24
Chapter

CO-ORDINATION COMPOUNDS

A SINGLE CORRECT CHOICE TYPE

Each of these questions has 4 choices (a), (b), (c) and (d) for its answer, out of which ONLY ONE is correct.

1. Which of the following compounds will give the test of Fe^{2+} in aqueous solution :

(a) $K_4[Fe(CN)_6]$

(b) $K_3[Fe(CN)_6]$

(c) $(NH_4)_2SO_4.Fe_2(SO_4)_3.24H_2O$

(d) $(NH_4)_2SO_4.Fe_2(SO_4)_3.24H_2O$

2. How many moles of AgCl would be obtained, when 100 ml of 0.1 *M* $Co(NH_3)_5Cl_3$ is treated with excess of $AgNO_3$?

(a) 0.01 (b) 0.02

(c) 0.03 (d) none of these

3. 0.001 mol of $Co(NH_3)_5(NO_3)(SO_4)$ was passed through a cation exchanger and the acid coming out of it required 20 ml of 0.1 *M* NaOH for neutralization. Hence, the complex is

(a) $[Co(NH_3)_5SO_4]NO_3$

(b) $[Co(NH_3)_5NO_3]SO_4$

(c) $[Co(NH_3)_5](SO_4)(NO_3)$

(d) none of these

4. When H_2S is passed through a cuperic salt added to excess of KCN, no black precipitate of CuS is obtained. This is due to the presence of copper largely as:

(a) $[Cu(CN)_4]^{2-}$ (b) $[Cu(CN)_6]^{4-}$

(c) $[Cu(CN)_3]^{2-}$ (d) $Cu(CN)_2$

5. Cu^{2+} shows a coordination number of

(a) 2 only (b) 2 or 4

(c) 4 only (d) 4 or 6

6. Which of the following is not chelating agent?

(a) thiosulphato (b) oxalato

(c) glycinato (d) ethylene diamine

7. Which of the following has five donor (coordinating) sites?

(a) Triethylene tetramine

(b) Ethylenediamine tetracetate ion

(c) Ethylenediamine triacetate ion

(d) Diethylene triamine

8. A compound contains 1.08 mol of Na, 0.539 mol of Cu and 2.16 mol of F. Its aqueous solution shows osmotic pressure which is three times that of urea having same molar concentration. The formula of the compound is :

(a) $Na_4[CuF_6]$ (b) $Na[CuF_4]$

(c) $Na_2[CuF_4]$ (d) $Na_2[CuF_3]$

9. The IUPAC name of the red coloured complex $[Fe(C_4H_7O_2N_2)_2]$ obtained from the reaction of Fe^{2+} and dimethyl glyoxime

(a) bis (dimethyl oxime) ferrate (II)

(b) bis (dimethyl oxime) iron (II)

(c) bis (2, 3- butanediol dioximato) iron (II)

(d) bis (2, 3- butanedione dioximato) iron (II)

10. When HgI_2 is added to excess of aqueous KI, mercury largely exists as.

(a) Hg_2I_2 (b) $[HgI_3]^-$

(c) $[HgI_4]^{2-}$ (d) none of these

MARK YOUR RESPONSE	1. ⓐⓑⓒⓓ	2. ⓐⓑⓒⓓ	3. ⓐⓑⓒⓓ	4. ⓐⓑⓒⓓ	5. ⓐⓑⓒⓓ
	6. ⓐⓑⓒⓓ	7. ⓐⓑⓒⓓ	8. ⓐⓑⓒⓓ	9. ⓐⓑⓒⓓ	10. ⓐⓑⓒⓓ

11. The solution of AgBr in presence of large excess of NH_3 contains mainly the cation.

(a) NH_4^+ (b) Ag^+

(c) $[Ag(NH_3)]^+$ (d) $[Ag(NH_3)_2]^+$

12. The molar ionic conductances of the octahedral complexes:

(I) $PtCl_4.5NH_3$ (II) $PtCl_4.4NH_3$

(III) $PtCl_4.3NH_3$ (IV) $PtCl_4.2NH_3$

Follow the order

(a) I < II < III < IV (b) IV < III < II < I

(c) III < IV < II < I (d) IV < III < I < II

13. On treatment of 100 ml of 0.1 *M* solution of the complex $CrCl_3.6H_2O$ with excess of $AgNO_3$, 4.305 g of AgCl was obtained. The complex is

(a) $[Cr(H_2O)_3Cl_3].3H_2O$

(b) $[Cr(H_2O)_4Cl_2]Cl.2H_2O$

(c) $[Cr(H_2O)_5Cl)Cl_2.H_2O$

(d) $[Cr(H_2O)_6]Cl_3$

14. Which of the following species is not expected to be a ligand

(a) $\overset{+}{NO}$ (b) NH_4^+

(c) $NH_2 - NH_3^+$ (d) CO

15. The formation constant of the complex $[Zn(NH_3)_4]^{2+}$ is the equilibrium constant of the reaction represented by

(a) $Zn^{2+}_{(aq)} + 4NH_{3(aq)} \rightleftharpoons [Zn(NH_3)_4]^{2+}_{(aq)}$

(b) $[Zn(NH_3)_3H_2O]^{2+}_{(aq)} + NH_{3(aq)} \rightleftharpoons [Zn(NH_3)_4]^{2+}_{(aq)} + H_2O$

(c) $Zn_{(s)} + 4NH_{3(aq)} \rightleftharpoons [Zn(NH_3)_4]^{2+}_{(aq)} + 2e^-$

(d) $[Zn(H_2O)_4]^{2+}_{(aq)} + 4NH_{3(aq)} \rightleftharpoons [Zn(NH_3)_4]^{2+}_{(aq)} + 4H_2O$

16. The number of donor sites in dimethyl glyoxime, glycinato, diethylene triamine and EDTA are respectively:

(a) 2, 2, 3 and 4 (b) 2, 2, 3 and 6

(c) 2, 2, 2 and 6 (d) 2, 3, 3 and 6

17. EAN of the central metal in the complexes : $K_2[Ni(CN_4],[Cu(NH_3)_4]SO_4$ and $K_2[PtCl_6]$ are respectively.

(a) 36, 35, 86 (b) 34, 35, 84

(c) 34, 35, 86 (d) 34, 36, 86

18. Which of the following pair of complexes have the same EAN of the central metal atoms/ions?

(a) $[Cu(NH_3)_4]SO_4$ and $K_3[Fe(CN)_6]$

(b) $K_4[Fe(CN)_6]$ and $[Co(NH_3)_6]Cl_3$

(c) $K_3[Cr(C_2O_4)_3]$ and $[Cr(NH_3)_6]Cl(NO_2)_2^{2+}$

(d) all

19. The complex that violates the Sidwicks's rule of EAN is

(a) Potassium ferrocyanide

(b) Hexamine cobalt (III) Chloride

(c) Tetramine copper (II) sulphate

(d) Potassium dichlorodioxalato cobaltate (III)

20. The IUPAC name for the coordination compound $NaBH_4$ is :

(a) Sodium boron hydride

(b) Sodium tetrahidridoboron (III)

(c) Sodium tetrahydridoborate (III)

(d) Sodium tetrahydridoborate (I)

21. The IUPAC name for the coordination compound $Ba[BrF_4]_2$ is

(a) Barium tetrafluorobromate (V)

(b) Barium tetrafluorobromate (III)

(c) Barium bis (tetrafluorobromate) (III)

(d) none of these

22. $K_2[OsCl_5N]$ is named as:

(a) Potassium pentachloro azo osmate (VI)

(b) Potassium pentachloro nitridoosmate (VI)

(c) Potassium pentachloro azidoosmate (VI)

(d) Potassium pentachloro nitronium osmate (II)

23. The formula of the complex hydridotrimethoxyborate (III) ion is.

(a) $[BH(OCH_3)_3]^{2-}$ (b) $[BH_2(OCH_3)_3]^{2-}$

(c) $[BH(OCH_3)_3]^-$ (d) $[BH(OCH_3)_3]^+$

24. The IUPAC name for the compound $K[SbCl_5Ph]$ is.

(a) Potassium chlorophenyl antimonate (V)

(b) Potassium pentachloro (phenyl) antimonate (V)

(c) Potassium pentachloro benzylantimonate (V)

(d) none of these

MARK YOUR RESPONSE	11. ⓐⓑⓒⓓ	12. ⓐⓑⓒⓓ	13. ⓐⓑⓒⓓ	14. ⓐⓑⓒⓓ	15. ⓐⓑⓒⓓ
	16. ⓐⓑⓒⓓ	17. ⓐⓑⓒⓓ	18. ⓐⓑⓒⓓ	19. ⓐⓑⓒⓓ	20. ⓐⓑⓒⓓ
	21. ⓐⓑⓒⓓ	22. ⓐⓑⓒⓓ	23. ⓐⓑⓒⓓ	24. ⓐⓑⓒⓓ	

25. The complex ion which has no '*d*' electrons in the central metal atom is

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

(c) $[Cr(H_2O)_6]^{3+}$ (d) $[MnO_4]^-$

26. In nitroprusside ion, the iron and NO exist as Fe (II) and $\overset{+}{NO}$ rather than Fe(III) and NO. This can be established by

(a) estimating the concentration of iron

(b) estimating the concentration of CN^-

(c) thermally decomposing the compound

(d) measuring the solid state magnetic moment

27. In the volumetric estimation of Fe(II) with $Cr_2O_7^{2-}$ in acidic medium, $K_3[Fe(CN)_6]$ is used as an external indicator. The end point will be reached when the solution of iron salt

(a) starts giving blue colour with indicator

(b) ceases to give blue colour with indicator

(c) starts giving red colour with indicator

(d) ceases to give red colour with indicator

28. Oxidation number of Fe in violet coloured complex $Na_4[Fe(CN)_5(NO)S]$ is.

(a) 0 (b) 2

(c) 3 (d) 4

29. Complexes $[Co(NH_3)_5SO_4]Br$ and $[Co(NH_3)_5Br]SO_4$ can be distinguished by

(a) conductance measurement

(b) using $BaCl_2$

(c) using $AgNO_3$

(d) both b and c

30. The coordination number, EAN of the central metal atom and geometry of the complex ion obtained by adding $CuSO_4$ to excess of aqueous KCN are respectively

(a) 4, 35, sp^2d (b) 6, 36, sp^3d^2

(c) 4, 36, sp^2d (d) 4, 35, sp^3

31. The complex $[Fe(H_2O)_5NO]^{2+}$ ion has a magnetic moment of 3.87 B.M. This is indicative of the fact that

(a) Fe in this complex exists in + 1 oxidation state and nitrosyl as $\overset{+}{NO}$ (nitrosonium ion)

(b) The complex is octahedral in geometry as attained by sp^3d^2 hybridization.

(c) There are three unpaired electrons in the central atom which is due to transfer of odd electron of $\overset{+}{No}$ to Fe^{2+}

(d) The complex is an octahedral low spin complex with Fe in + 2 oxidation state.

32. Amongst the following ions, which one has the highest paramagnetism ?

(a) $[Cr(H_2O)_6]^{3+}$ (b) $[Fe(H_2O)_6]^{2+}$

(c) $[Zn(H_2O)_6]^{2+}$ (d) $[Cu(H_2O)_6]^{2+}$

33. $Ni(CO)_4$ and $[Ni(NH_3)_4]^{2+}$ do not differ in

(a) magnetic moment (b) oxidation number of Ni

(c) geometry (d) EAN

34. Which of the following statements is not correct?

(a) $Ti(NO_3)_4$ is a colourless compound

(b) $[Cr(NH_3)_6]^{3+}Cl_3$ is a coloured compound

(c) $K_3[VF_6]$ is a colourless compound

(d) $[Cu(NC.CH_3)_4]BF_4$ is a colourless compound.

35. Which of the following reagents can be used to distinguish Fe^{3+} and Fe^{2+} in aqueous solution

(a) $K_3[Fe(CN)_6]$ (b) KSCN

(c) $Fe_4[Fe(CN)_6]_3$ (d) a, b

36. The geometry of $Ni(CO)_4$ and $[Ni(PPh_3)_2Cl_2]$ are

(a) both square planar

(b) tetrahedral and square planar

(c) both tetrahedral

(d) square planar and tetrahedral

37. Of the following which is diamagnetic in nature ?

(a) $[CoF_6]^{3+}$ (b) $[NiCl_4]^{2-}$

(c) $[CuCl_4]^{2-}$ (d) $[Ni(CN)_4]^{2-}$

MARK YOUR RESPONSE	25. ⓐⓑⓒⓓ	26. ⓐⓑⓒⓓ	27. ⓐⓑⓒⓓ	28. ⓐⓑⓒⓓ	29. ⓐⓑⓒⓓ
	30. ⓐⓑⓒⓓ	31. ⓐⓑⓒⓓ	32. ⓐⓑⓒⓓ	33. ⓐⓑⓒⓓ	34. ⓐⓑⓒⓓ
	35. ⓐⓑⓒⓓ	36. ⓐⓑⓒⓓ	37. ⓐⓑⓒⓓ		

38. The $[Fe(CN)_6]^{3-}$ complex ion

(a) exhibits planar geometry
(b) is diamagnetic
(c) should be very stable
(d) has 2 unpaired electrons

39. 50 ml of 0.2 *M* solution of a compound with empirical formula $CoCl_3$. $4NH_3$ on treatment with excess of $AgNO_{3(aq)}$ yields 1.435g of AgCl. Ammonia is not removed by treatment with concentrated H_2SO_4. The formula of the compound is:

(a) $Co(NH_3)_4Cl_3$ (b) $[Co(NH_3)_4Cl_2]Cl$
(c) $[Co(NH_3)_4]Cl_3$ (d) $[CoCl_3(NH_3)](NH_3)_3$

40. When MnO_2 is fused with KOH, a coloured compound is formed. The product and its colour are

(a) $KMnO_4$, purple
(b) K_2MnO_4, purple green
(c) Mn_2O_3, brown
(d) Mn_3O_4, black

41. In the process of extraction of gold,

Roasted gold ore $+CN^- + H_2O \xrightarrow{O_2} [x] + OH^-$;

$[x] + Zn \longrightarrow [y] + Au$

$[x]$ and $[y]$ are :

(a) $[x] = [Au(CN)_2]^-, [y] = [Zn(CN)_4]^{2-}$
(b) $[x] = [Au(CN)_4]^{3-}, [y] = [Zn(CN)_4]^{2-}$
(c) $[x] = [Au(CN)_2]^-, [y] = [Zn(CN)_6]^{4-}$
(d) $[x] = [Au(CN)_4]^-, [y] = [Zn(CN)_4]^{2-}$

42. Amongest $[Ni(CO)_4]$, $[Ni(CN)_4]^{2-}$ and $[NiCl_4]^{2-}$

(a) $[Ni(CO)_4]$ is diamagnetic and $(NiCl_4)^{2-}$ and $[Ni(CN)_4]^{2-}$ are paramagnetic
(b) $Ni(CO)_4$ and $[Ni(CN)_4]^{2-}$ are diamagnetic and $NiCl_4^{2-}$ is paramagnetic
(c) $Ni(CO)_4$ and $NiCl_4^-$ are diamagnetic and $[Ni(CN)_4^{2-}]$ is paramagnetic
(d) $[NiCl_4^{2-}]$ and $[Ni(CN)_4]^{2-}$ are diamagnetic and $Ni(CO)_4$ is paramagnetic

43. Which of the following is non-conducting ?

(a) $CoCl_3.6NH_3$ (b) $CoCl_3.5NH_3$
(c) $CoCl_3.4NH_3$ (d) $CoCl_3.3NH_3$

44. Aqueous solution of $FeSO_4$ gives tests for both Fe^{2+} and SO_4^{2-} but after addition of excess of KCN, solution ceases to give test for Fe^{2+}. This is due to of the formation

(a) the double salt $FeSO_4.2KCN.6H_2O$
(b) $Fe(CN)_3$
(c) the complex ion $[Fe(CN)_6]^{4-}$
(d) the complex ion $[Fe(CN)_6]^{3-}$

45. Which of the following statement(s) is / are correct with reference to Fe^{2+} and Fe^{3+} ions?

(1) Fe^{3+} gives brown colour with potassium ferricyanide
(2) Fe^{2+} gives blue colour with potassium ferricyanide
(3) Fe^{3+} gives red colour with potassium thiocyanate
(4) Fe^{2+} gives brown colour with ammonium thiocyanate

(a) 1, 2 (b) 1, 4
(c) 2, 3 (d) all of these

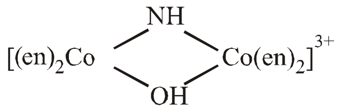
46. The number of sigma bonds in Ziese's salt is

(a) 4 (b) 6
(c) 8 (d) none of these

47. The disodium salt of ethylenediamine tetra acetic acid can be used to estimate the following ion(s) in the aqueous solution

(a) Mg^{2+} (b) Ca^{2+}ion
(c) Na^+ion (d) both Mg^{2+} & Ca^{2+}

48. The oxidation number of Co in the complex ion



is :

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

49. $[Cu(NH_3)_4]^{2+}$ has hybridisation and magnetic moment

(a) sp^3, 1.73 B.M. (b) sp^3d, 1.73 BM
(c) dsp^2, 2.83 BM (d) dsp^2, 1.73 BM

MARK YOUR RESPONSE	38. ⓐⓑⓒⓓ	39. ⓐⓑⓒⓓ	40. ⓐⓑⓒⓓ	41. ⓐⓑⓒⓓ	42. ⓐⓑⓒⓓ
	43. ⓐⓑⓒⓓ	44. ⓐⓑⓒⓓ	45. ⓐⓑⓒⓓ	46. ⓐⓑⓒⓓ	47. ⓐⓑⓒⓓ
	48. ⓐⓑⓒⓓ	49. ⓐⓑⓒⓓ			

50. $[\mathrm{FeF_6}]^{3-}$ has Fe atom ----hybridised with unpaired ------ electrons

(a) $d^2sp^3, 4$ (b) $d^2sp^3, 5$

(c) $sp^3d^2, 5$ (d) $sp^3d^2, 3$

51. Which of the following statements about $\mathrm{Fe(CO)_5}$ is correct?

(a) It is paramagnetic and high spin complex
(b) It is diamagnetic and high spin complex
(c) It is diamagnetic and low spin complex
(b) It is paramagnetic and low spin complex

52. Which of the following statements is *not* true?

(a) $[\mathrm{MnCl_4}]^{2-}$ ion has tetrahedral geometry and is paramagnetic

(b) $[\mathrm{Mn(CN)_6}]^{4-}$ ion has octahedral geometry and is diamagnetic

(c) $[\mathrm{CuCl_4}]^{2-}$ has square planar geometry and is paramagnetic

(d) $[\mathrm{Ni(Ph_3P)_2Br_3}]$ has trigonal bipyramidal geometry and one unpaired electron.

53. The increasing order of paramagnetism of

(I) $\mathrm{MnSO_4.4H_2O}$ (II) $\mathrm{FeSO_4.7H_2O}$

(III) $\mathrm{NiSO_4.6H_2O}$ and (IV) $\mathrm{CuSO_4.5H_2O}$

(a) I < II < III < IV (b) IV < III < II < I

(c) III < IV < II < I (d) III < IV < I < II

54. Which of the following statements is correct ?

(a) Geometrical isomerism is not observed in complexes of C.N. 4 having tetrahedral geometry.

(b) Square planar complexes generally do not show geometrical isomerism.

(c) The square planar complex of general formulae $\mathrm{Ma_3b}$ or $\mathrm{Mab_3}$ exhibits cis--trans isomerism

(d) The platinum glycinato complex, $[\mathrm{Pt(Gly)_2}]$ does not show geometrical isomerism.

55. Geometrical isomerism can be shown by

(a) $[\mathrm{Ag(NH_3)(CN)}]$ (b) $\mathrm{Na_2[Cd(NO_2)_4]}$

(c) $[\mathrm{Pt\,Cl_4I_2}]$

(d) $[\mathrm{Pt\,(NH_3)_3Cl][Au(CN)_4}]$

56. $[\mathrm{Co(en)_3}]^{3+}$ ion is expected to show (en– ethylenediamine)

(a) two optically active isomers : *d* and ℓ forms

(b) three optically active isomers : *d*, ℓ and meso forms

(c) four optically active isomers : *cis*, *d* and ℓ isomers and trans *d* and ℓ isomers

(d) none of these.

57. The number of geometrical isomers for octahedral $[\mathrm{Co(NH_3)_2Cl_4}]^-$, square planar $\mathrm{AuCl_2Br_2^-}$ and $[\mathrm{Co(NO_2)(NH_3)_5}]^{2+}$ are

(a) 2, 2, 2 (b) 2, 2 , no isomerism

(c) 3, 2, 2 (d) 2, 3, no isomerism

58. Which of the following statements is not true about the complex ion $[\mathrm{Cr(en)_2Cl_2}]^+$ (en = ethylene diamine)

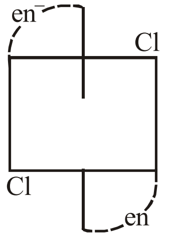
(a) It has two geometrical isomers - *cis* and trans

(b) Both the *cis* and trans isomers display optical activity

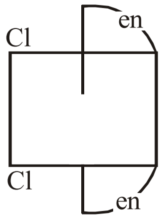
(c) Only the *cis* isomer displays optical activity

(d) Only the *cis* isomer has non-superimposable mirror image

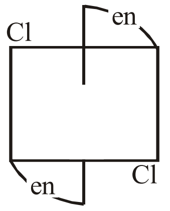
59. Of the following configurations, the optical isomers are



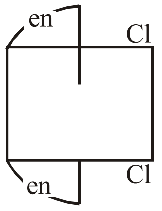
I



II



III



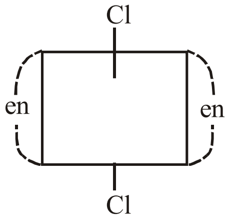
IV

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

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

MARK YOUR RESPONSE	50. ⓐⓑⓒⓓ	51. ⓐⓑⓒⓓ	52. ⓐⓑⓒⓓ	53. ⓐⓑⓒⓓ	54. ⓐⓑⓒⓓ
	55. ⓐⓑⓒⓓ	56. ⓐⓑⓒⓓ	57. ⓐⓑⓒⓓ	58. ⓐⓑⓒⓓ	59. ⓐⓑⓒⓓ

60. Identify the geometrical isomers of the following:



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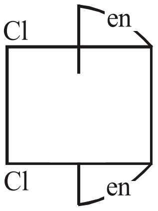
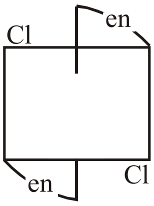
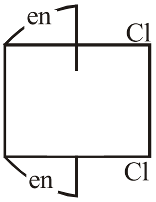


II



III



IV

(a) I with III
(b) II with IV
(c) I with II and IV
(d) none of these

61. Other than the X-ray diffractions, how could be the following pairs of isomers be distinguished from one another by

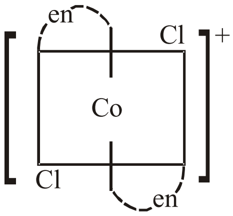
$[Cr(NH_3)_6][Cr(NO_2)_6]$ and $[Cr(NH_3)_4](NO_2)_2]$ $[Cr(NH_3)_2(NO_2)_4]$

(a) electrolysis of an aqueous solution
(b) measurement of molar conductance
(c) measuring magnetic moments
(d) observing their colours

62. How the isomeric complexes $[Co(NH_3)_6][Cr(NO_2)_6]$ and $[Cr(NH_3)_6][Co(NO_2)_6]$ can be distinguished from one another by

(a) conductivity measurement
(b) measuring magnetic moments
(c) electrolysis of their aqueous solutions
(d) optical measurement

63. Which of the following ions are optically active?



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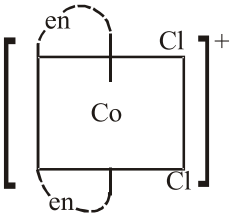

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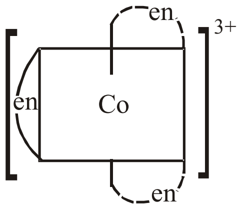
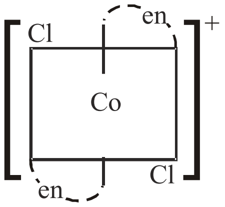


III



IV

(a) I only
(b) II only
(c) II and III
(d) IV only

64. Which of the following polymerisation isomers of the compound having empirical formula $Cr(NH_3)_3(NO_2)_3$ has the lowest molecular mass?

(a) $[Cr(NH_3)_4(NO_2)_2]^+ [Cr(NH_3)_2(NO_2)_4]^-$

(b) $[Cr(NH_3)_6]^{3+}[Cr(NO_2)_6]^{3-}$

(c) $[Cr(NH_3)_5(NO_2)]^{2+}[Cr(NH_3)(NO_2)_5]^{2-}$

(d) all

65. In Q.64, which of the isomers has the lowest molar conductance

(a) *a*
(b) *b*
(c) *c*
(d) all have equal values

66. Octahedral complex of Ni (II) must be

(a) inner orbital
(b) outer orbital
(c) inner or outer orbital depending upon the strong or weak field ligand
(d) none of these

67. Octahedral complex of Cr(III) will be

(a) sp^3d^2 in case of weak field ligand

(b) d^2sp^3 in case of strong field ligand

(c) d^2sp^3 always

(d) sp^3d^2 always

68. For the correct assignment of electronic configuration of a complex, the valence bond theory often requires the measurement of

(a) molar conductance
(b) optical activity
(c) magnetic moment
(d) dipole moment

MARK YOUR RESPONSE	60. ⓐⓑⓒⓓ	61. ⓐⓑⓒⓓ	62. ⓐⓑⓒⓓ	63. ⓐⓑⓒⓓ	64. ⓐⓑⓒⓓ
	65. ⓐⓑⓒⓓ	66. ⓐⓑⓒⓓ	67. ⓐⓑⓒⓓ	68. ⓐⓑⓒⓓ	

69. Mn^{2+} forms a complex with Br^- ion. The magnetic moment of the complex is 5.92 B.M. What would be the probable formula and geometry of the complex?

(a) $[MnBr_6]^{4-}$, octahedral

(b) $[MnBr_4]^{2-}$, square planar

(c) $[MnBr_4]^{2-}$, tetrahedral

(d) $[MnBr_5]^{3-}$, trigonal bipyramidal

70. How many isomers are possible for the complex ion $[Cr(NH_3)(OH)_2Cl_3]^{2-}$

(a) 2 (b) 3

(c) 4 (d) 5

71. A complex of certain metal has the magnetic moment of 4.91 BM whereas another complex of the same metal with same oxidation state has zero magnetic moment. The metal ion could be

(a) Co^{2+} (b) Mn^{2+}

(c) Fe^{2+} (d) Fe^{3+}

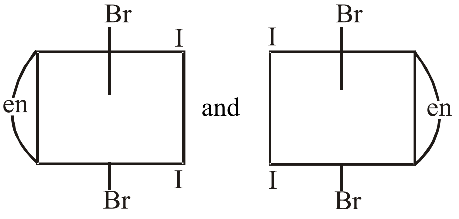
72. The tetrahedral $[CoI_4]^{2-}$ and square planar $[Pd\ Br_4]^{2-}$ complex ions are respectively

(a) low spin, high spin (b) high spin, low spin

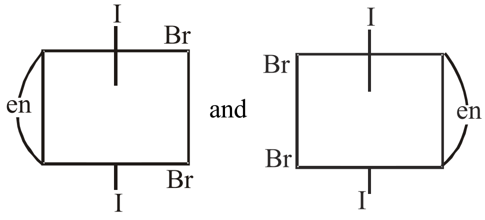
(c) both low spin (d) both high spin

73. The complex ion has two optical isomers. Their correct configurations are :

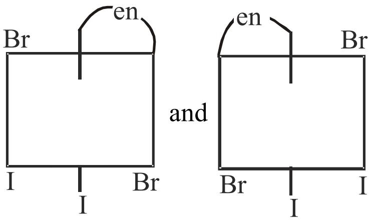
(a)



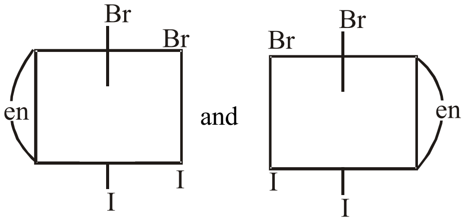
(b)



(c)



(d)



74. The EAN of metal atoms in $Fe(NO)_2(CO)_2$ and $Co_2(CO)_8$ respectively are

(a) 34, 35 (b) 34, 36

(c) 36, 36 (d) 36, 35

75. The value of x in $H_x\,Cr(CO)_5$ is

(a) 1 (b) 2

(c) 3 (4) 4

76. Following Sidwick's rule of EAN, $Co_2(CO)_x$ will be

(a) $Co_2(CO)_4$ (b) $Co_2(CO)_3$

(c) $Co_2(CO)_8$ (d) $Co_2(CO)_{10}$

77. In the reactions

$$[CoCl_2(NH_3)_4]^+ + Cl^- \rightarrow [CoCl_3(NH_3)_3 + NH_3$$

two isomers of the product are obtained. The initial complex is

(a) cis isomer (b) trans isomer

(c) cis or trans isomers (d) none of these

78. On treatment of $[Ni(NH_3)_4]^{2+}$ with concentrated HCl, two compounds I and II having the same formula, $Ni(NH_3)_2Cl_2$ are obtained. I can be converted into II by boiling with dilute HCl. A solution of I reacts with oxalic acid to form $[Ni(NH_3)_2(C_2O_4)]$ whereas II does not react. Point out the correct statement of the following

(a) I *cis*, II *trans*; both tetrahedral

(b) I *cis*, II *trans*; both square planar

(c) I *trans*, II *cis*; both tetrahedral

(d) I *trans*, II *cis*; both square planar

MARK YOUR RESPONSE	69. ⓐⓑⓒⓓ	70. ⓐⓑⓒⓓ	71. ⓐⓑⓒⓓ	72. ⓐⓑⓒⓓ	73. ⓐⓑⓒⓓ
	74. ⓐⓑⓒⓓ	75. ⓐⓑⓒⓓ	76. ⓐⓑⓒⓓ	77. ⓐⓑⓒⓓ	78. ⓐⓑⓒⓓ

79. The aqueous 0.01 *m* of $[Co(NH_{3/6}]_2[Co(NH_3)(NO_2)_5]_3$ is expected to have the depression of freezing point (K_f for water = 1.86 K/m)

(a) 0.018°C (b) 0.056°C
(c) 0.074°C (d) 0.093°C

80. Ethylenediaminetetraacetic acid (EDTA) is the antidote for lead poisoning. It is administered in the form of

(a) free acid
(b) sodium dihydrogen salt
(c) Calcium dihydrogen salt
(d) none of these

81. Which of the following ions are expected to be paramagnetic to the same extent?

I. $[FeF_6]^{3-}$ II. $[MnCl_4]^{2-}$
III. $[NiCl_4]^{2-}$

(a) I, II and III (b) I and II
(c) I and III (d) II and III

82. The coordination number of central metal atom/ion is determined by

(a) the number of sigma bonds around a metal formed by ligands
(b) the number of pi bonds around a metal formed by ligands
(c) the number of sigma and pi bonds around a metal formed by ligands
(d) the number of anionic ligands bonded to the metal ion

83. NH_3 forms complex ion $[Cu(NH_3)_4]^{2+}$ with Cu^{2+} ion in alkaline solution but not in acidic solution. This is due to the reason that

(a) in acidic solution hydration protects Cu^{2+} ions.
(b) in acidic solution proton coordinates with ammonia molecules forming NH_4^+ ions, lone pair of electrons on NH_3 is not available to be donated.
(c) in alkaline solution $Cu(OH)_2$ is precipitated which is soluble in excess of NH_3.
(d) $Cu(OH)_2$ is an amphoteric in nature.

84. Which of the following is an outer orbital complex ?

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

85. The most stable ion is

(a) $[Fe(OH)_5]^{3-}$ (b) $[FeCl_6]^{3-}$
(c) $[Fe(CN)_6]^{3-}$ (d) $[Fe(H_2O)_6]^{3+}$

86. Which of the following has the largest number of isomers?

(a) $[Co(NH_3)_5Cl]^{2+}$ (b) $[Ir(PR_3)_2(CO)]^{2+}$
(c) $[Ru(NH_3)_4Cl_2]^{+}$ (d) $[Co(en)_2Cl_2]^{+}$

87. The effective atomic number of Co in $Co(CO)_4$ is 35 and hence the complex has lesser stability. It attains the stability by

(a) oxidation of Co (b) reduction of Co
(c) dimerisation (d) tetramerisation

88. The number of geometric isomers of the complex $Cr(NH_3)_3Cl_3$ is

(a) 0 (b) 2
(c) 3 (d) 4

89. Consider the complex $[Co(NH_3)_3(NO_2)_3]$. Pick out the false statement of the following.
In cis-isomer of the complex

(a) all NH_3 groups occupy the same face of octahedron
(b) all NO_2 groups occupy the opposite face of octahedron
(c) all the like groups (either NH_3 or NO_2) do not occupy the same face.
(d) NH_3 groups occupy 1, 2, 3 positons and NO_2 groups occupy 4, 5, 6 positions.

90. A coordination complex having which one of the following descriptions would be paramagnetic to the maximum extent?

(a) d^6 (octahedral, low-spin)
(b) d^8 (octahedral)
(c) d^6 (octahedral, outer orbital)
(d) d^4 (octahedral,low-spin)

91. Consider the complex : $K_3[Co(C_2O_4)_2Cl_2]$
The coordination number, the oxidation number of Co and the number of unpaired electrons on the metal are respectively

(a) $4, +3, 6$ (b) $6, +3, 4$
(c) $6, +3, 2$ (d) $4, +1, 4$

92. Pick out the paramagnetic species of the following

(a) $Fe(CO)_5$ (b) $Cr(CO)_6$
(c) $[Fe(CN)_6]^{4-}$ (d) $[Ni(NH_3)_6]^{2+}$

MARK YOUR RESPONSE	79.ⓐⓑⓒⓓ	80.ⓐⓑⓒⓓ	81.ⓐⓑⓒⓓ	82.ⓐⓑⓒⓓ	83. ⓐⓑⓒⓓ
	84.ⓐⓑⓒⓓ	85.ⓐⓑⓒⓓ	86.ⓐⓑⓒⓓ	87.ⓐⓑⓒⓓ	88. ⓐⓑⓒⓓ
	89.ⓐⓑⓒⓓ	90.ⓐⓑⓒⓓ	91.ⓐⓑⓒⓓ	92.ⓐⓑⓒⓓ	

93. Arrange the following in the increasing order of paramagnetism :

I: $[Fe(H_2O)_6]Cl_3$

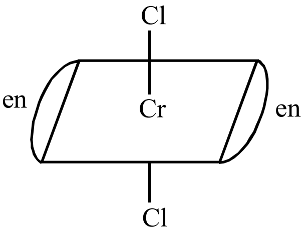
II: $K_4[Fe(CN)_6]$

III: $K_3[Fe(CN)_6]$

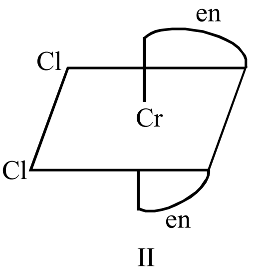
IV: $[Fe(H_2O)_6]SO_4.H_2O$

(a) I < II < III < IV (b) II < III < I < IV
(c) II < III < IV < I (d) III < II < IV < I

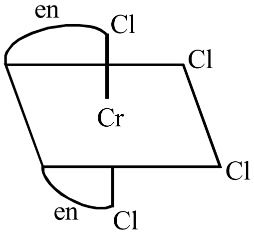
94. Which of the statements about the following structures is false ?



I



II



III

(a) I and either of the II and III are trans and cis-isomers
(b) I and II are enantiomers
(c) II and III are optical isomers
(d) I, II and III are isomers

95. Which of the following is a high spin complex ion ?

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

96. Which of the following is a spin paired complex ion ?

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

97. Which of the following complexes does not show the geometric isomerism ?

(a) $Pt(NH_3)_2Cl_2$
(b) $[Pt(NH_3)(NH_2OH)(NO_2)\ (C_6H_5N)]\ NO_2$
(c) $Pt(NH_2CH_2COO)_2$
(d) $[Cu(NH_3)_4]Cl_2$

98. The possible geometric isomers of the complex $[Pt(NH_3)(NH_2OH)(NO_2)(C_6H_5N)]\ NO_2$ are

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

99. The ion $Co(en)Cl_2Br_2^-$ is expected to have *x* isomers. *x* is

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

100. Which method can be used to distinguish $[Co(NH_3)_6][Cr(NO_2)_6]$ and $[Cr(NH_3)_6][Co(NO_2)_6]$

(a) by measurement of their conductivity
(b) by titration method
(c) by precipitation method with $AgNO_3$
(d) by electrolysis of their aqueous solutions

101. Select the complex that involves outer orbital hybridization of central metal ion.

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

102. A complex containing Mn^{2+} and Br^- ion was found to have a magnetic moment of 5.92 BM. The probable formula and geometry of the complex is most likely to be :

(a) $[MnBr_4]^{2-}$, tetrahedral
(b) $[MnBr_6]^{4-}$, octahedral
(c) $[MnBr_4]^{2-}$, square planar
(d) $[MnBr_5]^{3-}$, trigonal planar

103. A solution of '*X*' containing 0.02 mole of '*X*' per litre is mixed with another solution, a solution of '*Y*' containing 0.02 mole of '*Y*' per litre.

1 L of mixture solution + $AgNO_3 \longrightarrow 'A'\downarrow$

1 L of mixture solution + Excess $BaCl_2 \longrightarrow 'B'\downarrow$

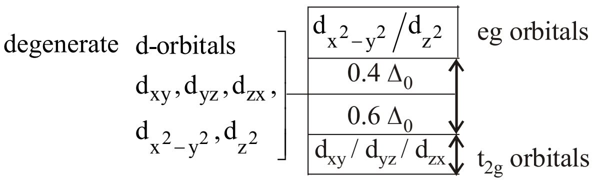
If '*X*' is $[Co(NH_3)_5SO_4]Br$, and
'*Y*' is $[Co(NH_3)_5Br]SO_4$,

then the number of moles of '*A*' and '*B*' obtained are, respectively

(a) 0.01, 0.01 (b) 0.02, 0.02
(c) 0.02, 0.01 (d) 0.01, 0.02

MARK YOUR RESPONSE	93.ⓐⓑⓒⓓ	94.ⓐⓑⓒⓓ	95.ⓐⓑⓒⓓ	96.ⓐⓑⓒⓓ	97.ⓐⓑⓒⓓ
	98.ⓐⓑⓒⓓ	99.ⓐⓑⓒⓓ	100.ⓐⓑⓒⓓ	101.ⓐⓑⓒⓓ	102.ⓐⓑⓒⓓ
	103.ⓐⓑⓒⓓ				

104. The splitting of degenerate *d*-orbitals in the formation of certain complex was observed as shown below



This type of splitting of *d*-orbitals occurs in the formation of

(a) tetrahedral complexes
(b) square planar complexes
(c) octahedral complexes
(d) In all the above type of complexes

105. Which is **not** a π-acceptor ligand ?

(a) I_3^- (b) NO^+
(c) $(CH_3)_3P$ (d) CN^-

106. A complex of a certain metal ion has a magnetic moment of 4.90 B.M. Another complex of the same metal ion in the same oxidation state has a zero magnetic moment. Which of the following could be the central metal ion in the two complexes ?

(a) Mn^{2+} (b) Fe^{3+}
(c) Fe^{2+} (d) Cr^{3+}

107. Which of the following is most acidic aqua ion ?

(a) $[Ti(H_2O)_6]^{3+}$ (b) $[Ni(H_2O)_6]^{3+}$
(c) $[Co(H_2O)_6]^{3+}$ (d) $[Fe(H_2O)_6]^{3+}$

108. Select the complex in which secondary valency is satisfied before the primary valency.

(a) RMgX (b) $[Cr(NH_3)_6]Cl_2$
(c) $K_4[Fe(CN)_6]$ (d) $Ni(CO)_4$

109. We get a copper complex with ammonia having the formula $[Cu(NH_3)_4]^{2+}$ only in alkaline solution and not in acidic solution. It can be explained on the basis of the fact that :

(a) in acidic solution, the protons forms NH_4^+ with NH_3 molecules
(b) in alkaline solution, $Cu(OH)_2$ gets precipitated and the precipitate dissolves in excess of alkali
(c) Copper hydroxide is amphoteric in nature
(d) in acidic solution, Cu^{2+} ions are protected because of hydration.

110. $[Ni(NH_3)_2]^{2+} \xrightarrow{\text{conc. HCl}} 'A' + 'B'$

The molecular formula of both '*A*' and '*B*' is same.
'*A*' can be converted to *B* by boiling in dil. HCl.
'*A*' on reaction with oxalic acid yields a complex having the formula $Ni(NH_3)_2(C_2O_4)$ but '*B*' does not.
From the above information we can say that

(a) '*A*' is square planar but '*B*' is tetrahedral
(b) '*A*' and '*B*' both are tetrahedral. '*A*' is optically active compound whereas '*B*' is optically inactive.
(c) Both '*A*' and '*B*' are square planar. '*A*' is **trans**-isomer and '*B*' is **cis**-isomer.
(d) Both '*A*' and '*B*' are square planar, '*A*' is cis-isomer and '*B*' is trans-isomer.

111. Select the complex that can be reduced most easily.

(a) $Ni(CO)_4$ (b) $Cr(CO)_6$
(c) $V(CO)_6$ (d) $Fe(CO)_5$

112. 0.001 mol of cobalt complex having molecular formula represented by $Co(NH_3)_5(NO_3)(SO_4)$ was passed through a cation exchange (RSO_3H) and the acid coming out of it was titrated with 0.1 M NaOH solution. For complete neutralization of acid coming out of cation exchanger the volume of NaOH required was 20.00 ml. From the above data we can say that the complex can be represented as

(a) $[Co(NH_3)_5](NO_3).(SO_4)$ (b) $[Co(NH_3)_5SO_4](NO_3)$
(c) $[Co(NH_3)_5(NO_3)](SO_4)$ (d) none of these

113. Three different solutions were prepared by dissolving same amounts of the following complexes I, II, III in water. The freezing points of these solutions were then determined. The correct orders of freezing points will be :

I. $[Co(NH_3)_3(NO_2)_3]$
II. $[Co(NH_3)_5(NO_2)]^{2+}[Co(NH_3)_2(NO_2)_4]_2$
III. $[Co(NH_3)_4(NO_2)_2]\,[Co(NH_3)_2(NO_2)_4]$

[Given : $K_f(H_2O) = 1.86°C/m$]

(a) I > II > III (b) III > II > I
(c) II > I > III (d) I = II = III

114. The possible number of isomers of the complex $[MCl_2Br_2]SO_4$ is

(a) 1 (b) 2
(c) 4 (d) 5

115. The correct order of ligands in the trans-directing series is

(a) $CN^- > CH_3^- > NO_2^- > Br^-$
(b) $CN^- > Br^- > NO_2^- > CH_3^-$
(c) $Br^- > NO_2^- > CN^- > CH_3^-$
(d) $CH_3^- > CN^- > NO_2^- > Br^-$

MARK YOUR RESPONSE	104.ⓐⓑⓒⓓ	105.ⓐⓑⓒⓓ	106.ⓐⓑⓒⓓ	107.ⓐⓑⓒⓓ	108.ⓐⓑⓒⓓ
	109.ⓐⓑⓒⓓ	110.ⓐⓑⓒⓓ	111.ⓐⓑⓒⓓ	112.ⓐⓑⓒⓓ	113.ⓐⓑⓒⓓ
	114.ⓐⓑⓒⓓ	115.ⓐⓑⓒⓓ			

B

COMPREHENSION TYPE

This section contains groups of questions. Each group is followed by some multiple choice questions based on a paragraph. Each question has 4 choices (a), (b), (c) and (d) for its answer, out of which ONLY ONE is correct.

PASSAGE-1

An exchange reaction is one in which ligands in the coordination sphere of a metal ion are interchanged for other ligands. Exchange reactions are observed at relatively slow rates between Co^{2+} and Co^{3+} ions. For hexaamine cobalt (III), the exchange reaction is given by Equation-1.

Equation - 1 : $Co(NH_3)_6^{3+} + Co(NH_3)_6^{2+} \rightleftharpoons Co(NH_3)_6^{2+} + Co(NH_3)_6^{3+}$

This reaction is believed to *p* proceed via the following mechanism

$$Co(NH_3)_6^{3+} + H_2O \rightleftharpoons Co(NH_3)_6^{3+} + OH^- + H^+ \text{(Fast)}$$

$$OH^- + Co(NH_3)_6^{3+} \longrightarrow Co(NH_3)_6OH^{2+} \text{(Slow)}$$

$$H^+ + Co(NH_3)_6OH^{2+} + Co(NH_3)_6^{2+} \longrightarrow Co(NH_3)_6^{2+} + H_2O + Co(NH_3)_6^{3+} \text{ (fast)}$$

The rates of reaction for this type of process are often elucidated using isotopic labeling.

Figure-1 shows how changes in pH affect the relative rate of Equaiton - 1

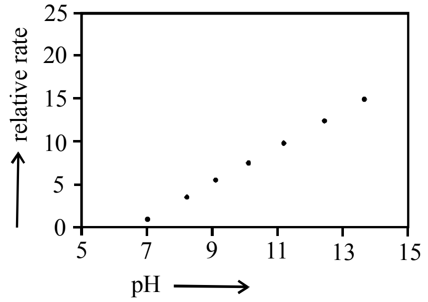


Figure - 1 Effect of pH change on Relative Rate

A chemist prepares a new solution for observation by placing 6.7 g of $Co(NH_3)_6Cl_3$ and 5.5 g of $Co(NH)_6Cl_2$ in a beaker containing 1L of water. The pH of the solution is adjusted to 9.

Mol. wt. $Co(NH_3)_6Cl_3 = 268$ g

Mol. wt. $Co(NH)_6Cl_2 = 232$ g

1. Which of the following is the correct molecular geometry of the $Co(NH_3)_6^{3+}$ complex ion?

(a) Square planar (b) Trigonal bipyramidal
(c) Octahedral (d) Tetrahedral

2. Which of the following rate laws is consistent with the mechanism given above?

(a) Rate $= k[Co(NH_3)_6^{3+}]^2$

(b) Rate $= k[H_2O]\,[Co(NH_3)_6^{3+}]^2$

(c) Rate $= k[H_2O]\,[Co(NH_3)_6^{3+}]$

(d) Rate $= k[OH^-]\,[Co(NH_3)_6^{3+}]$

3. Sodium oxide hydrolyzes in aqueous solution as follows :

$Na_2O + H_2O \longrightarrow 2NaOH$. If the chemist adds 0.0307 g Na_2O to this cobalt ammonium chloride solution, how is the relative reaction rate affected?

(a) It remians unchanged
(b) It increases by a factor of 4
(c) It increases by a factor of 2
(d) It decreases by a factor of 2

4. If the chemist now dissolves 27 g of $Co(NH_3)_6Cl_3$ and 22 g of $Co(NH)_6Cl_2$ in 1 L of water, what will be the molality of the solution?

(a) 0.2 *m* (b) 0.7 *m*
(c) 1.0 *m* (d) 2.0 *m*

5. Which of the following is the correct electronic configuration of the Co^{3+} ion?

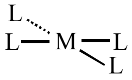
(a) $[Ar]4s^2 3d^7$ (b) $[Ar]4s^1 3d^5$
(c) $[Ar]4s^2 3d^5$ (d) $[Ar]3d^6$

PASSAGE-2

Transition metals have the ability to form a wide variety of complex ions in which other atoms or groups of atoms (called ligands) surround them in well-defined geometric shapes. When the central metal ions have partially filled *d*-orbitals, colors are often seen in the crystalline compounds or in their solutions. (Figure -1 shows three common shapes of complex ions.)

MARK YOUR RESPONSE	1. ⓐⓑⓒⓓ	2. ⓐⓑⓒⓓ	3. ⓐⓑⓒⓓ	4. ⓐⓑⓒⓓ	5. ⓐⓑⓒⓓ

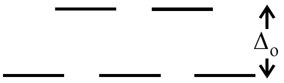
octahedral complex tetrahedral complex



square planar complex

Figure 1

Crystal field theory, and its subsequent extension ligand field theory, shows that for a metal ion surrounded by six ligands in a square bipyramidal (or octahedral) arrangement, the highest occupied *d*-orbital of the metal have energies in the "3 and 2" arrangement, as shown in Figure - 2.

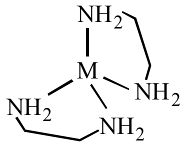


d – orbitals after ligand – field splitting

Figure 2

When determining the electronic configuration of a transition metal ion, recall that the uppermost 4*s*-electrons, for example, are removed before the 3*d* electrons in first-row transition metals, and that a similar relationship holds for later rows of transition metals.

Note that some ligands (described as bidentate) are large enough that they can bond to the central atom at two sites. An important example is ethylenediamine, $H_2NCH_2CH_2NH_2$, abbreviated en, which can bond to a central metal ion at each of its two nitrogen atoms. (See Figure-3)



M(en)$_2$tetrahedral complex

Figure 3

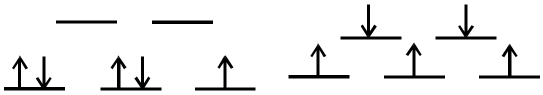
The value of the splitting factor, Δ_o, can be determined by measuring λ_{max} for absorption and converting to energy units. The magnitude of Δ_o depends not only upon the nature of the metal ion, but also upon the ligand, as the following list shows :

Patial "Spectroscopic Series"

$$I^- < Cl^- < OH^- < H_2O < NH_3 < NO_2^- < CO < CN^-$$

β "weak-field" ligands ⟶ β "strong-field" ligands

In case of mixed ligands (e.g., the $FeCl_3(CN)_3^{3+}$ ion), Δ_o is determined by the additive contributions of the ligand strengths. The size of Δ_o is critically important in determining how the energy levels are filled. An ion with five d-electrons may exhibit the configuration shown in Figure 4 (a) below ("low spin") – characteristic of large values of Δ_o. But, surprisingly, a low value for Δ_o will lead to the "high spin"configuration shown in Figure 4 (b). In the latter case, the extra energy needed to promote two electrons to the upper level is exceeded by the gain in stability that results when electrons move to separate orbitals.

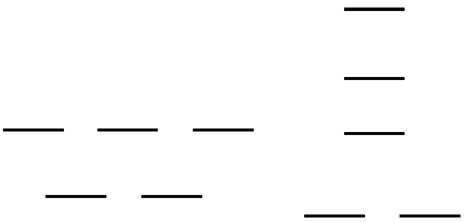


a. low - spin (due to strong - field ligands)
4 (a)

b. high - spin (due to weak - field ligands)
4 (b)

Figure 4

Although octahedral geometry is extremely common in transition metal complexes, it is the only posibility. Figure-5 shows the ordering of energy levels in tetrahedral and square planar complexes.



tetrahedral levels square-planar levels

Figure 5

Generally the ligand field splitting is low in tetrahedral complexes, which usually display high-spin configurations. The situation is reversed for square planar complexes, which display low-spin configurations.

6. Given the following data about the absorption maxima of several complex ions, what is the order of Δ_o for these ions?

Compound	λ_{max}
$[CrCl_6]^{3-}$	758
$[Cr(NH_3)_6]^{3+}$	465
$[Cr(H_2O)_6]^{3+}$	694

(a) $\Delta_o[CrCl_6]^{3-} < \Delta_o[Cr(NH_3)_6]^{3+} < \Delta_o[Cr(H_2O)_6]^{3+}$

(b) $\Delta_o[Cr(NH_3)_6]^{3+} < \Delta_o[Cr(H_2O)_6]^{3+} < \Delta_o[CrCl_6]^{3-}$

(c) $\Delta_o[CrCl_6]^{3-} < \Delta_o[Cr(H_2O)_6]^{3+} < \Delta_o[Cr(NH_3)_6]^{3+}$

(d) $\Delta_o[Cr(H_2O)_6]^{3+} < \Delta_o[Cr(NH_3)_6]^{3+} < \Delta_o[CrCl_6]^{3-}$

7. Predict the order of Δ_o for the following compounds :

I. $[\mathrm{Fe(H_2O)_6}]^{2+}$ II. $[\mathrm{Fe(CN)_2(H_2O)_4}]$

III. $[\mathrm{Fe(CN)_4(H_2O)_2}]^{2-}$

(a) $\Delta_o(\mathrm{I}) < \Delta_o(\mathrm{II}) < \Delta_o(\mathrm{III})$

(b) $\Delta_o(\mathrm{II}) < \Delta_o(\mathrm{I}) < \Delta_o(\mathrm{III})$

(c) $\Delta_o(\mathrm{III}) < \Delta_o(\mathrm{II}) < \Delta_o(\mathrm{I})$

(d) $\Delta_o(\mathrm{II}) < \Delta_o(\mathrm{III}) < \Delta_o(\mathrm{I})$

8. From the information given in the passage, what is the most likely configuration of the cobalt *d*-electrons for the species $\mathrm{CoCl_6^{3-}}$ and $\mathrm{Co(NO_2)_6^{3-}}$?

(a) $\mathrm{CoCl_6^{3-}}$: low spin; $\mathrm{Co(NO_2)_6^{3-}}$: low spin

(b) $\mathrm{CoCl_6^{3-}}$: high spin; $\mathrm{Co(NO_2)_6^{3-}}$: low spin

(c) $\mathrm{CoCl_6^{3-}}$: low spin; $\mathrm{Co(NO_2)_6^{3-}}$: high spin

(d) $\mathrm{CoCl_6^{3-}}$: high spin; $\mathrm{Co(NO_2)_6^{3-}}$: high spin

9. A chemist wants to determine the moleuclar geometry of the $[\mathrm{CoCl_4}]^{2-}$ ion. Which of the following gives the best suggestion for a measurement and for the interpretation of that measurement?

(a) Using absorption spectroscopy, measure λ_{max} then calculate Δ_o for octahedral geometry

(b) Measure the molecule's magnetic moment and use the result to estimate the number of unpaired spins in the molecule. If this number is low, the geometry is likely to be square planar; otherwise, it is likely to be tetrahedral

(c) Measure the molecule's magnetic moment and use the result to estimate the number of unpaired spins in the molcule.If this number is low, the geometry is likely to be tetrahedral; otherwise, it is likely to be square planar

(d) Measure the molecule's magnetic moment and use the result to estimate the number of unpaired spins in the molecule. If this number is low, the geometry is likely to be tetrahedral; otherwise, it is likely to be octahedral

10. Iron forms complexes such as $[\mathrm{Fe(CN)_4(H_2O)_2}]^{2-}$ when it is reacted with water and cyanide ions as ligands. If ligand X is bidentate, which of the following describes its reaction to form an octahedral complex with $\mathrm{Fe^{2+}}$ in water.

(a) $\mathrm{Fe^{2+}(aq) + X(aq) \longrightarrow FeX^{2+}(aq)}$

(b) $\mathrm{Fe^{2+}(aq) + 2X(aq) \longrightarrow FeX_2^{2+}(aq)}$

(c) $\mathrm{Fe^{2+}(aq) + 3X(aq) \longrightarrow FeX_3^{2+}(aq)}$

(d) $\mathrm{Fe^{2+}(aq) + 6X(aq) \longrightarrow FeX_6^{2+}(aq)}$

11. The equilibrium constant describing the formation of an aqueous transition metal complex containing bidentate ligands is usually much larger than the corresponding constant for a complex containing "monodentate" ligands (such as $\mathrm{Cl^-}$ or $\mathrm{H_2O}$). Which of the following best explains this generalization, taking the particular example of octahedral coordination?

(a) Since a bidentate ligand binds to two sites, the stabilizing enthalpy per ligand is about twice that which is expected for a monodentate ligand.

(b) When the bidentate lignads leave the solution to bind to the metal, entropy is reduced.

(c) When the six monodentate ligands leave the solution to bind to the metal, entropy is reduced, but is roughly balanced by the entropy increase due to the release of six water moleucles previously bound to the metal ion, keeping it in solution

(d) When the six monodentate ligands leave the soluton to bind to the metal, entropy is reduced, but is roughly balanced by the entropy increase due to the six water molecules previously bound to the metal ion, keeping it in solution. When the three bidentate ligands leave the solution to bind to the metal, entropy is reduced as well, but this reduction is more than counterbalanced by the entropy increase due to the release of six water molecules previously bound to the metal ion.

12. The oxygen carrying compound haemoglobin contains "heme" groups, each of which bind to $\mathrm{Fe^{2+}}$ through nitrogen atoms at four of its coordination sites. A nitrogen atom on the surrounding protein occupies the fifth site, leaving space for an $\mathrm{O_2}$ molecule to bind to the iron atom at the sixth site in the octahedral geometry. Which of the following is the most reasonable in light of the information presented in the passage?

(a) The CO molecule may be dangerous to humans because its position on the spectrochemical series indicates that it might bind strongly to $\mathrm{Fe^{2+}}$ and prevent other ligands from attaching.

(b) The $\mathrm{CN^-}$ ion may be dangerous to humans because it participates in high spin complexes.

(c) The $\mathrm{SCN^-}$ ion may be dangerous to humans because its position on the spectrochemical series indicates that it might bind strongly to $\mathrm{Fe^{2+}}$ and prevent other ligands from attaching.

(d) Human could be protected from the toxic effect of CO by high concentrations of chloride ion.

MARK YOUR RESPONSE	7. ⓐⓑⓒⓓ	8. ⓐⓑⓒⓓ	9. ⓐⓑⓒⓓ	10. ⓐⓑⓒⓓ	11. ⓐⓑⓒⓓ
	12. ⓐⓑⓒⓓ				

PASSAGE-3

On the basis of elemental analysis the empirical formula as also molecular formula of a chromium complex was found to be $CrN_4H_{12}Cl_2Br$. This complex could be isolated in two isomeric forms. One of these two forms was found to produce a white precipitate on reaction with $AgNO_3$ solution. The white precipitate was found to be readily soluble in dilute aqueous ammonia. The other isomer forms a yellow precipitate on reaction with $AgNO_3$ and this yellow precipitate is only partly soluble in concentrated ammonia solution.

13. The two isomeric forms of the complex are
(a) linkage isomers
(b) ionization isomers
(c) coordination isomers
(d) none of these

14. If we measure the conductivity of aqueous solutions of these two isomers the conductivity of the isomer forming white ppt with $AgNO_3$ and that forming yellow precipitate will be found to be as follows
(a) conductivity of isomer forming white precipitate with $AgNO_3$ is more than that of the other
(b) conductivity of isomer forming yellow precipitate with $AgNO_3$ will be more than the other
(c) conductivity of both the isomers will be same
(d) none of the above is correct

15. In the two isomers
(a) the oxidation state of Cr is +2
(b) the number of unpaired electrons is 3
(c) the number of unpaired electrons is 2
(d) In one there are two unpaired electrons where as in the other there are 3 unpaired electrons

PASSAGE-4

The isomerism in coordination compounds can be classified as
(i) Structural isomerism (ii) Stereo isomerism
Various types of structural isomerisms are :
(a) Ionization isomerism (b) Hydration isomerism
(c) Salt or linkage isomerism (d) Coordination isomerism

The **ionization isomerism** arises when the coordination compounds liberate different ions in solution.

i.e., $\underset{\text{'A'}}{\underset{\text{(violet)}}{[Co(NH_3)_5Br]SO_4}}$ and $\underset{\text{'B'}}{\underset{\text{(red)}}{[Co(NH_3)_5SO_4]Br}}$

The **hydration isomerism** arises when different number of water molecules are present within and outside the coordination sphere e.g.,

$\underset{\text{(violet)}}{\underset{\text{'C'}}{[Cr(H_2O)_6]Cl_3}}, \underset{\text{(green)}}{\underset{\text{'D'}}{[Cr(H_2O)_5Cl]Cl_2.H_2O}}; \underset{\text{(green)}}{\underset{\text{'E'}}{[Cr(H_2O)_4Cl_2]Cl.2H_2O}}$

Out of the three hydration isomers one does not react with conc. H_2SO_4. One of the three complexes (hydration isomers) loses 6.75% of its original weight when reacted with conc. H_2SO_4. One of the three hydration isomers loses 13.5% of its original weight when treated with conc. H_2SO_4.

16. An aqueous solution of one of the complexes (*A* to *E*) gives a white precipitate with $BaCl_2$ solution but not with $AgNO_3$ solution. This complex is
(a) *A* (b) *B*
(c) *D* (d) *C*

17. The hydration isomer that does not react with conc. H_2SO_4 is
(a) *C* (b) *D*
(c) *E* (d) Both '*D*' and '*E*'

18. The formula of hydration isomer that loses 13.5% of its original weight on reaction with conc. H_2SO_4 is
(a) $[Cr(H_2O)_6]Cl_3$ (b) $[Cr(H_2O)_5Cl]Cl_2.H_2O$
(c) $[Cr(H_2O)_4]Cl_2]Cl.2H_2O$ (d) none of these

MARK YOUR RESPONSE	13. ⓐⓑⓒⓓ	14. ⓐⓑⓒⓓ	15. ⓐⓑⓒⓓ	16. ⓐⓑⓒⓓ	17. ⓐⓑⓒⓓ
	18. ⓐⓑⓒⓓ				

C REASONING TYPE

In the following questions two Statement-1 (Assertion) and Statement-2 (Reason) are provided. Each question has 4 choices (a), (b), (c) and (d) for its answer, out of which ONLY ONE is correct. Mark your responses from the following options:

(a) Both Statement-1 and Statement-2 are true and Statement-2 is the correct explanation of Statement-1.
(b) Both Statement-1 and Statement-2 are true and Statement-2 is not the correct explanation of Statement-1.
(c) Statement-1 is true but Statement-2 is false.
(d) Statement-1 is false but Statement-2 is true.

1. **Statement-1** : Ethylenediaminetetra acetate ion forms an octahedral complex with the metal ion.
Statement-2 : It has six donor atoms which coordinate simultaneously to the metal ion.

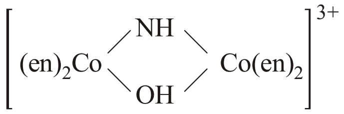
2. **Statement-1** : $[Ni(CN)_4]^{2-}$ is square planar and diamagnetic.
Statement-2 : It has no unpaired electrons due to presence of strong ligand.

MARK YOUR RESPONSE	1. ⓐⓑⓒⓓ	2. ⓐⓑⓒⓓ			

3. **Statement-1** : Oxalate ion is a bidentate ligand.
Statement-2 : Oxalate ion has two donor atoms.

4. **Statement-1** : The ligands nitro and nitrito are called ambidentate ligands.
Statement-2 : These ligands give linkage isomers.

5. **Statement-1** :



$\left[(en)_2Co\overset{NH}{\underset{OH}{\diamond}}Co(en)_2\right]^{3+}$

is named as tetrakis (ethylene diamine) μ-hydroxo-μ imido dicobalt (III) ions.
Statement-2 : In naming polynuclear complexes i.e., containing two or more metal atoms joined by bridging ligands, the word μ is added with hyphen before the name of such ligands.

6. **Statement-1** : Zeise's salt is a π-bonded organometallic compound.
Statement-2 : The oxidation number of plantinum in Zeise's salt is +2.

7. **Statement-1** : $[Ni(CO)_4]$ has square planar geometry while $[Ni(CN)_4]^{4-}$ has tetrahedral geometry.
Statement-2 : Geometry of any complex depends upon the nature of ligands attached.

8. **Statement-1** : $H_2N–NH_2$ is a chelating ligand.
Statement-2 : A chelating ligand must possess two or more lone pairs at such a distance that it may form suitable strain free rings at the metal ion.

9. **Statement-1** : Aqueous solution of potassium ferrocyanide does not give the test of iron (II).
Statement-2 : Potassium ferrocyanide is not poisonous like potassium cyanide.

10. **Statement-1** : $[FeF_6]^{3-}$ is a low spin complex.
Statement-2 : Low spin complexes have lesser number of unpaired electrons.

11. **Statement-1** : F^- ion is a weak ligand and forms outer orbital complex.
Statement-2 : F^- ion cannot force the electrons of d_{z^2} and $d_{x^2-y^2}$ orbitals of the inner shell to occupy d_{xy}, d_{yz} and d_{zx} orbitals of the same shell.

12. **Statement-1** : $[Ni(CN)_4]^{2-}$ has square planar and $[NiCl_4]^{2-}$ has tetrahedral shape.
Statement-2 : $[Ni(CN)_4]^{2-}$ is diamagnetic while $NiCl_4^{2-}$ is paramagnetic.

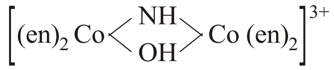
13. **Statement-1** : $[Pt(NH_3)_2Cl_2]$ is tetrahedral.
Statement-2 : The oxidation state of platinum is +2.

14. **Statement-1** : Generally the colour of complexes of different metal ions with same ligand are different.
Statement-2 : The crystal field splitting energy for different ions is different.

15. **Statement-1** : It is possible to differentiate the two isomers of the complex $[Co(NO_2)_3(NH_3)_3]$ by comparing their dipole moment values.
Statement-2 : The complex $[Co(NO_2)_3(NH_3)_3]$ shows **facial** and **meridonal** isomerism.

16. **Statement-1** : The complex $Ni(CO)_4$ is sp^3 hybridised whereas $[Ni(CN)_4]^{2-}$ is dsp^2 hybridised complex.
Statement-2 : CO is a stronger field ligand as compared to CN^-.

17. **Statement-1** : In polynuclear complexes, the bridging group is indicated in the formula of the complex by separating it from the rest of complex by hyphens and writing letter μ before its name.
Statement-2 : The complex



$\left[(en)_2\,Co<\begin{smallmatrix}NH\\OH\end{smallmatrix}>Co\,(en)_2\right]^{3+}$

is named as tetrakis (ethylene diamine) μ- hydroxo-μ imidodicobalt (III) ion or bis (ethylenediamine) cobalt (III) μ-hydroxo-μ-imido bis (ethylene diamine) cobalt (III) ion.

MARK YOUR RESPONSE	3. ⓐⓑⓒⓓ	4. ⓐⓑⓒⓓ	5. ⓐⓑⓒⓓ	6. ⓐⓑⓒⓓ	7. ⓐⓑⓒⓓ
	8. ⓐⓑⓒⓓ	9. ⓐⓑⓒⓓ	10. ⓐⓑⓒⓓ	11. ⓐⓑⓒⓓ	12. ⓐⓑⓒⓓ
	13. ⓐⓑⓒⓓ	14. ⓐⓑⓒⓓ	15. ⓐⓑⓒⓓ	16. ⓐⓑⓒⓓ	17. ⓐⓑⓒⓓ

D MULTIPLE CORRECT CHOICE TYPE

Each of these questions has 4 choices (a), (b), (c) and (d) for its answer, out of which ONE OR MORE is/are correct.

1. Which of the following statements is/ are correct ?

(a) The complex $CuCl_4^{2-}$ exists, but CuI_4^{2-} does not.

(b) A bidentate chelating ligand replaces two monodentate ligands located in *cis* positions of square planar complex.

(c) A singly bidentate chelating ligand replaces two monodentate ligands located in trans positions in square planar complex

(d) $[Fe(CN)_6]^{3-}$ is more stable than $[Fe(CN)_6]^{4-}$

MARK YOUR RESPONSE	1. ⓐⓑⓒⓓ				

2. Amongst the following which are *not* true ?

(a) EAN of iron in $Fe(C_5H_5)_2$ is 36.

(b) $[Fe(H_2O)_6]^{2+}$ has paramagnetism due to 4 unpaired electrons.

(c) $[Cr(NH_3)_6]^{3+}$ is diamagnetic.

(d) $[Co\ I_4]^{2-}$ has square planar geometry.

3. Metal *M* forms a highly coloured complex with ligand *A* and a colourless complex with ligand *B*, which has a larger formation constant than that of *M* with *A*. Concentration of *M* ion can be estimated by titration using *A* and *B* as reagents

(a) using *A* as titrant and *B* as the indicator

(b) the end point corresponds to just disappearance of colour

(c) using *B* as titrant and *A* as the indicator

(d) the end point will correspond to just disappearance of colour.

4. The species having tetrahedral shape is

(a) $[PdCl_4]^{2-}$ (b) $[Ni\ (CN)_4]^{2-}$

(c) $[Pd(CN)_4]^{2-}$ (d) $[Ni\ Cl_4]^{2-}$

5. The spin magnetic moment of cobalt in the compound $Hg[Co(SCN)_4]$ is

(a) $\sqrt{3}$ (b) $\sqrt{8}$

(c) $\sqrt{15}$ (d) $\sqrt{24}$

6. Which combination of the coordination complex and possible isomerism is/are correct ?

(a) $K[Ag(CN)_2]$, linkage

(b) $[Ag(NH_3)_2][CuCl_2]$, ionization

(c) $[CrCl(NH_3)_5]I_2$, ionization

(d) $[PtCl_4I_2]$, geometric

7. Coordination isomerism could not be shown by

(a) $[Ag(NH_3)_2][CuCl_2]$

(b) $[Al(H_2O)_6][Co(CN)_6]$

(c) $[Fe(NH_3)_6]_2[Pt(CN)_6]_3$

(d) $[Co(NH_3)_5Cl]SO_4$

8. In which of the following cases, the complex ion formed will migrate toward the anode under the electric field.

(a) Excess of aqueous KCN added to $CdSO_4$

(b) Aqueous solution of $CuSO_4$ containing excess of NH_3

(c) AgBr added to hypo solution in excess

(d) A solution of $AgNO_3$ in aqueous KCN

9. Amongst the following complexes, the chelates are

(a) bis (ethylenediamine) copper (II) ion

(b) ammonium diaminetetrathiocynato-S-chromate (III)

(c) bis (dimethyl glyoximato) iron (II)

(d) cis-diglycinato platinum (II)

10. In dimerizaion of $Co(CO)_4$ to $Co_2(CO)_8$

(a) both EAN and stability do not change

(b) EAN increases but stability decreases

(c) EAN increases from 35 to 36 and so also the stability

(d) EAN increases but the stability remains unchanged

11. Point out the correct statements amongst the following

(a) $[Cu(CN)_4]^{3-}$ has square planar geometry and sp^2d hybridization

(b) $[Ni(CN)_6]^{4-}$ is octahedral and Ni has d^2sp^3 hybridization

(c) $[Zn\ Br_4]^{2-}$ is tetrahedral and diamagnetic

(d) $[Cr\ (NH_3)_6]^{3+}$ has octahedral geometry and sp^3d^2 hybridization

12. In which of the following complexes there are d^5 configurations?

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

(c) $[Fe(H_2O)_6]^{3+}$ (d) $[MnCl_4]^{2-}$

13. In which of the following cases, the complex ion will migrate towards anode under the applied electric field?

(a) formed by adding $NH_{3(aq)}$ to AgCl

(b) formed by mixing $FeSO_{4(aq)}$ and $KCN_{(aq)}$

(c) formed by mixing $CuSO_{4(aq)}$ and $NH_{3(aq)}$

(d) formed by mixing $KCl_{(aq)}$ and $PtCl_{4(aq)}$

14. Which of the following statements is/are true?

(a) $[PtCl_2(NH_3)_4]Br_2$ will exhibit ionization isomerism

(b) $[Co(NO_2)(NH_3)_5]^{2+}$ will display linkage isomerism

(c) $[Co(NH_3)_6]\ [Cr(CN)_6]$ will exhibit coordination isomerism

(d) The oxidation number of Pt in the coordination compound $Na[Pt(C_2H_4)Cl_3]$ is +3.

15. Which of the following are weakly attracted by magnetic field?

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

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

16. Which of the following do not exhibit coordination isomerism?

(a) $[Co(NH_3)_6]\ [Cr(CN)_6]$ (b) $[Co(NH_3)_5Br]SO_4$

(c) $[Fe(NH_3)_6]_2\ [Pt(CN)_6]_3$ (d) $[Cu(NH_3)_4]\ [PtCl_4]$

MARK YOUR RESPONSE	2. ⓐⓑⓒⓓ	3. ⓐⓑⓒⓓ	4. ⓐⓑⓒⓓ	5. ⓐⓑⓒⓓ	6. ⓐⓑⓒⓓ
	7. ⓐⓑⓒⓓ	8. ⓐⓑⓒⓓ	9. ⓐⓑⓒⓓ	10. ⓐⓑⓒⓓ	11. ⓐⓑⓒⓓ
	12. ⓐⓑⓒⓓ	13. ⓐⓑⓒⓓ	14. ⓐⓑⓒⓓ	15. ⓐⓑⓒⓓ	16. ⓐⓑⓒⓓ

17. A freshly prepared aqueous solution of $Pd(NH_3)_2Cl_2$ does not conduct electricity. It suggests that
(a) the structure of the compound involves covalent bonding only
(b) the chlorine atoms must be in coordination sphere
(c) the van't Hoff factor of the compound would be unity
(d) on adding excess of aqueous $AgNO_3$ to 0.1 L of 0.1 M solution of the compound 0.02 moles of $AgCl_{(s)}$ would be obtained

18. Two compounds have empirical formulae corresponding to $Cr(NH_3)_3(NO_2)_3$ (formula mass = 241 g). In aqueous solution, one of these is a non-electrolyte while the other conducts electricity. Select the correct statements of the following :
(a) The lowest molecular mass of the conducting compound will be 241
(b) The lowest molecular mass of the conducting compound will be 482
(c) The highest molecular mass of the non-conducting compund will be 241
(d) None of these is correct

19. Which of the following type of isomerism is **not** exhibited by the complex, $[Cr(NH_3)_4Br_2]NO_2$:
(a) linkage isomerism (b) optical isomerism
(c) coordination isomerism (d) *cis-trans* isomerism

20. Select those which are **not** inner orbital complexes.
(a) $[Ni(NH_3)_6]^{2+}$ (b) $[Fe(H_2O)_6]^{3+}$
(c) $[V(H_2O)_6]^{3+}$ (d) $[Co(NH_3)_6]^{3+}$

21. Select the correct statement(s) about the stability of chelates.
(a) A chelate having five membered ring is more stable if it contains double bonds.
(b) For formation of a chelate the ligands involved must be at least bidentate.
(c) With increasing number of rings in a chelate, there is an increase in the stability of the chelate
(d) A chelate having six membered ring is more stable if it does not contain any double bonds.

22. Select the complexes that are paramagnetic in nature.
(a) $[FeF_6]^{4-}$ (b) $[Fe(CN)_6]^{3-}$
(c) $[Mn(CN)_6]^{4-}$ (d) $[Zn(NH_3)_4]^{2+}$

MARK YOUR RESPONSE	17. ⓐⓑⓒⓓ	18. ⓐⓑⓒⓓ	19. ⓐⓑⓒⓓ	20. ⓐⓑⓒⓓ	21. ⓐⓑⓒⓓ
	22. ⓐⓑⓒⓓ				

E

MATRIX-MATCH TYPE

Each question contains statements given in two columns, which have to be matched. The statements in Column-I are labeled A, B, C and D, while the statements in Column-II are labelled p, q, r, s and t. Any given statement in Column -I can have correct matching with ONE OR MORE statement(s) in Column-II. The appropriate bubbles corresponding to the answers to these questions have to be darkened as illustrated in the following example:
If the correct matches are A–p, s and t; B–q and r; C–p and q; and D–s then the correct darkening of bubbles will look like the given.

	p	q	r	s	t
A	●	ⓠ	ⓡ	●	●
B	ⓟ	●	●	ⓢ	ⓣ
C	●	●	ⓡ	ⓢ	ⓣ
D	ⓟ	ⓠ	ⓡ	●	ⓣ

1. Match the geometry and magnetic behaviour described in List II with the complex ions in List I.

Column I	**Column II**
(A) $MnCl_4^{2-}$	p. Square planar
(B) $NiCl_4^{2-}$	q. Tetrahedral
(C) $CuCl_4^{2-}$	r. Diamagnetic
(D) $Ni(CN)_4^{2-}$	s. Paramagnetic

2. Match the magnetic moments listed in column II with the electronic configurations of the complexes listed in column I :

Column I	**Column II**
(A) d^3 (octahedral)	p. 0.0 B.M.
(B) d^5 (octahedral, low spin)	q. $2\sqrt{6}$ B.M.
(C) d^6 (octahedral, low spin)	r. $\sqrt{15}$ B.M.
(D) d^6 (octahedral, outer orbital)	s. $\sqrt{3}$ B.M.

MARK YOUR RESPONSE

1.

	p	q	r	s
A	ⓟ	ⓠ	ⓡ	ⓢ
B	ⓟ	ⓠ	ⓡ	ⓢ
C	ⓟ	ⓠ	ⓡ	ⓢ
D	ⓟ	ⓠ	ⓡ	ⓢ

2.

	p	q	r	s
A	ⓟ	ⓠ	ⓡ	ⓢ
B	ⓟ	ⓠ	ⓡ	ⓢ
C	ⓟ	ⓠ	ⓡ	ⓢ
D	ⓟ	ⓠ	ⓡ	ⓢ

3. **Match the following :**

	Column I (Complexes)		**Column II (Isomers)**
(A)	$[Pt(NH_3)_2Cl_2]^{2+}$	p.	Zero
(B)	$[Cu(NH_3)_4]Cl_2$	q.	2, Geometric
(C)	$[Pt(NH_3)(NH_2OH)(NO_2)(C_6H_5N)]^+$	r.	4, Geometric
(D)	$[Co(en)Cl_2Br_2]^-$	s.	3, Geometric

4.

	Column - I		**Column - II**
A.	$[Fe(CN)_6]^{3-}$	p.	It is an inner orbital complex
B.	$[Cr(NH_3)_6]^{3+}$	q.	It is an outer orbital complex
C.	$[Ni(CN)_4]^{2-}$	r.	It shows paramagnetic behaviour
D.	$[Ni(NH_3)_6]^{3+}$	s.	It shows diamagnetic behaviour

5.

	Column - I		**Column - II**
A.	$[Cr(NH_3)_4ClBr]\ Br$	p.	optical isomers
B.	$[Cr(NH_3)_4Br_2]\ NO_2$	q.	ionisation isomers
C.	$[Cr(en)_2Cl_2]^+$	r.	linkage isomers
D.	$[Co(NH_3)_4(CO_3)(H_2O)]Cl.H_2O$	s.	geometrical isomers

MARK YOUR RESPONSE

3.

	p	q	r	s
A	ⓟ	ⓠ	ⓡ	ⓢ
B	ⓟ	ⓠ	ⓡ	ⓢ
C	ⓟ	ⓠ	ⓡ	ⓢ
D	ⓟ	ⓠ	ⓡ	ⓢ

4.

	p	q	r	s
A	ⓟ	ⓠ	ⓡ	ⓢ
B	ⓟ	ⓠ	ⓡ	ⓢ
C	ⓟ	ⓠ	ⓡ	ⓢ
D	ⓟ	ⓠ	ⓡ	ⓢ

5.

	p	q	r	s
A	ⓟ	ⓠ	ⓡ	ⓢ
B	ⓟ	ⓠ	ⓡ	ⓢ
C	ⓟ	ⓠ	ⓡ	ⓢ
D	ⓟ	ⓠ	ⓡ	ⓢ

Answerkey

A SINGLE CORRECT CHOICE TYPE

1.	c	**2.**	b	**3.**	b	**4.**	c	**5.**	d	**6.**	a	**7.**	c	**8.**	c	**9.**	d	**10.**	c
11.	d	**12.**	b	**13.**	d	**14.**	b	**15.**	a	**16.**	b	**17.**	c	**18.**	d	**19.**	c	**20.**	c
21.	b	**22.**	b	**23.**	c	**24.**	b	**25.**	d	**26.**	d	**27.**	b	**28.**	b	**29.**	d	**30.**	c
31.	d	**32.**	b	**33.**	a	**34.**	c	**35.**	d	**36.**	c	**37.**	d	**38.**	c	**39.**	b	**40.**	b
41.	a	**42.**	b	**43.**	d	**44.**	c	**45.**	d	**46.**	c	**47.**	d	**48.**	b	**49.**	d	**50.**	c
51.	c	**52.**	b	**53.**	b	**54.**	a	**55.**	c	**56.**	a	**57.**	b	**58.**	b	**59.**	c	**60.**	c
61.	b	**62.**	c	**63.**	c	**64.**	d	**65.**	a	**66.**	b	**67.**	c	**68.**	c	**69.**	c	**70.**	b
71.	c	**72.**	b	**73.**	c	**74.**	c	**75.**	b	**76.**	c	**77.**	a	**78.**	b	**79.**	d	**80.**	c
81.	b	**82.**	a	**83.**	b	**84.**	d	**85.**	c	**86.**	d	**87.**	c	**88.**	b	**89.**	c	**90**	c
91.	b	**92.**	d	**93.**	c	**94.**	b	**95.**	d	**96.**	d	**97.**	d	**98.**	b	**99.**	c	**100.**	d
101.	b	**102.**	a	**103.**	a	**104.**	c	**105.**	b	**106.**	c	**107.**	a	**108.**	d	**109.**	a	**110.**	d
111.	c	**112.**	c	**113.**	d	**114.**	c	**115.**	a										

B COMPREHENSION TYPE

1	(c)	**3**	(c)	**5**	(d)	**7**	(a)	**9**	(b)	**11**	(d)	**13**	(b)	**15**	(b)	**17**	(a)
2	(d)	**4**	(b)	**6**	(c)	**8**	(b)	**10**	(c)	**12**	(a)	**14**	(c)	**16**	(a)	**18**	(c)

C REASONING TYPE

1	(a)	**3**	(a)	**5**	(d)	**7**	(d)	**9**	(b)	**11**	(a)	**13**	(d)	**15**	(a)	**17**	(b)
2	(a)	**4**	(a)	**6**	(b)	**8**	(d)	**10**	(d)	**12**	(b)	**14**	(a)	**16**	(b)		

D MULTIPLE CORRECT CHOICE TYPE

1.	a,b,d	**2.**	c,d	**3.**	c,d	**4.**	d	**5.**	c	**6.**	a,c,d	**7.**	a,d	**8.**	a,c,d	**9.**	a,c,d	**10.**	c	**11.**	a,c
12.	c,d	**13.**	b,d	**14.**	a,b,c	**15.**	b,d	**16.**	b,c	**17.**	a,b,c	**18.**	b,c	**19.**	b	**20.**	a,b	**21.**	b,c	**22.**	a,b,c

E MATRIX-MATCH TYPE

1. **A-q, s; B-q, s; C-p, s; D-p, r**

2. **A-r; B-s; C-p; D-q**

3. **A-q; B-p; C-s; D-r**

4. **A-p, r; B-p, r; C-p, s; D-q, r**

5. **A-q, s; B-q, r, s; C-p, s; D-q, s**

Solutions

A SINGLE CORRECT CHOICE TYPE

2. **(b)** $Co(NH)_3Cl_3$ is an octahedral complex ionising in aqueous solution as :

$$[Co(NH_3)_5Cl]Cl_2 \rightarrow [Co(NH_3)_5Cl] + 2Cl^-$$

100 ml of 0.1 M

$\equiv 0.01$ mol of complex $\equiv 2 \times 0.01$ mol of AgCl

3. **(b)** 20 ml of 0.1 M NaOH

$\equiv 0.002$ mol of $H^+ \equiv 0.001$ mol of H_2SO_4

$$\underset{\text{cation exchanger}}{2R\ SO_3H} + \underset{0.001\,\text{mol}}{[Co(NH_3)_5NO_3]SO_4} \rightarrow$$

$$(RSO_3)_2[Co(NH_3)_5NO_3] + \underset{0.001\,\text{mol}}{H_2SO_4}$$

Hence, complex is $[Co(NH_3)_5NO_3]SO_4$

4. **(c)** $2Cu^{2+}_{(aq)} + 4KCN \rightarrow Cu_2(CN)_2 + (CN)_2 + 4K^+$;

$Cu_2(CN)_2 + 4KCN$

$\rightarrow 2K_2[Cu(CN)_3]$ (stable complex)

Hence, $[Cu^{2+}]$ is too small to give $CuS_{(s)}$ with H_2S.

6. **(a)** $S_2O_3^{2-}$ is monodentate ligand where as other ligands are bidentate.

8. **(c)** Mol ratio of Na, Cu and

$$F = \frac{1.08}{0.539} : \frac{0.539}{0.539} : \frac{2.16}{0.539} = 2:1:4$$

Empirical formula = Na_2CuF_4 : Van't Hoff factor (i) = 3 (given)

Hence, formula of the compound :

$$Na_2[CuF_4] \rightarrow 2Na^+ + [CuF_4]^{2-}$$

10. **(c)** $HgI_{2(s)} + 2I^-_{(aq)} \rightarrow [HgI_4]^{2-}_{(aq)}$

11. **(d)** $Ag\ Br_{(s)} + 2NH_{3(aq)} \rightarrow [Ag(NH_3)_2]Br_{(aq)}$

12. **(b)**

$PtCl_4.5NH_3$: $[Pt(NH_3)_5Cl]Cl_3 \rightarrow [Pt(NH_3)_5Cl]^{3+} + 3Cl^-$ (4 ions)

$PtCl_4.4NH_3$: $[Pt(NH_3)_4Cl_2]Cl_2 \rightarrow [Pt(NH_3)_4Cl_2]^{2+} + 2Cl^-$ (3 ions)

$PtCl_4.3NH_3$: $[Pt(NH_3)_3Cl_3]Cl \rightarrow [Pt(NH_3)_3Cl_3]^+ + Cl^-$ (2 ions)

$PtCl_4.2NH_3$: $[Pt(NH_3)_2Cl_4]$ Nonionic (no ion)

13. **(d)** Mol of $AgCl = \frac{4.305}{143.5} = 0.03$ = mol of Cl^- given by the complex.

Mol of the complex $= 100 \times 10^{-3} \times 1 = 0.01$;

$$\underset{0.01\text{ mol}}{[Cr(H_2O)_6]Cl_3} \rightarrow \underset{0.01\text{ mol}}{[Cr(H_2O)_6]^{3+}} + \underset{0.03\text{ mol}}{3Cl^-}$$

14. **(b)** N in NH_4^+ has no lone pair of electrons which it can donate to metal atom.

17. **(c)** EAN of Ni in $[Ni(CN)_4]^{2-} = 28 - 2\ (O.N) + 4 \times 2 = 34$;
EAN of Cu in $(Cu(NH_3)_4]^{2+} = 29 - 2\ (O.N) + 4 \times 2 = 35$;
EAN of Pt in $[PtCl_6]^{2-} = 78 - 4\ (O.\ N) - 6 \times 2 = 86$

18. **(d)** EAN of Fe in $(Fe(CN)_6]^{3-} = 26 - 3\ (O.\ N) + 6 \times 2 = 35$
EAN of Fe in $[Fe(CN)_6]^{4-} = 26 - 2\ (O.\ N) + 6 \times 2 = 36$
EAN of Co in $(Co(NH_3)_6]^{3+} = 27 - 3(O.N.) + 6 \times 2 = 36$
EAN of Cr in $[Cr(CrO_4)_3]^{3-} = 24 - 3\ (O.N) + 3 \times 4 = 33$
EAN of Cr in $[Cr(NH_3)_4]^{3+} = 24 - 3\ (O.\ N) + 6 \times 2 = 33$

19. **(c)** EAN of Cu in $[Cu(NH_3)_4]^{2+} = 29 - 2 + 4 \times 2 = 35$ in stead of 36.

25. **(d)** O.N. of Mn in $MnO_4^- = +7$; $Mn^{7+} = [Ar]3d^\circ 4s^\circ 4p^\circ$.

MnO_4^- is tetrahedral complex and uses sp^3 hybridisation of Mn^{7+}.It has no '*d*' electrons

26. **(d)** Fe(II) state – $3d^6$; due to strong CN^- ligand spin paired complex (d^2sp^3) will be formed .
Hence $n = 0$, $\mu = 0$ B.M
Fe(III) state $3d^5$; d^2sp^3 complex, $n = 1$, $\mu = 1.73$ B. M.

27. **(b)** Fe(II) gives blue colour with $K_3[Fe(CN)_6]$ but Fe (III) does not.

$$3Fe^{2+} + 2K_3[Fe(CN)_6] \rightarrow Fe_3[Fe(CN)_6]_2 (\text{blue}) + 6K^+$$

28. **(b)** O.N. of CN^-, NO^+ and S^{2-} are –1, + 1 and –2 respectively.

29. **(d)** $[Co(NH_3)_5Br]SO_4$ gives white precipitate of $BaSO_4$ with $BaCl_{2(aq)}$ whereas $[Co(NH_3)_5SO_4]Br$ gives yellow precipitate (AgBr) with $Ag\,NO_{3(aq)}$.

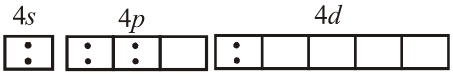
30. **(c)** $CuSO_4 + 2KCN \rightarrow Cu(CN)_2 + K_2SO_4;$

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

$Cu_2(CN)_2 + 6KCN \rightarrow K_3[Cu(CN)_4];$

O.N. of $Cu = +1$

$Cu^+(29) = (Ar)3d^{10}$

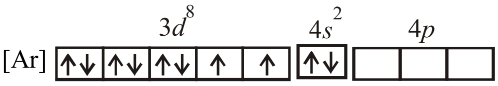


sp^2d hybridisation.

31. **(d)** Magnetic moment $= \sqrt{n(n+2)} = 3.87$ B.M $\Rightarrow n = 3$ (unpaired electrons). The comlex may be regarded as a high spin d^7 complex of Fe^+ and No^+

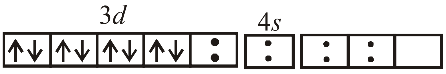
32. **(b)** Since H_2O is a weak field ligand, all the hexaaqua metal ions use sp^3d^2 hybridisation. $Cr^{3+}, Fe^{2+}, Zn^{2+}$ and Cu^{2+} have 3, 4, 0 and 1 unpaired electrons respectively.

33. **(a)** Ni(0):



Under the influence of strong field ligand CO, $Ni(0) = (Ar)3d^{10}, sp^3$ hybridisation and no unpaired electrons. $Ni(II) = [Ar]3d^8$; under the inffluence of strong field ligand NH_3,

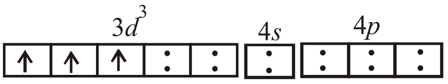
$Ni(II) = [Ar]$



; dsp^2 hybridisation and no unpaired electrons.

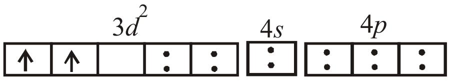
34. **(c)** Ti^{4+} has no d-electrons (colourless)

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



(d^2sp^3 hybridisation), coloured

$[VF_6]^{3-}$ i.e. V (III):



(d^2sp^3 hybridisation), coloured

$[Cu(NC.CH_3)_4]^+$ i.e;

$Cu(I): 3d^{10}$ (sp^2d hybridisation), colourless

35. **(d)** $Fe^{3+} 3KSCN \rightarrow Fe(SCN)_3$ (red coloured)

$3Fe^{2+} 2K_3[Fe(CN)_6] \rightarrow Fe_3[Fe(CN)_6]_2$

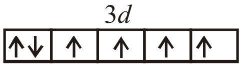
(blue coloured)

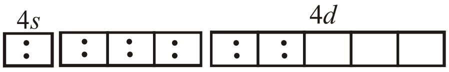
36. **(c)** $Ni(CO)_4$: tetrahedral (strong field ligand, CO, forces $4s^2$ electrons into $3d$ orbital.

$[NiP(Ph_3)_2Cl_2]$ i.e., $Ni(II): 3d^8 4s^0 4p^0$

(sp^3 hybridisation as weak field ligands $P'Ph_3$ and Cl do not force the two unpaired $3d$ electrons to be paired up.

37. **(d)** $[CoF_6]^{3-}$:

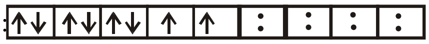




sp^3d^2

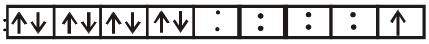
(Paramagnetic)

$[NiCl_4]^{2-}$:



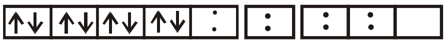
sp^3 (paramagnetic)

$[CuCl_4]^{2-}$:



dsp^2 (paramagnetic)

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



dsp^2 :

(diamagnetic)

38. **(c)** Both the high charge density of Fe^{3+} in $[Fe(CN)_6]^{3-}$ and strong basic (Lewis) character of the ligand CN^- attribute to the stability of the complex.

39. **(b)** Mol of $AgCl = \frac{1.435}{143.5} = 0.01$; 50 ml of 0.2 M complex $\equiv 0.01$ mol

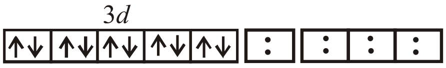
$[Co(NH_3)_4Cl_2]Cl \rightarrow [CoNH_3)_4Cl_2]^+ + Cl^-$

40. **(b)** $2MnO_2 + 4KOH + O_2(air) \rightarrow 2K_2MnO_4 + 2H_2O$

41. **(a)** $4Au + 8CN^- + 2H_2O \xrightarrow{O_2} 4(Au(CN)_2]^- + 4OH^-$

$2[Au(CN)_2]^- + Zn \rightarrow [Zn(CN)_4]^{2-} + 2Au$

42. **(b)** $[Ni(CO)_4]$:



sp^3

(diamagnetic)

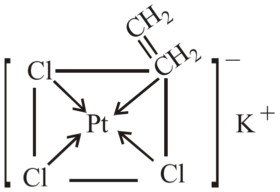
For $(NiCl_4)^{2-}$ and $[Ni(CN)_4]^{2-}$ see Q. 37

43. **(d)** $[Co(NH_3)_3Cl_3]$ is non-ionic complex.

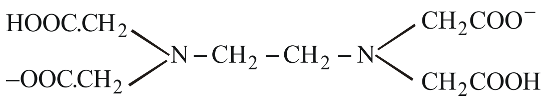
44. **(c)** $Fe\,SO_4 + 2KCN \rightarrow Fe(CN)_2 + K_2SO_4$;

$Fe(CN)_2 + 4KCN \rightarrow K_4[Fe(CN)_6]$

45. **(d)** Ziese salt :



47. **(d)** Disodium salt of ethylenediaminetetraacetic acid (EDTA)



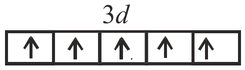
(say $Na_2H_2Y.2H_2O$)

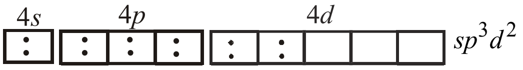
forms complexes with all metals with the exception of alkali metals.

$Na_2H_2Y + Ca^{2+} \rightarrow CaY + 2H^{2+} + 2Na^+$

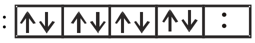
49. **(d)** $[Cu(NH_3)_4]^{2+}$: dsp^2 (one unpaired electron)

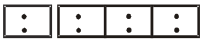
50. **(c)** $[FeF_6]^{3-}$:





51. **(c)** $Fe(CO)_5$:





dsp^3 strong field ligand CO forces $4s^2$ electrons shifted to $3d$ orbital.

52. **(b)** $[MnCl_4]^{2-}$: Mn (II) – $3d^5$, sp^3 (tetrahedral, n = 5, paramagnetic)

$[Mn(CN)_6]^{4-}$: Mn (IV) – $3d^5$, d^2sp^3 (octahedral, n = 1, paramagnetic)

$[CuCl_4]^{2-}$: Cu (II) – $3d^9$, dsp^2 (square planar, n =1, paramagnetic)

$[Ni(Ph_3P)_2Br_3]$: Ni (III) – $3d^7$, dsp^3 (trigonal bipyramidal, n = 1, paramagnetic)

53. **(b)** Mn^{2+} – $3d^5$ (5 U.P. electron) ; Fe^{2+} – $3d^6$ (4 U.P. electrons)

Ni^{2+} – $3d^8$ (2 U.P. electrons); Cu^{2+} – $3d^9$ (1. U.P. electron)

58. **(b)** The trans isomer and its mirror image are superimposable.

61. **(b)** The former would conduct as a (3+ and 3–) electrolyte while the latter would conduct as (1+ and –1) electrolyte.

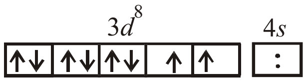
62. **(c)** In former case, cobalt (III) complex $[Co(NH_3)_6]^{3+}$ ion migrates toward the negative electrode where cobalt would be deposited. In the other case, chromium would be deposited at the negative electrode.

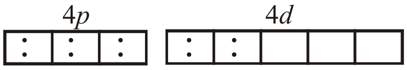
63. **(c)** Ions I and IV are the same (*trans*), with mirror plane through en groups.

64. **(d)** All are dimer isomers of the compound $Cr(NH_3)_3(NO_2)_3$.

65. **(a)** For number of ions being equal, smaller are the charges on ions, the smaller will be the conductivity.

66. **(b)** Ni^{2+} :





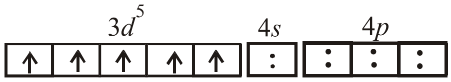
Since only one $3d$ orbital can be made available by pairing of electrons, there can not be inner orbital d^2sp^3 hybrisation. The possible octahedral hybridisation is sp^3d^2 using outer d-orbitals.

67. **(c)** Cr(III) has three $3d$ unpaired electrons with two vacant orbitals available for bonding. The outer orbital bonding is not required.

68. **(c)** Electron pairing is necessary in some cases of inner orbitals bonding. The magnetic moment indicates the orbitals (inner or outer) being used is complexation.

69. **(c)** Magnetic moment, $\sqrt{n(n+2)} = 5.92$ B.M. $\Rightarrow n$ (unpaired electrons) = 5

Mn^{2+} :



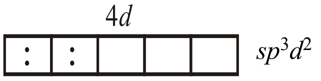
sp^3 hybridization (tetrahedral)

70. **(b)** Three: (1) all *cis*,

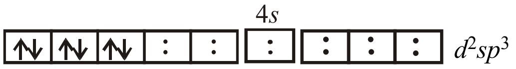
(2) Cl, OH *trans* (3) Cl *trans*, OH *cis*

71. **(c)** $\sqrt{n(n+2)} = 4.91$B.M $\Rightarrow n = 4$(unpaired electrons).

4 unpaired electrons in Fe^{2+} :



No unpaired electrons :



74. **(c)** $[Fe(NO)_2(CO)_2]$: 26 electrons of $Fe + 6$ electrons from 2NO molecules and 4 electrons from 2CO molecules = 36

$Co_2(CO)_8$: 27 electrons of Co + 1 electron shared from another Co atom + 8 electrons from 4 CO molecules = 36

75. **(b)** x electrons shared from x H atoms + 24 electrons of Cr atom + 10 electrons from 5 CO molecules $= 36$ (EAN) $\Rightarrow x = 2$

76. **(c)** $\text{EAN} = 36 = 27$ electrons of Co atom + 1 electron shared from another Co atom $+\frac{1}{2} \times 2x$ electrons of from x CO molecules $\Rightarrow x = 8$

77. **(a)** The initial complex must have two Cl^- ions in cis position as the third Cl^- ion could replace an ammonia cis to both or trans to one giving two isomers.If two Cl^- ions were in the trans positions, the other four positions which could be replaced are equivalent and only one isomer of the product would be obtained.

78. **(b)** Only cis isomer can easily form a chelate ring with oxalate group; the trans isomer can not form a chelate ring. Both are square planar.

79. **(d)** The compound dissociates into 5 ions as :

$$[Co(NH_3)_6]_2[Co(NH_3)(NO_2)_5]_3 \rightarrow$$

$$2[Co(NH_3)_6]^{3+} + 3[Co(NH_3)(NO_2)_5]^{2-}$$

The effective molality

$= 0.01 \times 5 = 0.05;\ \Delta T_f = 1.86 \times 0.05 = 0.093°C$

80. **(c)** EDTA forms a more stable coordination complex with lead than with calcium or sodium and in this form passes out from the body without harmful effects. The calcium salt is used so that any excess of EDTA will not remove Ca^{2+} ions from the body.

81. **(b)** $[FeF_6]^{3-}$: Fe (III) – $3d^5$; high spin complex (sp^3d^2), $n = 5$

$[MnCl_4]^{2-}$: Mn (II) – $3d^5$, high spin complex (sp^3), $n = 5$

$[NiCl_4]^{2-}$: Ni (II) – $3d^8$; high spin complex (sp^3), $n = 2$

84. **(c)** $[Fe(CN)_6]^{4-}$: Fe (II) – $3d^6$; inner orbital complex (d^2sp^3) ; $n = 0$

$[Mn(CN)_6]^{4-}$: Mn (II) – $3d^5$; inner orbital complex (d^2sp^3) ; $n = 1$

$[Co(NH_3)_6]^{3+}$: Co (III) – $3d^6$; inner orbital complex (d^2sp^3) ; $n = 0$

$[Ni(NH_3)_6]^{2+}$: Ni (II) – $3d^8$; NH_3, a strong ligand, can not make two $3d$-orbitals available by forcing the electrons paired up. Hence, outer orbital complex (sp^2d^2) ; $n = 2$

85. **(c)** OH^- and CN^- ions are strong nucleophiles (ligands) but $[Fe(OH)_5]^{3-}$ does not exist.

86. **(d)** (a) No isomer

(b) No isomer

(c) Two isomers – *cis* (Cl^- ions occupying 1, 2 positions) and *trans* (Cl^- ions occupying 1, 6 positions).

(d) Two geometric isomers, *cis* (1, 2) and *trans* (1, 6); *cis*-isomer exists in two optical modifications (*d* & *l*)

88. **(b)** Two isomers, *cis* and *trans*; in *cis*-isomer all NH_3 groups occupy one face of the octahedron and hence Cl atoms occupy another (opposite face).

90. **(c)** (a) $d^6 : d^2sp^3\ (n = 0)$ (b) $d^8 : sp^3d^2\ (n = 2)$

(c) $d^6 : sp^3d^2\ (n = 4)$ (d) $d^4 : (d^2sp^3)\ (n = 2)$

91. **(b)** $C_2O_4^{2-}$ is bidentate and Cl^- is monodentate ligand.

Hence, C. N. $= 2 \times 2 + 2 \times 1 = 6$

x (O. N. of Co) $+ 2(-2) + 2(-1) = -3 \Rightarrow x = +3$

Both $C_2O_4^{2-}$ and Cl^- are weak field ligands and hence form outer orbital (high spin) complex. Co (III) : $3d^6\ (n = 4)$

92. **(d)** (a) Fe (0) : $3d^6 4s^2$. CO is a strong field ligand and hence forces $4s^2$ electrons to shift and pair up into $3d$. Thus, dsp^3 geometry and $n = 0$.

(b) Cr (0) : $3d^5 4s^1 \rightarrow 3d^6$ (under the influence of strong ligand CO; d^2sp^3 hybridization ($n = 0$)

(c) Fe (II) : $3d^6$; d^2sp^3 hybridization (CN^-– strong ligand), $n = 0$

(d) Ni (II) : $3d^8$; sp^3d^2 complex (no availability of two vacant $3d$ orbtials), $n = 2$

93. **(c)** H_2O is a weak nucleophile (ligand) and CN^- is a strong nucleophile.

95. **(d)** Co (II) - $3d^7$: Two vacant $3d$ orbitals can not be made available by pairing up electrons.

96. **(d)** (a) & (b) Cr (III) – $3d^3$: d^2sp^3 (no pairing up);

(c) Fe (III) – $3d^5$: sp^3d^2 (high or free spin complex, $C_2O_4^{2-}$ being a weak ligand)

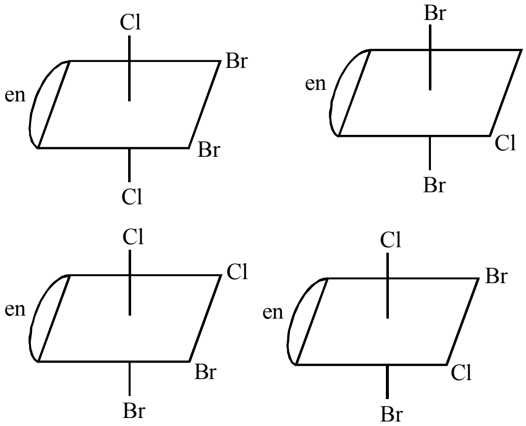
(d) Co (III) – $3d^6$: d^2sp^3 (low or paired spin complex, NH_3 being a strong ligand)

97. (d) (a) square planar - *cis* and trans isomers

(b) square planar - 3 isomers (while NH_3 at position 1, groups NH_2OH , NO_2 and C_6H_5N can occupy position 3.

(c) 2 isomers (*cis* and *trans*)

99. (c)



100. (d) The given compounds are isomeric. They can be distinguished by electrolysis of their aqueous solution. On electrolysis of its aqueous solution the complex ions of cobalt [i.e., $\{Co(NH_3)_6\}^{3+}$] of the complex $[Co(NH_3)_6][Cr(NO_2)_6]$ moves towards cathode (i.e., negative electrode) and on this electrode finally cobalt would be deposited.

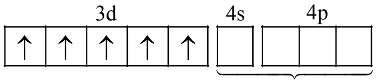
On electrolysis of aqueous solution of the complex ion of chromium [i.e., $\{Cr(NH_3)_6\}^{3+}$] of the complex $[Cr(NH_3)_6][Co(NO_2)_6]$ moves towards cathode (i.e., negative electrode) and on this electrode chromium would finally be deposited.

101. (b) In $[Zn(NH_3)_6]^{2+}$, Zn is in +2 state.

Zn^{2+}; $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10}$

102. (a) Since the complex has a magnetic moment 5.92 B.M. So it has 5 unpaired electrons. [$\mu = \sqrt{n(n+2)}$]

In Mn^{2+} the electronic configuration is $3d^5$ i.e.,



It will show sp^3 hybridisation and geometry will be tetrahedral.

103. (a) The total volume of mixture solution = 2 L(1L + 1L = 2L)

Moles of '*X*' i.e., $[Co(NH_3)_5SO_4]Br$ is 0.02 moles i.e., it is 0.01 mole/L

Similarly moles of '*Y*' i.e., $[Co(NH_3)_5Br]$ is also 0.01 mole/L.

1 L of solution $$\underset{0.01\text{ mole}}{[Co(NH_3)_5Br]SO_4} \xrightarrow[\text{(excess)}]{BaCl_2}$$

$$[Co(NH_3)_5Br]^{2+} + \underset{0.01\text{ mole}}{BaSO_4\downarrow}$$

1 litre of solution : 0.01 mole.

104. (c) The type of splitting occurs in strong ligand field complexes.

105. (b) NO^+ is not a π-acceptor ligand, because in it nitrogen atom has no vacant orbital to accomodate electron pair from the central metal atom.

106. (c) Since the magnetic moment of the complex is 4.90 BM so it contains 4 unpaired electrons $\mu = \sqrt{n(n+2)}$ in its oxidation state of the complex.

Since another complex of the same metal ion in the same oxidation state shows zero magnetic moment, so in this complex there is no unpaired electron.

To have either four or zero unpaired electrons in the complexes of the metal in this oxidation state is d^6.

Mn $3d^5 4s^2$; Mn^{2+}; $3d^5$
Fe $3d^6 4s^2$; Fe^{3+}; $3d^5$
Fe $3d^6 4s^2$; Fe^{2+}; $3d^6$
Cr $3d^5 4s^1$; Cr^{3+}; $3d^3$

i.e., the correct option is Fe^{2+}.

107. (a) $[Ti(H_2O)_6]^{3+}$ is the most acidic of those.

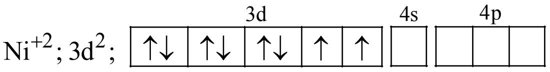
108. (d) In metal carbonyls the oxidation state of metal is zero. In this case oxidation state of Ni is zero.

109. (a) Since the NH_3 molecules form NH_4^+ ion in acidic solution, so NH_3 molecules are not available for formation of complex ion $[Cu(NH_3)_4]^{2+}$ and thus the complex is not formed.

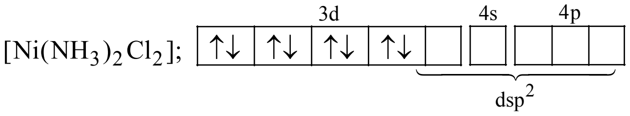
110. (d) $$[Ni(NH_3)_2]^{2+} \xrightarrow{\text{conc. HCl}}$$

$$[Ni(NH_3)_2Cl_2] + [Ni(NH_3)_2]Cl_2$$

In this complex the oxidation state of Ni is +2.



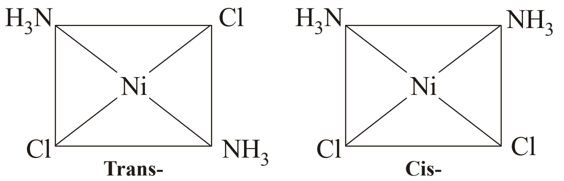
In complex $[Ni(NH_3)_2Cl_2]$, dsp^2 hybridisation takes place



(Strong field ligand)

Thus the complex is square planar.

The two isomer of this complex are



The *cis*-isomer can easily form a chelate ring with oxalate group.

The *cis*-isomer can be converted to *trans*-isomer on boiling with dil. HCl. Hence '*A*' is cis-isomer and '*B*' is trans-isomer.

111. (c) In it the E.A.N. of V is 35(23 + 12 = 35) so it can be reduced easily.

In all other cases the E.A.N. is 36.

112. (c) It is clear that the acid coming out of cation exchanger requires 20.0 ml of 0.1 M NaOH.

Now, 20 ml of 0.1 M NaOH $\equiv 20 \times 0.1$ mol of H^+

$\equiv 0.002$ mol of H^+

$\equiv 0.001$ mol of H_2SO_4.

$$\underset{\substack{\text{(Cation}\\\text{exchanger)}}}{2RSO_3H} + \underset{0.001\text{ mol}}{[Co(NH_3)_5NO_3]SO_4} \longrightarrow$$

$$\underset{\text{cation}}{[Co(NH_3)_5NO_3](RSO_3)_2} + \underset{0.001\,\text{mol}}{H_2SO_4}$$

113. (d) In each case same number of mole particles are formed so ΔT_f is same.

$$I = \frac{W \times 1}{248} = 'X'\text{mol} \qquad \text{(Only 1 particle formed)}$$

$$II = \frac{W}{744} \times 3 = \frac{W}{248} = 'X'\text{mol} \qquad \text{(3 ions formed)}$$

$$III = \frac{W \times 2}{496} = \frac{W}{248} = 'X'\text{mol} \qquad \text{(2 ions formed)}$$

114. (c)

115. (a) The **trans-effect** may be defined as the labelization of ligands trans- to the other trans-directing ligand.

[Note : The order of ligands in the trans-directing series is as follows :

$CN^- \sim CO \sim NO \sim H^- > CH_3^- \sim SC(NH_2)_2 \sim PR_3 > SO_3H > NO_2^- \sim I^- \sim SCN^- > Br^- > Cl^- > Py > RNH_2 \sim NH_3 > OH^- > H_2O$]

B COMPREHENSION TYPE

1. (c) The six secondary valencies (= C.N. of the complex ion) tend to orient in the space as far as possible giving rise to octahedral geometry.

2. (d) The slowest step is the rate determining step. Hence,

$$\text{Rate} = k[OH^-][Co(NH_3)_6^{3+}]$$

3. (c) Number of moles of Na_2O added

$$= \frac{\text{Mass of } Na_2O\text{ (g)}}{\text{Molar mass}} = \frac{0.0307}{62} = 0.5 \times 10^{-3}$$

Moles of OH^- added $= 2 \times 0.5 \times 10^{-3} = 1 \times 10^{-3}$

Hence, $[OH^-]_{\text{final}} = 1.0 \times 10^{-5}$ (initial) + 1×10^{-3} (added) $= 1.01 \times 10^{-3}\,\text{molL}^{-1}$

$$(p^{OH})_{\text{final}} = -\log 1.01 \times 10^{-3} \approx 3,\ pH = 14 - 3 = 11$$

According to the Fig- 1, the relative rate corresponding to pH 11 is 10 whereas for initial pH it is 5, i.e., the relative rate increases by a factor of 2.

4. (b) Molality of $Co(NH_3)_6Cl_3 = \dfrac{\text{Moles}}{\text{Mass of water (kg)}}$

$$= \frac{27/268}{\text{volume(L)}} = \frac{27}{268 \times 1} = 0.1$$

$$Co(NH_3)_6Cl_2 = \frac{23}{232 \times 1} = 0.1$$

$$\left[Co(NH_3)_6\right]Cl_{3(aq)} \longrightarrow \left[Co(NH_3)_{6(aq)}\right]^{3+} + 3Cl^-_{(aq)};$$

$$\left[Co(NH_3)_6\right]Cl_{2(aq)} \longrightarrow \left[Co(NH_3)_{6(aq)}\right]^{2+} + 2Cl^-_{(aq)}$$

Hence, total molality of all the species = 0.1 × (1 + 3) + 0.1 (1 + 2) = 0.7

5. (d) Electronic configuration of Co (27) = $[Ar]3d^7 4s^2$

For the formation of Co^{3+}, 2 electrons are lost from 4s-subshell and one electron from 3d subshell. Hence, configuration of Co^{3+} is $[Ar]3d^6$.

6. (c) The value of spilitting factor, Δ_o, is inversely related to the wavelength of maximum absorption, $\lambda_{\max}$,

$$\left(E = h\upsilon = \frac{hc}{\lambda}\right)$$

7. (a) The value of Δ_o for mixed ligands depends on the additive contributions of the ligand strengths. Since CN^- has greater ligand strength than H_2O, the strength increases as the number of CN^- ions increases.

8. (b) Weak field ligands (like Cl^-) giving low value of Δ_o form high spin octahedral complexes whereas strong field ligands (like NO_2^-) give rise to low spin (spin paired) complexes.

9. (b) In the complexes of C.N. 4, square planar geometry gives rise to low spin (spin paired) configurations whereas tetrahedral complexes display high spin configurations.

10. (c) A bidentate ligand has two sites per molecule, so three such ligands will coordinate to one Fe^{2+} ion to give octahedral coordination (six ligands sites).

12. (a) CO is a strong field ligand and hence it is difficult to dislodge from the iron atom in the heme group.

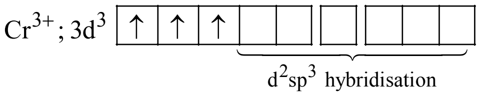
13. (b) In ionization isomers different ions are liberated in the solution. Since the two isomers react differently with $AgNO_3$, so they liberate different ion in solution and thus are ionization isomers.

14. **(c)** The two isomers are ionisation isomers and they may be represented as

$$\underset{'A'}{[Cr(NH_3)_4Cl_2]Br} \text{ and } \underset{'B'}{[Cr(NH_3)_4BrCl]Cl}$$

'*A*' forms yellow precipitate of AgBr with $AgNO_3$. '*B*' forms white precipitate of AgCl with $AgNO_3$. Since in solution both the isomers produce 2 ions, so their aqueous solutions will show approximately same conductivity.

15. **(b)** In both chromium is in +3 oxidation state and the number of unpaired electrons is three.



16. **(a)** '*A*' gives a white precipitate of $BaSO_4$ on reaction with $BaCl_2$ but no precipitate is formed with $AgNO_3$ solution.

17. **(a)** $[Cr(H_2O)_6]Cl_3$ will not react with conc. H_2SO_4 to lose water molecules. In it all molecules of water are in co-ordination sphere.

18. **(c)** This compound contains two water molecules and these are lost on reaction with conc. H_2SO_4. This is about 13.5% loss of its original weight.

Original mass of 1 mole of $[Cr(H_2O)_4Cl_2]Cl.2H_2O$

$$= 52 + 108 + 106.5 = 266.5$$

Loss of mass of 2 mole of H_2O in $[Cr(H_2O)_4Cl_2]Cl.2H_2O$

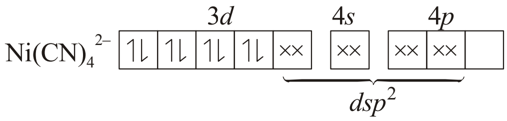
$$= 2 \times 18 = 36$$

$$\% \text{ loss of mass } = \frac{36}{266.5} \times 100 = 13.5$$

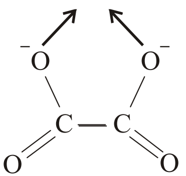
C REASONING TYPE

1. **(a)** Reason is the correct explanation of Assertion.

2. **(a)** $Ni \rightarrow 3d^8 4s^2$; $Ni^{2+} \rightarrow 3d^8 4s^0$

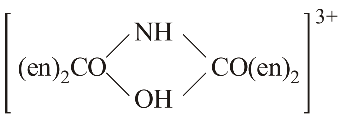


3. **(a)** Ligands which can co-ordinate to the central metal atom or ion through two donor atoms are known as bidentate ligands, e.g. oxalate ion.



oxalate ion

4. **(a)** When a monodentate ligand has two possible donor atoms and attached in two ways to the central metal atom are called ambidentate ligands.

5. **(d)** 

$$\left[(en)_2CO \underset{OH}{\overset{NH}{\diamond}} CO(en)_2\right]^{3+}$$

is named as tetrakis (ethylene diamine)-μ-hydroxo-μ-imido dicobalt (III) ion. For more than one bridging group the word μ is repeated before each bridging group.

6. **(b)** In these complexes, the metal and ligand form a bond that involves the π-electrons of the ligand and so it is a π-bonded organometallic compound.

7. **(d)** $Ni(CO)_4$ has tetrahedral geometry and $[Ni(CN)_4]^{4-}$ has square planar geometry. $[Ni(CO)_4]$ possesses sp^3 hybridization whereas $[Ni(CN)^{4-}$ has dsp^2 hybridization to show square planar geometry.

8. **(d)** $H_2N\ NH_2$ does not act as chelating ligand. The coordination by hydrazine leads to a three member highly unstable strained ring and thus it does not act as chelating agent.

9. **(b)** Being a complex salt, potassium ferrocyanide ionises to $4K^+$ and $[Fe(CN)_6]^{4-}$ ions. Absence of Fe(II) does not give the test of iron.

10. **(d)** $[FeF_6]^{3-}$ is a high spin complex since F^- is a weak ligand.

11. **(a)** Reason is the correct explanation of Assertion.

12. **(b)** In $[NiCl_4]^{2-}$, the Cl^- ligands present in the complex ion are less basic than CN^-. As such no pairing of electrons in the 3*d*-subshell takes place. This results in sp^3 hybridisation and the complex so formed is tetrahedral. On the other hand in case of $[Ni(CN)_4]^{2-}$ the CN^- ligands present in the complex ion are more basic than Cl^-. As such pairing of electrons can take place in the 3*d* subshell. Due to pairing of electrons in 3*d* subshell, one of the *d*-orbital becomes vacant. This results in dsp^2 hybridisation and the complex so formed is square planar.

13. **(d)** The outer electronic configuration of platinum in ground state is $5d^96s^1$. The Pt^{2+} ion formed by the loss of two electrons has outer electronic configuration of $5d^8$. In presence of strong ligands (NH_3 molecules) two unpaired electrons in 5*d* subshell pair up. This is followed by dsp^2 hybridisation resulting in the formation of four hybridised vacant orbitals which accommodate four pairs of electrons from four ligands (two from ammonia and two from Cl^-). As such the resulting complex is square planar.

14. **(a)** Both assertion and reason are correct and reason is the correct explanation of assertion.

15. **(a)** Both assertion and reason are correct and reason is the correct explanation of assertion.

16. **(b)** Assertion is true, reason is true but is not correct explanation of assertion.

17. **(b)** Both assertion and reason are correct. Reason is **not** correct explanation of assertion. It is an illustration of assertion.

D MULTIPLE CORRECT CHOICE TYPE

1. (a, b, d) (a) Cu^{2+} is reduced to Cu^+ by I^- but not by Cl^-.

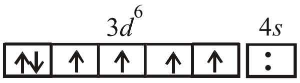
$Cu^{2+} + I^- \rightarrow CuI$; $CuI + 3I^- \rightarrow [CuI_4]^{3-}$

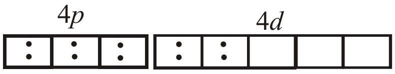
(c) The trans positions are too distant for a five-atom chain bidentate ligand to span.

(d) Fe (III) in $[Fe(CN)_6]^{3-}$ has greater charge density than Fe(II) in $Fe(CN)_6]^{4-}$; hence the former has greater stability than the latter.

2. (c, d) (a) In $[Fe(C_5H_5)_2$, EAN of $Fe = 26$ electron of $Fe + 10$ electron from two $C_5H_5^-$ ions

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

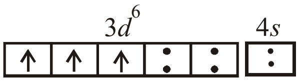


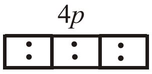


sp^3d^2

(($\because H_2O$ a weak field ligand)

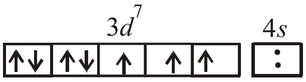
(c) $[Cr(NH_3)_6]^{3+}$:

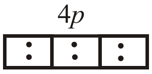




d^2sp^3 (3 unpaired electrons)

(d) $[CoI_4]^{2-}$:



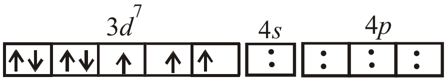


sp^3 (tetrahedral)

3. (c, d) Titrant *B* will react with the coloured complex of *M* and *A* when no free metal ion is left to react with *B*. Due to the dissociation of the complex of *M* with *A*, the colour will disappear indicating the end point of the titration.

4. (d) $[PdCl_4]^{2-}, [Pd(CN)_4]^{2-}$ and $[Ni(CN)_4]^{2-} : dsp^2$ hybridisation (square planar) ; $[NiCl_4]^{2-} : sp^3$ hybridisation (tetrahedral)

5. (c) Co(II) in the complex :



(sp^3)

magnetic moment $= \sqrt{3(3+2)} = \sqrt{15}$ BM.

8. (a, c, d) (a) $CdSO_4 + 4KCN \rightarrow K_2([Cd(CN)_4] + K_2SO_4$; complex ion : $[Cd(CN)_4]^{2-}$

(b) $CuSO_4 + 4NH_3 \rightarrow [Cu(NH_3)_4]SO_4$;
complex ion : $[Cu(NH_3)_4]^{2+}$

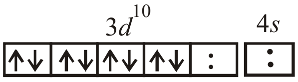
(c) $AgBr + 2Na_2S_2O_3 \rightarrow Na_3[Ag(S_2O_3)_2] + NaBr$;
complex ion : $[Ag(S_2O_3)_2]^{3-}$

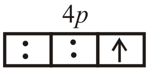
(d) $AgNO_3 + 2KCN \rightarrow K[Ag(CN)_2] + KNO_3$;
complex ion : $[Ag(CN)_2]^-$

10. (c) $Co(CO)_4$: EAN $= 27 + 8$ electrons from 4 CO molecules $= 35$

$Co_2(CO)_8$: EAN $= 27$ electrons of Co atom + 1 electron shared from another Co atom + 8 electrons from 4 Co molecules $= 36$

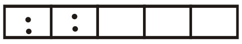
11. (a, c) $[Cu(CN)_4]^{3-}$:





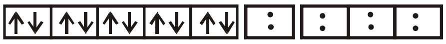
dsp^2 hybridization

$[Ni(CN)_6]^{2-}$:



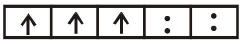
sp^3d^2 hybridization

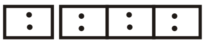
$[ZnBr_4]^{2-}$:



sp^3 hybridization

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





d^2sp^3 hybridization (always)

12. (c,d) (a) Fe(III) : $3d^1$; d^2sp^3 (paired spin complex, CN^- being a strong ligand)

(b) Fe(II) : $3d^0$; d^2sp^3 (paired spin complex)

(c) Fe(III) : $3d^5$; sp^3d^2 (free spin complex, H_2O being a weak ligand)

(d) Mn(II) : $3d^5$; sp^3 (free spin complex, Cl^- being a weak ligand)

13. (b,d) (a) $AgCl + 2NH_3 \longrightarrow [Ag(NH_3)_2]^+ Cl^-$;
cation is the complex ion.

(b) $FeSO_4 + 6KCN \longrightarrow K_4[Fe(CN)_6] + K_2SO_4$;
anion is complex ion.

(c) $CuSO_4 + 4NH_3 \longrightarrow [Cu(NH_3)_4]SO_4$; cation is the complex ion.

(d) $PtCl_4 + 2KCl \longrightarrow K_2[PtCl_6]$; anion is the complex ion.

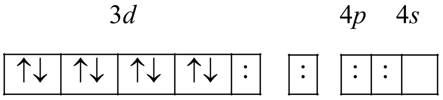
14. (a,b,d) (a) $[PtCl_2(NH_3)_4]Br_2$ is isomeric with $[PtBr_2(NH_3)_4]Cl_2$

(b) $[Co(NO_2)(NH_3)_5]^{2+}$ is isomeric with $[Pt(ONO)(NH_3)_5]^{2+}$

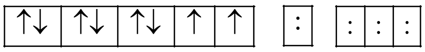
(c) $[Co(NH_3)_6]$ $[Cr(CN)_6]$ is isomeric with $[Cr(NH_3)_6]$ $[Co(CN)_6]$

(d) O.N. of Pt in the complex is +2.

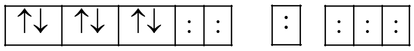
15. (b,d)

(a) Ni(II) –


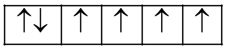
dsp^2 (No unpaired electrons, diamagnetic)

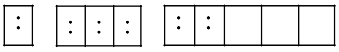
(b) Ni(II) –


sp^3 (Two unpaired electrons, paramagnetic)

(c) Co(III) –


d^2sp^3 (Diamagnetic)

(d) Co(III) –



sp^3d^2 (Paramagnetic)

16. (b,c) (a) $[Co(NH_3)_6]$ $[Cr(CN)_6]$ is isomeric with $[Cr(NH_3)_6]$ $[Co(CN)_6]$

(b) $[Co(NH_3)_5Br]SO_4$ is isomeric with $[Co(NH_3)_5SO_4]Br$

(d) $[Cu(NH_3)_4]$ $[PtCl_4]$ is isomeric with $[Pt(NH_3)_4]$ $[CuCl_4]$

17. (a,b,c) Since there are no ions involved in this compound, the Cl^- atoms are covalently bonded to Pd in the coordination sphere.

(d) No precipitate of AgCl would be formed for chlorine atoms are non-ionisable.

18. (b,c) (b) The lowest polymerisation isomer is the dimer :

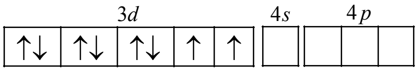
$[Cr(NH_3)_6]$ $[Cr(NO_2)_6]$: mol. mass = 482

(c) The highest non-conducting isomer is the monomer :

$[Cr(NH_3)_3(NO_2)_3]$: mol. mass = 241

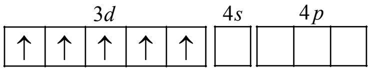
19. (b) This complex will not exhibit optical isomerism. It can exhibit all other given types of isomerism.

20. (a,b) In $[Ni(NH_3)_6]^{2+}$, Ni is in +2 oxidation state

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


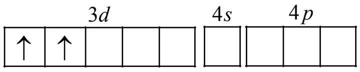
Its octahedral complex is an outer complex and not an inner complex.

In $[Fe(H_2O)_6]^{3+}$, Fe is in +3 oxidation state.

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


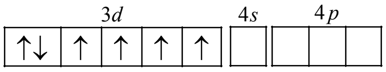
Its octahedral complex is an outer complex and not an inner complex. Weak field ligand H_2O does not force $3d^5$ spins to be paired up.

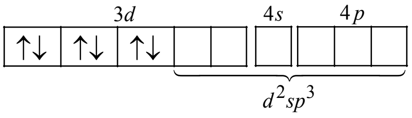
In $[V(H_2O)_6]^{3+}$, V is in +3 state.

$V^{3+};3d^2$


In it inner orbital octahedral complex formed.

In $[Co(NH_3)_6]^{3+}$, Co is +3 oxidation state.

$Co^{3+};3d^6$


In $Co(NH_3)_6$;


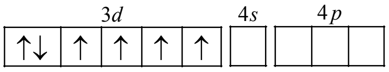
inner complex formed.

Strong field ligand NH_3 forces $3d^5$ spins paired up.

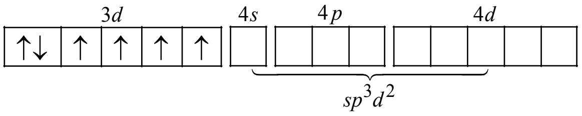
21. (b,c) The chelates having five membered rings are more stable in the absence of double bonds in them. The chelates having six membered rings are more stable if they contain double bond. Thus (a) and (d) are incorrect.

22. (a,b,c) Paramagnetic nature is shown by those complexes that contain unpaired electrons.

In $[FeF_6]^{4-}$; Fe^{+3}, $3d^6$.



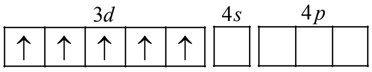
In $[FeF_6]^{4-}$

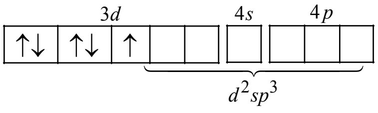


(F is weak field ligand)

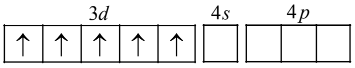
Contains 4 unpaired electrons.

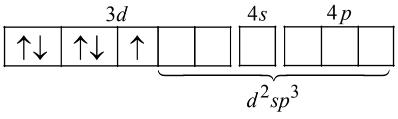
In $[Fe(CN)_6]^{3-}$; Fe^{+3}, $3d^5$,



In $[Fe(CN)_6]^{3-}$;


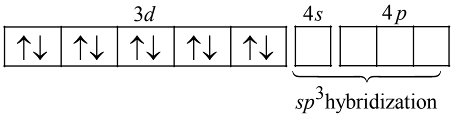
Contains one unpaired electron.

In $[Mn(CN)_6]^{4-}$; Mn^{2+}, $3d^5$,




Contains one unpaired electron.

In $[Zn(NH_3)_4]^{2+}$; Zn^{2+}, $3d^{10}$



In it all electrons are paired.

E MATRIX-MATCH TYPE

1. **A-q, s; B-q, s; C-p, s; D-p, r**

   (A) $\mathrm{Mn^{2+}}$ in $\mathrm{MnCl_4^{2-}}$: $3d^5 - sp^3$ hybridization ; 5 unpaired electrons

   (B) $\mathrm{Ni^{2+}}$ in $\mathrm{NiCl_4^{2-}}$: $3d^8 - sp^3$ hybridization ; 2 unpaired electrons

   (C) $\mathrm{Cu^{2+}}$ in $\mathrm{CaCl_4^{2-}}$: $3d^9 - dsp^2$ hybridization ; 1 unpaired electron

   (D) $\mathrm{Ni^{2+}}$ in $\mathrm{Ni(CN)_4^{2-}}$: $3d^8 - dsp^2$ hybridization ; no unpaired electron

2. **A-r; B-s; C-p; D-q**

   (A) $3d^3$ (Octahedral) : d^2sp^3 hybridization; 3 unpaired elecrtons

   (B) d^5 (Octahedral, low spin) : d^2sp^3 hybridization ; 1 unpaired electron

   (C) d^6 (Octahedral, low spin) : d^2sp^3 ; no unpaired electron

   (D) d^6 (Octahedral, outer orbital) : sp^3d^2 ; 4 unpaired electrons

   Magnetic moment $\sqrt{n\,(n+2)}$ B.M. (n unpaired electrons)

3. **A-q; B-p; C-s; D-r**

   (A) Square planar geometry : two geometric isomers - *cis* and *trans*

   (B) Square planar geometry ; no isomers as all the four ligands are identical.

   (C) Square planar geometry ; three geometric isomers having one ligand at position 1 and three ligands occupy *trans* position 3.

4. **A-p, r; B-p, r; C-p, s; D-q, r**

   (A) It is **paramagnetic** and **inner orbital** complex. It involves d^2sp^3 hybridisation and contains 1 unpaired electron.

   (B) It is **inner orbital** complex (d^2sp^3) and is paramagnetic (contains 3 unpaired electrons).

   (C) It is inner orbital complex (dsp^2 i.e., square planar) and diamagnetic in nature [contains no unpaired electrons (8 electrons are paired in 4 orbitals)]

   (D) It is an outer orbital complex and is paramagnetic in nature.

* * *