Solved Examples

JEE Main/Boards

Example 1: Which of the following will give white precipitate with $AgNO_3$ solution?

(A) $[Co\ (py)_2\ (H_2O)_2Cl_2]Cl$

(B) $[Co\ (py)_2H_2OCl_3]H_2O$

Sol: (a) will give white precipitate

$[Co\ (py)_2\ (H_2O)_2Cl_2]\ Cl \longrightarrow Co\ (py)_2\ (H_2O)_2Cl_2]^+ + Cl^-$

$AgNO_3 + Cl^- \longrightarrow AgCl + NO^-_3$

Example 2: Specify the oxidation numbers of the metals in the following coordination entities:

(A) $[Co\ (CN)\ (H_2O)\ (en)_2]^{2+}$

(B) $[PtCl_4]^{2-}$

(C) $[CrCl_3\ (NH_3)_3]$

(D) $[CoBr_2\ (en)_2]$ + (d) $K_3\ [Fe\ (CN)_6]$

Sol: (A) +3, (B) +2, (C) +3, (D) +3, (E) +3]

Example 3: Using IUPAC rules, write the formula for the following:

(A) Tetrahydroxozincate (II) ion

(B) Hexaamminecobalt (III) sulphate

(C) Potassium tetrachloropalladate (II)

(D) Potassium tri (oxalato) chromate (III)

(E) Diamminedichloroplatinum (II)

Sol: (A) $[Zn\ (OH)_4]^{2-}$

(B) $[Co\ (NH_3)_6]_2\ (SO_4)_3$ (C) $K_2\ [PdCl_4]$

(D) $K_3\ [Cr\ (C_2O_4)_3]$ (E) $[PtCl_2\ (NH_3)_2]$

Example 4: Using IUPAC norms write the systematic names of the following:

(A) $[Co\ (NH_3)_6]Cl_3$ (B) $[CoCl(NO_2)\ (NH_3)_4]Cl$

(C) $[Ni\ (NH_3)_6]Cl_2$ (D) $[PtCl\ (NH_2CH_3)\ (NH_3)_2]Cl$

(E) $[Mn\ (H_2O)_6]^{2+}$

Sol: (A) Hexaamminecobalt (III) chloride.

(B) Tetraamminechloronitrito-N-cobalt (III) chloride.

(C) Hexaamminenickel (II) chloride.

(D) Diamminechloro (methylamine) platinum (II) chloride.

(E) Hexaaquamanganese (II) ion.

Example 5: Write the correct formula for the following coordination compounds:

(A) $CrCl_3{\cdot}6H_2O$ (violet, with 3 chloride ions/unit formula)

(B) $CrCl_3{\cdot}6H_2O$ (light green, with 2 chloride ions/unit formula)

(C) $CrCl_3{\cdot}6H_2O$ (dark green, with I chloride ion/unit formula)

Sol: (A) $[Cr\ (H_2O)_6]\ Cl_3$

(B) $[CrCl\ (H_2O)_5]\ Cl_2{\cdot}H_2O$

(C) $[CrCl_2\ (H_2O)_4]\ Cl{\cdot}2H_2O]$

Example 6: Draw the structure of:

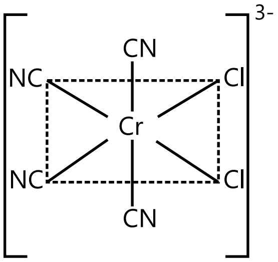
(A) Cis-dichlorotetracyanochromate (III) ion.

(B) Mer-triamminetrichlorocobalt (III).

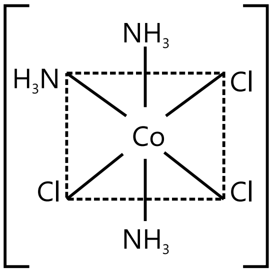
(C) Fac –triaquatrinitrito-N-cobalt (III).

Sol:

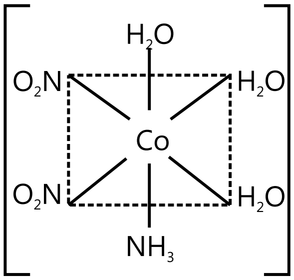
(A)



(B)



(C)



Example 7: Name the type of isomerism exhibited by

the following isomers:

(A) $[Cr(NH_3)_6][Cr(CN)_6]$ and $[Cr(NH_3)_4(CN)_2][Cr(NH_3)_2(CN)_4]$

(B) $[Co(py)_2(H_2O)_3Cl]Cl_2$ and $[Co(py)_2(H_2O)_2Cl_2]Cl{\cdot}H_2O$

(C) $[Pt(NH_3)4Br_2]Cl_2$ and $[Pt(NH_3)_4Cl_2]Br_2$

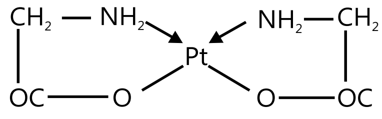
(D) $[Co(NH_3)_5NO_2]Cl_2$ and $[Co(NH_3)_5ONO]Cl_2$

Sol: (A) Coordination isomerism (B) Hydrate isomerism

(C) Ionization isomerism (D) Linkage isomerism

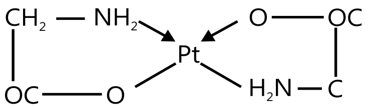
Example 8: Draw the structure of geometrical isomers of $[Pt(gly)_2]$ where gly is $NH_2CH_2COO^-$.

Sol:



cis-isomer

and

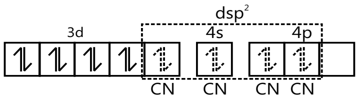


trans-isomer

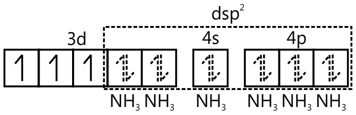
Example 9: $[Cr(NH_3)_6]^{3+}$ is paramagnetic while $[Ni(CN)_4]^{2-}$ is diamagnetic. Why?

Sol: Electronic structure of the two complexes may be written as

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



In $[Cr(NH_3)_6]^{3+}$, all the electrons are paired and hence it is diamagnetic.



Due to presence of three unpaired electrons in $[Ni(CN)_4]^{2-}$, it is paramagnetic.]

Example 10: $[Cu(CN)_4]^{2-}$ is more stable complex than $[Cu(NH_3)_4]^{2+}$. Why?

Sol: The higher stability constant $K = 2\times 10^{27}$ for $Cu^{2+} + 4CN^- \rightarrow [Cu(CN)_4]^{2-}$ than for $[Cu(NH_3)_4]^{2+}$ (which is 4.5×10^{11}) explains stability. Also CN^- is stronger ligand than NH_3.]

JEE Advanced/Boards

Example 1: What is the coordination number of the central metal ions in the following complexes?

(A) $[Cu(NH_3)_4]^{2+}$ (B) $[Fe(C_2O_4)_3]^{3-}$

(C) $[Pt(en)_2Cl_2]$ (D) $[Mo(CN)_8]^{4-}$

(E) $[Fe(EDTA)]^-$ (F) $[Pd(H_2O)_2(ONO)_2I_2]$

Sol: (A) NH_3 is a monodentate ligand, Coordination number of $Cu^{2+} = 4 \times$ no. of electron pairs accepted $= 4 \times 1 = 4$.

(B) $C_2O_4^{2-}$ is a bidentate ligand, coordination number of $Fe^{3+} = 3 \times 2 = 6$.

(C) 'en' is a bidentate ligand and Cl^- is a monodentate ligand, coordination number of

(D) $Mo^{4+} = 8 \times 1 = 8$.

(E) EDTA is a hexadentate ligand, coordination number of $Fe^{3+} = 6 \times 1 = 6$.

(F) H_2O, ONO and I_2 are monodentate ligands, coordination number of $Pd^{4+} = 2 \times 1 + 2 \times 1 + 2 \times 1 = 6$.

Example 2: A solution containing 2.665 g of $CrCl_3{\cdot}6H_2O$ is passed through a cation exchanger. The chloride ions obtained in solution were treated with excess of $AgNO_3$ to give 2.87 g of AgCl. Deduce the structure of compound.

Sol: Moles of Cl^- ions ionized from moles of $CrCl_3{\cdot}6H_2O$

$$= \frac{2.665}{2.665} = 0.01 \quad \text{Mol. Wt. of } CrCl_3{\cdot}6H_2O = 266.5$$

$\therefore$ Moles of AgCl obtained = Moles of Cl^- ionized

$$= \frac{2.87}{143.5} = 0.02$$

Thus, 0.01 mole of complex $CrCl_3{\cdot}6H_2O$ gives 0.02 moles of Cl^- on ionization.

Now, since the coordination number of Cr is 6 and only one Cl ion is attached to Cr by coordination bond or secondary valency, the compound is $[CrCl{\cdot}(H_2O)_5]Cl_2{\cdot}H_2O$.

$$[CrCl{\cdot}(H_2O)_5]Cl_2{\cdot}H_2O \longrightarrow [CrCl{\cdot}(H_2O)_5]^{2+} + 2Cl^- + H_2O$$

$$2Cl^- + 2AgNO_3 \longrightarrow 2AgCl + 2NO_3^-$$

Example 3: Two compounds have empirical formula corresponding to $Cr(NH_3)_3(NO_2)_3$. In aqueous solution, one of these is a non-electrolyte while the other conducts electricity. What is the lowest possible formula weight of the conducting reagent? What is the highest possible formula weight for the non-conducting reagent?

Sol: For complex Cr $(NH_3)_3\cdot$ $(NO_2)_3$ $(H_2O)_2$, the two structures can be written as:

$$\underset{\text{A}}{\underline{\left[\text{Cr}\ (\text{NO}_2)_2\cdot\ (\text{NH}_3)_3\cdot\ (\text{H}_2\text{O})\right]\cdot\text{NO}_2\cdot\text{H}_2\text{O}}}\ \text{and}$$

$$\underset{\text{B}}{\underline{\left[\text{Cr}\ (\text{NO}_2)_3\cdot\ (\text{NH}_3)_3\right]\cdot{}_2\text{H}_2\text{O}}}$$

A will be a conducting reagent as it will give two ions on dissolving in water. B will be a non-conducting reagent as it will not be ionized in water.

Example 4: Write the IUPAC name of the compound $[Cr(NH_3)_5(NCS)][ZnCl_4]$. Is this compound colored?

Sol: Pentammineisothicyanatochromium (III) tetrachlorozincate (II). Compound will be colored because Cr (III) has d^3 configuration and so d–d transition is possible.

Example 5: On the basis of valence bond theory explain geometry, nature of hybridization, magnetic property and optical isomerism in:

(i) $[Co\ (Ox)_3]^{3-}$ (ii) $[CoF_6]^{3-}$

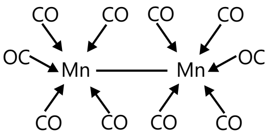
Sol: (i) $[Co\ (Ox)_3]^{3-}$ i.e., trioxalato cobaltate (III) ion has sp^3d^2 hybridization, having octahedral geometry and is paramagnetic in nature due to the presence of 4 unpaired electrons. It has 2 optical isomers.

(ii) $[CoF_6]^{3-}$ i.e., Hexafluoro cobaltate (III) ion has sp^3d^2 hybridization, having octahedral geometry and is paramagnetic in nature due to the presence of 4 unpaired electron. It does not show optical isomerism.

Example 6: The EAN of each Mn (Z = 25) in $Mn_2\ (CO)_{10}$ is 36. What is the structure of this complex?

Sol: EAN = 25 (electrons from Mn atom) + 10 (electrons from five CO ligand) + 1 (electron from Mn—Mn bond) = 36

Thus, structure will be,



Example 7: The magnetic moment of $[MnCl_4]^{2-}$ is 5.92 B.M. On the basis of its magnetic moment, write configuration of Mn^{2+} in this complex.

Sol: For an atom/ion

Magnetic moment (μ) = $\sqrt{n(n+2)}$

(n = No. of unpaired electrons)

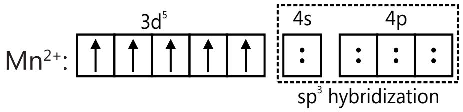
Given that $\mu = 5.92$ B.M.

$\therefore$ $5.92 = \sqrt{n(n+2)}$ $n = 5$

Thus is this complex Mn contains 5 unpaired electrons and so its possible configuration may be

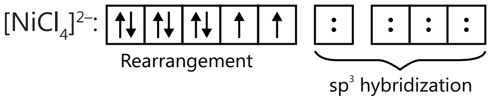
Mn^{2+} in $[MnCl_4]^{2-}$ = $[Ar]\ 3d^54s^0$

So hybridization of Mn^{2+} in the given complex must be sp^3.



Example 8: $[Ni\ (CN)_4]^{2-}$ is diamagnetic while $[NiCl_4]^{2-}$ is paramagnetic, Why?

Sol: In $[Ni\ (CN)_4]^{2-}$ all orbitals are doubly occupied, hence it is diamagnetic whereas in $[NiCl_4)]^{2-}$, two orbitals are singly occupied, hence it is paramagnetic in nature.



Strong field ligands like CN^-, CO, en, NO^{-2} have very strong electron donating tendency, hence electrons of central metal ion pair up against Hund's rule (low spin complex). In $[Ni\ (CO)_4]$, Ni is sp^3 hybridized with no unpaired electron, and hence it is diamagnetic.

Example 9: What is the coordination entity formed when excess of KCN is added to an aqueous solution of $CuSO_4$? Why is that no precipitate of CuS is obtained when $H_2S(g)$ is passed through this solution?

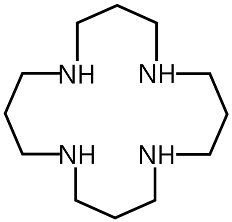
Sol: $CuSO_4 + 4KCN \longrightarrow K_2[Cu(CN)_4] + K_2SO_4$

$[Cu\ (CN)_4]^{2-}$ is stable complex having

$K = 2 \times 10^{27}$ and so it does not provide sufficient Cu^{2+} ion to give precipitate of CuS.

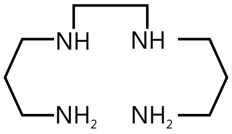
Example 10: What do you understand by macrocyclic effect?

Sol: It is the increased thermodynamic stability of a complex formed with a cyclic polydentate ligand when compared to the complex formed with a noncyclic ligand, e.g. Zn^{2+} complex with (I) is more stable than with (II).



(I) Cyclic

is



(II) Non-cyclic

JEE Main/Boards

Exercise 1

Q.1 Explain the bonding in coordination compounds in terms of Werner's postulates.

Q.2 $FeSO_4$ solution mixed with (NH_4) $2SO_4$ solution in 1: 1 molar ratio gives the test of Fe^{2+} ion but $CuSO_4$ solution mixed with aqueous ammonia in 1: 4 molar ratio does not give the test of Cu^{2+} ion. Explain why?

Q.3 How many geometrical isomers are possible in the following coordination entities?

(i) $[Cr\ (C_2O_4)_3]^{3-}$ (ii) $[PtCl_2\ (en)_2]^{2+}$

(iii) $[Cr\ (NH_3)_2Cl_2\ (en)]$

Q.4 Draw the structures of optical isomer of:

(i) $[Cr\ (C_2O_4)_3]^{3-}$ (ii) $[PtCl_2\ (en)_2]^{2+}$

(iii) $[Cr\ (NH_3)_2Cl_2\ (en)]$

Q.5 Draw all the isomers (geometrical and optical) of:

(i) $[CoCl_2\ (en)_2]^+$ (ii) $[Co\ (NH_3)\ Cl\ (en)_2]^{2+}$

(iii) $[Co\ (NH_3)_2Cl_2\ (en)]$

Q.6 Aqueous copper sulphate solution (blue in color) gives:

(i) A green precipitate with aqueous potassium fluoride and

(ii) A bright green solution with aqueous potassium chloride. Explain these experimental results.

Q.7 What is the coordination entity formed when excess of aqueous KCN is added to an aqueous solution of copper sulphate? Why is it that no precipitate of copper sulphide is obtained when H_2S (g) is passed through this solution?

Q.8 $[Cr\ (NH_3)_6]^{3+}$ is paramagnetic while $[Ni\ (CN)_4]^{2-}$ is diamagnetic. Explain why?

Q.9 A solution of $[Ni\ (H_2O)_6]^{2+}$ is green but a solution of $[Ni\ (CN)_4]^{2-}$ is colorless. Explain.

Q.10 $[Fe\ (CN)_6]^{4-}$ and $[Fe\ (H_2O)_6]^{2+}$ are of different colors in dilute solutions. Why?

Q.11 Give the oxidation state, d orbital occupation and coordination number of the central metal ion in the following complexes:

(i) $K_3\ [Co\ (C_2O_4)_3]$ (ii) $(NH_4)_2\ [CoF_4]$

(iii) cis- $[Cr\ (en)_2Cl_2]\ Cl$ (iv) $[Mn\ (H_2O)_6]\ SO_4$

Q.12 Write down the IUPAC name for each of the following complexes and indicate the oxidation state, electronic configuration and coordination number. Also give stereochemistry and magnetic moment of the complex:

(i) $K\ [Cr\ (H_2O)_2\ (C_2O_4)_2].3H_2O$

(ii) $[Co\ (NH_3)_4Cl]\ Cl_2$

(iii) $CrCl_3\ (py)_3$

(iv) $Cs\ [FeCl_4]$

(v) $K_4\ [Mn\ (CN)_6]$

Q.13 What is meant by the chelate effect? Give an example.

Q.14 Amongst the following ions which one has the highest magnetic moment value?

(i) $[Cr\ (H_2O_6)]^{3+}$ (ii) $[Fe\ (H_2O)_6]^{2+}$

(iii) $[Zn\ (H_2O)_6]^{2+}$

Q.15 What will be the correct order for the wavelengths of absorption in the visible region for the following?

$[Ni(NO_2)_6]^{4-}$, $[Ni(NH_3)_6]^{2+}$, $[Ni(H_2O)_6]^{2+}$?

Q.16 Why NH_4^+ ion does not form complexes?

Q.17 Write the formula of the following Complex.

Pentaamminechlorocobalt (III) ion

Exercise 2

Single Correct Choice Type

Q.1 Which of the following compound is not having synergic bonding?

(A) $Fe(CO)_5$ (B) $[Ni(CN)_4]^{2-}$

(C) $[Fe(\pi\text{–}C_5H_5)_2]$ (D) $[CoF_6]^{3-}$

Q.2 Which of the following is a low spin complex?

(A) $Ni(CO)_4$ (B) $[Ni(NH_3)_6]^{2+}$

(C) $[Cu(NH_3)_4]^{2+}$ (D) All of these

Q.3 Which of the following name is incorrect for the given complex. $K[Fe(H_2O)_2(NCS)_3(NO_3)]$

(A) Potassium diaquatrisothiocyanatonitrato ferrate (III)

(B) Potassium diaquanitratotrithiocyanato-N- ferrate (III)

(C) Potassium diaquatrithiocyanato-N-nitrito ferrate (III)

(D) Potassium diaquatrisothiocyanatonitrato ferrate (II)

Q.4 What is the hybridization of Fe in $[Fe(CO)_4]$?

(A) sp_3 (B) dsp^2 (C) sp (D) sp^3d^2

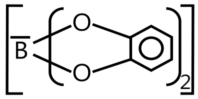
Q.5 Which of the following complex/molecule acts as a reducing agent?

(A) $[Co(NH_3)_6]^{2+}$ (B) $[Mn(CO)_6]$

(C) NO (D) All are acts as a Reducing

Q.6 Which of the following molecule is square planar.

(A) $K_4[Ni(CN)_4]$ (B) $[Be(acac)_2]$

(C) 

(D) $\left[Pd\left(NH_3\right)\left(H_2O\right)\left(Br\right)Cl\right]^{o}$

Q.7 Which type do d-electron configuration exhibit both low and high spin in octahedral complexes?

(A) d^1 (B) d^4 (C) d^3 (D) d^2

Q.8 Transition elements have the maximum tendency to form complexes because

(A) They are metals and all metal form complexes

(B) They contain incompletely filled d-orbitals

(C) Their charge/size ratio is quite large

(D) Both (B) and (C)

Q.9

$$[(H_2O)_5Co-\underset{(A)}{O-O}-Co(H_2O)_5]^{4+}$$
$$\downarrow$$
$$[(H_2O)_5Co-\underset{(B)}{O-O}-Co(H_2O)_5]^{5+}$$

What will be the bond length of O–O in complex A and B?

(A) A = B (B) A > B (C) B > A (D) None

Q.10 In the complex of [Ma3b3]n±, if two 'a' are replaced by AA type of ligand, then isomer of it, only one isomer of the product will be formed.

(A) Only Fac-isomer

(B) Only Mer-isomer

(C) Fac and Mer-isomer both

(D) None of these

Q.11 What is the hybridization of Fe in sodium thionitroprusside?

(A) sp^3d^2 (B) d^2sp^3

(C) sp^3d (D) No hybridization

Q.12 What is correct name of linkage isomer of $[Cr(H_2O)_5(NO_2)]Br_2$.

(A) Pentaaquanitro-'O' chromium (III) bromide

(B) Pentaaquanitro chromium (III) bromide

(C) Pentaaquonitro chromium (III) bromide

(D) Pentaaquanitrito-'O" chromium (II) bromide

Q.13 The effective atomic number of $Co(CO)_4$ is 35. It does not attain stability by

(A) Oxidation of $[Co(CO)_4]$

(B) Reduction of $[Co(CO)_4]$

(C) Dimerization of $[Co(CO)_4]$

(D) By both (B) and (C)

Q.14 Which one of the following ions is colored?

(A) Sc^{3+} (B) Ti^{4+} (C) Zn^{2+} (D) V^{2+}

Q.15 Which of the following statement is correct.

(A) The name of $[Fe(H_2O)_5NO]SO_4$ is pentaaquanitrosyliron (II) sulphate

(B) $[Co(C_2O_4)_3]^{3-}$ does not have any unpaired electron

(C) E.A.N. of $[Fe(CO)_2(NO)_2]$ is 34

(D) $[SnCl_3]^-$ acts as ligand where the Cl-atom as donor atom.

Q.16 How many stereoisomer are possible for complex $[Co(NH_3)_3Cl_3]$

(A) 1 (B) 2 (C) 3 (D) 4

Q.17 In the volumetric analysis, Mohr's salts is preferred to ferrous sulphate because

(A) It is more readily oxidizable than $FeSO_4$

(B) It is less easily oxidizable than $FeSO_4$

(C) It can undergo both oxidation and reduction

(D) It can be oxidized even in the absence of dilute H_2SO_4.

Q.18 $[RhF_6]^{5-}$ complex ion is a

(A) Outer orbital complex

(B) Inner orbital complex

(C) No outer or no inner orbital complex

(D) None of these

Q.19 Which of the following complex are tetrahedral in shape.

(A) $[FeCl_4]^-$ (B) $[BrF_4]^-$

(C) $[Cu(CN)_4]^{3-}$ (D) $[AuCl_4]^-$

Q.20 How many ions are produced from the complex $Co(NH_3)_6Cl_2$ in solution?

(A) 6 (B) 4 (C) 3 (D) 2

Q.21 The oxidation number of cobalt in $K[Co(CO)_4]$ is

(A) +1 (B) +3 (C) –1 (D) –3

Q.22 Amongst the following the most stable complex is

(A) $[Fe(H_2O_6)]^{3+}$ (B) $[Fe(NH_3)_6]^{3+}$

(C) $[Fe(C_2O_4)_3]^{3-}$ (D) $[FeCl_6]^{3-}$

Previous Years' Questions

Q.1 The coordination number of a central metal atom in a complex is determined by ***(2004)***

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

(B) The number around a metal ion bonded by pi-bonds

(C) The number of ligands around a metal ion bonded by sigma bonds

(D) The number of only anionic ligands bonded to the metal ion

Q.2 Among the properties (i) reducing (ii) oxidizing (iii) complexing, the set of properties shown by CN– ion towards metal species is ***(2004)***

(A) iii, i (B) ii, iii (C) i, ii (D) i, ii, iii

Q.3 Ammonia forms the complex ion $[Cu(NH_3)_4]^{2+}$ with copper ions in alkaline solutions but not in acidic solution. What is the reason for it? ***(2003)***

(A) In acidic solutions hydration protects copper ions

(B) In acidic solutions protons coordinate with ammonia molecules forming NH^{4+} ions and NH3 molecules are not available

(C) In alkaline solutions insoluble $Cu(OH)_2$ is precipitated which is soluble in excess of any alkali

(D) Copper hydroxide is an amphoteric substance

Q.4 In the coordination compound, $K_4[Ni(CN)_4]$ oxidation state of nickel is ***(2003)***

(A) –1 (B) 0 (C) +1 (D) +2

Q.5 The coordination number and the oxidation state of the element 'E' in the complex $[E(en)_2(C_2O_4)]NO_2$ (where (en) is ethylene diamine) are, respectively ***(2008)***

(A) 4 and 2 (B) 4 and 3

(C) 6 and 3 (D) 6 and 2

Q.6 Which among the following will be named as dibromidobis (ethylene diamine) chromium (III) bromide ***(2012)***

(A) $[Cr(en)_3]Br_3$ (B) $[Cr(en)_2Br_2]Br$

(C) $[Cr(en)Br_4]^-$ (D) $[Cr(en)Br_2]Br$

Q.7 The "spin-only" magnetic moment [in units of Bohr magneton, (μ_B)] of Ni^{2+} in aqueous solution would be (At. No. Ni = 28) ***(2006)***

(A) 2.83 (B) 4.90 (C) 0 (D) 1.73

Q.8 The pair in which both species have same magnetic moment (spin only value) is ***(2006)***

(A) $[Cr(H_2O)_6]^{2+}$, $[CoCl_4]^{2-}$ (B) $[Cr(H_2O)_6]^{2+}$, $[Fe(H_2O)_6]^{2+}$

(C) $[Mn(H_2O_6)]^{2+}$, $[Cr(H_2O)_6]^{2+}$ (D) $[CoCl_4]^{2-}$, $[Fe(H_2O)_6]^{2+}$

Q.9 Which of the following has an optical isomer? ***(2009)***

(A) $[Co(NH_3)_3Cl]^+$ (B) $[Co(en)(NH_3)_2]^{2+}$

(C) $[Co(H_2O)_4(en)]^{3+}$ (D) $[Co(en)_2(NH_3)_2]^{3+}$

Q.10 Which of the following pairs represents linkage isomers ? ***(2009)***

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

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

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

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

Q.11 Which one of the following has a square planner geometry? ***(2007)***

(A) $[CoCl_4]^{2-}$ (B) $[FeCl_4]^{2-}$ (C) $[NiCl_4]^{2-}$ (D) $[PtCl_4]^{2-}$

Q.12 Which of the following facts about the complex $[Cr(NH_3)_6]Cl_3$ is wrong ***(2011)***

(A) The complex involves d^2sp^3 hybridization and is octahedral in shape

(B) The complex is paramagnetic

(C) The complex is an outer orbital complex

(D) The complex gives white precipitate with silver nitrate solution

Q.13 One mole of the complex compound $Co(NH_3)_5Cl_3$, gives 3 moles of ions on dissolution in water. One mole of the same complex reacts with two moles of $AgNO_3$ solution to yield two moles of AgCl (s). The structure of the complex is ***(2003)***

(A) $[Co(NH_3)_5Cl]Cl_2$ (B) $[Co(NH_3)_3Cl_3].2NH_3$

(C) $[Co(NH_3)_4Cl_2]Cl.NH_3$ (D) $[Co(NH_3)_4Cl]Cl_2.NH_3$

Q.14 How many EDTA (ethylenediaminetetraacetic acid) molecules are required to make an octahedral complex with a Ca2+ion ***(2006)***

(A) Six (B) Three (C) One (D) Two

Q.15 In $Fe(CO)_5$, the Fe-C bond possesses ***(2006)***

(A) π-character only (B) Both σ and π characters

(C) Ionic character (D) σ-character only

Q.16 The coordination number and the oxidation state of the element 'E' in the complex $\left[E(en)_2(C_2O_4)\right]NO_2$ (where (en) is ethylene diamine) are respectively, ***(2008)***

(A) 6 and 2 (B) 4 and 2

(C) 4 and 3 (D) 6 and 3

Q.17 Being lesser energy difference between 5f and 6d than 4f and 5d orbitals. In which of the following octahedral complexes of Co (at no. 27), will the magnitude of be the highest? ***(2008)***

(A) $\left[Co(CN)_6\right]^{3-}$ (B) $\left[Co(C_2O_4)_3\right]^{3-}$

(C) $\left[Co(H_2O)_6\right]^{3+}$ (D) $\left[Co(NH_3)_6\right]^{3+}$

Q.18 Which of the following has an optical isomer? ***(2009)***

(A) $\left[Co(NH_3)_3Cl\right]^+$ (B) $\left[Co(en)(NH_3)_2Cl\right]^{2+}$

(C) $\left[Co(H_3O)_4(en)\right]^{3+}$ (D) $\left[Co(en)_2(NH_3)_2\right]^{3+}$

Q.19 Which of the following pairs represents linkage isomers? ***(2009)***

(A) $\left[(Cu(NH_3)_4)\right]\left[PtlCl_4\right]$ and $\left[Pt(NH_3)\right]\left[CuCl_4\right]$

(B) $\left[Pd(PPh_3)(NCS)_2\right]$ and $\left[Pd(P\,Ph_2)_2(SCN_2)\right]$

(C) $\left[Co(NH_3)_5NO_3\right]SO_4$ and $\left[Co(NH_3)_5SO_4\right]NO_3$

(D) $\left[PtCl_2(NH_3)_4\right]Be_2$ and $\left[PtBr_2(NH_3)_4\right]Cl_2$

Q.20 A solution containing 2.675 g of $CoCl_3.6NH_3$ (molar mass = 267.5 g mol-1) is passed through a cation exchanger. The chloride ions obtained in solution were treated with excess of $AgNO_3$ to give 4.78 g of AgCl (molar mass = 143.5 g mol^{-1}). The formula of the complex is (At. Mass of Ag = 108 u) ***(2010)***

(A) $\left[Co(NH_3)_6\right]Cl_3$ (B) $\left[CoCl_2(NH_3)_4\right]Cl$

(C) $\left[CoCl_3(NH_3)_3\right]$ (D) $\left[CoCl(NH_3)_5\right]Cl_2$

Q.21 Which one of the following has an optical isomer? ***(2010)***

(A) $\left[Zn(en)(NH_3)_2\right]^{2+}$ (B) $\left[Co(en)_3\right]^{3+}$

(C) $\left[Co(H_2O)_4(en)\right]^{3+}$ (D) $\left[Zn(en)_2\right]^{2+}$

Q.22 Which of the following facts about the complex $\left[Cr(NH_3)_6\right]Cl_3$ wrong? ***(2011)***

(A) The complex is paramagnetic

(B) The complex is an outer orbital complex

(C) The complex gives white precipitate with silver nitrate solution

(D) The complex involves $d^2\,sp^3$ hybridization and is octahedral in shape.

Q.23 The magnetic moment (spin only) of $\left[NiCl_4\right]^{2-}$ is ***(2011)***

(A) 5.46 BM (B) 2.83 BM (C) 1.41 BM (D) 1.82 BM

Q.24 Which among the following will be named as dibromidobis (ethylene diamine) chromium (III) bromide? ***(2012)***

(A) $\left[Cr(en)_3\right]Br_3$ (B) $\left[Cr(en)_2Br_2\right]Br$

(C) $\left[Cr(en)Br_4\right]^-$ (D) $\left[Cr(en)Br_2\right]Br$

Q.25 Which of the following complex species in not expected to exhibit option isomerism? ***(2013)***

(A) $\left[Co(en)_3\right]^{3+}$ (B) $\left[Co(en)_2Cl_2\right]^+$

(C) $\left[Co(NH_3)_3Cl_3\right]$ (D) $\left[Co(en)_2(NH_3)_2Cl_2\right]^+$

Q.26 The octahedral complex of a metal ion M^{3+} with four monodentate ligands L_1, L_2, L_3 and L_4 absorb wavelengths in the region of red, green, yellow and blue, respectively. The increasing order of ligand strength of the four ligands is ***(2014)***

(A) $L_4 < L_3 < L_2 < L_1$ (B) $L_1 < L_3 < L_2 < L_4$

(C) $L_3 < L_2 < L_4 < L_1$ (D) $L_1 < L_2 < L_3 < L_4$

Q.27 The number of geometric isomers that can exist for square planar $\left[Pt(Cl)(py)(NH_3)(NH_2OH)\right]^+$ is (py = pyridine): ***(2015)***

(A) 2 (B) 3 (C) 4 (D) 6

Q.28 Which of the following compounds is not colored yellow? ***(2015)***

(A) $Zn_2\left[Fe(CN)_6\right]$ (B) $K_3\left[Co(NO_2)_6\right]$

(C) $(NH_4)_3\left[As(Mo_3O_{10})_4\right]$ (D) $BaCrO_4$

Q.29 The pair having the same magnetic moment is:
[At. No.: Cr = 24, Mn = 25, Fe = 26, Co = 27] ***(2016)***

(A) $\left[Cr(H_2O)_6\right]^{2+}$ and $\left[Fe(H_2O)_6\right]^{2+}$

(B) $\left[Mn(H_2O)_6\right]^{2+}$ and $\left[Cr(H_2O)_6\right]^{2+}$

(C) $\left[CoCl_4\right]^{2-}$ and $\left[Fe(H_2O)_6\right]^{2+}$

(D) $\left[Cr(H_2O)_6\right]^{2+}$ and $\left[CoCl_4\right]^{2-}$

Q.30 Which one of the following complexes shows optical isomerism? ***(2016)***

(A) cis $\left[Co(en)_2Cl_2\right]Cl$ (B) trans $\left[Co(en)_2Cl_2\right]Cl$

(C) $\left[Co(NH_3)_4Cl_2\right]Cl$ (D) $\left[Co(NH_3)_3Cl_3\right]$

JEE Advanced/Boards

Exercise 1

Q.1 Explain with two examples each of the following: coordination entity, ligand, coordination number, coordination polyhedron, homoleptic and heteroleptic.

Q.2 What is meant by unidentate, bidentate and ambidentate ligands? Give two examples for each.

Q.3 (A) What is the basis of formation of spectrochemical series?

(B) Draw the structure of geometrical isomers of the following coordination complexes: $[Co(NH_3)_3Cl_3]$ and $[CoCl_2 (en)_2]^+$

Q.4 Write all the geometrical isomers of $[Pt (NH_3) (Br) (Cl) (py)]$ and how many of these will exhibit optical isomers?

Q.5 What is meant by stability of a coordination compound in solution? State the factors which govern stability of complexes.

Q.6 Draw a sketch to show the splitting of d-orbitals in an octahedral crystal filed. State for a d^5 ion how the actual configuration of the split d-orbitals in an octahedral crystal field is decided by the relative values of D and P.

Q.7 Writ the IUPAC name of $[Co (en)_2Cl_2]$ Cl and draw the structures of all the isomers with this formula of complex.

Q.8 Draw diagram to show crystal field splitting in a tetrahedral crystal field

Q.9 Discuss briefly giving an example in each case the role of coordination compounds in:

(i) Biological systems

(ii) Medicinal chemistry

(iii) Analytical chemistry and

(iv) Extraction/metallurgy of metals.

Q.10 $NH_2.NH_2$ although possesses two electron pair for donation but not acts as chelating agent. Why?

Q.11 Square planar complexes with co-ordination number four exhibit geometrical isomerism whereas tetrahedral complexes does not. Why?

Q.12 Determine the oxidation state of metal in the complex ion, $[PtCl_6]^{2-}$?

Q.13 The color of Hg_2Cl_2 changes from white to black when treated with NH_3. Why?

Q.14 $[Fe (CN)_6]^{3-}$ is weakly paramagnetic while $[Fe(CN)_6]^{4-}$ is diamagnetic, why?

Q.15 The magnetic moment of $[MnCl_4]^{2-}$ is 5.92 B.M. On the basic of its magnetic moment, write configuration of Mn^{2+} in this complex.

Q.16 List various types of isomerism possible for coordination compounds, giving an example of each.

Q.17 Discuss the nature of bonding in the following coordination entities on the basis of valence bond theory.

(A) $[Fe (CN)_6]^{4-}$ (B) $[FeF_6]^{3-}$

(C) $[Co (C_2O_4)_3]^{3-}$ (D) $[CoF_6]^{3-}$

Q.18 Draw figure to show the splitting of d orbital in an octahedral crystal field.

Q.19 What is spectrochemical series? Explain the difference between a weak field ligand and a strong field ligand.

Q.20 What is crystal field splitting energy? How does the magnitude of Δ_o decide the actual configuration of d orbital in a coordination entity?

Q.21 Discuss the nature of bonding in metal carbonyls.

Q.22 Specify the oxidation numbers of the metals in the following coordination entities and geometry of these compound?

(i) $[Co (H_2O) (CN) (en)_2]^{2+}$ (ii) $[CoBr_2(en)_2]^+$

(iii) $[PtCl_4]^{2-}$ (iv) $K_3 [Fe (CN)_6]$

(v) $[Cr (NH_3)_3Cl_3]$

Q.23 Using IUPAC norms write the formulas for the following and explain all property according to VBT?

(1) Tetrahydroxozincate (II)
(2) Potassium tetrachloridopalladate(II)
(3) Diamminedichloridoplatinum (II)
(4) Potassium tetracyanonickelate (II)
(5) Pentaamminenitrito-O-cobalt (III)
(6) Hexaamminecobalt (III) sulphate
(7) Potassium tri (oxalate) chromate (III)
(8) Hexaammineplatinum (IV)
(9) Tetrabromideocuprate (II)
(10) Pentaamminenitrito-N-cobalt (III)

Q.24 Write the difference between VBT and CFT?

Q.25 Write the formulas for the following coordination compounds:

(i) Tetraaminequachloridocobalt (III) chloride
(ii) Potassium tetrahydroxozincate (II)
(iii) Potassium trioxalatoaluminate (III)
(iv) Dichloridobis (ethane-1, 2-diamine) cobalt (III)
(v) Tetracrabonylnickel (0).

Exercise 2

Single Correct Choice Type

Q.1 Select the correct order of C—O bond order in following complexes.

(A) $[M\,(CO_3(PCl_3)_2(PMe_3)] > [M(CO)_3(PCl_3)_3] > [M(CO)_3(PCl_3)(PMe_3)_2]$

(B) $[M(CO)_3(PCl_3)_2(PMe_3)_2] > [M(CO)_3(PCl_3)_3] > [M(CO)_3(PCl_3)_2(PMe_3)]$

(C) $[M(CO)_3(PCl_3)(PMe_3)_2] = [M(CO)_3(PCl_3)_3] < [M(CO)_3(PCl_3)_2(PMe_3)]$

(D) $[M\,(CO)_3(PCl_3)_3] > [M(CO_3(PCl_3)_2(PMe_3)] > [M(CO)_3(PCl_3)(PMe_3)_2]$

Q.2 What is the hybridization of Fe in $[Fe\,(CO)_4]$?

(A) sp^3 (B) dsp^2 (C) sp (D) sp^3d^2

Q.3 Which of the following complex/molecule acts as a reducing agent.

(A) $[Co(NH_3)_6]^{2+}$ (B) $[Mn(CO)_6]$
(C) NO (D) All act as a reducing agent

Q.4 The effective atomic number of $Co(CO)_4$ is 35. It does not attain stability by

(A) Oxidation of $[Co(CO)_4]$ (B) Reduction of $[Co(CO)_4]$
(C) Dimerization of $[Co(CO)_4]$ (D) By both (B) and (C)

Q.5 In the volumetric analysis, Mohr's salt is preferred to ferrous sulphate because

(A) It is more readily oxidizable than $FeSO_4$
(B) It is less easily oxidizable than $FeSO_4$
(C) It can undergo both oxidation and reduction
(D) It can be oxidized even in the absence of dilute H_2SO_4

Multiple Correct Choice Type

Q.6 Select the correct statement.

(A) CO bond order in bridging carbonyl group is found to be lower than in that terminal carbonyl group in $Fe_2(CO)_9$.
(B) Bond angle in NO_2 < Bond angle in NO_2^-
(C) CO is a σ donor as well as π acceptor ligand.
(D) NO is the only σ donor ligand.

Q.7 Which of the following complex is/are square planar as well as paramagnetic?

(A) $[AuCl_4]^-$ (B) $[CuCl_4]^-$
(C) $[Cu\,(NH_3)_4]^{2+}$ (D) $[Co\,(dmg)_2]^{o}$

Q.8 Which one of the following statements is incorrect about transition elements?

(A) The last electron enters in the d-orbital
(B) Their properties are in between those of s-block elements and p-block elements
(C) The transition element with smallest atomic number is scandium
(D) Lanthanum is not a transition element but is a lanthanide.

Q.9 Which of the following type of complex (s) is/are having six number of stereoisomers.

(A) $[MA_2B_2C_2]^{n\pm}$ (B) $[M\,(AB)\,A_2BC]^{n\pm}$
(C) $[M\,(AA)\,A_2B_2]^{n\pm}$ (D) $[M\,(AB)\,A_2B_2]^{n\pm}$

Q.10 Which of the following complex (s) is/are low spin

(A) K_4 [Fe $(CN)_6$] (B) $[PtCl_4]^{2-}$

(C) [Co $(C_2O_4)_3]^{3-}$ (D) [Ni $(NH_3)_6]^{2+}$

Q.11 Which of the following molecules have same number of unpaired electrons.

(A) [Cu $(NH_3)_6]^{2+}$ (B) [Ti $(H_2O)_6]^{3+}$

(C) K4 [Fe $(CN)_6O_2$] (D) [Cr $(NH_3)_6]^{3+}$

Q.12 Which of the following type of complex (s) do/ does not produce optically active isomer (s).

(A) $MA_2B_2C_2$ (B) MA_4B_2

(C) MA_3B_2C (D) MA_2B_2CD

Q.13 For which of the complex, the E.A.N. of the central atom of the complex obeys Sidgwick E.A.N. rule.

(A) [Ti $(\sigma\text{–}C_5H_5)_5]_2$ (B) $[Fe(NO)_2(CO)_2]$

(C) $[Ag(CN)_2]^-$ (D)$[Hg(SCN)_4]^{2-}$

Q.14 Identify the ligands can cause the linkage isomerism.

(A) NO_3^- (B) NO_2^- (C) OCN^- (D) $S_2O_3^{2-}$

Assertion Reasoning Type

(A) Statement-I is true, statement-II is true and statement-II is correct explanation for statement-I.

(B) Statement-I is true, statement-II is true and statement-II is not the correct explanation for statement-I.

(C) Statement-I is true, statement-II is false.

(D) Statement-I is false, statement-II is true.

Q.15 Statement-I: $[Cr(NH_3)_6]^{3+}$ has three unpaired electron in t_{2g} orbital

Statement-II: $[Cr(NH_3)_6]^{3+}$ does not show geometrical isomerism.

Q.16 Statement-I: The square planar complex, $[M_{abcd}]^{n+}$ type shows geometrical isomerism.

Statement-II: Restricted rotation around the single bond is present within the above complex.

Comprehension Type

Paragraph 1: Isomerism is a phenomenon where the molecules are having same formula but they have different structures.

Q.17 Which of the following ligand can show linkage isomerism?

(A) NMe_3 (B) $\bar{O}CN$ (C) SO_4^{2-} (D) None of these

Q.18 Which of the following ligand can show linkages isomerism?

(A) It increase the stability of complex.

(B) It increase the strength of metal–ligand bond.

(C) More negative charge on the central atom causes more extent of synergic bonding.

(D) All of these

Q.19 Choose the incorrect statement from the following options.

(A) C_2H_2 can acts as π-acid ligand

(B) $[MA_3B_2C]^{n\pm}$: All isomers are optically inactive.

(C) $[MABCDE_2]^{n\pm}$ complex has total 12 optically active isomer

(D) All statements are incorrect.

Paragraph 2: Metals from complexes with various lewis bases called ligands, more the basic character better is the complex. Electron donating tendency decreases with increase in electronegativity of donor atoms in a period. Higher the bond order of metal ligand bond more is the stability of complex. Geometry and symmetry also influence the stability of complex. More symmetricity of the complex, more is the stability.

Q.20 Little Mohr's salt was dissolved in a water sample containing CO_3^{2-}, Cl^-, CN^- and OH^- in minute amounts. Fe2+ prefers formation of complex with

(A) CO_3^{2-} (B) Cl^- (C) CN^- (D) OH^-

Q.21 Fe^{2+} forms diamagnetic complex with either of CO_3^{2-}, Cl^-, CN^- or OH^-. Geometry of the complex formed is supposed to be

(A) Tetrahedral (B) Triangular bipyramidal

(C) Octahedral (D) Square planar

Q.22 Least stable complex is

(A) Mn $(CO)_5$ (B) K [V $(CO)_5$]

(C) K [Fe $(NC)_6]^{4-}$ (D) [Fe $(NC)_6]^{4-}$

Match the Columns

Q.23

Column I	Column II
(A) Na [Co $(CO)_4$] Pt	(p) Complex having only monodentate ligand
(B) (Trien) Cl_2	(q) Complex not following Sidgwick EAN rule.
(C) [Fe $(H_2O)_5NO$] SO_4	(r) Complex is having 3 or 5 member of ring within it.
(D) [Fe (EDTA)]$^-$	(s) Complex having positively charged ligand
	(t) Complex having chelating ligand

Q.24

Column I	Column II
(A) $[Co(CO)_4]^-$	(p) E.A.N $\neq$ 36
(B) $[Zn(gly)_2]$	(q) Synergic bonding is involved
(C) $[Ag(CN)_2]^-$	(r) Two optically active isomer
	(s) The complex is diamagnetic

Q.25

Column I	Column II
(A) $[M(AA)_3]$	(p) Two pair of enantiomer
(B) $[M(AB)B_2C_2]$	(q) Four geometrical isomer
(C) $[M(AB)_3]$	(r) Two optically inactive isomer
(D) $[MA_3BCD]$	(s) Two optically active isomer
	(t) At least one stereoisomer is planar

Note: $\widehat{AA}$,$\widehat{AB}$, a, b, c, d are not having chiral center.

Q.26

Column I	Column II
(A) Zn [Fe $(CN)_5NO$]	(p) Blue color due to charge transfer
(B) [Fe $(H_2O)_5NO$] SO_4	(q) d^2sp^3 hybridization
(C) Fe_4 [Fe $(CN)_6]_3$	(r) Paramagnetic compound
(D) $K_4[Fe(CN)_5O_2]$	(s) NO acts as positive ligand
	(t) Charge transfer metal to metal in complex.

Q.27

Column I	Column II
(A) [Pt $(NH_3)_5Cl$] Cl_3	(p) 229
(B) [Pt $(NH_3)_4Cl_2$] Cl_2	(q) 97
(C) [Pt $(NH_3)_3Cl_3$] Cl	(r) 404
(D) [Pt $(NH_3)_6$] Cl_3	(s) 523

Previous Years' Questions

Q.1 Amongst the following, the lowest degree of paramagnetism per mole of the compound at 298 K will be shown by ***(1988)***

(A) $MnSO_4 \cdot 4H_2O$ (B) $CuSO_4 \cdot 5H_2O$

(C) $FeSO_4 \cdot 6H_2O$ (D) $NiSO_4 \cdot 6H_2O$

Q.2 Which of the following is formed when excess of KCN is added to aqueous solution of copper sulphate? ***(1996)***

(A) $Cu(CN)_2$ (B) $K_2[Cu(CN)_4]$

(C) $K[Cu(CN)_2]$ (D) $K_3[Cu(CN)_4]$

Q.3 The complex ion which has no 'd' –electrons in the central metal atom is ***(2001)***

(A) $[MnO_4]^-$ (B) $[Co(NH_3)_6]^{3+}$

(C) $[Fe(CN)_6]^{3-}$ (D) $[Cr(H_2O)_6]^{3+}$

Q.4 The compound having tetrahedral geometry is ***(2004)***

(A) $[Ni(CN)_4]^{2-}$ (B) $[Pd(CN)_4]^{2-}$ (C) $[PdCl_4]^{2-}$ (D) $[NiCl_4]^{2-}$

Q.5 The IUPAC name of $[Ni(NH_3)_4]$ $[NiCl_4]$ is ***(2008)***

(A) Tetrachloronickel (II)-tetraamminenickel (II)

(B) Tetraamminenickel (II)-tetrachloRonickel(II)

(C) Tetraamminenickel (II)-tetrachloronickelate (II)

(D) Tetrachloronickel (II)-tetraamminenickelate (0)

Q.6 Geometrical shapes of the complexes formed by the reaction of Ni^{2+} with Cl^-, CN^- and H_2O, respectively, are ***(2011)***

(A) Octahedral, tetrahedral and square planar

(B) Tetrahedral, square planar and octahedral

(C) Square planar, tetrahedral and octahedral

(D) Octahedral, square planar and octahedral

Q. 7 Among the following metal carbonyls, the C—O bond order is lowest in ***(2007)***

(A) $[Mn(CO)_6]^+$ (B) $[Fe(CO)_5]$ (C) $[Cr(CO)_6]$ (D) $[V(CO)_6]^-$

Q.8 Statement-I: The geometrical isomers of the complex $[M(NH_3)_4Cl_2]$ are optically inactive.

Statement-II: Both geometrical isomers of the complex $[M(NH_3)_4Cl_2]$ possess axis of symmetry. ***(2008)***

(A) Statement-I is true, statement-II is true and statement- II is correct explanation for statement-I.

(B) Statement-I is true, statement-II is true and statement-II is not the correct explanation for statement-I.

(C) Statement-I is true, statement-II is false.

(D) Statement-I is false, statement-II is true

Q.9 Match the Columns ***(2007)***

Match the complexes in column I with their properties listed in column II.

Column-I	Column-II
(A) $[Co(NH_3)_4(H_2O)_2]Cl_2$	(p) Geometrical isomers
(B) $[Pt(NH_3)_2 Cl_2]$	(q) Paramagnetic
(C) $[Co(H_2O)_5Cl_2]$	(r) Diamagnetic
(D) $[Ni(H_2O)_6]Cl_2$	(s) Metal ion with+2 oxidation state

Q.10 Total number of geometrical isomers for the complex $[RhCl (CO) (PPh_3) (NH_3)]$ is ***(2010)***

Q.11 The volume (in mL) of 0.1 M $AgNO_3$ required for complete precipitation of chloride ions present in 30 mL of 0.01 M solution of $[Cr (H_2O)_5Cl] Cl_2$, as silver chloride is close to ……

Q.12 Identify the complexes which are expected to be colored. Explain ***(1994)***

(i) $[Ti (NO_3)_4]$ (ii) $[Cu (NCCH_3)] + BF_4$

(iii) $[Cr (NH_3)_6] Cl_3$ (iv) $K_3 [VF_6]$

Q.13 Draw the structures of $[Co (NH_3)_6]^{3+}$, $[Ni (CN)_4]^{2-}$ and $[Ni (CO)_4]$. Write the hybridization of atomic orbitals of the transition metal in each case. ***(2000)***

Q.14 Write the IUPAC name of the compound $K_2 [Cr (NO) (CN)_4(NH_3)]$. Spin magnetic moment of the complex μ = 1.73 BM. Give the structure of anion. ***(2003)***

Q.15 $NiCl_2$ in the presence of dimethyl glyoxime (DMG) gives a complex which precipitates in the presence of NH_4OH, giving a bright red color. ***(2004)***

(A) Draw its structure and show H-bonding

(B) Give oxidation state of Ni and its hybridization

(C) Predict whether it is paramagnetic or diamagnetic

Q.16 Statement-I: $\left[Fe(H_2O)_5 NO\right]SO_4$ is paramagnetic

Statement-II: The Fe in $\left[Fe(H_2O)_5 NO\right]SO_4$ has three unpaired electrons. ***(2008)***

(A) Statement-I is true, statement-II is true; statement-II is correct explanation for statement-I

(B) Statement-I is true, statement-II is true; statement-II is NOT a correct explanation for statement-I

(C) Statement-I is true, statement-II is false

(D) Statement-I is false, statement-II is true

Q.17 As per IUPAC nomenclature, the name of the complex is $\left[Co(H_2O)_4(NH_3)_2 Cl_3\right]$ ***(2012)***

(A) Tetraaquadiaminecobalt (III) chloride

(B) Tetraaquadiamminecobalt (III) chloride

(C) Diaminetetraaquacobalt (III) chloride

(D) Diamminetetraaquacobalt (III) chloride

Q.18 Consider the following complex ions, P, Q and R

$$P = \left[FeF_6\right]^{3-}, Q = \left[V(H_2O)_6\right]^{2+} \text{ and } R = \left[Fe(H_2O)_6\right]^{2+}$$

The correct order of the complex ions, according to their spin–only magnetic moment values (in B.M.) is ***(2013)***

(A) R < Q < P (B) Q < R < P

(C) R < P < Q (D) Q < P < R

Q.19 The pair(s) of coordination complexes/ions exhibiting the same kind of isomerism is(are) ***(2013)***

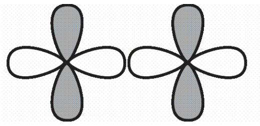
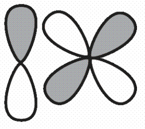
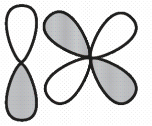
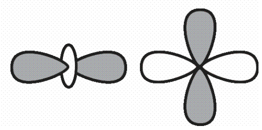
(A) $\left[Cr(NH_3)_5 Cl\right]Cl_2$ and $\left[Cr(NH_3)_4 Cl\right]Cl$

(B) $\left[Co(NH_3)_4 Cl_2\right]^+$ and $\left[Pt(NH_3)_2(H_2O)Cl\right]^+$

(C) $\left[CoBr_2Cl_2\right]^{2-}$ and $\left[PtBr_2Cl_2\right]^{2-}$

(D) $\left[Pt(NH_3)_3(NO_3)\right]Cl$ and $\left[Pt(NH_3)_3 Cl\right]Br$

Q.20 Match the orbital overlap figures shown in list-I with the description given in list-II and select the correct answer using the code given below the lists. ***(2014)***

List-I	List-II
(A) 	(p) $p-d\pi$ anticoding
(B) 	(q) $d-d\sigma$ bonding
(C) 	(r) $p-d\pi$ bonding
(D) 	(s) $d-d\sigma$

Code:

	p	Q	r	Ss
(A)	2	1	3	4
(B)	4	3	1	2
(C)	2	3	1	4
(D)	4	1	3	2

Q.21 For the octahedral complexes of Fe^{3+} in SCN^- (thiocyanato-S) and in CN^- ligand environments, the difference between the spin-only magnetic moments in Bohr magnetons (When approximated to the nearest integer) is

[Atomic number of Fe = 26] ***(2015)***

Q.22 Among the complex ions,

$$\left[Co\left(NH_2-CH_2-CH_2-NH_2\right)Cl_2\right]^+,\left[CrI_2\left(C_2O_4\right)_2\right]^{3-},$$

$$\left[Fe\left(H_2O\right)_4\left(OH\right)_2\right]^+,\left[Fe\left(NH_3\left(CN_4\right)\right)\right]^{-}.$$

$$\left[Co\left(NH_2-CH_2-CH_2-NH_2\right)Cl\right]^{2+}$$

and $\left[Co\left(NH_3\right)_4\left(H_2O\right)Cl_2\right]^{2+}$

the number of complex ion(s) that show(s) cis-trans isomerism is ***(2015)***

Q.23 In the complex acetylbromidodicarbonylbis (triethylphosphine) iron(II), the number of Fe–C bond(s) is ***(2015)***

Q.24 Among $[Ni(CO)_4]$, $[NiCl_4]^{2-}$, $[Co(NH_3)_4\ Cl_2]Cl$, $Na_3[CoFe_6]$, Na_2O_2 and CsO_2 the total number of paramagnetic is ***(2016)***

(A) 2 (B) 3 (C) 4 (D) 5

Q.25 The number of geometric isomers possible for the complex $[CoL_2Cl_2]^-$ ($L = H_2NCH_2CH_2O^-$) is ***(2016)***

Q.26 The geometries of the ammonia complexes of respectively, are ***(2016)***

(A) Octahedral, square planar and tetrahedral

(B) Square planar, octahedral and tetrahedral

(C) Tetrahedral, square planar and octahedral

(D) Octahedral, tetrahedral and square planar

MASTERJEE Essential Questions

JEE Main/Boards

Exercise 1

Q.2 Q.5 Q.12

Exercise 2

Q.6 Q.8 Q.13
Q.18 Q.22

Previous Years' Questions

Q.2 Q.5 Q.8
Q.10 Q.11 Q.14

JEE Advanced/Boards

Exercise 1

Q.6 Q.13 Q.19
Q.23 (iii, v, vii, ix) Q.25

Exercise 2

Q.4 Q.11 Q.15
Q.18 Q.29

Previous Years' Questions

Q.1 Q.6 Q.12

Answer Key

JEE Main/Boards

Exercise 2

Single Correct Choice Type

Q.1 D **Q.2** D **Q.3** D **Q.4** B **Q.5** D **Q.6** D **Q.7** B
Q.8 D **Q.9** B **Q.10** C **Q.11** B **Q.12** A **Q.13** B **Q.14** D
Q.15 B **Q.16** B **Q.17** B **Q.18** B **Q.19** A **Q.20** C **Q.21** C
Q.22 C

Previous Years' Questions

Q.1 C **Q.2** A **Q.3** B **Q.4** B **Q.5** C **Q. 6** B **Q.7** A
Q.8 B **Q.9** D **Q.10** B **Q.11** D **Q.12** C **Q.13** A **Q.14** C
Q.15 B **Q.16** D **Q.17** A **Q.18** D **Q.19** B **Q.20** A **Q.21** B
Q.22 B **Q.23** B **Q.24** B **Q.25** C **Q.26** B **Q.27** B **Q.28** A
Q.29 A **Q.30** A

JEE Advanced/Boards

Exercise 2

Single Correct Choice Type

Q.1 D **Q.2** B **Q.3** D **Q.4** A **Q.5** B

Multiple Correct Choice Type

Q. 6 A, C **Q.7** C, D **Q.8** C, D **Q.9** A, D **Q.10** A, B, C **Q.11** A, B, C

Q.12 A, B, C, D **Q.13** A, C, D **Q.14** B, C, D

Assertion Reasoning Type

Q.15 B **Q.16** C

Comprehension Type

Paragraph 1: Q.17 B **Q.18** D **Q.19** C **Paragraph 2: Q.20** C **Q.21** C **Q.22** B

Match the Colulmns

Q.23 A → p; B → q, r, t; C → p, q, s; D → q, r, t

Q.24 A → q, s; B → r, s; C → p, q, s

Q.25 A → s; B → p, q, r; C → p; D → q, s

Q.26 A → q, s; B → r, s; C → p, q, r, t; D → q, r

Q.27 A → r; B → p; C → q; D → s

Previous Years' Questions

Q.1 B **Q.2** D **Q.3** A **Q.4** D **Q.5** C **Q.6** B **Q.7** B

Q.8 B **Q.9** A → p, q; B → p, r; C → q; D → q, s **Q.10** 3 **Q.11** 6 mL **Q.12** (iii) (iv)

Q.16 A → p, q, s; B → p, r, s; C → q, s; D → q, s **Q.17** B **Q.18** C **Q.19** B

Q.20 A **Q.21** D **Q.22** 5 **Q.23** D **Q.24** B **Q.25** 5 **Q.26** A

Solutions

JEE Main/Boards

Exercise 1

Sol 1: According to Werner Metal show two types of linkages /valences namely primary and secondary. Primary are ionisable and exhibit negative charge. Secondary are non-ionisable. Secondary valency is the coordination no. of central metal atom and is fixed.

Sol 2: 1: 1 ratio, $FeSO_4.(NH_2)_2SO_4$ is a double salt. So, we can detect all the ions.

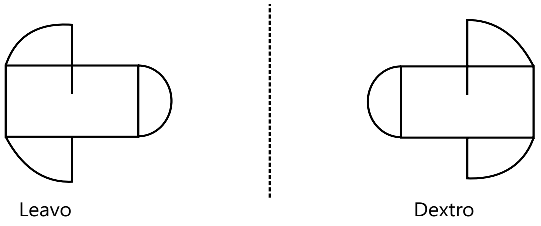
In 2nd case, we get $[Cu(NH_3)_4]^{2+}$, so we cannot get positive test for Cu^{2+}

Sol 3: (i) $[Cr(C_2O_4)_3]^{3-}$ doesn't exhibit geometric isomerism.

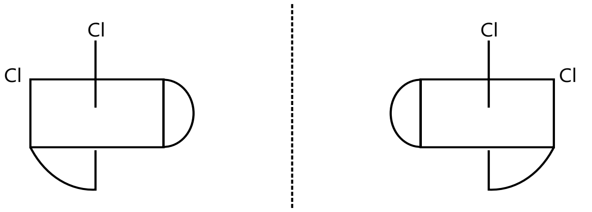
(ii) $[PtCl_2(en)_2]^{2+}$ has 2 geometrical isomers.

(iii) $[Cr(NH_3)_2\ Cl_2(en)]$ has 2 geometrical isomers.

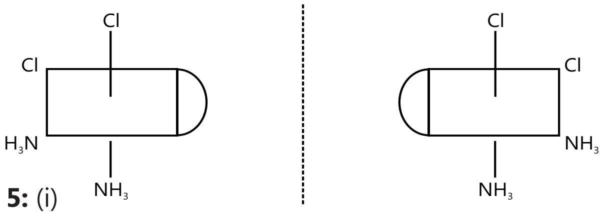
Sol 4: (i)



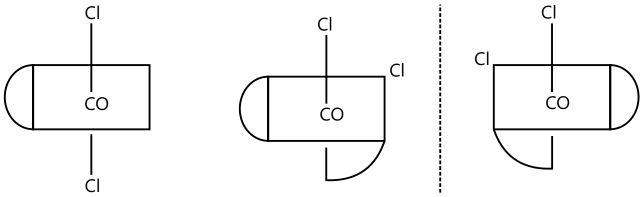
(ii)



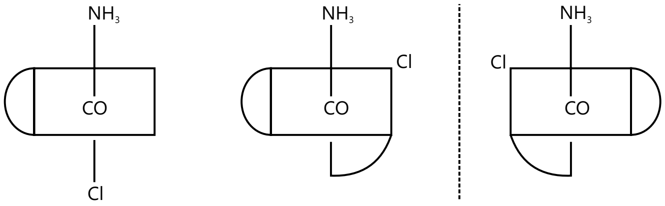
(iii)



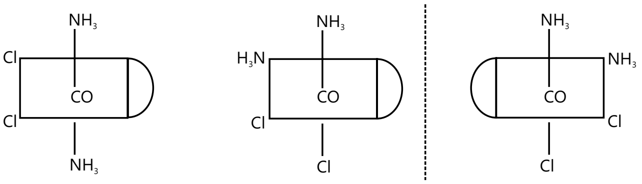
Sol 5: (i)



(ii)



(iii)

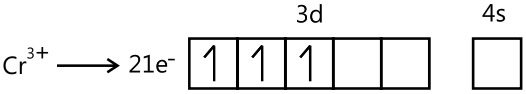


Sol 6: (i) We get a precipitate of CuF_2.

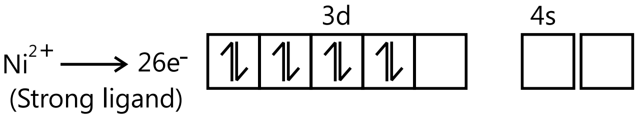
(ii) We get a complex $K_2[CuCl_4]$.

Sol 7: $K_3[Cu(CN)_4]$ is formed. No precipitate is obtained because of the lack of Cu^{2+} ions in the solutions. All the copper is in complex form.

Sol 8:



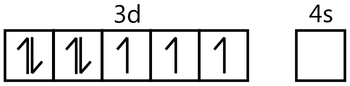
3 unpaired e^- which do not pair up after hybridisation as is a weak field ligand.



Present even after hybridisation as CN^- is a strong field ligand.

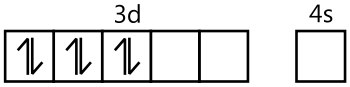
Sol 9: Ni^{2+} is present in both cases but H_2O is present weak ligand

∴ Configuration in 1st Case



2 unpaired e$^-$

Configuration in 2nd Case

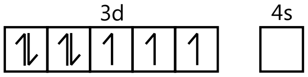


no unpaired e$^-$

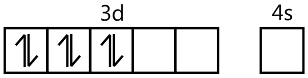
Due to presence of unpaired e$^-$ $[Ni(H_2O)_6]^{2+}$ is coloured

Sol 10: Both the complexes have Fe^{2+} as the central metal ion, but H_2O is weak ligand, CN^- is strong ligand.

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



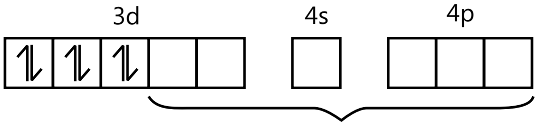
$[Fe(CN)_6]^{4-}$



Hence, no. of unpaired e$^\ominus$ are different in both cases which results in different colours in dilute solutions.

Sol 11: (i) $K_3[Co(C_2O_4)_3]$

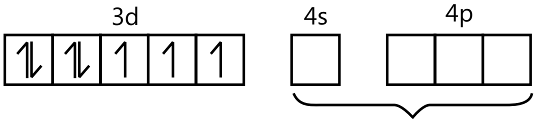
$Co \longrightarrow +3$



Co.no=6

(ii) $[CoF_4]^{2-}$

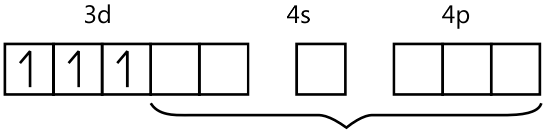
$Co \longrightarrow +2$



Co.no=4

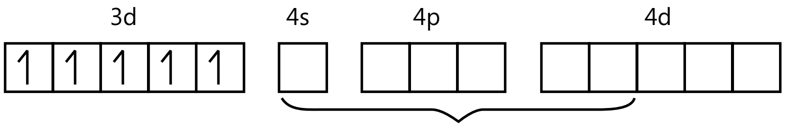
(iii) Cis $[Cr(en)_2Cl_2]Cl$

$Cr \longrightarrow +3$



Co.no=6

(iv) $Mn \longrightarrow 2+$

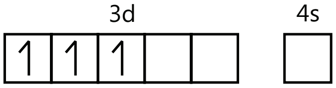


Co.no=6

Sol 12: (i)$K[Cr(H_2O)_2(C_2O_4)_2]\cdot 3H_2O$

Potassium diaquadioxalateochromate (III) Trihydrate

$Cr \longrightarrow +3$ Co. No. = 6



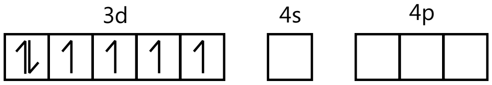
It shows geometric, optical isomerism

MM = $\sqrt{3(5)} = \sqrt{15}$ BM [$\because$ MM = $\sqrt{n(n+2)}$ BM] where n is no. of unpaired e^-

(ii) $[Co(NH_3)_4Cl]Cl_2$

Tetraammine chloro Cobalt (III) Chloride

Co ⟶ +3 co. = 5



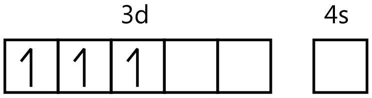
No stereo isomerism

MM = $\sqrt{4(6)} = \sqrt{24}$ BM

(iii) $CrCl_3(py)_3$

Trichloro Tripyridinium Chromium (III)

Cr ⟶ +3 Co. No. = 6

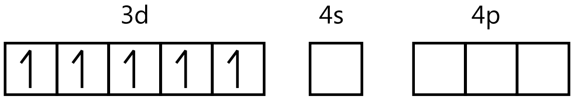


Shows geometric isomerism

MM = $\sqrt{3(5)} = \sqrt{15}$ BM

(iv) $Cs(FeCl_4) \rightarrow$ Caesium Tetrachloro Ferrate (III)

Fe ⟶ +3 Co. No. = 4

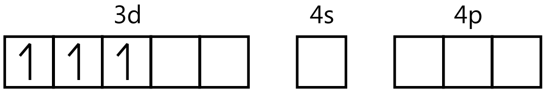


No. isomerism, MM = $\sqrt{5(7)} = \sqrt{35}$ BM

(v) $K_4[Mn(CN)_6]$

Potassium Hexacyano Maganate (II)

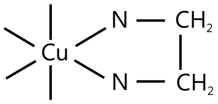
Mn ⟶ +2, Co. No. = 6



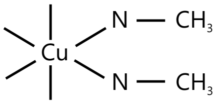
No Isomerism, MM = $\sqrt{(5)7}$ BM= $\sqrt{35}$BM

Sol 13: Chelation describes a particular way that ions and molecules bind metal ions. Chelation involves the formation or presence of two or more separate coordinate bonds between a polydentate ligand and a metal atom.

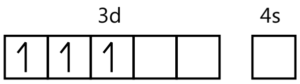
Chelate effect describes the enhanced affinity of chelating ligands for a metal ion compared to the affinity of collection of similar non-chelating ligands for same metal.



is stable than

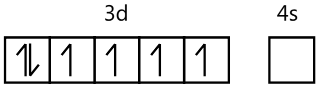


Sol 14: (i) $[Cr(H_2O)_6]^{3+}$, H_2O is weak ligand.



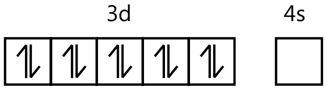
3 unpaired e^- i.e. n = 3

(ii) $[Fe(H_2O)_6]^{2+}$, H_2O is weak ligand



3 unpaired e^- i.e. n = 4

(iii) $[Zn(H_2O)_6]^{2+}$, H_2O is weak ligand



No unpaired e^- i.e. n = 0

(ii) Has highest magnetic moment as it has highest no. of unpaired e^-

Sol 15: Strength of ligands $\longrightarrow$ $NO_2^- > NH_3 > H_2O$

$\therefore$ Wavelength of $[Ni(H_2O)_6]^{2+} > [Ni(NH_3)_6]^{2+} > [Ni(NO_2)_6]^{4-}$

Sol 16: NH_4^+ cannot form complexes due to lack of lone pair

Sol 17: $[Co(NH_3)_5Cl]^{2+}$

Exercise 2

Single Correct Choice Type

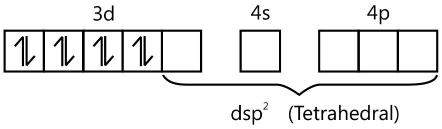
Sol 1: (D) $[CoF_6]^{3-}$ doesn't have synergic bonding due to lack of empty orbitals in F^-.

Sol 2: (D) CO, NH_3 are strong ligands. So all are low spin complexes

Sol 3: (D) $K[Fe(H_2O)_2(NCS)_3NO_3]$

Potassium di aqua-tri-isothiocynato-nitrato Ferrate (III)

Sol 4: (B) Fe $\longrightarrow$ 26



CO is a strong ligand. Pairing takes place.

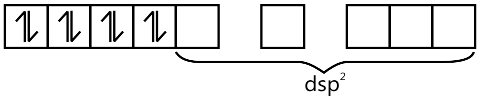
Sol 5: (D) NO $\longrightarrow$ NO^+, Co^{2+} $\longrightarrow$ Co^{3+} (Stable)

Mn^+ can form stable complex with strong ligand CO.

So, all are reducing agents

Sol 6: (D) Ni $\longrightarrow$ O (zero), dsp^2 hybridisation is not possible.

Pd^{2+} $\longrightarrow$ Square planar

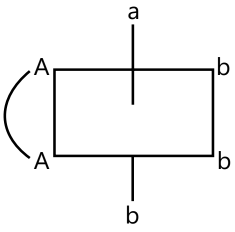


Sol 7: d^4, d^5, d^6, d^7

Sol 8: (D) Reasons are vacant d-orbitals and that their charge to size ratio is large but not that they are metals

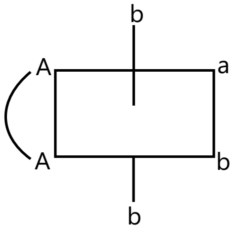
Sol 9: (B) In (A) charge is +4, so there is more donation in (A) from Co to O. So B.O. in A is low. So, bond length is A is higher.

Sol 10: (C)



Only 1 Isomer

Facial



Only 1 Isomer

Meridional

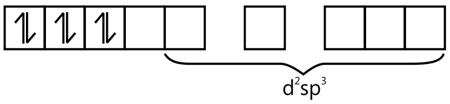
Sol 11: (B) It has 5 CN^- ligands (strong) Fe^{2+}, pairing takes place. So, d^2sp^3

Sol 12: (A) IUPAC of $[Cr(H_2O)_5ONO]Br_2$ Penta-aquo-nitrito-O chromium(III) Bromide

Sol 13: (B) By reduction or dimension, it can attain EAN of 36. So, oxidation doesn't lead to stability.

Sol 14: (D) V^{2+} because of presence of unpaired e^-. Rest all have no unpaired e^-.

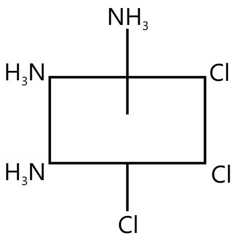
Sol 15: (B) Co^{3+} $\longrightarrow$ 24



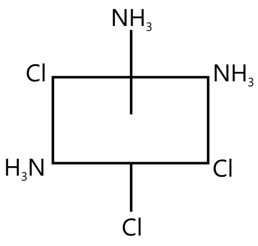
So, (b) is correct . In (a) Not exists as NO^+

In $[Fe(CO)_2(NO)_2]$, EAN = 36 (Since not exists as NO^+)

Sol 16: (B)



Facial



Meridional

Both have plane of symmetries

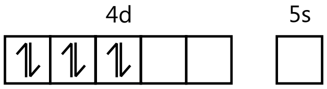
So, no optical isomer.

Stereo -2

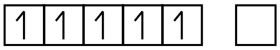
Sol 17: (B) Mohr's salt has very high mol wt but same reducing points. So, its less readily oxidizable than $FeSO_4$ and error in calculations decrease.

Sol 18: (B) $[RhF_6]^{3-} \longrightarrow Rh^{3+}$

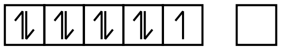
It's low spin inner orbital complex



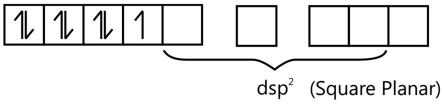
Sol 19: (A) Fe^{3+}, weak Tetrahedral



$[Cu(CN)_4]^{3-}$ Cu^+



$[AuCl_4]^-$ Au^{3+}



Sol 20: (C) $[Co(NH_3)_6]Cl_2$

3 ions i.e. $[Co(NH_3)_6]^{2+}$, $2Cl^-$

Sol 21: (C) $K[Co(CO)_4]$

CO → Neutral

K → +1 ⇒ Co → –1

Sol 22: (C) $[Fe(C_2O_4)_3]^{3-}$ is most stable because of chelate effect

Previous Years' Questions

Sol 1: (C) The number of atoms of the ligand that are directly bonded to the central metal atom or ion by coordinate bond is known as the coordination number of the metal atom or ion coordination number of metal = number of σ bonds formed by metal with ligand.

Sol 2: (A) CN^- ions acts both as reducing agent as well as good complexion agent.

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

$4 + x - 4 = 0 \Rightarrow x = 0$ for Ni.

Sol 5: (C) C.N. of E in complex is 6 and oxidation state is

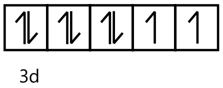
$x + 0 - 2 - 1 = 0 ; x = 3$

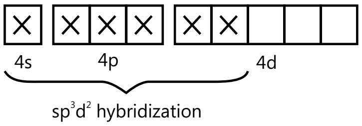
Sol 6: (B) $[Cr(en)_2Br_2]Br$

Dibromidobis (ethylenediamine) chromium (III) Bromide.

Sol 7: (A) Ni^{2+} in aqueous solution means $[Ni(H_2O)_6]^{2+}$. The electronic configuration of

Ni^{2+}(aq) :





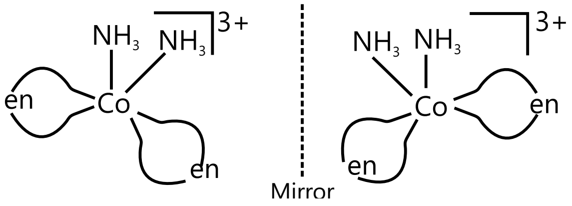
Total number of unpaired electron = 2

$\therefore$ Spin only magnetic moment of Ni^{2+} = $\sqrt{2(2+2)}$

= $2\sqrt{2}$ = 2.83 B.M.

Sol 8: (B) both have 4 unpaired electron.

Sol 9: (D) cis-form $[Co(en)_2(NH_3)_2]^{3+}$ has optical isomers.

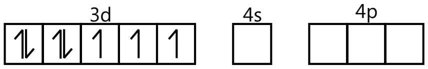


Sol 10: (B) SCN– ion can coordinate through the sulphur or nitrogen atom. Such possibilities give rise to linkage isomerism in coordination compounds.

M ← SCN Thiocyanato or thiocyanato-S

M ← NCS Isothiocyanato or thiocyanato-N

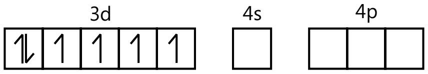
Sol 11: (D) $_{27}Co^{2+}$ – $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^7\ 4s^0$



As Cl^- is weak field ligand so no pairing up.

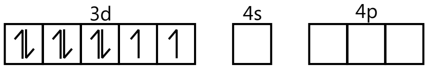
Hence it is sp^3 hybridized giving tetrahedral geometry.

Fe^{2+} – $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^6\ 4s^0$



Due to Cl^-, back pairing is not observed so it will be sp^3 hybridized giving tetrahedral geometry.

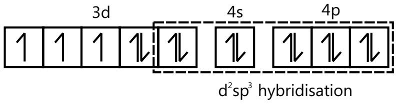
Ni^{2+} – $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^6\ 4s^0$



Because of weak ligand, back pairing is not observed so it will be sp^3 i.e. tetrahedral geometry. All the complexes of Pt^{2+} are square planner including those with weak field ligand such as halide ions thus (d) is correct.

Sol 12: (C) In case of d^3 configuration, the number of unpaired electrons remains 3 whether the ligand is strong field or weak field. The hybridization scheme can be shown as follow

$[Cr(NH_3)_3]^{3+}$ =



Hence, the complex is inner orbital complex as it involves (n – 1)d orbitals for hybridization, 3.93 = $\sqrt{n(n+2)}$; so n = 3 (here n is number of unpaired electron(s)).

Sol 13: (A) $2Cl^-$ ions are ionizable

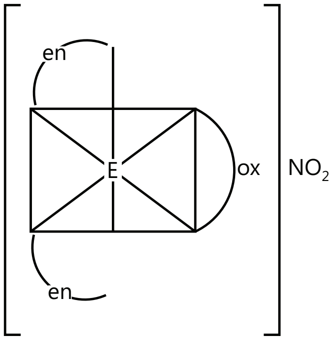
$$\therefore [Co(NH_3)_5Cl]Cl_2 \rightleftharpoons \underbrace{[Co(NH_3)_5Cl]^{2+} + 2Cl^-}_{3\text{ ion}}$$

$2Cl^- + 2AgNO_3 \rightarrow 2AgCl + 2NO_3^-$.

Sol 14: (C) As EDTA is an Hexadentate Ligand, only one molecule of EDTA will be required to form an octahedral complex with a Ca^{2+} ion.

Sol 15: (B) There is $d\pi$-$p\pi$ metal to ligand back bonding in Fe-C bond of the organometallic compound $Fe(CO)_5$. So it possesses both σ and π characters.

Sol 16: (D)



Coordination no = 6 and Oxidation no = 3

Sol 17: (A) CN^- is stronger ligand hence Δ_o is highest.

Sol 18: (D) It is octahedral complex of the type $[M(AA)_2x_2]$ Where AA is bidentate ligand.

Sol 19: (B) NSC^- is ambidentate ligand and it can be linked through N (or) S

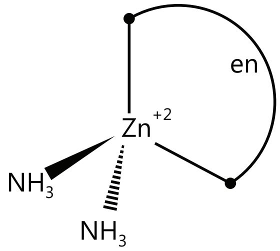
Sol 20: (A) $CoCl_3.6NH_3 \rightarrow xCl^- \xrightarrow{AgNO_3} x\ AgCl\downarrow$

$$n(AgCl) = x\ n(CoCl_3.6NH_3)$$

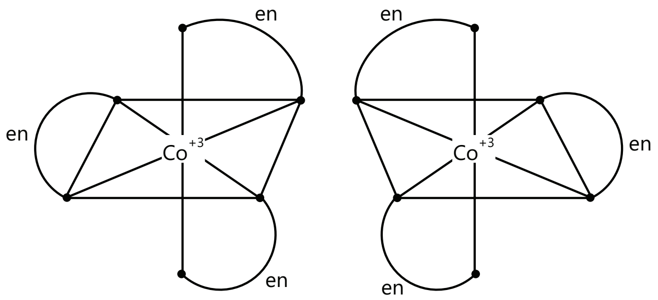
$$\frac{4.78}{143.5} = x\frac{2.675}{267.5} \qquad \therefore x = 3$$

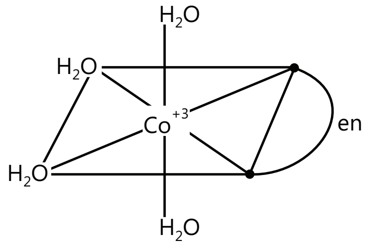
$\therefore$ The complex is $\left[Co(NH_3)_6\right]Cl_3$

Sol 21: (B) Only option (B) is having non-super imposable mirror image & hence one optical isomer.

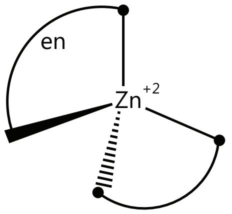


No optical isomer. It is
Tetrahedral with a plane of symmetry





Horizontal plane is plane symmetry



No optical isomer it is
tetrahedral with a plane of symmetry

Sol 22: (B) $\left[Cr\left(NH_3\right)_6\right]Cl_3$ involves $d^2\,sp^3$ hybridization and it is an inner orbital complex.

Sol 23: (B) In $\left[NiCl_4\right]^{2-}$, n = 2

$$\mu = \sqrt{n\left(n+2\right)}\ \text{BM}$$

$$= \sqrt{2\left(2+2\right)} = 2.82\ \text{BM}$$

Sol 24: (B) $\left[Cr\left(en\right)_2Br_2\right]Br$ - dibromido bis (ethylene diamine)chromium(III) bromide

Sol 25: (C) $\left[Co\left(NH_3\right)_3Cl_3\right]$ show facial as well as meridional isomerism. But both contain plane of symmetry. So, the answer is (C).

Sol 26: (B) The energy of red light is less than that of violet light.

So energy order is

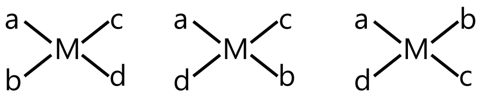
Red < Yellow < Green < Blue

The complex absorbs lower energy light lower will be its strength. So order of ligand strength is $L_1 < L_3 < L_2 < L_4$

Sol 27: (B) The complex is of the type [Mabcd]

M = metal

a, b, c, d = Monodentate ligands.



3 geometrical isomers

Sol 28: (A) $Zn_2\left[Fe\left(CN\right)_6\right]$ is white.

Sol 29: (A) Each $\left[Cr\left(H_2O\right)_6\right]^{2+}$ and $\left[Fe\left(H_2O\right)_6\right]^{2+}$

Contain 4 unpaired electron.

Sol 30: (A) With coordination number six, if two bidentate ligands in cis-position are present, then it is optically active.

JEE Advanced/Boards

Exercise 1

Sol 1: $[Co(NH)_3Cl_3] \longrightarrow$ Coordination entity

NH_3, Cl → ligand

Co. no = 6

Polyhedron ⟶ octahedral, different ligands so heteroleptic

$[Cr(C_2O_4)_3]^{3-}$

$CO_4^{2-} \rightarrow$ ligand

Co. no = 6

Octahedral and homoleptic

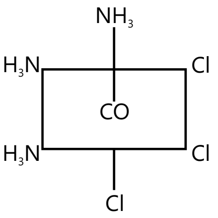
Sol 2: Unidentate → ligand with single e^- donor, ex. H_2O, NH_3

Bidentate → ligand with two e^- donor atoms, ex. $C_2O_4^{2-}$, en

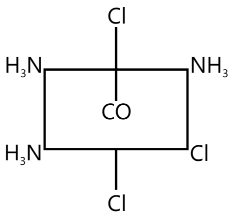
Ambidentate → ligand with more than $1e^-$ donor atom but both cannot donate pair at the same time.

Sol 3: (A) The main basis of the spectrochemical series is the energy difference in the orbitals of the control metal atom after coming close to the ligands. More is the Δ_0, stronger is ligand.

(B)

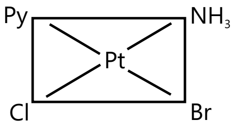


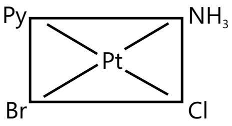
Facial

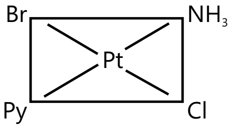


Meridional

Sol 4:







No one shows opitcal isomers as all of these are planare and have plane of symmetry.

Sol 5: Stability of a complex in solution refers to the degree of association between the species involved in the state of equilibrium.

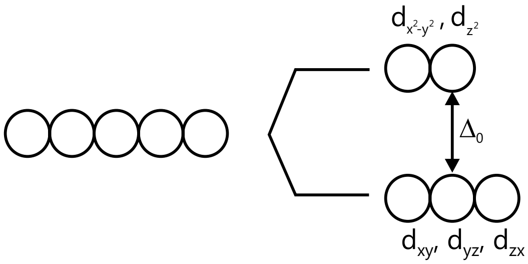
Ex. M + 4L ⇔ ML4

$$\beta = \frac{[ML_4]}{[M]\,[L]^4}$$

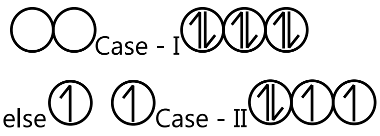
Their stability depends on

- Chelate effect
- Macrocyclic effect
- Geometric factors (like shape)
- Charge of metal ions
- Ionic radius

Sol 6:

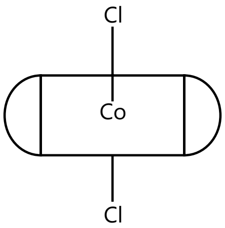


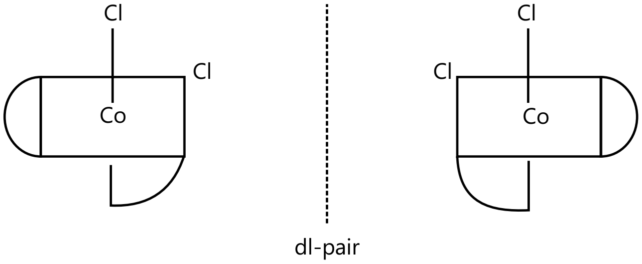
If energy released while pairing is higher than D. We get.



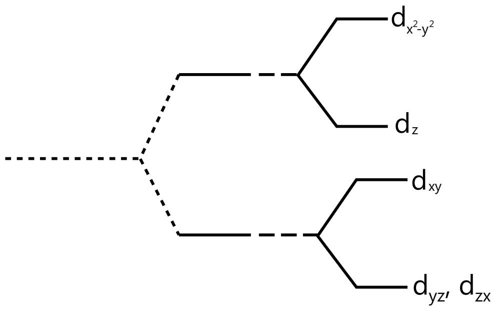
Sol 7: $[Co(en)_2Cl_2]Cl$

Dichloro Bisethylene Diamine Cobalt (III) Chloride



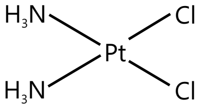


Sol 8:



Sol 9: (i) Enzymes

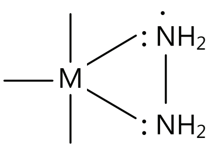
(ii) Ex. Cisplatin



(iii) For determining the presence of certain ions using complexing ligands

(iv) Au, Ag Complexes Ex. $[Au(CN)_2]^-$

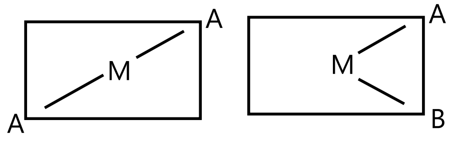
Sol 10: If it acts as a chelating agent



There is a formation of 3-membered ring. It's unstable because of high steric hindrance.

Sol 11: Square planar exhibit geometric isomerism because of possibility of 2 different locations from a single location.

E.g.



It's not possible in Tetrahedral. So, it can't show geometric isomerism

Sol 12: Let pt 0.5 be x

$x + (-6) = -2 \Rightarrow x = 4$

$Pt \rightarrow +4$

Sol 13: In Hg_2Cl_2, $Hg_2Cl_2 \longrightarrow HgCl_2 + Hg$

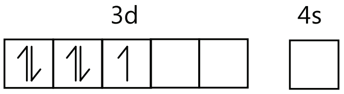
$$HgCl_2 + 2NH_3 \longrightarrow [Hg(NH_3)_2Cl_2]$$

$$\downarrow$$

$$[Hg(NH_2)Cl]\downarrow + NH_4Cl$$

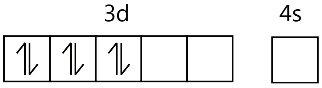
The liberated mercury renders this precipitate black

Sol 14: $[Fe(CN)_6]^{3-} \longrightarrow Fe^{3+}$



1 unpaired e^-

$[Fe(CN)_6]^{4-} \longrightarrow Fe^{2+}$

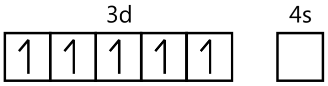


No unpaired e^-

Sol 15: $\sqrt{n(n+2)} = 5.92 \Rightarrow n = 5$

i.e. There are 5 unpaired e^-

$\therefore Mn^{2+} \longrightarrow$



Sol 16: Structural Isomerism

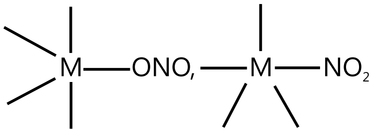
→ Ionisation Isomerism

$[Co(NH_3)_4Br_2]SO_4[Co(NH_3)SO_4]Br_2$

→ Hydrate Isomerism

$[Cr(H_2O)_6]Cl_3$ $[Cr(H_2O)_5Cl]Cl_2 \cdot H_2O$

→ Linkage Isomerism

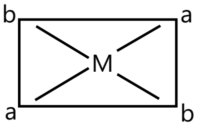


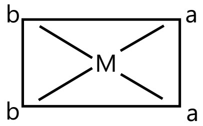
→ Coordination Isomerism

$[Co(NH_3)_6]$ $[Cr(CN)_6]$, $[CO(CN)_6]$ $[Cr(NH_3)_6]$

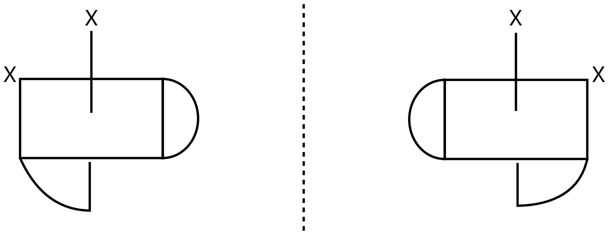
Stereo Isomerism

→ Geometrical Isomerism



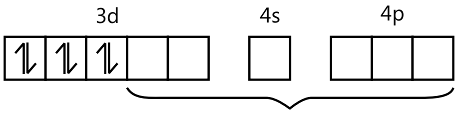


→ Optical Isomerism

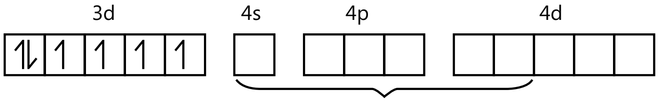


Sol 17: All the bonds between and ligand are coordinate covalent bonds.

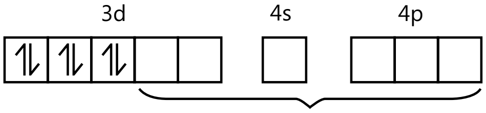
(i) $[Fe(CN)_6]^{4-} \longrightarrow Fe^{2+}$, strong ligand



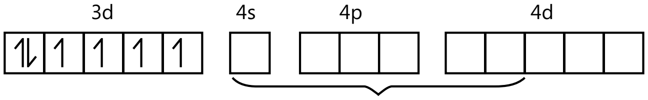
(ii) $[FeF_6]^{4-} \longrightarrow Fe^{2+}$, weak ligand



(iii) $[Co(C_2O_4)_3]^{3-} \longrightarrow Co^{3+}$, strong



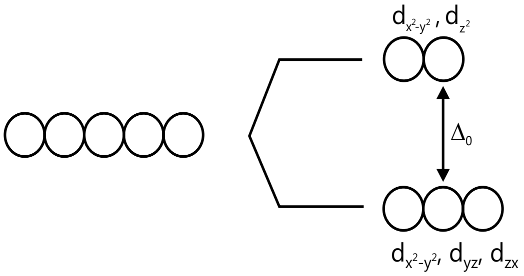
(iv) $[CoF_6]^{3-} \longrightarrow Co^{3+}$, weak



(i), (iii) → d^2sp^3

(ii), (iv) → sp^3d^2

Sol 18:



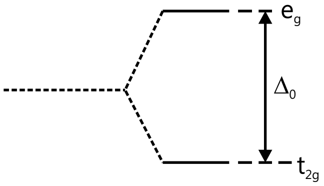
Sol 19: Spectrochemical series is a series depicting the strength of the ligands during complex formation.

Weak field ligand create small Δ_o (energy difference b/w newly formed orbitals) compared to strong field ligands.

So, pairing is not preferred against weak ligands

Sol 20: It's the energy difference between the new formed orbitals in the field of a ligand.

If Δ_o is high pairing is preferable

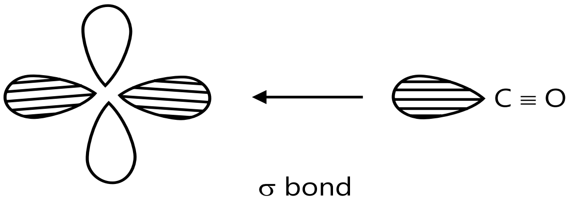


for ex. if we take d^6 configuration.

if Δ_o is high ↿⇂ ↿⇂ ↿⇂ is more stable

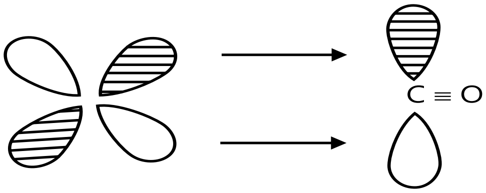
if Δ_o is low ↿⇂ ⇂ ⇂ is more stable

Sol 21: In metal carbonyls, CO acts as a ligand and forms



σ bond

After the formation of σ bonding. There is a possibility for back bonding from metals to CO.



The new e^- in CO enters into the anti bonding orbitals of CO and reduces its bond order. The bond order between M and C increase. The extent depends on no. of lone pairs present on metal for donation. It's called synergic effect

Sol 22: (i) $[Co(H_2O)CN(en)_2]^{2+}$

Co ⟶ +3, Octahedral

(ii) $[PtCl_4]^{2-}$

Pt ⟶ +2, Square Planar

(iii) $[Cr(NH_3)_3Cl_3]$

Cr ⟶ +3, Octahedral

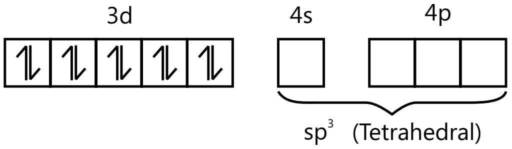
(iv) $[CoBr_2(en)_2]^+$

Co ⟶ +3, Octahedral

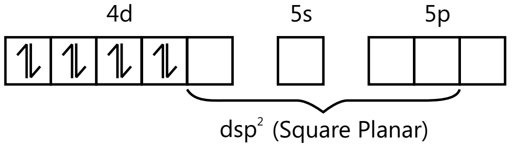
(v) $K_3[Fe(CN)_6]$

Fe ⟶ +3, Octahedral

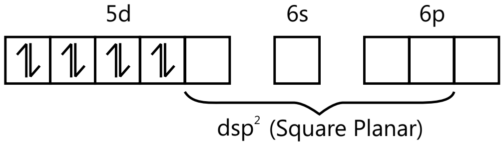
Sol 23: (i) $[Zn(H_2O)_4]^{2+} \longrightarrow$



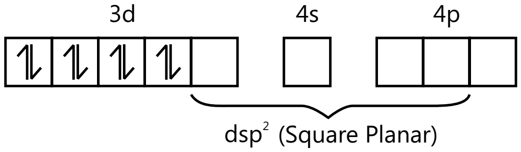
(ii) $K_2[PdCl_4] \longrightarrow$



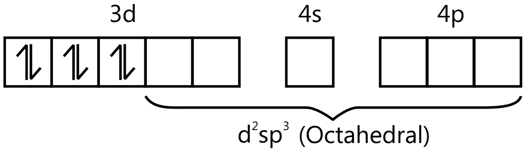
(iii) $[Pt(NH_3)_2Cl_2] \longrightarrow$



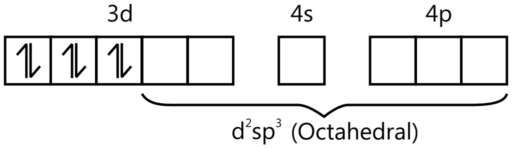
(iv) $K_2[Ni(CN)_4] \longrightarrow$



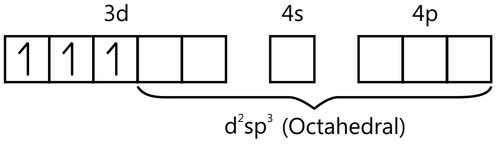
(v) $[Co(NH_3)_5ONO]^{2+} \longrightarrow$



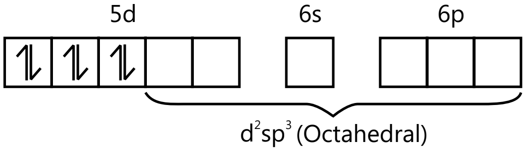
(vi) $[Co(NH_3)_6]_2(SO_4)_3 \longrightarrow$



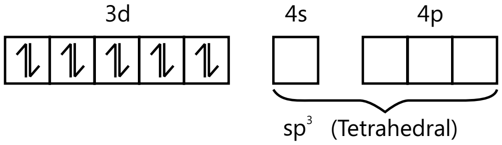
(vii) $K_3[Cr(C_2O_4)_3] \longrightarrow$



(viii) $[Pt(NH_3)_6]^{4+} \longrightarrow$



(ix) $[CoBr_4]^{2-} \longrightarrow$



Sol 24: VBT doesn't account for the difference in configuration with ligands of different strengths. It also doesn't account for the colour of complexes.

Where as CFT clearly explains the configurations of metals with different ligands using crystal field model so, that we can account for shape, colour and magnetic properties.

Sol 25: (i) $[Co(NH_3)_4H_2OCl]Cl_2$

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

(iii) $K_3[Al(C_2O_4)_3]$

(iv) $[CoCl_2(NH_2 - CH_2 - CH_2 - NH_2)_2]^+$

(v) $[Ni(CO)_4]$

Exercise 2

Single Correct Choice Type

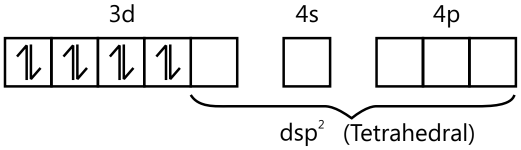
Sol 1: (D) Back bonding in $PCl_3 > PMe_3$

So complex having more PMe_3 will save higher back bonding to CO. So, it will have lower C–O bond order.

∴ BO of CO in.

$[M(CO)_3(PCl_3)_3] > [M(CO)_3(PCl_3)_2PMe_3] > [M(CO)_3PCl_3(PMe_2)_2]$

Sol 2: (B) Fe $\longrightarrow$ 26



Co is a strong ligand. Pairing takes place.

Sol 3: (D) NO $\longrightarrow$ NO^+, $Co^{2+} \longrightarrow Co^{3+}$ (Stable) Mn+ can form stable complex with strong ligand Co.

So, all are reducing agents

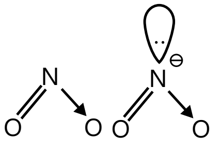
Sol 4: (A) By reduction or dimension, it can attain EAN of 36. So, oxidation doesn't lead to stability.

Sol 5: (B) Mohr's salt has very high mol wt but same reducing points. So, its less readily oxidizable than $FeSO_4$ and error in calculations decrease.

Multiple Correct Choice Type

Sol 6: (A, C) (A) is true because bridge CO will take e^- pair from 2 Fe atoms.

(B) is false.

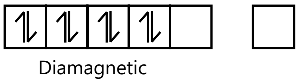


more repulsion by LP. So angle is less

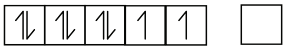
(C) is true.

No can also act as acceptor ligand

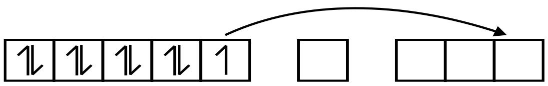
Sol 7: (C, D) (A) $Au^{3+} \longrightarrow$



(B) $Cu^{3+} \longrightarrow$

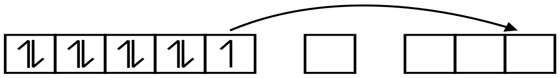


(C) $Cu^{2+} \longrightarrow$ Tetrahedral



Paramagnetic, Square Planar

(D) Co ⟶

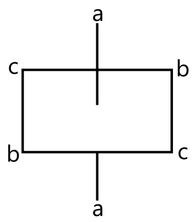


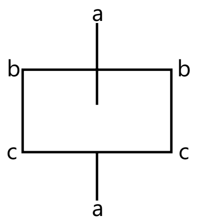
Paramagnetic, Square Planar

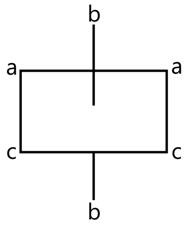
Sol 8: (C, D) Transition elements → last e⁻ enters in d-orbital and they are named as such because their properties lie between s and p block.

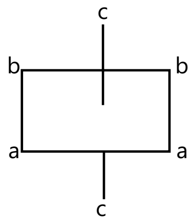
Lanthanum is a d-block transition metal

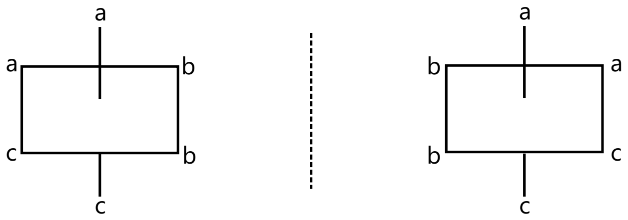
Sol 9: (A, D) (A)





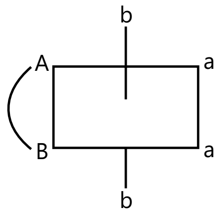


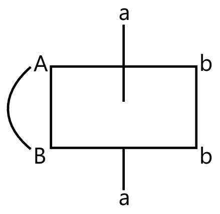


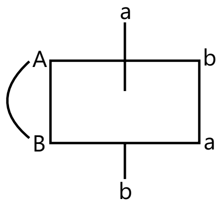


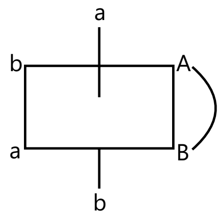
(A) Has 6 stereoisomer

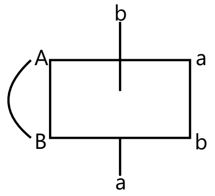
(D) $[M(AB)A_2B_2]$

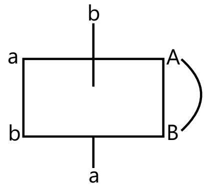












6 Stereoisomers

(C) Will have less than (D) as (3), (5) and (4), (6) Coincide

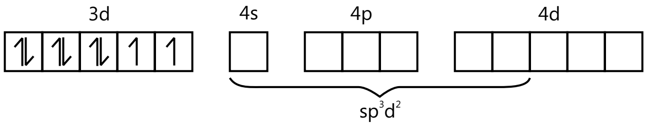
(B) Will have more than 6, as we can get 2 for each of (3), (4), (5), (6)

Sol 10: (A, B, C) $[Fe(CN)_6]^{4-}$ ⟶ low spin as CN^- is strong

$[PtCl_4]^{2-}$ ⟶ Pt^{2+} always forms low spin even with weak ligands

$[Co(C_2O_4)_3]^3$ ⟶ low spin as $C_2O_4^{2-}$ is strong ligand

$[Ni(NH_3)_6]^{2+}$ ⟶



High spin as 6 orbital are needed for hybridisation. Pairing need not occur.

Sol 11: (A, B, C) Cu^{2+} ⟶ 1 unpaired e⁻

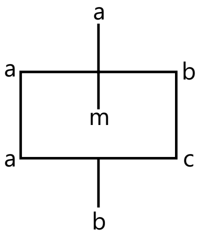
Ti^{3+} ⟶ 1

Fe^{3+}, strong ligand ⟶ 1

$[Cr(NH_3)_6]^{3+}$ ⟶ 3

Sol 12: (A, B, C, D) MA_4B_2 can't produce due to presence of plane of symmetry.

MA_3B_2C will also have plane of symmetry.



has a plane of symmetry

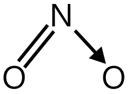
Sol 13: (A, C, D) (A) 22 + 4(2) = 30

(B) 26 + 2 + 4 (2) = 36 Not exists as NO+

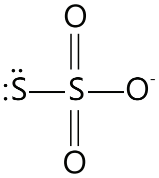
(C) 46 + 2(2) = 50

(D) 78 + 4(2) = 86

Sol 14: (B, C, D) NO_3^- can't show because of no LP on N.

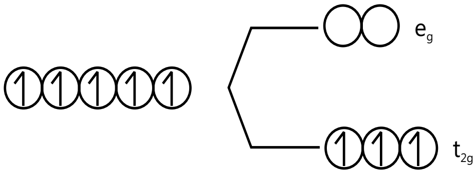


$^-$O-C≡N :



Assertion Reasoning Type

Sol 15: (B) $Cr^{+3} \longrightarrow 21e^-$

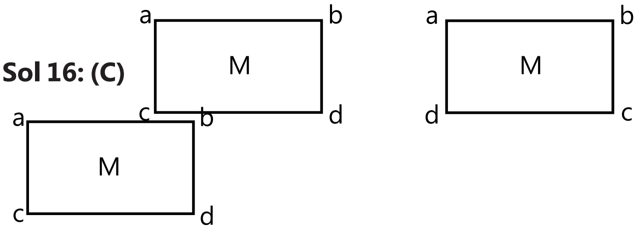


as all ligands are identical, it doesn't show geometrical isomerism.

But S-2 doesn't imply S-1

S-1 reason is that t_{2g} orbitals have less energy compared to eg orbitals.

Sol 16: (C)



S-2 is false, as rotation is possible around a single bond and $[MABCD]^{n\pm}$ can show geometrical isomerism

Comprehension Type

Paragraph 1:

Sol 17: (B) $NMe_3 \longrightarrow$ only N can donate e⁻ pair.

$SO_4^{2-} \longrightarrow$ only O can donate e⁻ pair.

$^{\ominus}OCN \longrightarrow$ O and N can donate e⁻ pair.

So, $OCN^{\ominus}$ can show linkage isomerism

Sol 18: (D) Due to synergic bonding M-L bond strength increases, so complex stability increases More negative charge of M, increases synergic bonding as more e⁻ pairs can be donated.

Sol 19: (C) C_2H_2 can act as π-acid ligand All $[MA_3B_2C]$ Isomers are optically inactive due to presence of plane of symmetry. Complex of type $[MABCDE_2]$ has 15 active isomers

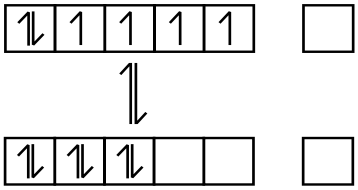
Paragraph 2:

Sol 20: (C) CN⁻, because in CO_3^{2-}, OH⁻ the e⁻ donar.

N, Cl have same EN but CN⁻ is a strong ligand

Sol 21: (C) $Fe \longrightarrow 26$

$Fe^{2+} \longrightarrow 24$



as there are 2 d orbitals octahedral

Sol 22: (B) $[V(CO)_5]^-$ Metals are mostly unstable under negative charge

Match the Columns

Sol 23: A → p; B → q, r, t; C → p, q, s; D → q, r, t

(A) $Na[Co(CO)_4] \longrightarrow$ monodentate ligand Follows EAN rule

(B) $[Pt(triene)Cl_2] \longrightarrow$ no EAN (80) 5 membered ring chelating ligand (trien)

(C) $[Fe(H_2O)_5NO]SO_4 \longrightarrow$ No EAN (37) all monodentate NO⁺ is +ve charged ligand

(D) $[Fe(EDTA)]^- \longrightarrow$ hexadentate ligand No EAN 5, membered ring (Chelating ligand)

Sol 24: A → q, s; B → r, s; C → p, q, s

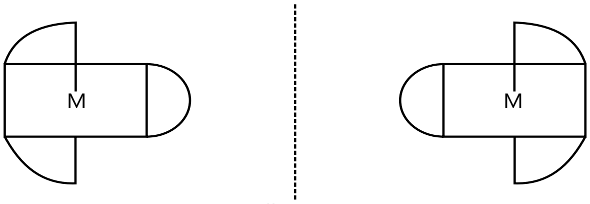
(A) $[Co(CO)_4]^- \longrightarrow$ EAN = 36 Synergic bonding is present Diamagnetic, no isomers

(B) $[Zn(sly)_2] \longrightarrow$ EAN = 36 dimagnetic, dl pair

(C) $[Ag(CN)_2]^- \longrightarrow$ EAN ≠36 (50) There is synergic bonding It's diamagnetic

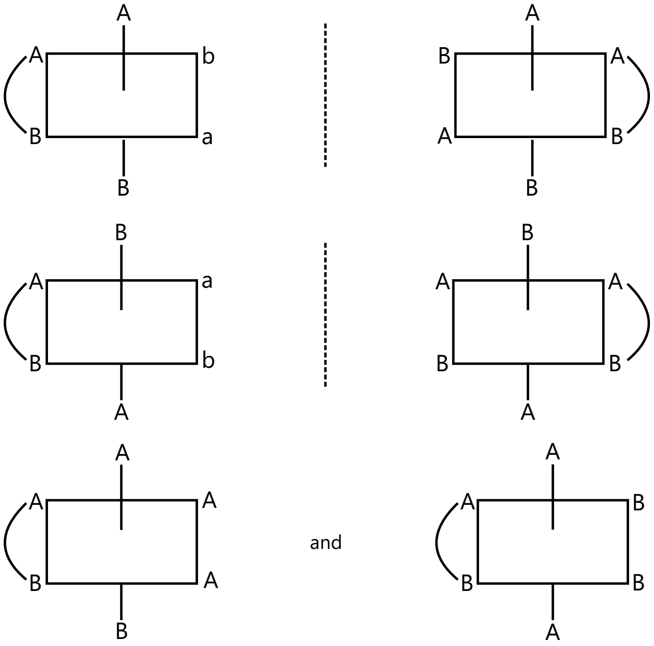
Sol 25: A → s; B → p, q, r; C → p; D → q, s

(A)

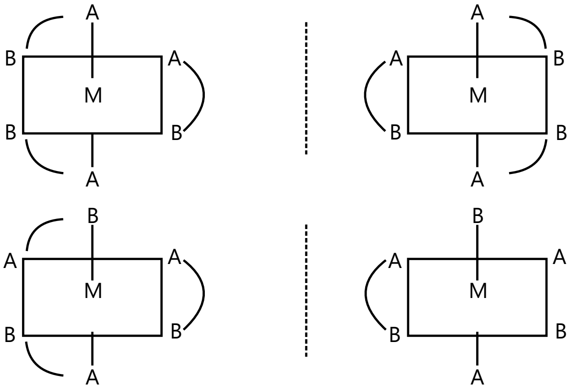


Two optically active isomers

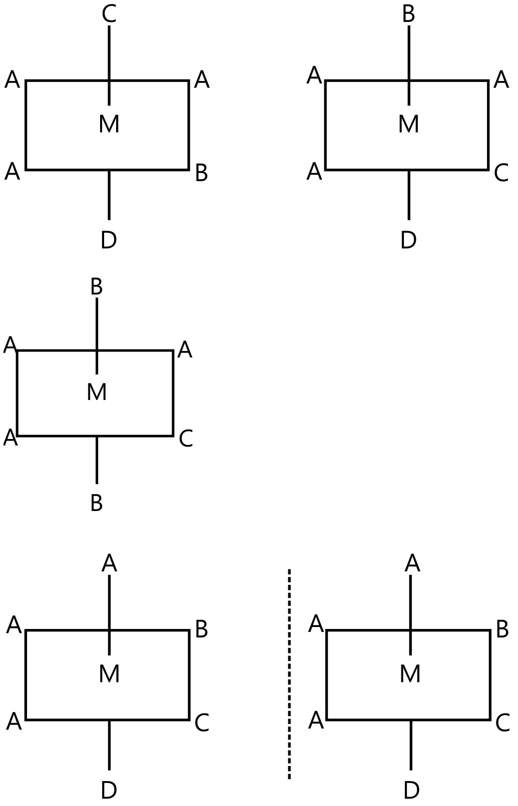
(B) $[M(AB)b_2c_2]$



(C) $[M(AB)_3]$



(D) $[Ma_3bcd]$



4 geometric, 2 optically active

Sol 26: A → q, s; B → r, s; C → p, q, r, t; D → q, r

(A) $Zn[Fe(CN)_5NO] \longrightarrow d^2sp^3$, Fe $\longrightarrow$ +2, So diamagnetic, NO $\longrightarrow NO^+$

(B) $[Fe(H_2O)_5NO]SO_4 \longrightarrow sp^3d^2$ paramagnetic

[$\because$ H_2O is a weak ligand]NO $\longrightarrow NO^+$

(C) $Fe_4[Fe(CN)_6]_3$

$[Fe(CN)_6]^{4-}$ i.e. $F^{2+} \longrightarrow d^2sp^3$

There is charge transfer between Fe ions.

$Fe^{3+} \longrightarrow$ Paramagnetic

(D) $K_4[Fe(CN)_5O_2]$

$Fe^{3+} \longrightarrow d^2sp^3$ and paramagnetic

(CN^- is strong ligand)

Sol 27: A → r; B → p; C → q; D → s

(A) No. of ions $\longrightarrow$ 4

(B) $\longrightarrow$ 3

(C) $\longrightarrow$ 2

(D) $\longrightarrow$ 5

$\therefore$ C $\longrightarrow$ 97 (q)

$B \longrightarrow 229$ (p)

$A \longrightarrow 404$ (r)

$D \longrightarrow 523$ (s)

Previous Years' Questions

Sol 1: (B) Salt with least no. of unpaired electrons in d-orbital of central metal will show lowest degree of paramagnetism.

$Mn^{2+}(3d^5$, 5 unpaired electrons)

$Cu^{2+}(3d^9$, 1 unpaired electron)

$Fe^{2+}(3d^6$, 4 unpaired electrons)

$Ni^{2+}(3d^8$, 2 unpaired electrons)

Hence, $CuSO_4 \cdot 5H_2O$ has lowest degree of paramagnetism.

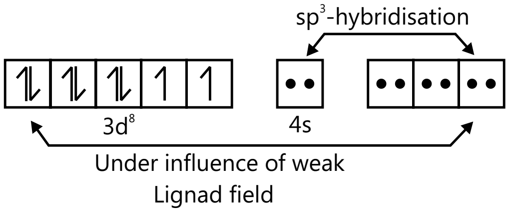
Sol 2: (D) $Cu^{2+} + CN^- \longrightarrow CuCN\downarrow$

$CuCN + 3CN^- \longrightarrow [Cu(CN)_4]^{3-}$

Sol 3: (A) In MnO^-_4, Mn^{+7} has $3d^0$ configuration.

Sol 4: (D) $[NiCl_4]^{2-}$: Ni^{2+} $(3d^8)$

(tetrahedral)



In all other complexes, hybridization at central metal is dsp^2 and complexes have square planar geometries.

Sol 5: (C) $[Ni(NH_3)_4]^{2+}$ = tetraamminenickel (II)

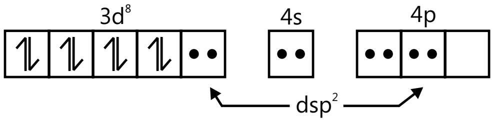
$[NiCl_4]^{2-}$ = tetrachloronickelate (II)

Cationic part is named first, hence :

tetraamminenickel (II)-tetrachloronickelate(II)

Sol 6: (B) $Ni^{2+} + 4CN^- \rightarrow [Ni(CN)_4]^{2-}$

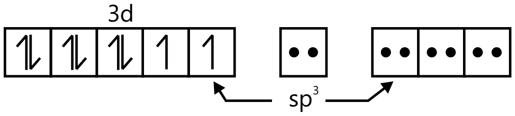
Here Ni^{2+} has d^8-configuration which CN^- as strong ligand



d^8-configuration in strong ligand field gives dsp^2 hybridisation, hence square planar geometry.

$N^{2+} + 4Cl^- \rightarrow [NiCl_4]^{2-}$

Here Ni^{2+} has d^8-configuration with Cl^- as weak ligand.



d^8- configuration in weak ligand field gives sp^3 hybridisation, hence tetrahedral geometry.

Ni^{2+} with H_2O forms $[Ni(H_2O)_6]^{2+}$ complex and H_2O is a weak ligand.

Sol 7: (B) (A) $Mn^+ = 3d^54s^1$ in presence of CO effective configuration = $3d^54s^0$ Three lone pair for back bonding with vacant orbital of C in CO.

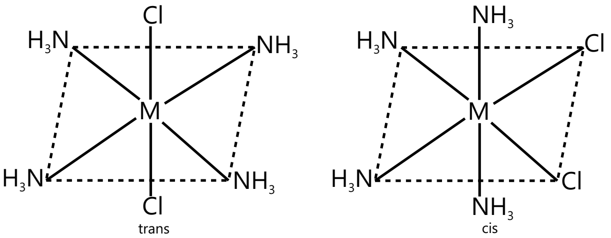
(B) $Fe^0 = 3d^64s^2$ in presence of CO effective configuration = $3d^8$ four lone pair for back bonding with CO.

(C) $Cr^0 = 3d^54s^1$ Effective configuration $3d^6$. Three lone pair for back bonding with CO.

(D) $V^- = 3d^44s^2$ effective configuration = $3d^6$ three lone pair for bonding with CO.

Maximum back bonding is present in $Fe(CO)_5$ there for CO bond order is lowest here.

Sol 8: (B) Both statements are true. However, axis of symmetry is not a criteria of optical isomerism. Optical inactivity of the two geometrical isomers of $[M(NH_3)_4Cl_2]$ is due to presence of lane of symmetry.

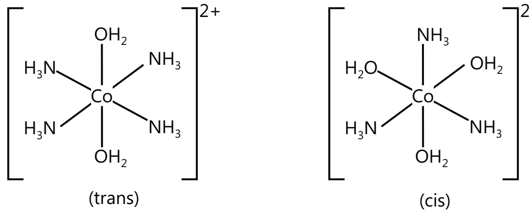


trans
(has several planes of symmetry)

cis
(has several planes of symmetry)

Sol 9:

(A)



(trans)

(cis)

$Co^{2+}=3d^7$ (Paramagnetic)

$[Pt(NH_3)_2Cl_2]$ is square planar.

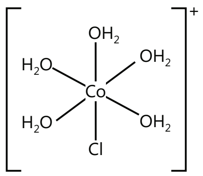
(B)

(cis)

(trans)

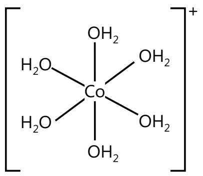
$Pt^{2+}=5d^84s^0$ (Diamagnetic)

(C)



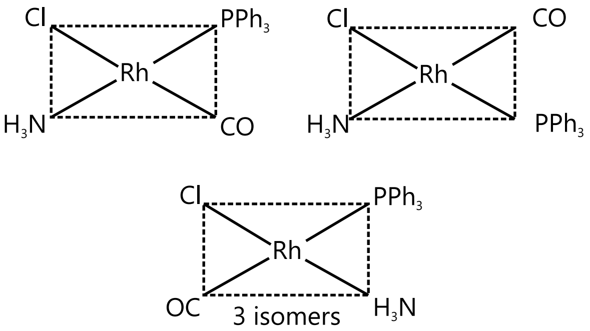
$Co^{2+}=3d^7$ (Paramagnetic)

(D)



$Ni^{2+}=3d^8$ (weak field ligand, paramagnetic)

Sol 10:



3 isomers

Sol 11: m mol of complex = 30 × 0.01 = 0.3

Also, 1 mole of complex $[Cr(H_2O)_5Cl]Cl_2$ gives only tow moles of chloride ion when dissolved in solution

$[Cr(H_2O)_5Cl]Cl_2 \longrightarrow [Cr(H_2O)_5Cl]^{2+} + 2Cl^-$

$\Rightarrow$ m mol of Cl^- ion produced from its 0.3 m mol = 0.6

Hence, 0.6 m mol of Ag^+ would be required for precipitation.

$\Rightarrow$ 0.60 m mol of Ag^+ = 0.1M × V(in mL) $\Rightarrow$ V = 6 mL.

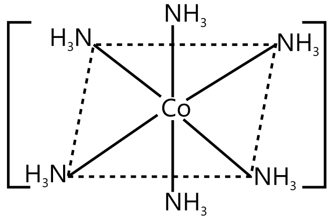
Sol 12: (i) $[Ti(NO_3)_4]$: Ti^{4+} ($3d^0$) No d-electron, no d-d transition possible, colourless.

(ii) $[Cu(NCCH_3)]BF_4$: Cu^+ ($3d^{10}$) All d-orbitals are completely filled, no d-d transition possible, colourless.

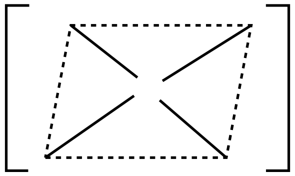
(iii) $[Cr(NH_3)_6]Cl_3$: Cr^{3+} ($3d^3$) Complex has allowed d-d transitions from t_{2g} to e_g level, hence, coloured.

(iv) $K_3[VF_6]$: V^{3+} ($3d^2$) Complex has allowed d-d transitions from t_{2g} to e_g level, hence, coloured.

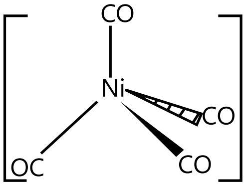
Sol 13:



d^2sp^3-octahedral



dsp^2-square planar



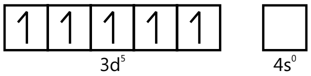
sp^3-tetrahedral

Sol 14: The spin-only magnetic moment (μ) of the complex is 1.73 BM. It indicates that nucleus of complex, chromium ion has one unpaired electron. So, the ligand NO is unit positively charged.

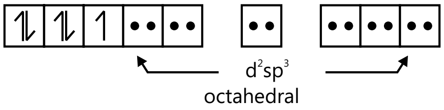
$K_2[Cr(NO)(CN)_4(NH_3)]$

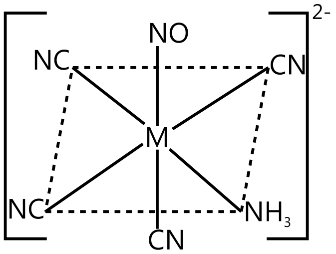
Potassium ammine tetracyanonitrosonium-chromate (I)

Cr^{+1} :



Cr(I) "under influence of strong ligand field".

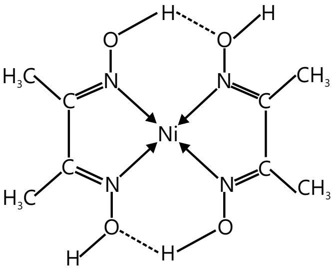




(octahedral geometry)

Sol 15: Oxidation state of Ni is +2 and hybridization is dsp^2. μ = 0

(nounpaired electron).



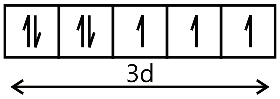
Ni-DMG complex

Sol 16: (A) $\left[Fe\left(H_2O\right)_5 NO\right]SO_4$

Here Fe has +1 oxidation state.

$Fe^+ = 3d^6 4s^1$ in presence of NO^+ $4s^1$ electron are paired in 3d sub shell.

So electronic configuration of Fe^+ is



Sol 17: (D) $\left[Co\left(H_2O\right)_4\left(NH_3\right)_2 Cl_3\right]$

Diamminetetraaquacobalt (III) chloride

Sol 18: (B) P = Fe^{+3} (no. of unpaired $\bar{e} = 5$)

Q = V^{+2} (no. of unpaired $\bar{e} = 3$)

R = Fe^{+2} (no. of unpaired $\bar{e} = 4$)

As all ligands are weak field, hence the no. of unpaired electrons remains same in the complex ion.

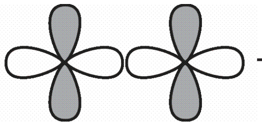
$\mu = \sqrt{n\left(n+2\right)}$B.M

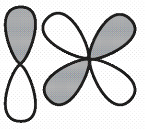
Hence (B) is correct.

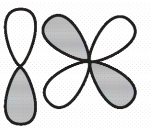
Sol19: (B,D) $\left[Co\left(NH_3\right)_4 Cl_2\right]^+$ and $\left[Pt\left(NH_3\right)_2\left(H_2O\right)Cl\right]^+$ (a square planar complex) will show geometrical isomerism.

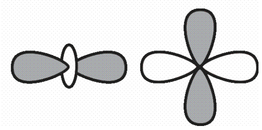
$\left[Pt\left(NH_3\right)_3\left(NO_3\right)\right]Cl$ and $\left[Pt\left(NH_3\right)_3 Cl\right]Br$ will show ionization isomerism.

Sol 20: (C)

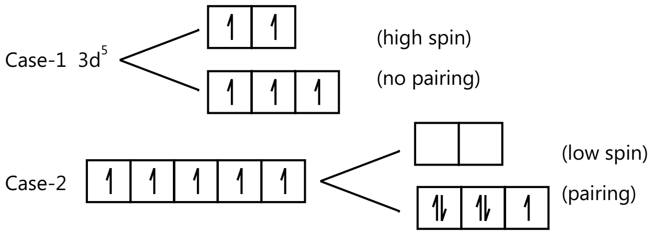
(p)  $\longrightarrow$ d – dσ bonding

(q)  $\longrightarrow$ p – dπ bonding

(r)  $\longrightarrow$ p – dπ anticoding

(s)  $\longrightarrow$ d – dσ anticoding

Sol 21: (D) $[Fe(SCN)_6]^{3-}$ and $[Fe(CN)_6]^{3-}$. In both the cases the electronic configuration of Fe^{3+} will be $1s^2, 2s^2, 2p^6, 3p^6, 3d^5$. Since $\bar{S}CN$ is a weak field ligand and $\bar{C}N$ is a strong field ligand, the pairing will occur in case of



Case-1 $\mu = \sqrt{n\left(n+2\right)} = \sqrt{5\left(5+2\right)} = \sqrt{35} = 5.91$ BM

Case-2 $\mu = \sqrt{n\left(n+2\right)} = \sqrt{1\left(1+2\right)} = \frac{3}{\ } = 1.73$ BM

Sol 22: (5) $[Co(en_2Cl_2)]^+ \rightarrow$ will show cis - trans isomerism

$[CrCl(C_2O_4)]^{3-} \rightarrow$ will show cis - trans isomerism

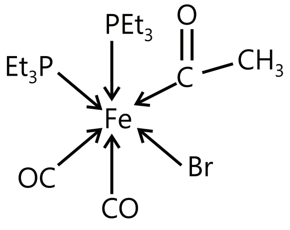
$[Fe(H_2O)_4(OH)_2]^+ \rightarrow$ will show cis trans isomerism

$[Fe(CN)_4(NH)_3]^- \rightarrow$ will show cis trans isomerism

$[Co(en)_2(NH_3)Cl]^{2+} \rightarrow$ will show cis trans isomerism

$[Co(NH_3)_4(H_3O)Cl]^{2+} \rightarrow$ Will not show cis – trans isomerism (Although it will show geometrical isomerism)

Sol 23: (D)



Sol 24: (B) $[Ni(CO)_4]$ – sp^3 – Diamagnetic

$[NiCl_4]^{2-}$ – sp^3 – Paramagnetic

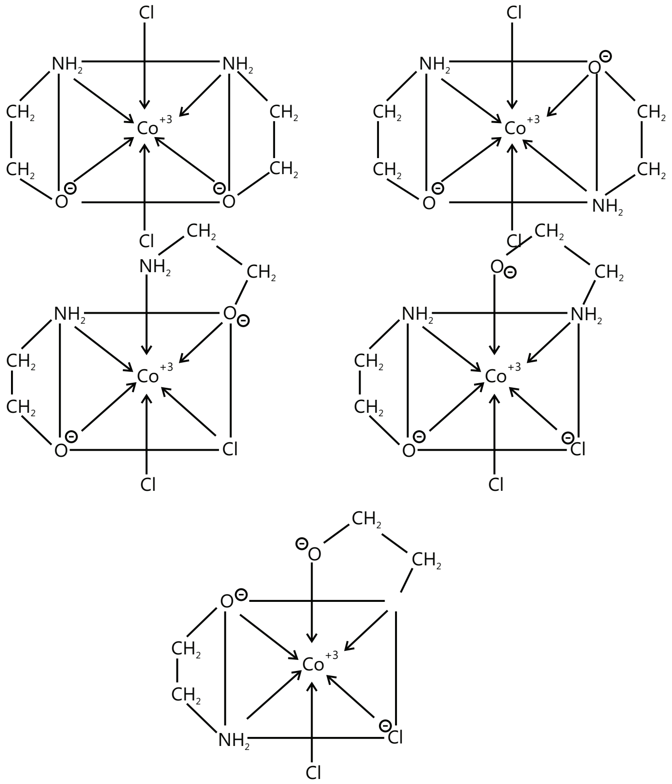
$[Co(NH_3)_4 Cl_2]Cl_2$ – d^2sp^3 – Diamagnetic

Na_3 $[CoF_6]$ – sp^3d^2 Paramagnetic

Na_2O_2 i.e. O_2^{2-} – Diamagnetic

CsO_2 i.e. O_2^- – Paramagnetic

Sol 25: (5)



Sol 26: (A) $[Ni(NH_3)_6]^{2+}$ = Octahedral

$[Pt(NH_3)_4]^{+2}$ = Square planar

$[Zn(NH_3)_4]^{+2}$ = Tetrahedral