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# UNIT-17 CO-ORDINATION COMPOUNDS

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## Important Points

- ^ The salt that is obtained when two or more salts having independent existence combine according to the laws of combination and which maintain the properties of original salts is called double salt e.g. Alum is a double salt.
- ^ Similarly, the compound that is obtained when two or more salts having independent existence combine according to laws of chemical combination and compound having new properties, formed is called complex compound. e.g.  $K_3[Fe(CN)_6]$  is a complex salt.
- ^ Most of the complex compounds are formed by elements of d-block (transition elements). In the electronic configuration of these elements, there is successive arrangement of electrons in d-orbitals. when the atom or ion of transition elements has vacant  $(n-1)d$ ,  $ns$  and  $np$  or  $ns$ ,  $np$  and  $nd$  orbitals, these transition elements accept negative ions or neutral molecules and they form the compounds which are called complex compounds. In this type of compounds, the bond that is formed between metal ions of elements and the negative ion or neutral molecules is called co-ordinate covalent bond. Around the centre of the metal ions of the molecules of these compounds, the negative ions or neutral molecules are combined with co-ordinate covalent bond.
- ^ Alfred Werner, first of all gave the theory for complex compounds which is known as Werner's co-ordination theory. Some metals have the secondary valency in addition to their primary valency. By this the ions of that metal combine strongly with the negative ion or neutral molecules in first attraction sphere [ ].
- ^ According to Werner's theory, the metal ion possesses two types of valencies : Primary valency and secondary valency.
- ^ The primary valency of the metal is equal to its oxidation number or equal to the positive electric charge of the positive ion, which forms ionic bond, so that it gets ionized. The negative ion combines with primary valency.
- ^ The secondary valency depends on the vacant orbitals in metal ion. The secondary valency is satisfied by negative ions or neutral molecules. It does not get ionized. The secondary valency mentions its co-ordination number. The secondary valency is fixed for the metal ion but now, it has been proved that the transition metal ions possess more than one co-ordination number. As the secondary valence being directional determines the geometrical shape of complex compound. From the magnetic properties also the shape of complex can be determined. e.g. In  $[Cr(NH_3)_6]Cl_3$ , Cr is metal ion and six molecules of neutral molecule ammonia ( $NH_3$ ) are combined with it by secondary valency which do not get ionized. Hence, the co-ordination number is six. Three  $Cl^-$  are combined by primary valency which gets ionized. Hence the primary valency of Cr is three.

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- ^ Ligand is an ion having negative electric charge or neutral molecule. The classification of ligand is made on the basis of the number of electron pair donating atoms.
- ^ If the negative ion or neutral molecule in the ligand forms one co-ordinate covalent bond by giving one electron pair to metal ion, then it is called unidentate ligand. Neutral molecules like  $\text{H}_2\text{O}$ ,  $\text{NH}_3$ ,  $\text{CO}$ ,  $\text{NO}$  and negative ions like  $\text{Cl}^-$ ,  $\text{Br}^-$ ,  $\text{CN}^-$  act as unidentate ligands.
- ^ The ligand which donates two electron pairs to metal ion, and form two co-ordinate covalent bonds is called didentate ligand. e.g. ethane 1,2-diamine (en), neutral and  $\text{SO}_4^{2-}$ ,  $\text{CO}_3^{2-}$  negative ions act as didentate ligands.
- ^ The ligand in which three co-ordinate sites are indicated then it is called tridentate. In this type of ligand the atoms donate three pairs of electrons to metal ion and form three co-ordinate covalent bonds. e.g. Propane-1, 2, 3-triamine (ptn) neutral and  $\text{PO}_4^{3-}$ ,  $\text{AsO}_4^{3-}$  act as negative tridentate ligand.
- ^ Six atoms in EDTA, (ethylene diaminetetracetate) ion, the six atoms donate six electron pairs and form six co-ordinate covalent bonds, which act as hexadentate ligand.
- ^ Generally, the ligand in which two or more than two co-ordination sites are indicated, or the ligand in which two or more than two atoms form co-ordinate covalent bonds by donating electron pairs to metal ion is called polydentate ligand, which combines with metal ion and form complex compounds. They are called chelate compounds which are cyclic and possess higher stability.
- ^ The basic requirements for formation of complex compounds are ligand which can easily donate electron pairs, there must be vacant d-orbitals in the metal ion to accept electron pairs and the metal ion should have the symmetry same as that of the ligand.
- The ion satisfying these basic requirements can easily form complex compounds.
- ^ The strength of formation of co-ordinate covalent bonds of different ligands being different, the stronger ligand possesses more attraction towards metal ion and form strong coordinate covalent bond. As a result, the stability of complex having strong ligand is more and the weak ligand containing complex compounds have less stability e.g. The strength of  $[\text{Ni}(\text{CN})_4]^{2-}$  is more than that of  $[\text{NiCl}_4]^{2-}$ .
- ^ A complex compound, in which different types of ligands combine with metal ion and form complex compound, is called mixed ligand complex. If in any of the complex compounds only one metal ion is present, then it is called uncentred complex compound. If in any complex compound, more than one metal ions are present then it is called polycentred complex compound. In such uncentred or polycentred complex compounds, the three dimensional arrangement of ligand, the different geometrical structures are produced in co-ordination compounds, it is called polyhedra. Mostly the geometrical structures are of shapes-tetrahedral square planar, octahedral square pyramidal, trigonal bipyramidal. To understand these geometrical structures, the hybridization of orbitals of metal ion and magnetic properties are very useful.  $\text{sp}^3$  hybridisation,  $\text{dsp}^2$  hybridisation,  $\text{d}^3\text{s}$  hybridization in metal ions of co-ordination number four is seen. In  $\text{sp}^3\text{d}^2$  hybridization and  $\text{d}^2\text{sp}^3$  hybridization, the metal ions of transition elements is seen in

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metal ions having co-ordination number six. The metal ions of transition elements, magnetic moments of complex compounds of ions, their geometrical structures, types of ligands etc. are described.

^ The nomenclature of complex compounds keeping in mind the rules of IUPAC is carried out. In complex compounds the rules are applicable.

^ In nomenclature in co-ordination sphere, the name of the ligand according to English alphabets are first mentioned. Then the name of metal is written. The suffix "O" is attached after the name of negatively charged ligand. The name of the neutral ligand is mentioned as its original name. If the number of same ligand is more than the one the prefixes di, tri, tetra...etc. are applied. In the prefix of organic ligand, the prefix is a number then the ligand is placed in bracket and the prefix bis, tris, are attached. If the complex is negative ion then the name of ligand is written first and, in the end the suffix 'ate' is applied to the metal ion. Its oxidation state is shown in Roman number in bracket. If the complex is positive ion or neutral molecule, then successively writing the name of ligand, the name of metal is added at the end and oxidation state is shown in the Roman number.

^ The geometry of complex compounds and magnetic properties of the complex depends on the hybridization in it. In complexes having co-ordination number 6 if strong ligand is attached with metal ion in complex, the oxidation state is shown in Roman numbers.

^ In complex compounds, the geometrical structures are dependent on hybridization in it. In complex having co-ordination number 4, if the strong ligand is combined with metal ion then  $dsp^2$  hybridization takes place in the complex and the structure is square planar. The example of this are  $[Ni(CN)_4]^{2-}$ ,  $[Ni(NH_3)_4]^{2+}$  etc. If the co-ordination number is 4 in the complex, and the weak ligand combines with the metal ion then  $sp^3$  hybridization takes place e.g.  $[NiF_4]^{2-}$ ,  $[Ni(H_2O)_4]^{2+}$ , etc. If the co-ordination number in complex ion is six, and the strong ligand is combined with metal ion, then  $d^2sp^3$  hybridization and if weak ligand is combined with metal ion, then  $sp^3d^2$  hybridization takes place, e.g. In  $[Cr(NH_3)_6]^{3+}$ ,  $[Fe(CN)_6]^{4-}$ ,  $[Co(NH_3)_6]^{3+}$   $d^2sp^3$  hybridization is there, while in  $[FeF_6]^{4-}$ ,  $[Fe(H_2O)_6]^{2+}$   $sp^3d^2$  hybridization is there. In  $MnO_4^-$  and  $CrO_4^{2-}$  there is  $d^3s$  hybridization, there are no unpaired electrons in d-orbital due to  $Mn^{7+}$  and  $Cr^{6+}$  oxidation states; but d-d transition takes place by electrons of ligand, and so it becomes coloured.

^ Three types of isomerism are observed in complex compounds-geometrical isomerism, optical isomerism and structural isomerism.

^ In geometrical isomerism, complex compounds having co-ordination number four-  $ML_2A_2$  type, cis and trans isomerism is observed. In complex compounds having co-ordination number six -  $ML_4A_2$  type, cis and trans while in  $ML_3A_3$  facial and meridional isomerism are observed. In optical isomerism, leavo and dextro isomers are observed.

^ In structural isomerism, ionic isomerism, hydration isomerism, co-ordination number isomerism and linkage isomerism are observed.

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- ^ In formation of co-ordination compounds the magnetic nature and structural formation with the help of valence bond theory; it has limitations. It does not produce more hindrance in magnetic property and can not explain about the colour in co-ordination compounds. It can not give the magnitude of hindrance in thermodynamical stability of co-ordination compounds, also it is not able to detect the difference between weak and strong ligand. To overcome these limitations the crystal field theory (CFT) was presented.
- ^ Crystal field theory is known as electrostatic model in which it is believed that there is ionic bond between metal ion and ligand. According to this theory negatively charged ligand or neutral molecule forms ionic bond. In free metal atom in gaseous state, all the five types of d-orbitals are of equal energy (degenerate) but when ligands are arranged around the metal atom or ion in the complex, the d-orbitals do not remain of equal energy but get splitted. The splitting of orbitals depends on the nature of the crystal field.
- ^ The crystal field splitting ( $\Delta_0$ ) depends on the field produced by electric charge of metal ion and the ligand. Some ligands produce strong field and so splitting is in more proportion. Some ligands produce weak field, so that the splitting is in less proportion. The series of ligands on the basis of the strength of the field produced by ligand can be shown as below :
- $I^- < Br^- < SCN^- < Cl^- < S^{2-} < F^- < OH^- < C_2O_4^{2-} < H_2O < NCS^- < EDTA < NH_3 < en < NO_2^- < CN^- < CO$  : Spectrochemical series.
- ^ Metal complexes have large magnitude of colours. When the white light passes through the sample, then it forms a specific visible spectrum and the remaining colours of white light are removed. The absorption of colour by complex compounds is dependent on wavelength. If green colour is absorbed then it appears of red colour.
- ^ The colour of co-ordination compounds can be explained on the basis of crystal field theory e.g.  $[Ti(H_2O)_6]^{3+}$  violet colour,  $[Ni(H_2O)_6]^{2+}$  green colour, and  $[Ni(en)_3]^{2+}$  violet colour,
- ^ Co-ordination compounds have great importance. They have immense utility value in nutrition of minerals in plants and animals, analytical chemistry, metallurgy, biological systems and industries. They are also used in various drugs.

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### M.C.Q.

- The complex  $[\text{Co}(\text{NH}_3)_5\text{Br}]\text{SO}_4$  will give white ppt with :  
(A)  $\text{PbCl}_2$  (B)  $\text{AgNO}_3$  (C)  $\text{KI}$  (D) None.
- Exchange of co-ordination group by a water molecule in complex molecule results in :  
(A) Ionization isomerism (B) Ligand isomerism  
(C) Hydration isomerism (D) Geometrical isomerism.
- $[\text{Co}(\text{NH}_3)_6]^{3+}$  ion is :  
(A) Paramagnetic (B) Diamagnetic (C) Square planar (D) None.
- Which of the following is most likely structure of  $\text{CrCl}_3 \cdot 6\text{H}_2\text{O}$  if  $1/3$  of total chlorine of the compound is precipitated by adding  $\text{AgNO}_3$  to its aqueous solution :  
(A)  $\text{CrCl}_3 \cdot 6\text{H}_2\text{O}$  (B)  $[\text{Cr}(\text{H}_2\text{O})_3\text{Cl}_3](\text{H}_2\text{O})_3$   
(C)  $[\text{CrCl}_2(\text{H}_2\text{O})_4]\text{Cl} \cdot 2\text{H}_2\text{O}$  (D)  $[\text{CrCl}_2(\text{H}_2\text{O})_5]\text{Cl}_2 \cdot \text{H}_2\text{O}$ .
- Which one of the following will be able to show cis-trans isomerism:  
(A)  $\text{MA}_3\text{B}$  (B)  $\text{M}(\text{AA}')_2$  (C)  $\text{MAB}_3$  (D)  $\text{MA}_4$
- $\text{K}_3\text{CoF}_6$  is high spin complex. What is the hybrid state of Co atom in this complex:  
(A)  $\text{sp}^3\text{d}$  (B)  $\text{sp}^3\text{d}^2$  (C)  $\text{d}^2\text{sp}^3$  (D)  $\text{dsp}^2$ .
- The type of isomerism shown by  $[\text{Co}(\text{en})_2(\text{NCS})_2]\text{Cl}$  and  $[\text{Co}(\text{en})_2(\text{NCS})\text{Cl}]\text{NCS}$  is:  
(A) Coordination (B) Ionization (C) Linkage (D) all above.
- The co-ordination number and oxidation number of X in  $[\text{X}(\text{SO}_4)(\text{NH}_3)_4]\text{Cl}$  is :  
(A) 10 and 3 (B) 2 and 6 (C) 6 and 3 (D) 6 and 4
- The IUPAC name of the compound  $[\text{Cu}(\text{NH}_3)_4](\text{NO}_3)_2$  is :  
(A) Cuprammonium nitrate (B) Tetraammine copper (II) dinitrate  
(C) Tetraammine copper (II) nitrate (D) Tetraammine copper (III) dinitrate
- Hexafluoroferrate (III) ion is an outer orbital complex. The number of unpaired electrons present in it is :  
(A) 1 (B) 5 (C) 4 (D) Unpredictable.
- Which of the following complex species involves  $\text{d}^2\text{sp}^3$  hybridisation :  
(A)  $[\text{CoF}_6]^{3-}$  (B)  $[\text{Co}(\text{H}_2\text{O})_6]^{3+}$  (C)  $[\text{Fe}(\text{CN})_6]^{3-}$  (D)  $[\text{Fe}(\text{H}_2\text{O})_6]^{3+}$ .
- How many ions are produced from  $[\text{Co}(\text{NH}_3)_6]\text{Cl}_2$  in solution :  
(A) 6 (B) 4 (C) 3 (D) 2.
- In the complex  $\text{Fe}(\text{CO})_x$ , the value of x is :  
(A) 3 (B) 4 (C) 5 (D) 6.
- Which is the central ion in  $[\text{Cu}(\text{H}_2\text{O})_4]^{2+}$  ion :  
(A)  $\text{Cu}^{2+}$  (B)  $\text{H}_3\text{O}^+$  (C)  $\text{Cu}^+$  (D) None.
- In  $\text{K}_4[\text{Fe}(\text{CN})_6]$  the number of unpaired electrons in iron are :  
(A) 0 (B) 2 (C) 3 (D) 5.
- All ligands are :  
(A) Lewis acid (B) Lewis base (C) Neutral (D) None.

17. The hybridization in  $\text{Ni}(\text{CO})_4$  is :  
 (A)  $sp$  (B)  $sp^2$  (C)  $sp^3$  (D)  $dsp^2$ .
18. A group of atoms can function as a ligand only when  
 (A) It is a small molecule (B) It has an unshared electron pair  
 (C) It is a negatively charged ion (D) It is a positively charged ion.
19. A complex compound in which the oxidation number of a metal is zero, is  
 (A)  $\text{K}_4[\text{Fe}(\text{CN})_6]$  (B)  $\text{K}_3[\text{Fe}(\text{CN})_6]$  (C)  $[\text{Ni}(\text{CO})_4]$  (D)  $[\text{Pt}(\text{NH}_3)_4]\text{Cl}_2$ .
20. A ligand can also be regarded as  
 (A) Lewis acid (B) Bronsted base (C) Lewis base (D) Bronsted acid.
21. The primary and secondary valencies of chromium in the complex ion, dichlorodioxalatochromium (III), are  
 (A) 4,4 (B) 4,3 (C) 3,6 (D) 6,3
22. The number of unidentate ligands in the complex ion is called  
 (A) Oxidation number (C) Primary valency  
 (C) Coordination number (D) EAN.
23. The tetrahedral complexes have coordination number  
 (A) 3 (B) 6 (C) 4 (D) 8
24. The number of moles of ions gives on complete ionization of one mole of  $[\text{Co}(\text{NH}_3)_6]\text{Cl}_3$  is/are  
 (A) 4 (B) 3 (C) 2 (D) 1
25. The compound having lowest oxidation state of iron is.  
 (A)  $\text{K}_4\text{Fe}(\text{CN})_6$  (B)  $\text{K}_2\text{FeO}_4$  (C)  $[\text{FeCO}_5]$  (D)  $\text{K}_3[\text{Fe}(\text{CN})_6]$ .
26. Ethylene diamine is an example of  
 (A) Monodentate ligand (C) Bidentate ligand  
 (C) Tridentate ligand (D) Hexadentate ligand. dinitrate.
27. Which of the following does not have optical isomer ?  
 (A)  $[\text{Co}(\text{NH}_3)_3\text{Cl}]^+$  (B)  $[\text{Co}(\text{en})(\text{NH}_3)_2\text{Cl}_2]^+$   
 (C)  $[\text{Co}(\text{en})_2(\text{NH}_3)_2\text{Cl}]^{3+}$  (D)  $[\text{Co}(\text{H}_2\text{O})_4(\text{en})]^{3+}$
28. The IUPAC name of  $[\text{Ni}(\text{NH}_3)_4][\text{NiCl}_4]$  is  
 (A) Tetrachlorido nickel (II) - Tetraammine nickel (II)  
 (B) Tetraammine nickel (II) - Tetrachlorido nickel (II)  
 (C) Tetraammine nickel (II) - Tetrachlorido nickelate (II)  
 (D) Tetrachlorido nickel (II) - Tetraammine nickelate (II)
29. According to IUPAC nomenclature sodium nitroprusside is named as  
 (A) Sodium pentacyanonitrosonium ferrate (II) (B) Sodium pentacyanonitrosyl ferrate (III)  
 (C) Sodium nitroferrocyanide (D) Sodium nitroferrocyanide
30. IUPAC name of  $\text{Na}_3[\text{Co}(\text{NO}_2)_6]$  is  
 (A) Sodium hexanitrito cobaltate (II) (B) Sodium hexanitro cobaltate (III)  
 (C) Sodium hexanitrito cobaltate (III) (D) Sodium cobaltinitrite (II).

31. Which of the following compound shows optical isomerism ?  
 (A)  $[\text{Co}(\text{CN})_6]^{3-}$  (B)  $[\text{Cr}(\text{C}_2\text{O}_4)_3]^{3-}$  (C)  $[\text{ZnCl}_4]^{2-}$  (D)  $[\text{Cu}(\text{NH}_3)_4]^{2+}$
32. The coordination compounds,  $[\text{Co}(\text{NH}_3)_6]^{3+}$ ,  $[\text{Cr}(\text{CN})_6]^{3-}$  and  $[\text{Cr}(\text{NH}_3)_6]^{3+}[\text{Co}(\text{CN})_6]^{3-}$  are examples of...  
 (A) Linkage isomerism (B) coordination isomerism  
 (C) ionization isomerism (D) geometrical isomerism
33. Number of possible optical isomers in  $[\text{Co}(\text{en})_2\text{Cl}_2]^+$  is  
 (A) 2 (B) 3 (C) 4 (D) 6
34. According to postulates of Werner's theory for coordination compounds, which of the following is true ?  
 (A) Primary valencies are ionizable (B) Secondary valencies ionizable  
 (C) Only primary valencies are non-ionizable  
 (D) Primary and secondary valencies are non-ionizable
35. Geometrical shapes of the complexes formed by the reaction of  $\text{Ni}^{2+}$  with  $\text{Cl}^-$ ,  $\text{CN}^-$  and  $\text{H}_2\text{O}$  respectively are  
 (A) Octahedral, tetrahedral and square planer (B) Tetrahedral, square planer and octahedral  
 (C) Square planer, tetrahedral and Octahedral (D) Octahedral, square planer and tetrahedral
36. Which of the following facts about the complex  $[\text{Cr}(\text{NH}_3)_6]\text{Cl}$  is wrong ?  
 (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
37. The magnetic moment (spin only) of  $[\text{NiCl}_4]^{2-}$  is  
 (A) 1.82 BM (B) 5.46 BM (C) 2.82 BM (D) 1.41 BM
38. Among the ligands  $\text{NH}_3$ ,  $\text{en}$ ,  $\text{CN}^-$  and  $\text{CO}$  the correct order of their increasing field strength, is  
 (A)  $\text{CO} < \text{NH}_3 < \text{en} < \text{CN}^-$  (B)  $\text{NH}_3 < \text{en} < \text{CN}^- < \text{CO}$   
 (C)  $\text{CN}^- < \text{NH}_3 < \text{CO} < \text{en}$  (D)  $\text{en} < \text{CN}^- < \text{NH}_3 < \text{CO}$
39. The complex showing a spin-only magnetic moment of 2.82 BM is  
 (A)  $\text{Ni}(\text{CO})_4$  (B)  $[\text{NiCl}_4]^{2-}$  (C)  $[\text{Ni}(\text{NH}_3)_4]^{2+}$  (D)  $[\text{Ni}(\text{CN})_4]^{2-}$
40. The spin only magnetic moment value (in Bohr magneton units) of  $\text{Cr}(\text{CO})_6$  is  
 (A) 0 (B) 2.84 (C) 4.90 (D) 5.92
41. Potassium ferrocyanide is an example of  
 (A) Tetrahedral (B) Octahedral (C) Square Planar (D) Linear
42. In an octahedral structure, the pair of d-orbitals involved in  $d^2sp^3$  hybridisation is  
 (A)  $d_x^2 - y^2, d_z^2$  (B)  $d_{xz}, d_x^2 - y^2$  (C)  $d_z^2, d_{xz}$  (D)  $d_{yz}, d_{xy}$
43. Which of the following species will be diamagnetic ?  
 (A)  $[\text{Fe}(\text{CN})_6]^{4-}$  (B)  $[\text{FeF}_6]^{3+}$  (C)  $[\text{Co}(\text{C}_2\text{O}_4)_3]^{3-}$  (D)  $[\text{CoF}_6]^{3-}$

44. In which of the following octahedral complexes of Co (at. no.27) will be magnitude of  $\Delta_0$  be the highest ?  
 (A)  $[\text{Co}(\text{CN})_6]^{3-}$  (B)  $[\text{Co}(\text{C}_2\text{O}_4)_3]^{3-}$  (C)  $[\text{Co}(\text{H}_2\text{O})_6]^{3+}$  (D)  $[\text{Co}(\text{NH}_3)_6]^{3+}$
45. The number of unpaired electrons calculated in  $[\text{Co}(\text{NH}_3)_6]^{3+}$  and  $[\text{Co}(\text{F}_6)]^{3-}$  are  
 (A) 4 and 4 (B) 0 and 2 (C) 2 and 4 (D) 0 and 4
46. In the grignard reaction, which metal forms an organometallic bond ?  
 (A) Sodium (B) Titanium (C) Magnesium (D) Palladium
47. The  $\pi$  - bonded organometallic compound which has ethane as one of its component is  
 (A) Zeise's salt (B) Ferrocene  
 (C) Dibenzene chromium (D) Tetraethyl tin
48. Which one of the following complex is an outer orbital complex ?  
 (At. no. Mn=25, Fe=24, Co=27, Ni=28)  
 (A)  $[\text{Fe}(\text{CN})_6]^{4-}$  (B)  $[\text{Mn}(\text{CN})_6]^{4-}$  (C)  $[\text{Co}(\text{NH}_3)_6]^{3+}$  (D)  $[\text{Ni}(\text{NH}_3)_6]^{2+}$
49. The magnetic moment of  $[\text{Co}(\text{NH}_3)_6]\text{Cl}_3$  is  
 (A) 1.73 (B) 2.83 (C) 6.6 (D) Zero
50. In  $\text{Fe}(\text{CO})_5$  the Fe - C bond possesses  
 (A)  $\pi$  - character only (B) both  $\sigma$  and  $\pi$  - character  
 (C) ionic character (D)  $\sigma$  - character only
51. According to werner's theory :  
 (A) Primary Valency can be ionized  
 (B) Secondary valency can be ionized  
 (C) Primary and secondary valencies cannot be ionized  
 (D) Only primary valency cannot be ionized
52. Ligand in a complex salt are :  
 (A) Anions linked by coordinate bonds to a central metal atom or ion  
 (B) Cation linked by coordinate bonds to a central metal atom or ion  
 (C) Molecules linked by coordinate bonds to a central metal atom or ion  
 (D) Ions or molecules linked by coordinate bonds to a central metal atom or ion
53. According to Lewis the ligand are :  
 (A) Acidic in nature (B) Basic in nature  
 (C) Neither acidic nor basic (D) some are acidic and other are basic
54. Which of the following acts as a bidentate ligand in complex formation ?  
 (A) Acetate (B) oxalate (C) Thiocyanate (D) EDTA
55. The coordination number of cobalt in the complex  $[\text{Co}(\text{en})_2\text{Br}_2]\text{Cl}_2$ ,  
 (A) 2 (B) 6 (C) 5 (D) 4
56. Which is the example of hexadentate ligand ?  
 (A) 2,2-dipyridyl (B) Dimethyl glyoxime  
 (C) Aminodiacetate ion (D) Ethylene diammine tetra acetate ion

57. Which of the following is tridentate neutral Ligand ?  
 (A) Pn (B) Ptn (C)  $\text{PO}_4^{3-}$  (D) A and B both
58. The primary valency of the metal ion in the coordinateion compound  $\text{K}_2[\text{Ni}(\text{CN})_4]$  is..  
 (A) Four (B) Zero (C) Two (D) Six
59. The metal which forms polynuclear carbonyl is ?  
 (A) Mn (B) Co (C) Cr (D) Fe
60. Potassium ferrocyanide is a....  
 (A) Normal salt (B) Mixed salt (C) Double salt (D) Complex salt
61. Given the molecular formula of the hexa coordinated complexes.  
 (A)  $\text{Co Cl}_3 6\text{NH}_3$   
 (B)  $\text{Co Cl}_3 5\text{NH}_3$   
 (C)  $\text{Co Cl}_3 4\text{NH}_3$   
 If the number of coordinated  $\text{NH}_3$  molecules in A,B and C respectively are 6,5 and 4 the primary valency (A), (B) and (C) are:  
 (A) 6,5,4 (B) 3,2,1 (C) 0,1,2 (D) 3,3,3
62. In the compound lithium tetrahydroaluminate the ligand is:  
 (A)  $\text{H}^+$  (B)  $\text{H}^-$  (C) H (D) None of these
63. Which of the following is the odd one out.  
 (A) Potassium ferrocyanide (B) Ferrous ammonium sulphate  
 (C) Potassium ferricyanide (D) Tetrammine copper (II) sulphate
64. Ligand in complex compounds  
 (A) Accept  $e^-$  - pair (B) Donate  $e^-$  - pair  
 (C) Neither accept  $e^-$  - pair nor donate (D) All of these.
65. Which of the following is a common donor atom in ligands ?  
 (A) Arsenic (B) Nitrogen (C) Oxygen (D) Both B and C
66. Finely divided iron combines with CO to give  
 (A)  $\text{Fe}(\text{CO})_5$  (B)  $\text{Fe}_2(\text{CO})_9$  (C)  $\text{Fe}_2\text{CO}_{12}$  (D)  $\text{Fe}(\text{CO})_6$
67. Zeigler-Natta catalyst is used for which type of reaction.  
 (A) Hydrogenation (B) Polymerisation (C) Oxidation (D) Reduction
68. An aqueous solution of potash Alum gives.  
 (A) Two types of ions (B) Only one type of ion  
 (C) Four type of ions (D) Three types of ions.
69. Camalite in solution in  $\text{H}_2\text{O}$  shows the properties of.  
 (A)  $\text{K}^+, \text{Mg}^{+2}, \text{Cl}^-$  (B)  $\text{K}^+, \text{Cl}^-, \text{SO}_4^{2-}, \text{Br}^-$   
 (C)  $\text{K}^+, \text{Mg}^{+2}, \text{CO}_3^{-2}$  (D)  $\text{K}^+, \text{Mg}^{+2}, \text{Cl}^-, \text{Br}^-$
70. In a complex, the highest possible coordination number is :  
 (A) 6 (B) 12 (C) 4 (D) 8
71. Number of ions present in aqueous solution of  $\text{Fe}_4[\text{Fe}(\text{CN})_6]_3$  is  
 (A) 5 (B) 2 (C) 7 (D) 6
72. How many ions are produced in aqueous solution of  $[\text{Co}(\text{H}_2\text{O})_6] \text{Cl}_2$  ?  
 (A) 2 (B) 3 (C) 4 (D) 6

73. Oxidation state of nitrogen is incorrectly given for ?
- | Compound   | Oxidation state |
|--|-----------------|
| (A) $[\text{Co}(\text{NH}_3)_5\text{Cl}]\text{Cl}_2$ | 0               |
| (B) $\text{NH}_2\text{OH}$                           | -1              |
| (C) $(\text{N}_2\text{H}_5)_2\text{SO}_4$            | +2              |
| (D) $\text{Mg}_3\text{N}_2$                          | -3              |
74. The formula of dichlorido bis (urea) copper (II) is ?
- |   |   |
|---|---|
| (A) $[\text{Cu}(\text{O}=\text{C}(\text{NH}_2)_2)\text{Cl}_2]$        | (B) $[\text{CuCl}_2(\text{O}=\text{C}(\text{NH}_2)_2)_2]$           |
| (C) $[\text{Cu}(\text{O}=\text{C}(\text{NH}_2)_2)\text{Cl}]\text{Cl}$ | (D) $[\text{CuCl}_2(\text{O}=\text{C}(\text{NH}_2)_2)_2\text{H}_2]$ |
75. Correct formula of diammine silver (I) chloride is ?
- |                                       |                                       |   |   |
|---------------------------------------|---------------------------------------|---|---|
| (A) $\text{Ag}(\text{NH}_3)\text{Cl}$ | (B) $\text{Ag}(\text{NH}_2)\text{Cl}$ | (C) $[\text{Ag}(\text{NH}_3)_2]\text{Cl}$ | (D) $[\text{Ag}(\text{NH}_2)_2]\text{Cl}$ |
|---------------------------------------|---------------------------------------|---|---|
76. The formula of sodium nitroprusside ?
- |   |  |
|---|--|
| (A) $\text{Na}_4[\text{Fe}(\text{CN})_5\text{NOS}]$ | (B) $\text{Na}_2[\text{Fe}(\text{CN})_5\text{NO}]$   |
| (C) $\text{NaFe}[\text{Fe}(\text{CN})_6]$           | (D) $\text{Na}_2[\text{Fe}(\text{CN})_6\text{NO}_2]$ |
77. The IUPAC name of  $[\text{Co}(\text{NH}_3)_3(\text{NO}_2)_3]$  is ?
- |  |                                       |
|--|---------------------------------------|
| (A) Trinitrotriammine cobalt (III)     | (B) Trinitrotriammine cobalt (II)     |
| (C) Trinitrotriammine cobalt (III) ion | (D) Trinitrotriammine cobaltate (III) |
78. The oxidation numbers of chromium in  $\text{Na}_2[\text{CrF}_4\text{O}]$  complex is ?
- |        |        |        |         |
|--------|--------|--------|---------|
| (A) II | (B) IV | (C) VI | (D) III |
|--------|--------|--------|---------|
79. The correct IUPAC name of  $\text{Fe}_4[\text{Fe}(\text{CN})_6]_3$  is ?
- |                                       |                                  |
|---------------------------------------|----------------------------------|
| (A) Ferroso - Ferric cyanide          | (B) Ferric - Ferrous hexacyanide |
| (C) Iron (III) hexacyano ferrate (II) | (D) Hexacyano ferrate (III-II)   |
80. In which of the following complex the oxidation number of metal is zero ?
- |   |                                |   |   |
|---|--------------------------------|---|---|
| (A) $[\text{Pt}(\text{NH}_3)_2\text{Cl}_2]$ | (B) $[\text{Cr}(\text{CO})_6]$ | (C) $[\text{Cr}(\text{NH}_3)_2\text{Cl}_3]$ | (D) $[\text{Cr}(\text{en})_2\text{Cl}_2]$ |
|---|--------------------------------|---|---|
81. In the complex compound  $\text{K}_4[\text{Ni}(\text{CN})_4]$  oxidation state of nickel is ?
- |        |       |        |        |
|--------|-------|--------|--------|
| (A) -1 | (B) 0 | (C) +1 | (D) +2 |
|--------|-------|--------|--------|
82. The pair of the compounds in which both the metals are in the highest possible oxidation state is ?
- |   |  |
|---|--|
| (A) $[\text{Fe}(\text{CN})_6]^{3-}$ , $[\text{Co}(\text{CN})_6]^{3-}$ | (B) $\text{CrO}_2\text{Cl}_2$ , $\text{MnO}_4^-$     |
| (C) $\text{TiO}_3$ , $\text{MnO}_2$                                   | (D) $[\text{Co}(\text{CN})_6]^{3-}$ , $\text{MnO}_3$ |
83. The number of unpaired electrons in the complex ion  $[\text{CoF}_6]^{3-}$  is (Atomic no of Co=27)
- |          |       |       |       |
|----------|-------|-------|-------|
| (A) zero | (B) 2 | (C) 3 | (D) 4 |
|----------|-------|-------|-------|
84. Which one of the following will not show geometrical isomerism ?
- |  |  |
|--|--|
| (A) $[\text{Cr}(\text{NH}_3)_4\text{Cl}_2]\text{Cl}$   | (B) $[\text{Co}(\text{en})_2\text{Cl}_2]\text{Cl}$ |
| (C) $[\text{Co}(\text{NH}_3)_5\text{NO}_2]\text{Cl}_2$ | (D) $[\text{Pt}(\text{NH}_3)_2\text{Cl}_2]$        |
85. Which would exhibit co-ordination isomerism.
- |  |   |
|--|---|
| (A) $[\text{Cr}(\text{NH}_3)_6][\text{Co}(\text{CN})_6]$ | (B) $[\text{Co}(\text{en})_2\text{Cl}_2]$ |
| (C) $[\text{Cr}(\text{NH}_3)_6]\text{Cl}_3$              | (D) $[\text{Cr}(\text{en})_2\text{Cl}_2]$ |

86.  $[\text{Co}(\text{NH}_3)_5\text{NO}_2]\text{Cl}_2$  and  $[\text{Co}(\text{NH}_3)_5(\text{ONO})]\text{Cl}_2$  are related to each other as ?  
 (A) Geometrical isomer (B) Optical isomer  
 (C) Linkage isomer (D) Co-ordination isomer
87.  $[\text{Co}(\text{NH}_3)_5\text{Br}]\text{SO}_4$  and  $[\text{Co}(\text{NH}_3)_5\text{SO}_4]\text{Br}$  are examples of which type of isomerism ?  
 (A) Linkage (B) Geometrical (C) Ionisation (D) Optical
88. Which would exhibit ionisation isomerism. ?  
 (A)  $[\text{Cr}(\text{NH}_3)_6]\text{Cl}_3$  (B)  $[\text{Co}(\text{NH}_3)_5\text{Br}]\text{SO}_4$   
 (C)  $[\text{Cr}(\text{en})_2\text{Cl}_2]$  (D)  $[\text{Cr}(\text{en})_3\text{Cl}_3]$
89. Among the following ions which one has the highest paramagnetism ?  
 (A)  $[\text{Cr}(\text{H}_2\text{O})_6]^{+3}$  (B)  $[\text{Fe}(\text{H}_2\text{O})_6]^{+2}$   
 (C)  $[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$  (D)  $[\text{Zn}(\text{H}_2\text{O})_6]^{2+}$
90. The type of isomerism present in nitro pentamine chromium (III) Chloride is ?  
 (A) Optical (B) Linkage (C) Ionisation (D) Polymerisation
91. Pick out from the following complex compounds, a poor electrolytic conductor in solution ?  
 (A)  $\text{K}_2[\text{PtCl}_6]$  (B)  $[\text{Co}(\text{NH}_3)_3(\text{NO}_2)_3]$   
 (C)  $\text{K}_4[\text{Fe}(\text{CN})_6]$  (D)  $[\text{Cu}(\text{NH}_3)_4]\text{SO}_4$
92. The critical Magnetic moment of  $[\text{Cu}(\text{NH}_3)_4]^{2+}$  ion is ?  
 (A) 1.414 (B) 1.73 (C) 2.23 (D) 2.38
93. Which of the following is paramagnetic ?  
 (A)  $[\text{Ni}(\text{CO})_4]^{2-}$  (B)  $[\text{Co}(\text{NH}_3)_6]^{3+}$  (C)  $[\text{Ni}(\text{CN})_4]^{2-}$  (D)  $[\text{NiCl}_4]^{2-}$
94. The numbers of unpaired electrons in  $\text{Ni}(\text{CO})_4$  is ?  
 (A) zero (B) One (C) Three (D) Five
95. Which of the following has highest paramagnetism ?  
 (A)  $\text{Ni}(\text{CO})_4$  (B)  $[\text{Ni}(\text{NH}_3)_4]\text{Cl}_2$   
 (C)  $[\text{Ni}(\text{NH}_3)_6]\text{Cl}_2$  (D)  $[\text{Cu}(\text{NH}_3)_4]\text{Cl}_2$
96. Which of the following does not have optical isomer ?  
 (A)  $[\text{Co}(\text{NH}_3)_3\text{Cl}_3]$  (B)  $[\text{Co}(\text{en})_3]\text{Cl}_3$   
 (C)  $[\text{Co}(\text{en})_2\text{Cl}_2]\text{Cl}$  (D)  $[\text{Co}(\text{en})(\text{NH}_3)_2\text{Cl}_2]\text{Cl}$
97. The colour of tetrammine copper (II) sulphate is ?  
 (A) Blue (B) Red (C) Violet (D) Green
98. Cuprammonium ion  $[\text{Cu}(\text{NH}_3)_4]^{2+}$  is ?  
 (A) Tetrahedral (B) Square planar  
 (C) Triangularbipyramidal (D) Octahedral
99. The type of hybridisation involved in the metal ion of  $[\text{Ni}(\text{H}_2\text{O})_6]^{2+}$  complex is ?  
 (A)  $d^3sp^2$  (B)  $sp^3d^2$  (C)  $sp^3$  (D)  $dsp^2$

100. One mole of the complex compound  $\text{Co}(\text{NH}_3)_5\text{Cl}_3$  gives 3 moles of ions on dissolution in water. One mole of the same complex reacts with two moles of  $\text{AgNO}_3$  solution to yield two moles of  $\text{AgCl}_{(s)}$ . The structure of the complex is...
- (A)  $[\text{Co}(\text{NH}_3)_5\text{Cl}]\text{Cl}_2$  (B)  $[\text{Co}(\text{NH}_3)_3\text{Cl}_3]\text{Z NH}_3$   
 (C)  $[\text{Co}(\text{NH}_3)_4\text{Cl}_2]\text{Cl}\cdot\text{NH}_3$  (D)  $[\text{Co}(\text{NH}_3)_4\text{Cl}]\text{Cl}_2\cdot\text{NH}_3$
101. Which one of the following has square planar geometry?
- (A)  $[\text{Ag}(\text{NH}_3)_2]^+$  (B)  $[\text{Cu}(\text{en})_2]^{2+}$  (C)  $[\text{MnCl}_4]^{-2}$  (D)  $[\text{Ni}(\text{CO})_4]$
102. The complex ion which has no 'd' electrons in the central metal atom is
- (A)  $[\text{MnO}_4]^-$  (B)  $[\text{Co}(\text{NH}_3)_6]^{3+}$  (C)  $[\text{Fe}(\text{CN})_6]^{3-}$  (D)  $[\text{Cr}(\text{H}_2\text{O})_6]^{3+}$
103. The strongest ligand in the following is
- (A)  $\text{CN}^-$  (B)  $\text{Br}^-$  (C)  $\text{HO}^-$  (D)  $\text{F}^-$
104. The most stable ion is
- (A)  $[\text{Fe}(\text{OX})_3]^{3-}$  (B)  $[\text{Fe}(\text{Cl})_6]^{3-}$  (C)  $[\text{Fe}(\text{CN})_6]^{3-}$  (D)  $[\text{Fe}(\text{H}_2\text{O})_6]^{3+}$
105. Wilkinson's catalyst is used in
- (A) Polymerisation (B) Condensation (C) Halogenation (D) Dehydrogenation
106. Mixture X = 0.02 mole of  $[\text{Co}(\text{NH}_3)_5\text{SO}_4]\text{Br}$  and 0.02 mole of  $[\text{Co}(\text{NH}_3)_5\text{Br}]\text{SO}_4$  was prepared in 2 litre of solution.  
 1 Litre of mixture X + excess  $\text{AgNO}_3 \rightarrow \text{Y}$   
 1 Liter of mixture X + excess  $\text{BaCl}_2 \rightarrow \text{Z}$   
 Number of moles of Y and Z are respectively
- (A) 0.01, 0.01 (B) 0.02, 0.01 (C) 0.01, 0.02 (D) 0.02, 0.02
107. In  $[\text{Ni}(\text{NH}_3)_4]\text{SO}_4$  the valency and coordinate number of Ni will be respectively?
- (A) 3 and 6 (B) 2 and 4 (C) 4 and 2 (D) 4 and 4
108. Which of the following compounds shows optical isomerism?
- (A)  $[\text{Cu}(\text{NH}_3)_4]^{2+}$  (B)  $[\text{ZnCl}_4]^{2-}$  (C)  $[\text{Cr}(\text{C}_2\text{O}_4)_3]^{3-}$  (D)  $[\text{Co}(\text{CN})_6]^{3-}$
109. In the process of extraction of gold, Roasted gold ore +  $\text{CN}^- + \text{H}_2\text{O} \xrightarrow{\text{O}_2} \text{X} + \text{OH}^-$   
 $[\text{X}] + \text{Zn} \rightarrow \text{Y} + \text{Au}$  Identify the complexes [X] and [Y]
- (A)  $\text{X} = [\text{Au}(\text{CN})_2]^-$   $\text{Y} = [\text{Zn}(\text{CN})_4]^{2-}$  (B)  $\text{X} = [\text{Au}(\text{CN})_4]^{3-}$   $\text{Y} = [\text{Zn}(\text{CN})_4]^{2-}$   
 (C)  $\text{X} = [\text{Au}(\text{CN})_2]^-$   $\text{Y} = [\text{Zn}(\text{CN})_6]^{4-}$  (D)  $\text{X} = [\text{Au}(\text{CN})_4]^-$   $\text{Y} = [\text{Zn}(\text{CN})_4]^{2-}$
110. Which of the following statement is incorrect?
- (A) In  $\text{K}_3[\text{Fe}(\text{CN})_6]$ , the ligand has satisfied both primary and secondary valencies of ferric ion  
 (B) In  $\text{K}_4[\text{Fe}(\text{CN})_6]$ , the ligand has satisfied both primary and secondary valencies of ferrous ion  
 (C) In  $\text{K}_3[\text{Fe}(\text{CN})_6]$ , the ligand has satisfied only secondary valencies of ferric ion  
 (D)  $\text{K}_4[\text{Fe}(\text{CN})_6]$  is diamagnetic while  $\text{K}_3[\text{Fe}(\text{CN})_6]$  is paramagnetic

### Assertion and Reason

Read the assertion and reason carefully to mark the correct option out of the option given below :

- (A) If both assertion and reason are true and the reason is the correct explanation of the assertion.

- (B) If both a ssertion and reason are true but reason is not the correct explanation of the assertion.
- (C) If assertion is true but reason is false.
- (D) If the assertion and reason both are false.
- (E) If the assertion is false but reason is true.
- (111) Assertion : Potassium ferrocyanide and potassium ferricyanide both are diamagnetic.  
Reason : Both have unpaired election.
- (112) Assertion : The  $[\text{Ni}(\text{en})_3]\text{Cl}_2$  has lower stability than  $(\text{Ni}(\text{NH}_3)_6)\text{Cl}_2$   
Reason : In  $[\text{Ni}(\text{en})_3]\text{Cl}_2$  the geometry of Ni is trigonal bipyramidal.
- (113) Assertion : Geometrical isomerism is also called cis - trans isomerism.  
Reason : tetrahedral complexes show geometrical isomerism.
- (114) Assertion :  $\text{H}_2\text{N} - \text{NH}_2$  is a chelating ligand.  
Reason : A chelating ligand must possess two or more lone pair at such distance that it may form suitable strain free ring at the metal ion.
- (115) Assertion :  $[\text{Ti}(\text{H}_2\text{O})_6]^{+3}$  is coloured while  $[\text{Sc}(\text{H}_2\text{O})_6]^{+3}$  is Colourless  
Reason : d-d transition is not possible in  $[\text{Sc}(\text{H}_2\text{O})_6]^{+3}$
- (116) Asserion : All the octahedral complexes of  $\text{Ni}^{+2}$  must be outer orbital complexes.  
Reason : Outer orbital octahedral complexes are given by weak ligand.

### ANSWER KEY

1	a	26	b	51	a	76	b	101	b
2	c	27	b	52	d	77	a	102	a
3	b	28	c	53	b	78	b	103	a
4	c	29	a	54	b	79	c	104	c
5	b	30	b	55	b	80	b	105	d
6	b	31	b	56	b	81	b	106	a
7	b	32	b	57	b	82	b	107	b
8	c	33	a	58	c	83	d	108	c
9	c	34	a	59	a	84	c	109	a
10	b	35	b	60	d	85	a	110	c
11	c	36	c	61	d	86	c	111	d
12	c	37	c	62	b	87	c	112	c
13	c	38	b	63	b	88	b	113	c
14	a	39	b	64	b	89	b	114	e
15	a	40	a	65	d	90	b	115	a
16	b	41	b	66	a	91	b	116	b
17	c	42	a	67	b	92	b		
18	b	43	a	68	d	93	d		
19	c	44	a	69	a	94	a		
20	c	45	d	70	d	95	d		
21	c	46	c	71	c	96	a		
22	c	47	a	72	b	97	a		
23	c	48	d	73	a	98	b		
24	a	49	d	74	b	99	b		
25	c	50	b	75	c	100	a		