23

Co-ordination Compounds

TOPIC 1 Coordination Number, Nomenclature and Isomerism of Coordination Compounds

1. The total number of coordination sites in ethylenediaminetetraacetate (EDTA^{4-}) is ______.
[NV, Sep. 05, 2020 (I)]

2. Consider the complex ions, *trans*-$[Co(en)_2Cl_2]^+$ (A) and *cis*-$[Co(en)_2Cl_2]^+$ (B). The correct statement regarding them is : **[Sep. 05, 2020 (II)]**
- (a) both (A) and (B) cannot be optically active.
- (b) (A) can be optically active, but (B) cannot be optically active.
- (c) both (A) and (B) can be optically active.
- (d) (A) cannot be optically active, but (B) can be optically active.

3. The number of isomers possible for $[Pt(en)(NO_2)_2]$ is : **[Sep. 04, 2020 (I)]**
(a) 2 (b) 4 (c) 1 (d) 3

4. The complex that can show optical activity is : **[Sep. 03, 2020 (I)]**
- (a) *trans*-$[Cr(Cl_2)(ox)_2]^{3-}$
- (b) *trans*-$[Fe(NH_3)_2(CN)_4]^-$
- (c) *cis*-$[Fe(NH_3)_2(CN)_4]^-$
- (d) *cis*-$[CrCl_2(ox)_2]^{3-}$ (ox = oxalate)

5. Complex A has a composition of $H_{12}O_6Cl_3Cr$. If the complex on treatment with conc. H_2SO_4 loses 13.5% of its original mass, the correct molecular formula of A is :
[Given : atomic mass of Cr = 52 amu and Cl = 35 amu] **[Sep. 03, 2020 (II)]**
- (a) $[Cr(H_2O)_6]Cl_3$
- (b) $[Cr(H_2O)_3Cl_3]\cdot 3H_2O$
- (c) $[Cr(H_2O)_5Cl]Cl_2\cdot H_2O$
- (d) $[Cr(H_2O)_4Cl_2]Cl\cdot 2H_2O$

6. The one that is not expected to show isomerism is : **[Sep. 02, 2020 (II)]**
- (a) $[Ni(NH_3)_4(H_2O)_2]^{2+}$ (b) $[Ni(en)_3]^{2+}$
- (c) $[Ni(NH_3)_2Cl_2]$ (d) $[Pt(NH_3)_2Cl_2]$

7. Complex X of composition $Cr(H_2O)_6Cl_n$ has a spin only magnetic moment of 3.83 BM. It reacts with $AgNO_3$ and shows geometrical isomerism. The IUPAC nomenclature of X is: **[Jan. 09, 2020 (I)]**
- (a) Hexaaqua chromium (III) chloride
- (b) Tetraaquadichlorido chromium (IV) chloride dihydrate
- (c) Dichloridotetraaqua chromium (IV) chloride dihydrate
- (d) Tetraaquadichlorido chromium (III) chloride dihydrate

8. The isomer(s) of $[Co(NH_3)_4Cl_2]$ that has/have a Cl–Co–Cl angle of 90°, is/are : **[Jan. 09, 2020 (II)]**
- (a) meridional and *trans* (b) *cis* and *trans*
- (c) *trans* only (d) *cis* only

9. The complex that can show *fac*- and *mer*- isomers is: **[Jan. 08, 2020 (I)]**
- (a) $[Co(NH_3)_4Cl_2]^+$ (b) $[Pt(NH_3)_2Cl_2]$
- (c) $[CoCl_2(en)_2]$ (d) $[Co(NH_3)_3(NO_2)_3]$

10. Among (a) - (d), the complexes that can display geometrical isomerism are: **[Jan. 08, 2020 (II)]**
- (a) $[Pt(NH_3)_3Cl]^+$ (b) $[Pt(NH_3)Cl_5]^-$
- (c) $[Pt(NH_3)_2Cl(NO_2)]$ (d) $[Pt(NH_3)_4ClBr]^{2+}$
- (1) (b) and (c) (2) (d) and (a)
- (3) (c) and (d) (4) (a) and (b)

11. The IUPAC name of the complex $[Pt(NH_3)_2Cl(NH_2CH_3)]Cl$ is: **[Jan. 07, 2020 (I)]**
- (a) Diamminechlorido (methanamine) platinum (II)chloride
- (b) Diammine (methanamine) chlorido platinum (II)chloride
- (c) Diamminechlorido (aminomethane) platinum (II)chloride
- (d) Bisammine (methanamine) chlorido platinum (II)chloride

12. The number of possible optical isomers for the complexes MA_2B_2 with sp^3 and dsp^2 hybridized metal atom, respectively, is:
Note: A and B are unidentate neutral and unidentate monoanionic ligands, respectively. **[Jan. 07, 2020 (II)]**
(a) 0 and 2 (b) 2 and 2 (c) 0 and 0 (d) 0 and 1

13. Among the statements (A)-(D), the incorrect ones are: **[Jan. 07, 2020 (II)]**

(A) Octahedral Co(III) complexes with strong field ligands have very high magnetic moments.

(B) When $\Delta_0 < P$, the *d*-electron configuration of Co(III) in an octahedral complex is $t_{2g}^4 e_g^2$.

(C) Wavelength of light absorbed by $[Co(en)_3]^{3+}$ is lower than that of $[CoF_6]^{3-}$.

(D) If the Δ_0 for an octahedral complex of Co(III) is 18,000 cm^{-1}, the Δ_t for its tetrahedral complex with the same ligand will be 16,000 cm^{-1}.

(a) (A) and (D) only (b) (C) and (D) only

(c) (A) and (B) only (d) (B) and (C) only

14. The coordination numbers of Co and Al in $[Co(Cl)(en)_2]Cl$ and $K_3[Al(C_2O_4)_3]$, respectively, are :
(en = ethane-1, 2-diamine) **[April 12, 2019 (II)]**

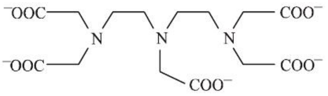
(a) 5 and 3 (b) 3 and 3 (c) 6 and 6 (d) 5 and 6

15. The species that can have a trans-isomer is :
(en = ethane – 1, 2–diamine, Ox = oxalate) **[April 10, 2019 (I)]**

(a) $[Zn(en)Cl_2]$ (b) $[Pt(en)Cl_2]$

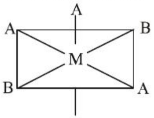
(c) $[Cr(en)_2(Ox)]^+$ (d) $[Pt(en)_2Cl_2]^{2+}$

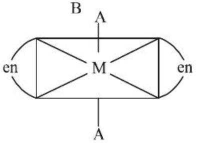
16. The maximum possible denticities of a ligand given below towards a common transition and inner-transition metal ion, respectively, are: **[April 9, 2019 (II)]**

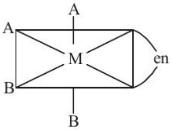


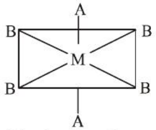
(a) 8 and 6 (b) 6 and 8 (c) 6 and 6 (d) 8 and 8

17. The one that will show optical activity is:
(en = ethane 1, 2-diamine) **[April 9, 2019 (I)]**

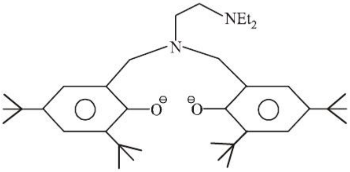
(a)


(b)


(c)


(d)


18. The following ligand is: **[April 8, 2019 (I)]**



(a) hexadentate (b) tetradentate

(c) bidentate (d) tridentate

19. The coordination number of Th in $K_4[Th(C_2O_4)_4(H_2O)_2]$ is: ($C_2O_4^{2-}$ = oxalato) **[Jan. 11, 2019 (II)]**

(a) 14 (b) 6 (c) 8 (d) 10

20. The total number of isomers for a square planar complex $[M(F)(Cl)(SCN)(NO_2)]$ is: **[Jan. 10, 2019 (I)]**

(a) 16 (b) 8 (c) 4 (d) 12

21. A reaction of cobalt(III) chloride and ethylenediamine in a 1 : 2 mole ratio generates two isomeric products A (violet coloured) and B (green coloured). A can show optical activity, but, B is optically inactive. What type of isomers does A and B represent? **[Jan. 10, 2019 (II)]**

(a) Geometrical isomers (b) Coordination isomers

(c) Linkage isomers (d) Ionisation isomers

22. Consider the following reaction and statements: **[2018]**

$[Co(NH_3)_4Br_2]^+ + Br^- \rightarrow [Co(NH_3)_3Br_3] + NH_3$

(I) Two isomers are produced if the reactant complex ion is a *cis*-isomer.

(II) Two isomers are produced if the reactant complex ion is a *trans* -isomer

(III) Only one isomer is produced if the reactant complex ion is a *trans* -isomer

(IV) Only one isomer is produced if the reactant complex ion is a *cis*-isomer.

The correct statements are:

(a) (I) and (II) (b) (I) and (III)

(c) (III) and (IV) (d) (II) and (IV)

23. Which of the following complexes will show geometrical isomerism? **[Online April 16, 2018]**
(a) Potassium tris(oxalato) chromate (III)
(b) Pentaaquachlorochromium (III) chloride
(c) Aquachlorobis (ethylenediamine) cobalt (II) chloride
(d) Potassium amminetrichloroplatinate (II)

24. The total number of possible isomers for square-planar $[Pt(Cl)(NO_2)(NO_3)(SCN)]^{2-}$ is: **[Online April 15, 2018 (II)]**
(a) 16 (b) 12 (c) 8 (d) 24

25. On treatment of 100 mL of 0.1 M solution of $CoCl_3 . 6H_2O$ with excess $AgNO_3$; 1.2×10^{22} ions are precipitated. The complex is : **[2017]**
(a) $[Co(H_2O)_4Cl_2]Cl.2H_2O$ (b) $[Co(H_2O)_3Cl_3].3H_2O$
(c) $[Co(H_2O)_6]Cl_3$ (d) $[Co(H_2O)_5Cl]Cl_2.H_2O$

26. The pair of compounds having metals in their highest oxidation state is : **[Online April 8, 2017]**
(a) MnO_2 and CrO_2Cl_2
(b) $[NiCl_4]^{2-}$ and $[CoCl_4]^{2-}$
(c) $[Fe(CN)_6]^{3-}$ and $[Cu(CN)_2]^{2-}$
(d) $[FeCl_4]^-$ and Co_2O_3

27. Which one of the following complexes shows optical isomerism? **[2016]**
(a) *trans* $[Co(en)_2Cl_2]Cl$ (b) $[Co(NH_3)_4Cl_2]Cl$
(c) $[Co(NH_3)_3Cl_3]$ (d) *cis*$[Co(en)_2Cl_2]Cl$
(en = ethylenediamine)

28. Which one of the following complexes will consume more equivalents of aqueous solution of $AgNO_3$? **[Online April 9, 2016]**
(a) $Na_2[CrCl_5(H_2O)]$ (b) $Na_3[CrCl_6]$
(c) $[Cr(H_2O)_5Cl]Cl_2$ (d) $[Cr(H_2O)_6]Cl_3$

29. Which of the following is an example of homoleptic complex? **[Online April 10, 2016]**
(a) $[Co(NH_3)_6]Cl_3$ (b) $[Pt(NH_3)_2Cl_2]$
(c) $[Co(NH_3)_4Cl_2]$ (d) $[Co(NH_3)_5Cl]Cl_2$

30. The number of geometric isomers that can exist for square planar complex $[Pt (Cl) (py) (NH_3) (NH_2OH)]^+$ is (py = pyridine) : **[2015]**
(a) 4 (b) 6 (c) 2 (d) 3

31. The correct statement on the isomerism associated with the following complex ions, **[Online April 10, 2015]**
(A) $[Ni(H_2O)_5NH_3]^{2+}$, (B) $[Ni(H_2O)_4(NH_3)_2]^{2+}$ and
(C) $[Ni(H_2O)_3(NH_3)_3]^{2+}$ is :
(a) (A) and (B) show only geometrical isomerism
(b) (A) and (B) show geometrical and optical isomerism
(c) (B) and (C) show geometrical and optical isomerism
(d) (B) and (C) show only geometrical isomerism

32. Which of the following name formula combinations is not correct? **[Online April 11, 2014]**

Formula		
(1)	$K_2[Pt(CN)_4]$	Potassium tetracyanoplatinate (II)
(2)	$[Mn(CN)_5]^{2-}$	Pentacyanomagnate (II) ion
(3)	$K[Cr(NH_3)_2Cl_4]$	Potassium diammine tetrachlorochromate (III)
(4)	$[Co(NH_3)_4(H_2O)I]SO_4$	Tetraammine aquaiodo cobalt (III) sulphate.

33. An octahedral complex with molecular composition $M.5 NH_3.Cl.SO_4$ has two isomers, A and B. The solution of A gives a white precipitate with $AgNO_3$ solution and the solution of B gives white precipitate with $BaCl_2$ solution. The type of isomerism exhibited by the complex is: **[Online April 19, 2014]**
(a) Linkage isomerism (b) Ionisation isomerism
(c) Coordinate isomerism (d) Geometrical isomerism

34. Which of the following complex species is not expected to exhibit optical isomerism ? **[2013]**
(a) $[Co(en)_3]^{3+}$ (b) $[Co(en)_2 Cl_2]^+$
(c) $[Co(NH_3)_3 Cl_3]$ (d) $[Co(en) (NH_3)_2 Cl_2]^+$

35. Type of isomerism which exists between $[Pd(C_6H_5)_2(SCN)_2]$ and $[Pd(C_6H_5)_2(NCS)_2]$ is : **[Online April 9, 2013]**
(a) Linkage isomerism (b) Coordination isomerism
(c) Ionisation isomerism (d) Solvate isomerism

36. Which among the following will be named as dibromido bis (ethylenediamine) chromium (III) bromide? **[2012]**
(a) $[Cr (en)_3]Br_3$ (b) $[Cr(en)_2Br_2]Br$
(c) $[Cr(en)Br_4]^-$ (d) $[Cr(en)Br_2]Br$

37. Which of the following complex ions will exhibit optical isomerism? (en = 1, 2-diamine ethane). **[Online May 12, 2012]**
(a) $[Cr(NH_3)_2Cl_2]^+$ (b) $[Co(en)_2Cl_2]^+$
(c) $[Co(NH_3)_4Cl_2]^+$ (d) $[Zn(en)_2]^{2+}$

38. The complex ion $[Pt (NO_2)(Py) (NH_3) (NH_2OH)]^+$ will give
(a) 2 isomers (Geometrical) **[Online May 26, 2012]**
(b) 3 isomers (Geometrical)
(c) 6 isomers (Geometrical)
(d) 4 isomers (Geometrical)

39. Which one of the following complex ions has geometrical isomers ? **[2011]**
(a) $[Ni(NH_3)_5Br]^+$ (b) $[Co(NH_3)_2(en)_2]^{3+}$
(c) $[Cr(NH_3)_4(en)_2]^{3+}$ (d) $[Co(en)_3]^{3+}$
(en-ethylenediamine)

40. A solution containing 2.675 g of $CoCl_3$. 6 NH_3 (molar mass = 267.5 g mol^{-1}) is passed through a cation exchanger. The chloride ions obtained in solution were treated with excess of $AgNO_3$ to give 4.78 g of AgCl (molar mass = 143.5 g mol^{-1}). The formula of the complex is
(At. mass of Ag = 108 u) **[2010]**

(a) $[Co(NH_3)_6]Cl_3$ (b) $[CoCl_2(NH_3)_4]Cl$

(c) $[CoCl_3(NH_3)_3]$ (d) $[CoCl(NH_3)_5]Cl_2$

41. Which one of the following has an optical isomer? **[2010]**

(a) $[Zn(en)(NH_3)_2]^{2+}$ (b) $[Co(en)_3]^{3+}$

(c) $[Co(H_2O)_4(en)]^{3+}$ (d) $[Zn(en)_2]^{2+}$

(en = ethylenediamine)

42. Which of the following shows optical isomerism **[2009]**

(a) $[Co(en)(NH_3)_2]^{2+}$ (b) $[Co(H_2O)_4(en)]^{3+}$

(c) $[Co(en)_2(NH_3)_2]^{3+}$ (d) $[Co(NH_3)_3Cl]^{+}$

43. Which of the following pairs represent linkage isomers? **[2009]**

(a) $[Pd(PPh_3)_2(NCS)_2]$ and $[Pd(PPh_3)_2(SCN)_2]$

(b) $[Co(NH_3)_5NO_3]SO_4$ and $[Co(NH_3)_5SO_4]NO_3$

(c) $[PtCl_2(NH_3)_4]Br_2$ and $[PtBr_2(NH_3)_4]Cl_2$

(d) $[Cu(NH_3)_4][PtCl_4]$ and $[Pt(NH_3)_4][CuCl_4]$

44. The coordination number and the oxidation state of the element 'E' in the complex $[E(en)_2(C_2O_4)]NO_2$ (where (en) is ethylene diamine) are, respectively, **[2008]**

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

45. The IUPAC name for the complex $[Co(NO_2)(NH_3)_5]Cl_2$ is : **[2006]**

(a) pentaammine nitrito-N-cobalt(II) chloride

(b) pentaammine nitrito-N-cobalt(III) chloride

(c) nitrito-N-pentaamminecobalt(III) chloride

(d) nitrito-N-pentaamminecobalt(II) chloride

46. The oxidation state Cr in $[Cr(NH_3)_4Cl_2]^+$ is **[2005]**

(a) 0 (b) +1 (c) +2 (d) +3

47. The IUPAC name of the coordination compound $K_3[Fe(CN)_6]$ is **[2005]**

(a) Tripotassium hexacyanoiron (II)

(b) Potassium hexacyanoiron (II)

(c) Potassium hexacyanoferrate (III)

(d) Potassium hexacyanoferrate (II)

48. Which of the following compounds shows optical isomerism? **[2005]**

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

(c) $[ZnCl_4]^{2-}$ (d) $[Cu(NH_3)_4]^{2+}$

49. The coordination number of a central metal atom in a complex is determined by **[2004]**

(a) the number of ligands around a metal ion bonded by sigma and pi-bonds both

(b) the number of ligands around a metal ion bonded by pi-bonds

(c) the number of ligands around a metal ion bonded by sigma bonds

(d) the number of only anionic ligands bonded to the metal ion.

50. Coordination compounds have great importance in biological systems. In this context which of the following statements is **incorrect** ? **[2004]**

(a) Cyanocobalamin is B_{12} and contains cobalt

(b) Haemoglobin is the red pigment of blood and contains iron

(c) Chlorophylls are green pigments in plants and contain calcium

(d) Carboxypeptidase - A is an enzyme and contains zinc.

51. Which one of the following has largest number of isomers? **[2004]**

(a) $[Ir(PR_3)_2H(CO)]^{2+}$ (b) $[Co(NH_3)_5Cl]^{2+}$

(c) $[Ru(NH_3)_4Cl_2]^+$ (d) $[Co(en)_2Cl_2]^+$

(R = alkyl group, en = ethylenediamine)

52. Among the properties (a) reducing (b) oxidising (c) complexing, the set of properties shown by CN^- ion towards metal species is **[2004]**

(a) c, a (b) b, c (c) a, b (d) a, b, c

53. One mole of the complex compound $Co(NH_3)_5Cl_3$, gives 3 moles of ions on dissolution in water. One mole of the same complex reacts with two moles of $AgNO_3$ solution to yield two moles of AgCl (s). The structure of the complex is **[2003]**

(a) $[Co(NH_3)_3Cl_3].2NH_3$ (b) $[Co(NH_3)_4Cl_2]Cl.NH_3$

(c) $[Co(NH_3)_4Cl]Cl_2.NH_3$ (d) $[Co(NH_3)_5Cl]Cl_2$

54. In the coordination compound, $K_4[Ni(CN)_4]$, the oxidation state of nickel is **[2003]**

(a) 0 (b) +1 (c) +2 (d) –1

55. The type of isomerism present in nitropentammine chromium (III) chloride is **[2002]**

(a) optical (b) linkage

(c) ionization (d) polymerisation.

TOPIC 2 Magnetic Moment, Valence Bond Theory and Crystal Field Theory

56. The species that has a spin-only magnetic moment of 5.9 BM, is : (T_d = tetrahedral) **[Sep. 06, 2020 (I)]**

(a) $[Ni(CN)_4]^{2-}$ (square planar)

(b) $[NiCl_4]^{2-}(T_d)$

(c) $Ni(CO)_4(T_d)$

(d) $[MnBr_4]^{2-}(T_d)$

57. For a d^4 metal ion in an octahedral field, the correct electronic configuration is : **[Sep. 06, 2020 (II)]**

(a) $t_{2g}^3 e_g^1$ when $\Delta_0 < P$ (b) $t_{2g}^3 e_g^1$ when $\Delta_0 > P$

(c) $t_{2g}^4 e_g^0$ when $\Delta_0 < P$ (d) $e_g^2 t_{2g}^2$ when $\Delta_0 < P$

58. The values of the crystal field stabilization energies for a high spin d^6 metal ion in octahedral and tetrahedral fields, respectively, are : **[Sep. 05, 2020 (I)]**

(a) $-0.4\,\Delta_o$ and $-0.6\,\Delta_t$ (b) $-2.4\,\Delta_o$ and $-0.6\,\Delta_t$

(c) $-1.6\,\Delta_o$ and $-0.4\,\Delta_t$ (d) $-0.4\,\Delta_o$ and $-0.27\,\Delta_t$

59. Considering that $\Delta_0 > P$, the magnetic moment (in BM) of $[Ru(H_2O)_6]^{2+}$ would be ___________.
[NV, Sep. 05, 2020 (II)]

60. The pair in which both the species have the same magnetic moment (spin only) is : **[Sep. 04, 2020 (I)]**

(a) $[Cr(H_2O)_6]^{2+}$ and $[Fe(H_2O)_6]^{2+}$

(b) $[Co(OH)_4]^{2-}$ and $[Fe(NH_3)_6]^{2+}$

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

(d) $[Cr(H_2O)_6]^{2+}$ and $[CoCl_4]^{2-}$

61. The Crystal Field Stabilization Energy (CFSE) of $[CoF_3(H_2O)_3]$ $(\Delta_0 < P)$ is : **[Sep. 04, 2020 (II)]**

(a) $-0.8\Delta_0 + 2P$ (b) $-0.4\Delta_0$

(c) $-0.8\Delta_0$ (d) $-0.4\Delta_0 + P$

62. The one that can exhibit highest paramagnetic behaviour among the following is : **[Sep. 04, 2020 (II)]**
gly = glycinato; bpy = 2, 2'-bipyridine
(a) $[Pd(gly)_2]$
(b) $[Fe(en)(bpy)(NH_3)_2]^{2+}$
(c) $[Co(OX)_2(OH)_2]^-$ $(\Delta_0 > P)$
(d) $[Ti(NH_3)_6]^{3+}$

63. The electronic spectrum of $[Ti(H_2O)_6]^{3+}$ shows a single broad peak with a maximum at 20,300 cm^{-1}. The crystal field stabilization energy (CFSE) of the complex ion, in kJ mol^{-1}, is :
($1\ kJ\ mol^{-1} = 83.7\ cm^{-1}$) **[Sep. 03, 2020 (I)]**
(a) 145.5 (b) 242.5 (c) 83.7 (d) 97

64. The *d*-electron configuration of $[Ru(en)_3]Cl_2$ and $[Fe(H_2O)_6]Cl_2$, respectively are : **[Sep. 03, 2020 (II)]**

(a) $t_{2g}^6\ e_g^0$ and $t_{2g}^6\ e_g^0$ (b) $t_{2g}^4\ e_g^2$ and $t_{2g}^6\ e_g^0$

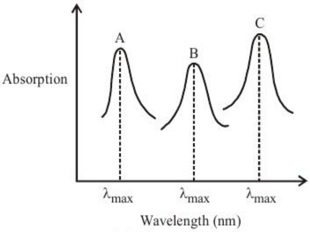
(c) $t_{2g}^6\ e_g^0$ and $t_{2g}^4\ e_g^2$ (d) $t_{2g}^4\ e_g^2$ and $t_{2g}^4\ e_g^2$

65. Consider that a d^6 metal ion (M^{2+}) forms a complex with aqua ligands, and the spin only magnetic moment of the complex is 4.90 BM. The geometry and the crystal field stabilization energy of the complex is :**[Sep. 02, 2020 (I)]**
(a) octahedral and $-2.4\Delta_0 + 2P$
(b) tetrahedral and $-0.6\ \Delta_t$
(c) octahedral and $-1.6\ \Delta_0$
(d) tetrahedral and $-1.6\Delta_t + 1P$

66. For octahedral Mn(II) and tetrahedral Ni(II) complexes, consider the following statements : **[Sep. 02, 2020 (I)]**
(I) both the complexes can be high spin.
(II) Ni(II) complex can very rarely below spin.
(III) with strong field ligands, Mn(II) complexes can be low spin.
(IV) aqueous solution of Mn(II) ions is yellow in color.

The correct statements are :
(a) (I) and (II) only
(b) (I), (III) and (IV) only
(c) (I), (II) and (III) only
(d) (II), (III) and (IV) only

67. Simplified absorption spectra of three complexes ((i), (ii) and (iii)) of M^{n+} ion are provided below; their λ_{max} values are marked as A, B and C respectively. The correct match between the complexes and their λ_{max} values is :
[Sep. 02, 2020 (II)]



(i) $[M(NCS)_6]^{(-6+n)}$
(ii) $[MF_6]^{(-6+n)}$
(iii) $[M(NH_3)_6]^{n+}$
(a) A-(iii), B-(i), C-(ii) (b) A-(ii), B-(i), C-(iii)
(c) A-(ii), B-(iii), C-(i) (d) A-(i), B-(ii), C-(iii)

68. $[Pd(F)(Cl)(Br)(I)]^{2-}$ has *n* number of geometrical isomers. Then, the spin-only magnetic moment and crystal field stabilisation energy [CFSE] of $[Fe(CN)_6]^{n-6}$, respectively, are:
[**Note :** Ignore the pairing energy] **[Jan. 09, 2020 (I)]**
(a) 2.84 BM and $-1.6\ \Delta_0$ (b) 5.92 BM and 0
(c) 1.73 BM and $-2.0\ \Delta_0$ (d) 0 BM and $-2.4\ \Delta_0$

69. The correct order of the spin-only magnetic moments of the following complexes is: **[Jan. 09, 2020 (II)]**
(A) $[Cr(H_2O)_6]Br_2$ (B) $Na_4[Fe(CN)_6]$
(C) $Na_3[Fe(C_2O_4)_3]$ $(\Delta_0 > P)$ (D) $(Et_4N)_2[CoCl_4]$
(a) (C) > (A) > (D) > (B) (b) (C) > (A) > (B) > (D)
(c) (A) > (D) > (C) > (B) (d) (B) ≈ (A) > (D) > (C)

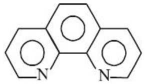
70. The volume (in mL) of 0.125 M $AgNO_3$ required to quantitatively precipitate chloride ions in 0.3 g of $[Co(NH_3)_6]Cl_3$ is _______. **[NV, Jan. 08, 2020 (I)]**
$M_{[Co(NH_3)_6]Cl_3} = 267.46$ g/mol
$M_{AgNO_3} = 169.87$ g/mol

71. The correct order of the calculated spin-only magnetic moments of complexes (A) to (D) is: **[Jan. 08, 2020 (II)]**
(A) $Ni(CO)_4$ (B) $[Ni(H_2O)_6]Cl_2$
(C) $Na_2[Ni(CN)_4]$ (D) $PdCl_2(PPh_3)_2$
(a) (A) ≈ (C) < (B) ≈ (D) (b) (C) < (D) < (B) < (A)
(c) (C) ≈ (D) < (B) < (A) (d) (A) ≈ (C) ≈ (D) < (B)

72. Complexes (ML_5) of metals Ni and Fe have ideal square pyramidal and trigonal bipyramidal geometries, respectively. The sum of the 90°, 120° and 180° L-M-L angles in the two complexes is ________. **[NV, Jan. 08, 2020 (II)]**

73. The complex ion that will lose its crystal field stabilization energy upon oxidation of its metal to +3 state is : **[April 12, 2019 (I)]**

(Phen =



and

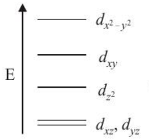
ignore pairing energy)

(a) $[Co(phen)_3]^{2+}$ (b) $[Ni(phen)_3]^{2+}$

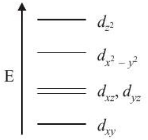
(c) $[Zn(phen)_3]^{2+}$ (d) $[Fe(phen)_3]^{2+}$

74. Complete removal of both the axial ligands (along the z-axis) from an octahedral complex leads to which of the following splitting patterns ? (relative orbital energies not on scale) **[April 12, 2019 (I)]**

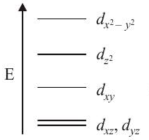
(a)



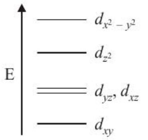
(b)



(c)



(d)



75. Three complexes, $[CoCl(NH_3)_5]^{2+}$(I), $[Co(NH_3)_5H_2O]^{3+}$(II) and $[Co(NH_3)_6]^{3+}$ (III) absorb light in the visible region. The correct order of the wavelength of light absorbed by them is : **April 10, 2019 (I)]**

(a) (III) > (I) > (II) (b) (III) > (II) > (I)

(c) (II) > (I) > (III) (d) (I) > (II) > (III)

76. The crystal field stabilization energy (CFSE) of $[Fe(H_2O)_6]Cl_2$ and $K_2[NiCl_4]$, respectively are : **[April 10, 2019 (II)]**

(a) $-0.6\,\Delta_o$ and $-0.8\,\Delta_t$ (b) $-0.4\,\Delta_o$ and $-0.8\,\Delta_t$

(c) $-2.4\,\Delta_o$ and $-1.2\,\Delta_t$ (d) $-0.4\,\Delta_o$ and $-1.2\,\Delta_t$

77. The degenerate orbitals of $[Cr(H_2O)_6]^{3+}$ are: **[April 9, 2019 (I)]**

(a) d_{xz} and d_{yz} (b) d_{yz} and d_{z^2}

(c) d_{z^2} and d_{xz} (d) $d_{x^2-y^2}$ and d_{xy}

78. The correct statements among I to III are: **[April 9, 2019 (II)]**

(I) Valence bond theory cannot explain the color exhibited by transition metal complexes.

(II) Valence bond theory can predict quantitatively the magnetic properties of transition metal complexes.

(III) Valence bond theory cannot distinguish ligands as week and strong field ones.

(a) (II) and (III) only (b) (I), (II) and (III)

(c) (I) and (III) only (d) (I) and (II) only

79. The correct order of the spin-only magnetic moment of metal ions in the following low-spin complexes, $[V(CN)_6]^{4-}$, $[Fe(CN)_6]^{4-}$, $[Ru(NH_3)_6]^{3+}$, and $[Cr(NH_3)_6]^{2+}$, is **[April 8, 2019 (I)]**

(a) $Cr^{2+} > Ru^{3+} > Fe^{2+} > V^{2+}$ (b) $V^{2+} > Cr^{2+} > Ru^{3+} > Fe^{2+}$

(c) $V^{2+} > Ru^{3+} > Cr^{2+} > Fe^{2+}$ (d) $Cr^{2+} > V^{2+} > Ru^{3+} > Fe^{2+}$

80. The calculated spin-only magnetic moments (BM) of the anionic and cationic species of $[Fe(H_2O)_6]_2$ and $[Fe(CN)_6]$, respectively, are: **[April 8, 2019 (II)]**

(a) 0 and 4.9 (b) 2.84 and 5.92

(c) 4.9 and 0 (d) 0 and 5.92

81. The metal *d*-orbitals that are directly facing the ligands in $K_3[Co(CN)_6]$ are : **[Jan. 12, 2019 (I)]**

(a) d_{xy} and $d_{x^2-y^2}$ (b) $d_{x^2-y^2}$ and d_{z^2}

(c) d_{xz}, d_{yz} and d_{z^2} (d) d_{xy}, d_{xz} and d_{yz}

82. The magnetic moment of an octahedral homoleptic Mn(II) complex is 5.9 BM. The suitable ligand for this complex is : **[Jan. 12, 2019 (II)]**

(a) Ethylenediamine (b) CN^-

(c) NCS^- (d) CO

83. Match the metals **(column I)** with the coordination compound(s)/enzyme(s) **(column II)** : **[Jan. 11, 2019 (I)]**

(column I) **Metals**	**(column II)** **Coordination compound(s)/enzyme(s)**
(A) Co	(i) Wilkinson catalyst
(B) Zn	(ii) Chlorophyll
(C) Rh	(iii) Vitamin B_{12}
(D) Mg	(iv) Carbonic anhydrase

(a) (A)-(iii); (B)-(iv); (C)-(i); (D)-(ii)

(b) (A)-(i); (B)-(ii); (C)-(iii); (D)-(iv)

(c) (A)-(ii); (B)-(i); (C)-(iv); (D)-(iii)

(d) (A)-(iv); (B)-(iii); (C)-(i); (D)-(ii)

84. The difference in the number of unpaired electrons of a metal ion in its high-spin and low-spin octahedral complexes is two. The metal ion is: **[Jan. 10, 2019 (II)]**

(a) Ni^{2+} (b) Fe^{2+} (c) Co^{2+} (d) Mn^{2+}

85. Two complexes $[Cr(H_2O)_6]Cl_3$ (A) and $[Cr(NH_3)_6]Cl_3$ (B) are violet and yellow coloured, respectively. The incorrect statement regarding them is: **[Jan. 9, 2019 (I)]**

(a) Δ_0 values of (A) and (B) are calculated from the energies of violet and yellow light, respectively.

(b) both are paramagnetic with three unpaired electrons.

(c) both absorb energies corresponding to their complementary colors.

(d) Δ_0 value for (A) is less than that of (B).

86. The complex that has highest crystal field splitting energy (Δ) is: **[Jan. 9, 2019 (II)]**

(a) $[Co(NH_3)_5(H_2O)]Cl_3$ (b) $K_2[CoCl_4]$

(c) $[Co(NH_3)_5Cl]Cl_2$ (d) $K_3[Co(CN)_6]$

87. Homoleptic octahedral complexes of a metal ion 'M^{3+}' with three monodentate ligands L_1, L_2 and L_3 absorb wavelengths in the region of green, blue and red respectively. The increasing order of the ligand strength is: **[Jan. 9, 2019 (II)]**

(a) $L_3 < L_1 < L_2$ (b) $L_3 < L_2 < L_1$

(c) $L_1 < L_2 < L_3$ (d) $L_2 < L_1 < L_3$

88. In Wilkinson's catalyst, the hybridisation of central metal ion and its shape are respectively : **[Online April 16, 2018]**

(a) sp^3d, trigonal bipyramidal

(b) d^2sp^3, octahedral

(c) dsp^2, square planar

(d) sp^3, tetrahedral

89. The correct combination is : **[Online April 15, 2018 (I)]**

(a) $[NiCl_4]^{2-}$-square-planar; $[Ni(CN)_4]^{2-}$-paramagnetic

(b) $[Ni(CN)_4]^{2-}$-tetrahedral; $[Ni(CO)_4]$-paramagnetic

(c) $[NiCl_4]^{2-}$-paramagnetic; $[Ni(CO)_4]$-tetrahedral

(d) $[NiCl_4]^{2-}$-dimagnetic; $[Ni(CO)_4]$-square-planar

90. The correct order of spin-only magnetic moments among the following is: (Atomic number: Mn = 25, Co = 27, Ni = 28, Zn = 30) **[Online April 15, 2018 (II)]**

(a) $[ZnCl_4]^{2-} > [NiCl_4]^{2-} > [CoCl_4]^{2-} > [MnCl_4]^{2-}$

(b) $[CoCl_4]^{2-} > [MnCl_4]^{2-} > [NiCl_4]^{2-} > [ZnCl_4]^{2-}$

(c) $[NiCl_4]^{2-} > [CoCl_4]^{2-} > [MnCl_4]^{2-} > [ZnCl_4]^{2-}$

(d) $[MnCl_4]^{2-} > [CoCl_4]^{2-} > [NiCl_4]^{2-} > [ZnCl_4]^{2-}$

91. The pair having the same magnetic moment is:
[At. No.: Cr = 24, Mn = 25, Fe = 26, Co = 27] **[2016]**

(a) $[Mn(H_2O)_6]^{2+}$ and $[Cr(H_2O)_6]^{2+}$

(b) $[CoCl_4]^{2-}$ and $[Fe(H_2O)_6]^{2+}$

(c) $[Cr(H_2O)_6]^{2+}$ and $[CoCl_4]^{2-}$

(d) $[Cr(H_2O)_6]^{2+}$ and $[Fe(H_2O)_6]^{2+}$

92. Identify the correct trend given below : **[Online April 9, 2016]**

(Atomic No. = Ti : 22, Cr : 24 and Mo : 42)

(a) Δ_o of $[Cr(H_2O)_6]^{2+} > [Mo(H_2O)_6]^{2+}$ and Δ_o of $[Ti(H_2O)_6]^{3+} > [Ti(H_2O)_6]^{2+}$

(b) Δ_o of $[Cr(H_2O)_6]^{2+} > [Mo(H_2O)_6]^{2+}$ and Δ_o of $[Ti(H_2O)_6]^{3+} < [Ti(H_2O)_6]^{2+}$

(c) Δ_o of $[Cr(H_2O)_6]^{2+} < [Mo(H_2O)_6]^{2+}$ and Δ_o of $[Ti(H_2O)_6]^{3+} > [Ti(H_2O)_6]^{2+}$

(d) Δ_o of $[Cr(H_2O)_6]^{2+} < [Mo(H_2O)_6]^{2+}$ and Δ_o of $[Ti(H_2O)_6]^{3+} < [Ti(H_2O)_6]^{2+}$

93. Which of the following compounds is not colored yellow?

(a) $(NH_4)_3[As(Mo_3O_{10})_4]$ (b) $BaCrO_4$ **[2015]**

(c) $Zn_2[Fe(CN)_6]$ (d) $K_3[Co(NO_2)_6]$

94. The color of $KMnO_4$ is due to : **[2015]**

(a) L → M charge transfer transition

(b) $\sigma - \sigma^*$ transition

(c) M → L charge transfer transition

(d) d – d transition

95. Which of the following complex ions has electrons that are symmetrically filled in both t_{2g} and e_g orbitals ? **[Online April 11, 2015]**

(a) $[FeF_6]^{3-}$ (b) $[Mn(CN)_6]^{4-}$

(c) $[CoF_6]^{3-}$ (d) $[Co(NH_3)_6]^{2+}$

96. The octahedral complex of a metal ion M^{3+} with four monodentate ligands L_1, L_2, L_3 and L_4 absorb wavelengths in the region of red, green, yellow and blue, respectively. The increasing order of ligand strength of the four ligands is: **[2014]**

(a) $L_4 < L_3 < L_2 < L_1$ (b) $L_1 < L_3 < L_2 < L_4$

(c) $L_3 < L_2 < L_4 < L_1$ (d) $L_1 < L_2 < L_4 < L_3$

97. An octahedral complex of Co^{3+} is diamagnetic. The hybridisation involved in the formation of the complex is: **[Online April 9, 2014]**

(a) sp^3d^2 (b) dsp^2 (c) d^2sp^3 (d) sp^3d

98. The correct statement about the magnetic properties of $[Fe(CN)_6]^{3-}$ and $[FeF_6]^{3-}$ is (Z = 26) :

(a) both are paramagnetic. **[Online April 9, 2014]**

(b) both are diamagnetic.

(c) $[Fe(CN)_6]^{3-}$ is diamagnetic, $[FeF_6]^{3-}$ is paramagnetic.

(d) $[Fe(CN)_6]^{3-}$ is paramagnetic, $[FeF_6]^{3-}$ is diamagnetic.

99. Consider the coordination compound, $[Co(NH_3)_6]Cl_3$. In the formation of this complex, the species which acts as the Lewis acid is: **[Online April 11, 2014]**

(a) $[Co(NH_3)_6]^{3+}$ (b) Cl^-

(c) Co^{3+} (d) NH_3

100. Among the following species the one which causes the highest CFSE, Δ_o as a ligand is: **[Online April 12, 2014]**

(a) CN^- (b) NH_3 (c) F^- (d) CO

101. Which one of the following complexes will most likely absorb visible light?
(At nos. Sc = 21, Ti = 22, V = 23, Zn = 30) **[Online April 12, 2014]**

(a) $[Sc(H_2O)_6]^{3+}$ (b) $[Ti(NH_3)_6]^{4+}$

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

102. Nickel (Z = 28) combines with a uninegative monodentate ligand to form a diamagnetic complex $[NiL_4]^{2-}$. The hybridisation involved and the number of unpaired electrons present in the complex are respectively:
[Online April 19, 2014]

(a) sp^3, two (b) dsp^2, zero
(c) dsp^2, one (d) sp^3, zero

103. Which of the following is diamagnetic ?
[Online April 22, 2013]

(a) $[Fe(CN)_6]^{3-}$ (b) $[Co(ox)]^{3-}$
(c) $[FeF_6]^{3-}$ (d) $[Co(F_6)]^{3-}$

104. The magnetic moment of the complex anion $[Cr(NO)(NH_3)(CN)_4]^{2-}$ is : **[Online April 23, 2013]**

(a) 5.91 BM (b) 3.87 BM (c) 1.73 BM (d) 2.82 BM

105. In which of the following octahedral complex species the magnitude of Δ_o will be maximum ?
[Online April 25, 2013]

(a) $[Co(H_2O)_6]^{2+}$ (b) $[Co(CN)_6]^{3-}$
(c) $[Co(C_2O_4)_3]^{3-}$ (4) $[Co(NH_3)_6]^{3+}$

106. The structure of which of the following chloro species can be explained on the basis of dsp^2 hybridisation ?
[Online April 25, 2013]

(a) $PdCl_4^{2-}$ (b) $FeCl_4^{2-}$ (c) $CoCl_4^{2-}$ (d) $NiCl_4^{2-}$

107. 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 the lowest paramagnetic behaviour?

(Atomic no. Cr = 24, Mn = 25, Fe = 26, Co = 27).
[Online May 7, 2012]

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

108. The correct order of ligands in the spectrochemical series is **[Online May 19, 2012]**

(a) $Cl^- > en > CN^- > NCS^-$ (b) $CN^- > en > NCS^- > Cl^-$
(c) $NCS^- > CN^- > Cl^- > en$ (d) $en > CN^- > Cl^- > NCS^-$

109. Which of the following paramagnetic ions would exhibit a magnetic moment (spin only) of the order of 5 BM?
[Online May 19, 2012]

(At. Nos. Mn = 25, Cr = 24, V = 23, Ti = 22)

(a) Mn^{2+} (b) Ti^{2+} (c) V^{2+} (d) Cr^{2+}

110. Square-planar geometry is shown by **[Online May 19, 2012]**

(a) $[PtCl_2(NH_3)_2]$ (b) $[NiCl_4]^{2-}$
(c) MnO_4^- (d) CrO_4^{2-}

111. In which of the following complexes of the Co (at. no. 27), will the magnitude of Δ_0 be the highest? **[2008]**

(a) $[Co(CN)_6]^{3-}$ (b) $[Co(C_2O_4)_3]^{3-}$
(c) $[Co(H_2O)_6]^{3+}$ (d) $[Co(NH_3)_6]^{3+}$

112. Which of the following has a square planar geometry?

(a) $[PtCl_4]^{2-}$ (b) $[CoCl_4]^{2-}$ **[2007]**
(c) $[FeCl_4]^{2-}$ (d) $[NiCl_4]^{2-}$

(At. nos.: Fe = 26, Co = 27, Ni = 28, Pt = 78)

113. Nickel (Z = 28) combines with a uninegative monodentate ligand X^- to form a paramagnetic complex $[NiX_4]^{2-}$. The number of unpaired electron(s) in the nickel and geometry of this complex ion are, respectively : **[2006]**

(a) one, square planar (b) two, square planar
(c) one, tetrahedral (d) two, tetrahedral

114. How many EDTA (ethylenediaminetetraacetic acid) molecules are required to make an octahedral complex with a Ca^{2+} ion? **[2006]**

(a) One (b) Two (c) Six (d) Three

115. Which one of the following cyano complexes would exhibit the lowest value of paramagnetic behaviour ? **[2005]**

(a) $[Co(CN)_6]^{3-}$ (b) $[Fe(CN)_6]^{3-}$
(c) $[Mn(CN)_6]^{3-}$ (d) $[Cr(CN)_6]^{3-}$

(At. Nos : Cr = 24, Mn = 25, Fe = 26, Co = 27)

116. Which one of the following complexes is an outer orbital complex ? **[2004]**

(a) $[Co(NH_3)_6]^{3+}$ (b) $[Mn(CN)_6]^{4-}$
(c) $[Fe(CN)_6]^{4-}$ (d) $[Ni(NH_3)_6]^{2+}$

(Atomic nos. : Mn = 25; Fe = 26; Co = 27, Ni = 28)

117. A square planar complex is formed by hybridisation of which atomic orbitals? **[2002]**

(a) s, p_x, p_y, d_{yz} (b) $s, p_x, p_y, d_{x^2-y^2}$
(c) s, p_x, p_y, d_{z^2} (d) s, p_y, p_z, d_{xy}

TOPIC 3 Organometallic Compounds

118. The theory that can completely/properly explain the nature of bonding in $[Ni(CO)_4]$ is: **[Jan. 07, 2020 (I)]**

(a) Werner's theory (b) Molecular orbital theory
(c) Crystal field theory (d) Valence bond theory

119. The compound used in the treatment of lead poisoning is :
[April 12, 2019 (II)]

(a) D-penicillamine (b) desferrioxime B
(c) *Cis*-platin (d) EDTA

120. The compound that inhibits the growth of tumors is : **[April 8, 2019 (II)]**

(a) *trans*-$[Pt(Cl)_2(NH_3)_2]$ (b) *cis*-$[Pd(Cl)_2(NH_3)_2]$

(c) *cis*-$[Pt(Cl)_2(NH_3)_2]$ (d) *trans*-$[Pd(Cl)_2(NH_3)_2]$

121. $Mn_2(CO)_{10}$ is an organometallic compound due to the presence of : **[Jan. 12, 2019 (I)]**

(a) Mn–C bond (b) Mn–Mn bond

(c) Mn–O bond (d) C–O bond

122. The number of bridging CO ligand(s) and Co-Co bond(s) in $Co_2(CO)_8$, respectively are: **[Jan. 11, 2019 (II)]**

(a) 2 and 1 (b) 2 and 0 (c) 0 and 2 (d) 4 and 0

123. Wilkinson catalyst is: **[Jan. 10, 2019 (I)]**

(a) $[(Ph_3P)_3IrCl]$ (b) $[(Et_3P)_3RhCl]$

(c) $[(Ph_3P)_3RhCl]$ (d) $[(Et_3P)_3IrCl]$

124. $[Co_2(CO)_8]$ displays : **[Online April 9, 2017]**

(a) one Co – Co bond, six terminal CO and two bridging CO

(b) one Co – Co bond, four terminal CO and four bridging CO

(c) no Co – Co bond, six terminal CO and two bridging CO

(d) no Co – Co bond, four terminal CO and four bridging CO

125. Which molecule/ion among the following cannot act as a ligand in complex compounds ? **[Online April 10, 2015]**

(a) CH_4 (b) CO (c) CN^- (d) Br^-

126. In $Fe(CO)_5$, the Fe – C bond possesses **[2006]**

(a) ionic character (b) σ-character only

(c) π-character (d) both σ and π characters

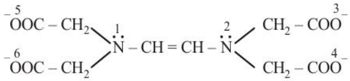
127. $CH_3 - Mg - Br$ is an organo metallic compound due to

(a) Mg – Br bond (b) C – Mg bond **[2002]**

(c) C – Br bond (d) C – H bond.

Hints & Solutions

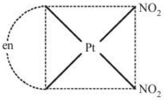
1. **(6)**

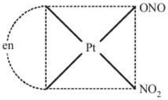


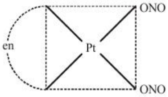
EDTA^{4-} is a hexadentate ligand, since hexa means six and the ligand attaches six times.

2. **(d)** *trans*-$[Co(en)_2Cl_2]^+$ (A) contains a plane of symmetry so (A) cannot be optically active, whereas, (B) *cis* $[Co(en)_2Cl_2]^+$ does not contain any plane of symmetry, so (B) will be optically active.

3. **(d)** $[Pt(en)(NO_2)_2]$







So, total possible isomers are 3.

4. **(d)** Only *cis*-$[CrCl_2(ox)_2]^{3-}$ shows optical isomerism while its *trans* form do not show optical isomerism due to presence of plane of symmetry.

5. **(d)** Conc. H_2SO_4 acts as dehydrating agent.
Molar mass of given complex = 266.5 g/mol.
On treating with conc. H_2SO_4 the mass lost by the

$$\text{complex } = \frac{13.5}{100}(266.5) \approx 36\,\text{g } = 2 \text{ moles of } H_2O$$

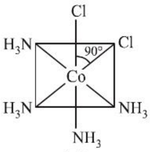
Formula of the complex = $[Cr(H_2O)_4Cl_2]Cl \,.\, 2H_2O$

6. **(c)**
(a) $[Ni(NH_3)_4(H_2O)_2]^{2+}$ shows geometrical isomerism.
(b) $[Ni(en)_3]^{2+}$ shows optical isomerism.
(c) $[Ni^{2+}(NH_3)_2Cl_2] \Rightarrow Ni^{2+} \Rightarrow 3d^8 4s^0$
$\Rightarrow sp^3$ hybridisation
$\Rightarrow$ tetrahedral
So, $[Ni(NH_3)_2Cl_2]$ does not show isomerism.
(d) $[Pt(NH_3)_2Cl_2]$ shows geometrical isomerism.

7. **(d)** $\mu = \sqrt{n(n+2)}$ B.M. = 3.83 B.M.

$n = 3$ (n = No. of unpaired e^-)
Therefore, oxidation number of Cr should be +3.
Hence complex is $Cr(H_2O)_6Cl_3$.
Complex shows geometrical isomerism therefore formula of complex is $[Cr(H_2O)_4Cl_2]Cl.2H_2O$.
IUPAC Name:
Tetraaquadichlorido chromium(III) Chloride dihydrate

8. **(d)**



cis-Form

9. **(d)** $[Ma_3b_3]$ type complex shows facial and meridional isomerism.

So, the complex $[CO(NH_3)_3(NO_2)_3]$ will show fac-and mer-isomers.

10. **(c)** $[Pt(NH_3)_2Cl(NO_2)]$ and $[Pt(NH_3)_4ClBr]^{2+}$ are the Ma_4bc and Ma_2bc type of complexes.

Each shows two geometrical isomers i.e., cis and trans isomers.

11. **(a)** $[Pt(NH_3)_2Cl(NH_2CH_3)]Cl$

Diamine chlorido (methanamine) platinum (II) chloride

12. **(c)** $[MA_2B_2]$ will not exhibit optical isomerism in both conditions.

13. **(a)** Co^{3+} with strong field ligand forms complex of low magnetic moment.

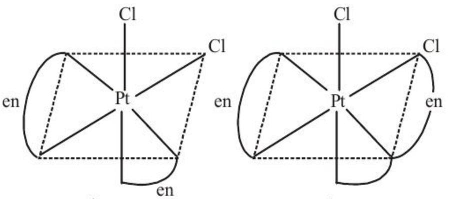
$$\Delta_t = \left(\frac{4}{9}\right)\Delta_0$$

$$\Rightarrow \quad \Delta_t = \frac{4}{9} \times 18000 = 8000\ \text{cm}^{-1}$$

14. **(d)** $[Co(en)_2Cl]Cl$

Cl^- - monodentate ligand
en - bidentate ligand
$\therefore$ Co-ordination Number of Co = $(2 \times 2) + 1 = 5$
$K_3[Al(C_2O_4)_3]$
$C_2O_4^{2-}$ - bidentate ligand
$\therefore$ Co-ordination Number of Al = $2 \times 3 = 6$

15. **(d)**

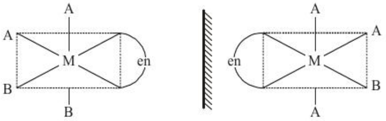


cis *trans*

cis-trans Isomerism is possible with $[Pt(en)_2Cl_2]^{2+}$. $[Cr(en)_2Ox]^+$ shows only optical isomerism. The other two complexes, i.e., $[Pt(en)Cl_2]$ and $[Zn(en)Cl_2]$ do not show stereoisomerism.

16. **(b)** The maximum possible denticites of the given ligand towards transition metal ion is 6 and towards inner transition metal ion (due to greater ionic radii and more atomic orbitals) is 8.

17. **(c)**



No plane of symmetry or centre of symmetry is present.

Hence, it will be optically active.

18. **(b)** It has four atoms containing lone pair of e^-, therefore, it will be able to donate these lone pairs and acts as a tetradentate ligand.

19. **(d)** $K_4[Th(C_2O_4)_4(H_2O)_2]$

$C_2O_4^{2-}$ (oxalato) : bidentate ligand

H_2O (aqua): monodentate

$\therefore$ Co-ordination no. of Th $= 2 \times 4 + 2 = 10$

20. **(d)**

Possible complexes	No. of isomers
$[M(F)(Cl)(SCN)(NO_2)]$	→ 3
$[M(F)(Cl)(SCN)(ONO)]$	→ 3
$[M(F)(Cl)(NCS)(NO_2)]$	→ 3
$[M(F)(Cl)(NCS)(ONO)]$	→ 3
Total = 12	

21. **(a)** Reaction for the given condition can be written as:

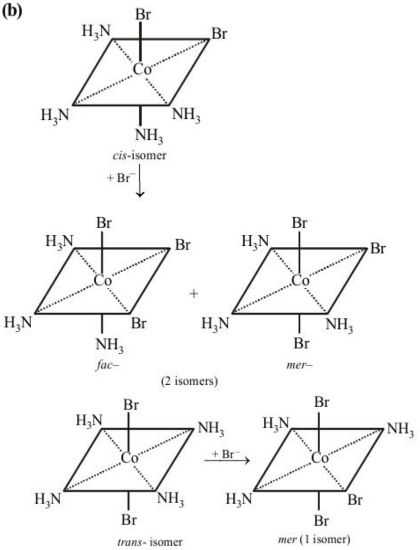
$$[CoCl_6]^{3-} + 2(en) \longrightarrow [CoCl_2(en)_2]^+$$

(1:2 mole ratio) (*cis-trans*-isomer)

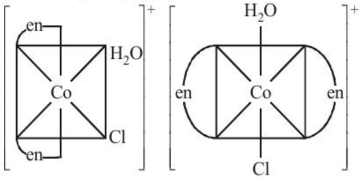
A = optically active (*cis*-isomer), violet

B = optically inactive (*trans*-isomer), green

22. **(b)**



23. **(c)** $[Co(H_2O)Cl(en)_2]Cl$



(Geometrical isomers)

24. **(b)** The square planar complex of the type $[Mabcd]^{n\pm}$, where all four ligands are different, has 3 geometrical isomers. But if one of the ligands is ambidentate, then $2 \times 3 = 6$ geometrical isomers are possible. But if two ligands are ambidentate, then $4 \times 3 = 12$ geometrical isomers are possible.

In the given example, NO_2^- and SCN^- are ambidentate ligands.

25. **(d)** Moles of complex $= \dfrac{\text{Molarity} \times \text{Volume(mL)}}{1000}$

$$= \frac{100 \times 0.1}{1000} = 0.01 \text{ mole}$$

Moles of ions precipitated with excess of

$$AgNO_3 = \frac{1.2 \times 10^{22}}{6.02 \times 10^{23}} = 0.02 \text{ moles}$$

$\therefore$ Number of Cl^- present in ionisation sphere

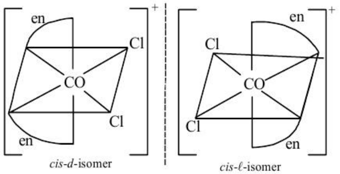
$$= \frac{\text{Number of moles of ions precipitated}}{\text{Number of moles of complex}}$$

$$= \frac{0.02}{0.01} = 2$$

It means $2Cl^-$ ions present in ionization sphere.
Thus formula of the complex is
$[Co(H_2O)_5Cl]Cl_2.H_2O$

26. **(a)** $Cr\overset{2-}{O_2}\overset{-1}{Cl_2}$ Cr = +6; $Mn\overset{2-}{O_2}$ Mn = +4
(Highest oxidation state)
$[Ni\overset{-1}{Cl_4}]^{2-}$ Ni = +2; $[Co\overset{-1}{Cl_4}]^{2-}$ Co = +2
$[Fe(\overset{-1}{CN})_6]^{3-}$ Fe = +3; $[Cu(\overset{-1}{CN})_4]^{2-}$ Cu = +2
(4) $[Fe\overset{-1}{Cl_4}]^-$ Fe = +3; $Co_2\overset{-2}{O_3}$ Co = +3

27. **(d)** Optical isomerism occurs when a molecule is non-super imposable with its mirror image hence the complex *cis*-$[Co(en)_2Cl_2]Cl$ is optically active.

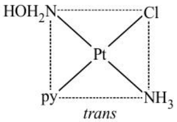


cis-d-isomer *cis-ℓ*-isomer

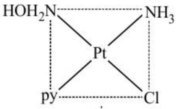
28. **(d)** More equivalents of $AgNO_3$ aqueous solution will be consumed if complex will furnish more Cl^- ions in solution. Hence complex $[Cr(H_2O)_6]Cl_3$ will consume more equivalents of aqueous solution of $AgNO_3$.

29. **(a)** Complexes having only one type of ligands are examples of homoleptic complex.

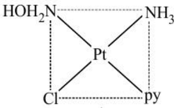
30. **(d)** Square planar complexes of type M[ABCD] form three isomers. Their position may be obtained by fixing the position of one ligand and placing at the *trans* position any one of the remaining three ligands one by one.



trans



cis



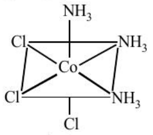
cis

31. **(d)** It does not show optical and geometrical isomerism (B) and (C) shows only geometrical isomerism.

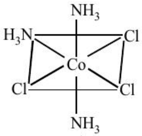
32. **(b)** Pentacyanomangnate (III) is the correct IUPAC name of $[Mn(CN)_5]^{2-}$.

33. **(b)** The two possible isomers for the given octahedral complex are $[M(NH_3)_5SO_4]Cl$ and $[M(NH_3)_5Cl]SO_4$. They respectively give chloride ion (indicated by precipitation with $BaCl_2$) and SO_4 ion (indicated by precipitation with $AgNO_3$). Hence the type of isomerism exhibited by the complex is ionisation isomerism.

34. **(c)** Octahedral coordination entities of the type Ma_3b_3 exhibit geometrical isomerism. The compound exists both as facial and meridional isomers, both contain plane of symmetry



fac-isomer

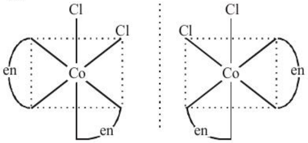


mer-isomer

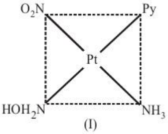
35. **(a)** The compound shows linkage isomerism because the ligand in the compound is an ambidenate ligand that can bond at more than one atomic site.
i.e., $:NCS^-$ and $:SCN^-$

36. **(b)** $[Cr(en)_2Br_2]Br$
dibromido bis(ethylenediamine) chromium (III) Bromide.

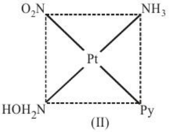
37. **(b)** Non superimposable mirror images are called optical isomers and may be described as "chiral'. They are also called enantiomers and rotate plane polarised light in opposite directions.



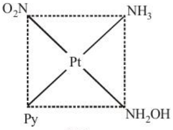
38. **(b)** Complexes of the type M_{ABCD} may exist in three isomeric form. Similarly $[Pt(NO_2)(Py)(NH_3)(NH_2OH)^+]$ may exist in three isomeric form.



(I)

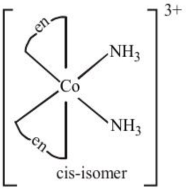


(II)

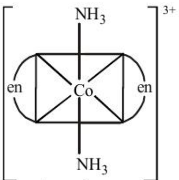


(III)

39. **(b)**



cis-isomer



trans-isomer

40. **(a)** $\underset{2.675\text{ g}}{CoCl_3.6NH_3} \longrightarrow xCl^-$

$xCl^- + AgNO_3 \longrightarrow \underset{4.78\text{ g}}{x\,AgCl\downarrow}$

Number of moles of the complex

$= \dfrac{2.675}{267.5} = 0.01$ mol

Number of moles of AgCl obtained

$= \dfrac{4.78}{143.5} = 0.03$ mol

$\therefore$ No. of moles of AgCl obtained

$= 3 \times$ No. of moles of complex

$\therefore\ n = \dfrac{0.03}{0.01} = 3$

41. **(b)** For a substance to be optical isomer following conditions should be fulfiled

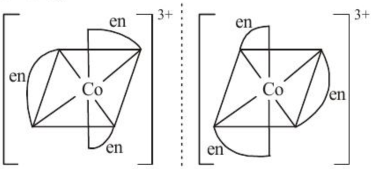
(a) A coordination compound which can rotate the plane of polarised light is said to be optically active.

(b) When the coordination compounds have same formula but differ in their abilities to rotate directions of the plane of polarised light are said to exhibit optical isomerism and the molecules are optical isomers. The optical isomers are pair of molecules which are non-superimposable mirror images of each other.

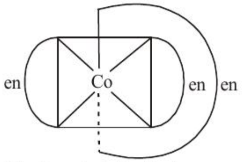
(c) This is due to the absence of elements of symmetry in the complex.

(d) Optical isomerism is expected in tetrahedral complexes of the type Mabcd.

Based on this only option (b) shows optical isomerism $[Co(en)_3]^{3+}$



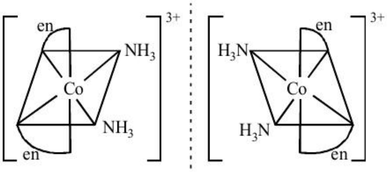
d-form Mirror *l*-form



'Meso' or optically inactive form

Complexes of Zn^{2+} cannot show optical isomerism as they are tetrahedral complexes with plane of symmetry. $[CO(H_2O)_4(en)]^{3+}$ has two planes of symmetry hence it is also optically inactive.

42. **(c)**



Enantiomers of *cis*-$\left[Co(en)_2(NH_3)_2\right]^{3+}$

43. **(a)** The SCN$^-$ ion can coordinate through S or N atom giving rise to linkage isomerism

M $\leftarrow$ SCN thiocyanato

M $\leftarrow$ NCS isothiocyanato.

44. **(d)** In the given complex we have two bidentate ligands (i.e en and C_2O_4), so coordination number of E is 6 $(2 \times 2 + 1 \times 2 = 6)$

Let the oxidation state of E in complex be x, then $[x + (-2) = 1]$ or $x - 2 = 1$

or $x = +3$, so its oxidation state is $+3$

Thus option (d) is correct.

45. **(b)** $[Co(NO)_2(NH_3)_5]Cl_2$

Pentaamminenitrito-N-cobalt (III) chloride

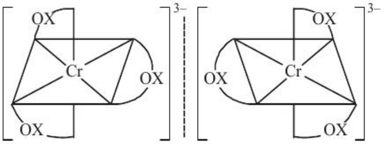
46. **(d)** Oxidation state of Cr in $[Cr(NH_3)_4Cl_2]^+$.

Let it be x, $1 \times x + 4 \times 0 + 2(-1) = 1$

Therefore $x = 3$.

47. **(c)** $K_3[Fe(CN)_6]$ is potassium hexacyanoferrate (III).

48. **(b)**



Non-superimposable mirror images, hence optical isomers.

49. **(c)** The coordination number of central metal atom in a complex is equal to number of monovalent ligands, twice the number of bidentate ligands and so on, around the metal ion bonded by coordinate bonds.

Hence coordination number = No. of σ bonds formed by metals with ligands.

50. **(c)** The chlorophyll molecule plays an important role in photosynthesis. It has porphyrin rings and the metal Mg, not Ca.

51. **(d)** Isomers

$\underset{cis\text{ and }trans}{[Ru(NH_3)_4Cl_2]^+}, \underset{\text{none}}{[Co(NH_3)_5Cl]^{2+}},$

$\underset{cis\text{ and }trans}{[Ir(PR_3)_2H(CO)]^{2+}}, \underset{cis\text{ and }trans\text{ and optical isomers}}{[Co(en)_2Cl_2]^+}$

52. **(a)** CN^- ion acts good complexing as well as reducing agent.

53. **(d)** $Co(NH_3)_5Cl_3 \rightleftharpoons [Co(NH_3)_5Cl]^{+2} + 2Cl^-$

$\therefore$ Structure is $[Co(NH_3)_5Cl]Cl_2$.

Now $[Co(NH_3)_5Cl]Cl_2 + 2AgNO_3$

$$\longrightarrow [Co(NH_3)_5Cl](NO_3)_2 + 2AgCl$$

54. **(a)** Let the O. N. of Ni in $K_4[Ni(CN)_4]$ be $= x$ then

$4(+1) + x + (-1) \times 4 = 0$

$\Rightarrow 4 + x - 4 = 0$

$x = 0$

55. **(b)** The chemical formula of nitropentammine chromium (III) chloride is

$\left[Cr(NH_3)_5NO_2\right]Cl_2$

It can exist in following two structures

$\left[Cr(NH_3)_5NO_2\right]Cl_2$ and

Nitropentamminechromium (III) chloride

$\left[Cr(NH_3)_5ONO\right]Cl_2$

Nitritopentamminechromium (III) chloride

Therefore the type of isomerism found in this compound is linkage isomerism as NO_2 group is linked through N as $-NO_2$ or through O as $-ONO$.

56. **(d)** $[MnBr_4]^{2-} \Rightarrow Mn^{2+} \Rightarrow d^5(Td)$

[$\because$ Br is weak field ligand]

d^5(Td) is high spin complex.

So, $\mu = \sqrt{5(5+2)} = 5.91$ B.M.

57. **(a)** If $\Delta_0 > P$ then fot $d^4 \Rightarrow t_{2g}^4\, e_g^0$

If $\Delta_0 < P$ then for $d^4 \Rightarrow t_{2g}^3\, e_g^1$

58. **(a)** For d^6 configuration, high spin complex.

(i) In case of octahedral field, $t_{2g}^4\, e_g^2$

$CFSE = [-0.4p + 0.6q]\Delta_0 + n(P)$

$= [-0.4 \times 4 + 0.6 \times 2]\Delta_0 + 0 = -0.4\Delta_0$

(ii) In case of tetrahedral field, e^3, t_2^3

$CFSE = [-0.6p + 0.4q]\Delta t$

$= [-0.6 \times 3 + 0.4 \times 3]\Delta t = -0.6\Delta t.$

59. **(0.0)**

$Ru^{2+} = 4d^6 = t_{2g}^6 e_g^0$ since $\Delta_0 > P$

No. of unpaired electrons = 0

$\therefore$ Magnetic moment = 0 B.M.

60. **(a)** $[Cr(H_2O)_6]^{2+} \Rightarrow Cr^{2+} \Rightarrow 3d^4 \Rightarrow t_{2g}^{1,1,1}, e_g^{1,0}$

No. of unpaired e^- : 4

$[Fe(H_2O)_6]^{2+} \Rightarrow Fe^{2+} \Rightarrow 3d^6 \Rightarrow t_{2g}^{2,1,1}, e_g^{1,1}$

No. of unpaired e^- : 4

$[Fe(NH_3)_6]^{2+} \Rightarrow Fe^{2+} \Rightarrow 3d^6 \Rightarrow t_{2g}^{2,1,1}, e_g^{1,1}$

No. of unpaired e^- : 4

$[Co(OH)_4]^{2-} \Rightarrow Co^{2+} \Rightarrow 3d^7 \Rightarrow e^{2,2}, t_2^{1,1,1}$

No. of unpaired e^- : 3

$[CoCl_4]^{2-} \Rightarrow Co^{2+} \Rightarrow 3d^7 \Rightarrow e^{2,2}, t_2^{1,1,1}$

No. of unpaired e^- : 3

$[Mn(H_2O)_6]^{2+} \Rightarrow Mn^{2+} \Rightarrow 3d^5 \Rightarrow t_{2g}^{1,1,1}, e_g^{1,1}$

No. of unpaired e^- : 5

So $[Cr(H_2O)_6]^{2+}$ and $[Fe(H_2O)_6]^{2+}$ have same magnetic moment (spin only).

61. **(b)** $[CoF_3(H_2O)_3] \Rightarrow Co^{3+} \Rightarrow d^6$ or $t_{2g}^4 e_g^2$

$CFSE = -[0.4p + 0.6q]\Delta_0 + n(P)$

$= [-4 \times 0.4 + 2 \times 0.6]\Delta_0 + 0 = -0.4\,\Delta_0.$

62. **(c)**

		No. of unpaired electrons
$[Fe(en)(bpy)(NH_3)_2]^{2+}$	:	$Fe^{2+} - 3d^6$ 0
$[Pd(gly)_2]$	:	$Pd^{2+} - 3d^8$ 0
$[Co(OX)_2(OH)_2]^-$	:	$Co^{5+} - 3d^4$ 2
$[Ti(NH_3)_6]^{3+}$	:	$Ti^{3+} - 3d^1$ 1

Thus, $[Co(OX)_2(OH)_2]^-$ exhibits highest paramagnetic behaviour due to highest number of unpaired electrons.

63. **(d)** $[Ti(H_2O)_6]^{3+} \Rightarrow Ti^{3+} = 3d^1 4s^0$

$\therefore$ Electronic configuration is $t_{2g}^1 e_g^0$

$CFSE = [-0.4n_{t_{2g}} + 0.6n_{e_g}]\Delta_0 + n(p)$

$= [(-0.4) \times 1 + 0]\, 20300$

$= -8120\ cm^{-1}$

$= \dfrac{-8120}{83.7}$ kJ/mol $= -97$ kJ/mol

64. **(c)** $[Ru(en)_3]Cl_2 \Rightarrow Ru^{2+} = 4d^6 = t_{2g}^6, e_g^0$

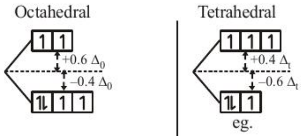
$[Fe(H_2O)_6]^{2+} \Rightarrow Fe^{2+} = 3d^6 = t_{2g}^4, e_g^2$

So, correct answer is (c).

65. **(b)** Spin only magnetic moment $= 4 \cdot 9 = \sqrt{n(n+2)}$

$\therefore$ number of unpaired electrons = 4

Two possible arrangements are



$\text{CFSE} = t_{2g}$
$= 4 \times (-0.4)\Delta_0 + 2\,(0.6)\Delta_0$
$= -0.4\Delta_0$

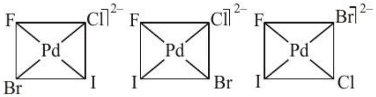
$\text{CFSE} = 3 \times (-0.6)\Delta_t + 3 \times (0.4)\Delta_t$
$= -0.6\Delta_t$

So, option (b) is correct.

66. **(c)** With weak field ligands Mn(II) will be of high spin and with strong field ligands it will be of low spin. Ni(II) tetrahedral complexes will be generally of high spin due to sp^3 hybridisation. Mn(II) is of light pink colour in aqueous solution.

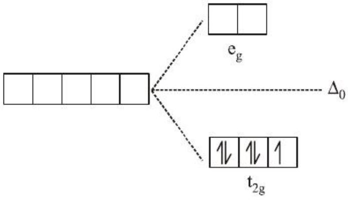
67. **(a)** Stronger the ligand greater is splitting of *d* orbitals and smaller will be wavelength of light absorbed. According to spectrochemical series, the splitting power of ligands is $NH_3 > NC\bar{S} > F^-$.
Thus, order of wavelength of light absorbed is
$\lambda_{NH_3} < \lambda_{NC\bar{S}} < \lambda_{F^-}$.

68. **(c)** Number of Geometrical isomers (*n*) in square planar
$[Pd(F)(Cl)(Br)(I)]^{2-} = 3$



$[Fe(CN)_6]^{3-6} = [Fe(CN)_6]^{3-}$

$Fe^{3+} = 3d^5$



$\mu = \sqrt{n(n+2)} = 1.73\text{ B.M.}$

$\text{CFSE} = -0.4\,\Delta_0 \times nt_{2g} + 0.6\Delta_0 \times n_{2g}$

$= -0.4\,\Delta_0 \times 5 = -2.0\,\Delta_0$

69. (c) As, $\mu_s = \sqrt{n(n+2)}$

$Na_4[Fe(CN)_6] \rightarrow Fe^{2+}$

$\Rightarrow$ S.F.L. $\Rightarrow t_{2g}{}^6\, e_g{}^0 \Rightarrow \mu_s = 0$

$[Cr(H_2O)_6]\,Br_2 \rightarrow Cr^{2+}$

$\Rightarrow$ W.F.L. $\Rightarrow t_{2g}{}^3\, e_g{}^1 \Rightarrow \mu_s = \sqrt{24}$ B.M.

$(Et_4N)_2[CoCl_4] \rightarrow Co^{2+}$

$\Rightarrow$ W.F.L. $\Rightarrow e^4\, t_2{}^3 \Rightarrow \mu_s = \sqrt{15}$ B.M.

$Na_3[Fe(C_2O_4)_3] \rightarrow Fe^{3+}$

$\Rightarrow$ S.F.L. $\Rightarrow t_{2g}{}^5\, e_g{}^0 \Rightarrow \mu_s = \sqrt{3}$ B.M.

70. **(26.92)**

$$\underset{0.3\text{ g}}{[ML_6]Cl_3} + \underset{V\text{ mL, }0.125\text{ M}}{3AgNO_3} \longrightarrow 3AgCl$$

Number of moles of the complex $= \dfrac{0.3}{267.46}$

Number of moles of $AgNO_3 = 0.125 \times V \times 10^{-3}$

$$\frac{0.3}{267.46} \times 3 = 0.125 \times V \times 10^{-3}$$

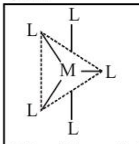
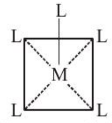
$$\text{Or, } V = \frac{0.3 \times 3 \times 1000}{267.46 \times 0.125} = 26.92\text{ mL}$$

71. **(d)**

		No. of unpaired e^-		μ
(A)	$Ni(CO)_4$;	$Ni = 3d^8 4s^2$(SFL)	0	0
(B)	$[Ni(H_2O)_6]\,;Cl_2$	$Ni^{2+} = 3d^8$(WFL)	2	$\sqrt{8}$ BM
(C)	$Na_2[Ni(CN)_4]$;	$Ni^{2+} = 3d^8$ (SFL)	0	0
(D)	$PdCl_2(PPh_3)_2$;	$Pd^{2+} = 4d^8$	0	0

Correct order of the calculated spin only magnetic moments of complexes A to D is (A) ≈ (C) ≈ (D) < B

72. **(20.0)**

 (Trigonal bipyramidal)	 (Square pyramidal)
∠120° = 3; ∠90° = 6; ∠180° = 1 ⇒ Total = 10	∠90° = 8; ∠180° = 2 ⇒ Total = 10

Total number of 180°, 90° and 120° L–M–L bond angles $= 10 + 10 = 20$

73. **(d)** CFSE $\Rightarrow [-0.4\,p + 0.6\,q]\Delta_0$

$$\underset{t_{2g}^6 e_g^2}{Ni^{2+}(d^8)} \longrightarrow \underset{t_{2g}^6 e_g^1}{Ni^{3+}(d^7)}$$

CFSE $\Rightarrow -1.2$ $\quad -1.8$

$$\underset{t_{2g}^6 e_g^1}{Co^{2+}(d^7)} \longrightarrow \underset{t_{2g}^6 e_g^0}{Co^{3+}(d^6)}$$

CFSE $\Rightarrow -1.8$ $\quad -2.4$

$$\underset{t_{2g}^6 e_g^4}{Zn^{2+}(d^{10})} \longrightarrow \underset{t_{2g}^6 e_g^3}{Zn^{3+}(d^9)}$$

CFSE $\Rightarrow 0.0$ $\quad -0.6$

$$\underset{t_{2g}^6 e_g^0}{Fe^{2+}(d^6)} \longrightarrow \underset{t_{2g}^5 e_g^0}{Fe^{3+}(d^5)}$$

CFSE $\Rightarrow -2.4$ $\quad -2.0$

So, only Fe^{2+} will lose crystal field stabilisation energy upon oxidation to +3, others will gain crystal field stabilisation energy.

74. **(a)** After removal of both axial ligands from octahedral complex the field becomes square planar and leads to following energy patterns.

$$d_{x^2-y^2} > d_{xy} > d_{z^2} > d_{xz} = d_{yz}$$

75. **(d)** Wavelength of the energy absorbed by the co-ordination compound is inversely proportional to ligand field strength of the given co-ordination compound. The strong field ligand causes higher splitting of the *d*-orbitals. The decreasing order of ligand field strength is $NH_3 > H_2O > Cl$. Therefore decreasing order of absorbed wavelength is (I) > (II) > (III).

76. **(b)** $[Fe(H_2O)_6]^{2+}$ $\quad t_2{}^4{}_g\, e_g^2$

CFSE $= (-4 \times 0.4 + 2 \times 0.6)\,\Delta_0 = -0.4\,\Delta_0$

$[NiCl_4]^{2-}$ $\quad e^4\, t_2{}^4$ $\qquad$ CFSE $= (-4 \times 0.6 + 4 \times 0.4)\,\Delta_t = -0.8\,\Delta_t$

77. **(a)** Cr^{3+} has d^3 configuration and forms an octahedral inner orbitals complex, therefore the set of degenerate orbitals are (d_{xy}, d_{yz} and d_{xz}) and ($d_{x^2-y^2}$ and d_{z^2}).

78. **(c)** Valence bond theory cannot distinguish between weak field ligands and strong field ligands. Therefore, it cannot predict quantitatively the magnetic properties of transition metal complexes.

79. **(b)**

Complex	Metal ion	No. of unpaired electrons
$[V(CN)_6]^{4-}$	V^{2+}	3
$[Ru(NH_3)_6]^{3+}$	Ru^{3+}	1
$[Fe(CN)_6]^{4-}$	Fe^{2+}	0
$[Cr(NH_3)_6]^{2+}$	Cr^{2+}	2

$\because$ Spin magnetic moment $\propto$ no. of unpaired electrons.

So the order of spin magnetic moment is:

$$V^{2+} > Cr^{2+} > Ru^{3+} > Fe^{2+}$$

80. **(a)** $[Fe(H_2O)_6]^{2+}$: cationic species of $[Fe(H_2O)_6]_2$

$[Fe(CN)_6]^{4-}$: anionic species of $[Fe(CN)_6]$

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

Where n = no. of unpaired electrons

Now, $[Fe(H_2O)_6]^{2+}$ $\quad [Fe(CN)_6]^{4-}$

$n = 4$ $\qquad n = 0$

$\therefore\ \mu = \sqrt{4(4+2)}$ $\qquad \mu = \sqrt{0(0+2)}$

$\mu = 4.9$ $\qquad \mu = 0$

81. **(b)** $K_3[Co(CN)_6]$ is an octahedral complex.

During splitting of *d* orbitals in octahederal complexes, $d_{x^2-y^2}$ and d_{z^2} orbitals point towards the direction of ligands (i.e. they experience more repulsion and will be raised in energy by $\frac{3}{5}\Delta_0$).

82. **(c)** Electronic configuration of Mn^{2+} is,

$$Mn^{2+} : 3d^5\ \underset{3d^5}{\boxed{1}\boxed{1}\boxed{1}\boxed{1}\boxed{1}}$$

Presence of 5 unpaired e^- shows that the complex of Mn^{2+} has only weak field ligand (NCS^-).

83. **(a)** Wilkinson catalyst : $[Rh(PPh)_3Cl]$

Chlorophyll : $C_{55}H_{72}O_5N_4Mg$

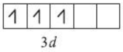
Vitamin B_{12} contains Co.

Carbonic anhydrase contains a Zn ion.

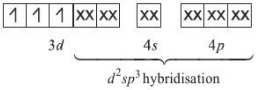
84. **(c)**

Metal ion	No. of unpaired elec.		Difference in the unpaired electrons
	High spin	Low spin	
Ni^{2+} $(3d^8)$	2	2	0
Mn^{2+} $(3d^5)$	5	1	4
Fe^{2+} $(3d^6)$	4	0	4
Co^{2+} $(3d^7)$	3	1	2

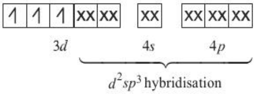
85. **(a)** E.C. of Cr^{3+} $(3d^3)$:



For complex A $[Cr(H_2O)_2]^{3+}$:



For complex B $[Cr(NH_3)_6]^{3+}$:



Here, both the complexes (A) and (B) are paramagnetic with 3 unpaired electrons each. H_2O is also a weak field ligand, which causes lesser splitting than NH_3, which is comparatively stronger field ligand. Hence, the (Δ_0) value of (A) and (B) are calculated from the wavelengths of light absorbed and not from the wavelengths of light emitted.

86. **(d)** In case of similar metal atom or ion, the value of co-ordination number and the strength of the ligands determine the value of crystal field splitting energy.

Greater the co-ordination number and strength of value of the ligand, greater will be the value of CFSE.

Strength of ligands : $CN^- > NH_3 > H_2O > Cl^-$

$\therefore$ $K_3[Co(CN)_6]$ has the highest crystal field splitting energy.

87. **(a)** Lesser the wavelength of light absorbed (more energy) greater will be ligand strength.

Energy:	Blue	>	Green	>	Red
Ligand strength:	L_2	>	L_1	>	L_3

88. **(c)** Wilkinson catalyst is $[RhCl(PPh_3)_3]$.

Rh belongs to 4*d* series, so it terms square planar complexes and contains dsp^2 hybridisation.

89. **(c)** $[Ni(CN)_4]^{2-}$ is square planar, diamagnetic (0 unpaired electrons) with dsp^2 hybridisation.

$[Ni(CO)_4]$ - is tetrahedral,diamagnetic (0 unpaired electrons) with sp^3 hybridisation.

$[NiCl_4]^{2-}$ is tetrahedral, paramagnetic (2 unpaired electrons) with sp^3 hybridisation.

Hence, the option (c) is the correct answer.

90. **(d)** The complex having higher number of unpaired electrons will have higher value of spin only magnetic moment.

In all these complexes, the central metal ion is in +2 oxidation state.

Zn^{2+} has $3d^{10}$ outer electronic configuration with 0 unpaired electron.

Ni^{2+}has $3d^8$ outer electronic configuration with 2 unpaired electrons.

Co^{2+} has $3d^7$ outer electronic configuration with 3 unpaired electrons.

Mn^{2+} has $3d^5$ outer electronic configuration with 5 unpaired electrons

Hence the correct order of spin-only magnetic moments is $[MnCl_4]^{2-} > [CoCl_4]^{2-} > [NiCl_4]^{2-} > [ZnCl_4]^{2-}$.

91. **(d)**

	Metal ion	**Unpaired electron**	**Magnetic moment**
(i)	Cr^{2+}	4	$\sqrt{24}$ B.M.
(ii)	Fe^{2+}	4	$\sqrt{24}$ B.M.
(iii)	Co^{2+}	3	$\sqrt{15}$ B.M.
(iv)	Mn^{2+}	5	$\sqrt{35}$ B.M.

Since (i) and (ii), each has 4 unpaired electron, so they will exhibit same magnetic moment. Thus option (d) is correct.

92. **(d)** The splitting is affected by the oxidation state of the central metal ion. A higher oxidation state leads to larger splitting, hence

$$\Delta_o \text{of}[Ti(H_2O)_6]^{3+} < \Delta_o \text{of}[Ti(H_2O)_6]^{2+}$$

Further Δ_o also depends of $Z_{eff.}$ and $Z_{eff.}$ of 4*d* series is more than 3*d* series.

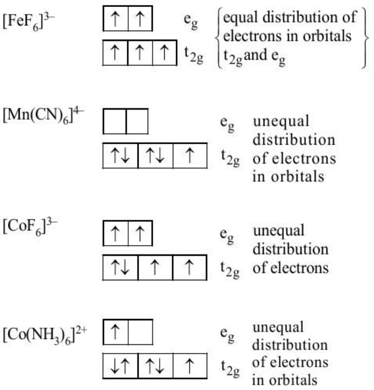
Hence

$$\Delta_o \text{ of } [Cr(H_2O)_6]^{2+} < \Delta_o \text{ of } [Mo(H_2O)_6]^{2+}$$

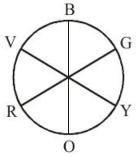
93. **(c)**

94. **(a)** L → M charge transfer spectra. $KMnO_4$ is colored because it absorbs light in the visible range of electromagnetic radiation. The permanganate ion is the source of color, as a ligand to metal (L → M) charge transfer takes place between oxygen's *p* orbitals and the empty *d*-orbitals on the metal. This charge transfer takes place when a photon of light is absorbed which leads to the purple color of the compound.

95. **(a)** Symmetrically filled t_{2g} and e_g are those, which contain equal distribution of electrons.



96. **(b)**



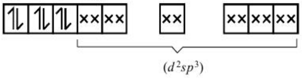
For a given metal ion, weak field ligands create a complex with smaller Δ, which will absorbs light of longer λ and thus lower frequency. Conservely, stronger field ligands create a larger Δ, absorb light of shorter λ and thus higher *v* i.e. higher energy.

$$\underset{\lambda = 650\text{ nm}}{\text{Red}} < \underset{570\text{ nm}}{\text{Yellow}} < \underset{490\text{ nm}}{\text{Green}} < \underset{450\text{ nm}}{\text{Blue}}$$

So order of ligand strength is

$L_1 < L_3 < L_2 < L_4$

97. **(c)** $[Co(NH_3)_6]^{3+}$



Octahedral and diamagnetic.

98. **(a)** Both are paramagnetic, the only difference is that CN^- is a strong field ligand whereas F^- is a weak field ligand.

99. **(c)** $$\underset{\text{Lewis acid}}{Co^{3+}} + \underset{\text{Lewis base}}{6NH_3} \longrightarrow \underset{\text{adduct}}{\left[Co(NH_3)_6\right]^{3+}}$$

100. **(d)** Following is the order of increasing value of Δ_o for the ligands

$I^- < Br^- < Cl^- < F^- < H_2O < Py = NH_3 < en < NO_2^- << CN^- < CO$

101. **(c)** The absorption of visible light is responsible for coloured nature of the transition metal cation due to the promotion of one or more unpaired - *d* - electron from a lower to higher level within same *d*-subshell. Hence higher the number of unpaired electron higher will be the absorpion in visible light.

The electronic configuration of the given elements is

Sc^{3+} (18) = $1s^2\,2s^2\,2p^6\,3s^2\,3p^6\,3d^0\,4s^0$ - no unpaired e^-.

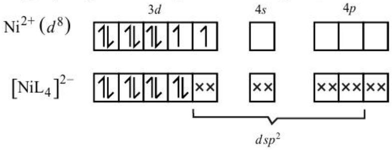
Ti^{4+} (18) = $1s^2\,2s^2\,2p^6\,3s^2\,3p^6\,3d^0\,4s^0$ - no unpaired e^-.

V^{3+} (20) = $1s^2\,2s^2\,2p^6\,3s^2\,3p^6\,3d^2\,4s^0$ - Two unpaired e^-.

Zn^{2+} (28) = $1s^2\,2s^2\,2p^6\,3s^2\,3p^6\,3d^{10}\,4s^0$ - no unpaired e.

hence $[V(NH_3)_6]^{3+}$ will most likely absorb visible light.

102. **(b)** $[NiL_4]^{2-}$ ⇒ Diamagnetic in nature (given)



So, no. of unpaired electron = 0

hybridisation – dsp^2.

103. **(b)** Among four ligands CN^- and OX^{2-} are strong field ligands. So pairing takes places in $[(FeCN)_6]^{3-}$ and $[Co(OX)_3]^{3-}$ complexes. Fe^{3+} having one unpaired electron in its complex white Co^{3+} does not have unpaired electron in its complex. So option b is correct.

104. **(c)** In $[Cr(NO)(NH_3)(CN)_4]^{2-}$,

$Cr^+(d^5)$ has electronic configuration as :

So, 1 unpaired electron is present. Thus,

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

105. (b) Crystal field splitting depends upon the nature of ligand. The nature of ligand decreases as shown below

$C_2O_4^{2-} < H_2O < NH_3 < CN^-$

Hence the crystal field splitting will be maximum for $[Co(CN)_6]^{3-}$

106. (a) $[PdCl_4]^{2-}$ is dsp^2 hybridised and square planar in shape.

107. (a)

	Electronic configuration		No. of unpaired electrons
Co^{2+}	d^7	⇅ ⇅ ↑ ↑ ↑	3
Cr^{2+}	d^4	↑ ↑ ↑ ↑ ☐	4
Mn^{2+}	d^5	↑ ↑ ↑ ↑ ↑	5
Fe^{2+}	d^6	⇅ ↑ ↑ ↑ ↑	4

∴ Since Co^{3+} has lowest no. of unpaired electrons hence lowest paramagnetic behaviour is shown by $[Co(H_2O)_6]^{2+}$

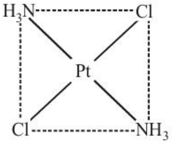
108. (b) Correct order is : $CN^- > en > NCS^- > Cl^-$

109. (d)

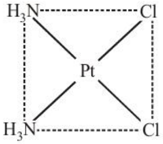
Ion	Electronic Configuration	Magnetic moment $\left(\sqrt{n(n+2)}\right)$
Cr^{2+} d^4	↑ ↑ ↑ ↑ ☐	$\sqrt{4(4+2)} = 4.9$
$Mn^{2+} d^5$	↑ ↑ ↑ ↑ ↑	$\sqrt{5(5+2)} = 5.8$
Ti^{2+} d^2	↑ ↑ ☐ ☐ ☐	$\sqrt{2(2+2)} = 2.4$
V^{2+} d^3	↑ ↑ ↑ ☐ ☐	$\sqrt{3(3+2)} = 3.8$

Hence Cr^{2+} has magnetic moment of the order of 5 B.M.

110. (a) $[PtCl_2(NH_3)_2]$ has square planar geometry.



trans-Isomer

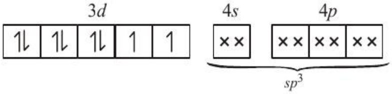


cis-isomer

111. (a) In octahedral complex, the magnitude of Δ_0 will be highest in a complex having strongest ligand. Of the given ligands, CN^- is strongest, so Δ_0 will be highest for $[Co(CN)_6]^{3-}$. Thus option (a) is correct.

112. (a) Complexes with dsp^2 hybridisation are square planar. All the complexes of Pt^{2+} are square planar including those with weak field ligand such as halide ions. Thus option (a) is correct.

113. (d) $[Ni\,X_4]^{2-}$, the electronic configuration of Ni^{2+} is



It contains two unpaired electrons and the hybridisation is sp^3 (tetrahedral).

114. (a) EDTA is hexadentate, four donor O atoms and 2 donor N atoms, and for the formation of octahedral complex one molecule is required.

115. (b)

		No. of unpaired electron
(a)	Co^{3+}	4
(b)	Fe^{3+}	1
(c)	Mn^{3+}	4
(d)	Cr^{3+}	3

The effective magnetic moment is given by the number of unpaired electrons in a substance, the lesser the number of unpaired electrons lower is its magnetic moment in Bohr – Magneton and lower shall be its paramagnetism

116. (d) $\underset{d^2sp^3}{[Fe(CN)_6]^{4-}}, \underset{d^2sp^3}{[Mn(CN)_6]^{4-}}$,

$\underset{d^2sp^3}{[Co(NH_3)_6]^{3+}}, \underset{sp^3d^2}{[Ni(NH_3)_6]^{2+}}$

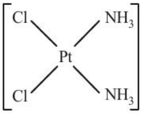
Hence $[Ni(NH_3)_6]^{2+}$ is outer orbital complex.

117. (b) A square planar complex is formed by hybridisation of s, p_x, p_y and $d_{x^2-y^2}$ atomic orbitals

118. (b) The covalant character of the bonding (M – C σ and M – C π bonding) which exists between the metal and the carbon atom of the CO can only be explained by the molecular orbital theory.

119. (d) EDTA is used in the treatment of lead poisoning. Deferrioxime B is used in treatment of iron poisoning and D-penicillamine is used in treatment of heavy metal poisoning, while *cis*-platin is used for treating cancer.

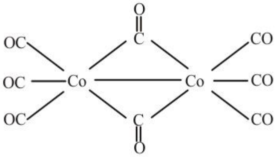
120. (c) *cis*-Platin is used as an anti-cancer drug.



cis-$[Pt(Cl)_2(NH_3)_2]$

121. (a) Compounds having atleast one carbon metal (M – C) bond are known as organometallic compounds. It contains Mn-C bond.

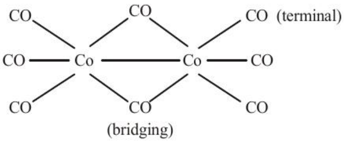
122. (a) The structure of $Co_2(CO)_8$ is represented as



It contains two bridging CO ligands and one metal – metal (Co – Co) bond.

123. (c) Wilkinson's catalyst is $[Rh(PPh_3)_3Cl]$

124. (a)



125. (a) The donor atoms, molecules or anions which donate a pair of electrons to the metal atom or ion and form a coordinate bond with it are called ligands. In methane there is no electrons for donation to central metal atom/ion, it is stable with complete octet configuration.

126. (d) Due to some backbonding by sideways overlapping between *d*-orbitals of metal and *p*-orbital of carbon, the Fe–C bond in $Fe(CO)_5$ has both σ and π character.

127. (b) Compounds that contain carbon-metal bond are known as organometallic compounds.

In CH_3-Mg-Br (Grignard's reagent), a bond is present between carbon and Mg (metal), hence it is an organometallic compound.