{3+}$; $Co(27): [Ar]^{18} 3d^7 4s^2$

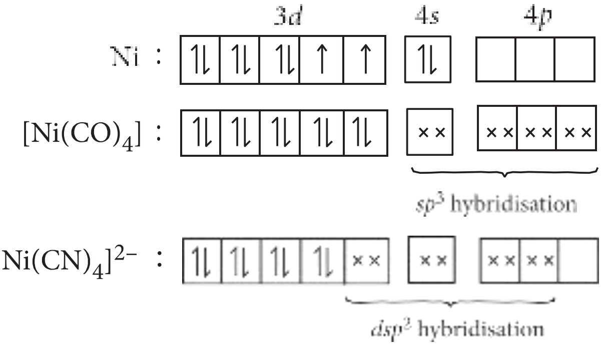


$Co^{3+}: [Ar]^{18} 3d^6$

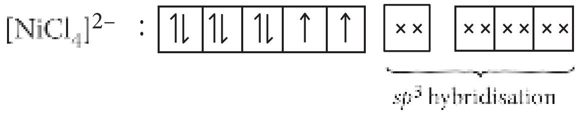


electron pair from six ligands(NH_3)
$d^2sp^3 \rightarrow$ inner octahedral complex and diamagnetic.
$[Zn(NH_3)_6]^{2+} \rightarrow sp^3d^2$(outer)and diamagnetic.
$[Cr(NH_3)_6]^{3+} \rightarrow d^2sp^3$(inner)and paramagnetic.
$[Ni(NH_3)_6]^{2+} \rightarrow sp^3d^2$(outer)and paramagnetic.

63. (b) :



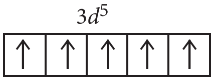
as CN^- is a strong field ligand.



as Cl^- is a weak field ligand.

64. (b) : Cyanide ion is strong field ligand because it is a pseudohalide ion. Pseudohalide ions are stronger coordinating ligands and they have the ability to form σ-bond (from the pseudohalide to the metal) and π bond (from the metal to pseudohalide).

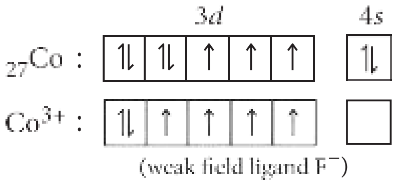
65. (b) : Mn (25) : $3d^5 4s^2$

$Mn^{2+}:$


In presence of weak field ligand, there will be no pairing of electrons. So, it will form a high spin complex, *i.e.*, the number of unpaired electrons =5.

66. (a) : In the formation of d^2sp^3 hybrid orbitals, two $(n-1)d$ orbitals of e_g set [*i.e.* $(n-1)d_z^2$ and $(n-1)d_{x^2-y^2}$ orbitals)], one *ns* and three $np(np_x, np_y$ and $np_z)$ orbitals combine together and form six d^2sp^3 hybrid orbitals.

67. (c) : $[CoF_6]^{3-}$:



Thus, the number of unpaired electrons = 4.

68. (d) : Odd electrons, ions and molecules are paramagnetic.

In $Cr(CO)_6$ molecule 12 electrons are contributed by CO group and it contains no odd electron.

Cr : $3d^5 4s^1$

$Fe(CO)_5$ molecule also does not contain odd electron.

Fe : $3d^6 4s^2$

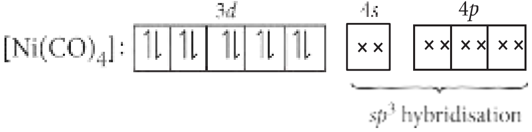
In $[Fe(CN)_6]^{4-}$ ion Fe(+2) : $3d^6 4s^0$

$\therefore$ No odd electrons.

In $[Cr(NH_3)_6]^{3+}$ ion Cr(+3) : $3d^3 4s^0$

This ion contains odd electron so it is paramagnetic.

69. (a) : In $Ni(CO)_4$ complex, Ni(0) will have $3d^{10}$ configuration.



Hence, $[Ni(CO)_4]$ will have tetrahedral geometry and diamagnetic as there are no unpaired electrons.

70. (b) : Based on the number of metal atoms present in a complex, they are classified as :

e.g., : $Fe(CO)_5$: mononuclear

$Co_2(CO)_8$: dinuclear ; $Fe_3(CO)_{12}$: trinuclear

71. (a) : In sigma bonded organometallic complexes, the metal atom and carbon atom of the ligand are joined together with a sigma bond, *i.e.*, ligand contributes one electron and is therefore, called one electrons donor, *e.g.*, Grignard's reagent R-Mg-X.

72. (a) : The greater the negative charge on the carbonyl complex, the more easy it would be for the metal to permit its electrons to participate in the back bonding, the higher would be the M—C bond order and simultaneously there would be larger reduction in the C—O bond order. Thus, $[Fe(CO)_4]^{2-}$ has the lowest C—O bond order means the longest bond length.

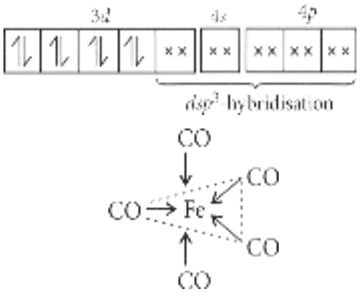
73. (a) : The presence of positive charge on the metal carbonyl would resist the flow of the metal electron charge to π^* orbitals of CO. This would increase the CO bond order and hence, CO in a metal carbonyl cation would absorb at a higher frequency compared to its absorption in a neutral metal carbonyl.

74. (a) : $Al(OC_2H_5)_3$ contains bonding through O and thus it does not have metal - carbon bond.

75. (d) : π-bonded organometallic compound includes organometallic compounds of alkenes, alkynes and some other carbon containing compounds having electrons in their p-orbitals.

76. (c) : $[Co(CO)_5NH_3]^{2+}$: In this complex, Co-atom is attached with NH_3 through σ bonding and with CO through dative π-bond.

77. (c) : In $Fe(CO)_5$, the 'Fe' atom is dsp^3 hybridised, therefore, shape of the molecule is trigonal bipyramidal. Fe atom in $Fe(CO)_5$



78. (d) : In $M(CO)_4$, metal is bonded to the ligands via carbon atoms with both σ and π-bond character. Both metal to ligand and ligand to metal bonding are possible.

79. (b)

80. (c) : First cupric cyanide is formed which decomposes to give cuprous cyanide and cyanogen gas. Cuprous cyanide dissolves in excess of potassium cyanide to form a complex, potassium cyanide $[K_3Cu(CN)_4]$.

$[CuSO_4 + 2KCN \rightarrow Cu(CN)_2 + K_2SO_4] \times 2$

$2Cu(CN)_2 \rightarrow Cu_2(CN)_2 + (CN)_2$

$Cu_2(CN)_2 + 6KCN \rightarrow 2K_3Cu(CN)_4$

$2CuSO_4 + 10KCN \rightarrow 2K_3Cu(CN)_4 + 2K_2SO_4 + (CN)_2$

81. (c) : *cis-platin*, is *cis*-$[PtCl_2(NH_3)_2]$ is used as an anticancer agent.

82. (d) : Copper being more electropositive readily precipitate silver from their salt (Ag^+) solution.

$Cu + 2AgNO_3 \rightarrow Cu(NO_3)_2 + Ag$

In $K[Ag(CN)_2]$ solution, a complex anion $[Ag(CN)_2]^-$ is formed so Ag^+ ions are less available in the solution and Cu cannot displace Ag from this complex ion.

83. (b) : Copper sulphate reacts with potassium cyanide giving a white precipitate of cuprous cyanide and cyanogen gas. The cuprous cyanide dissolves in excess of KCN forming potassium cuprocyanide $K_3[Cu(CN)_4]$.

$2CuSO_4 + 4KCN \rightarrow 2CuCN + (CN)_2 + 2K_2SO_4$

$CuCN + 3KCN \rightarrow K_3[Cu(CN)_4]$

84. (c) : Undecomposed AgBr forms a soluble complex with hypo and the reaction is given as :

$$AgBr + 2Na_2S_2O_3 \rightarrow \underset{\text{Soluble complex}}{Na_3[Ag(S_2O_3)_2]} + NaBr$$