Solution

CET25C5 COORDINATION COMPOUNDS

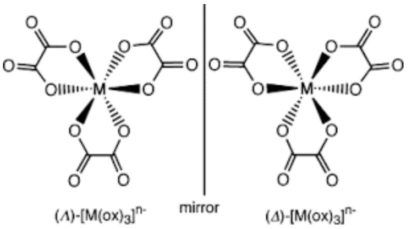
Class 12 - Chemistry

1. **(a)** $K_3[Fe(CN)_6]$

   Explanation: In given complex, there are 3 K^+ ions and so the anion has overall -3 charge. In $[Fe(CN)_6]^{3-}$, there are $6CN^-$ ligands and an overall charge of -3 on the complex and hence Fe is in +3 oxidation state so its electronic configuration is $1s^2 2s^2 2p^6 3s^2 3p^6 3d^5$. Since CN^- is a strong field ligand and it causes pairing of electrons. But there is one unpaired electron which makes this complex paramagnetic.

2. **(b)** Optical isomerism

   Explanation: This complex has non-superimposable mirror images as shown.



   where M=Cr, n=3

   Thus, this complex shows optical isomerism

3. **(b)** Both $CuSO_4$ and CuF_2

   Explanation: Both $CuSO_4$ and CuF_2 are white in colour when they are anhydrous.

4. **(c)** Both the field produced by the ligand and the charge on the metal ion.

   Explanation:

   The splitting of degenerate d orbitals in presence of ligands in a definite geometry is called crystal field splitting. The extent of the splitting depends upon the charge on the metal ion and field of the ligand. Some ligands produce strong field and cause a large splitting whereas some ligands produce weak field and cause a small splitting.

5. **(c)** 0

   Explanation: Let x be the oxidation state of Ni in $Ni(CO)_4$.

   Since the overall charge on the complex $Ni(CO)_4$ is 0, the sum of oxidation states of all elements in it should be equal to 0.

   Therefore, $x + 4(0) = 0$

   Hence, $x = 0$

   Thus, the oxidation state of Ni in $Ni(CO)_4$ is equal to 0.

6. **(c)** It is an electrostatic model.

   Explanation: The crystal field theory is an electrostatic model which considers the metal-ligand bond to be ionic arising purely from electrostatic interactions between the metal ion and the ligand.

7. **(b)** No isomerism

   Explanation: The two compounds are completely different and therefore will not show isomerism because for showing isomerism the basic criteria are both of the compounds should have the same molecular formula and in the given question both of the compounds have a different formula.

8.

(d) $[Ti(NO_3)_4]$

Explanation: Ti has atomic number 22. And its electronic configuration is $1s^22s^22p^63s^23p^64s^23d^2$.

In the given complex, there are four NO_3^- groups bonded to Ti. Each NO_3^- carries -1 charge, hence there is -4 charge on the ligands and overall the complex is neutral which means Ti is in +4 oxidation state. So Ti^{4+} has an electronic configuration $1s^22s^22p^63s^23p^6$ means there are no electrons in d orbital and hence d-d transition is not possible. So it is expected to be colourless.

9.

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

Explanation: The formula of the complex Iron (III) hexacyanidoferrate (II) is: $Fe_4[Fe(CN)_6]_3$

10. **(a)** 5

Explanation: The complex of Fe with CO ligand is $[Fe(CO)_5]$ i.e. pentacarbonyliron(0). So the value of x =5.

11.

(b) EDTA

Explanation: EDTA (ethylenediaminetetraacetato) is a hexadentate ligand and it forms a stable chelate complex with given metal ions. The selective estimation of these ions can be done due to the difference in stability constants of complexes of these ions with EDTA.

12.

(b) 6

Explanation: The oxidation state of cobalt is +3, and hence, the primary valency will be 3. The secondary valency is 6, as there are 4 NH_3 molecules and 2 Cl^- ions linked to the cobalt atom.

13. **(a)** NH_4^+

Explanation: Ligand must donate a pair of electron or loosely held electron pair to metal and from an M-L bond.

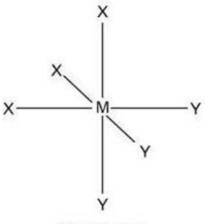
14.

(d) Coordination number

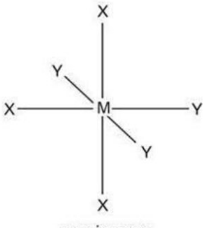
Explanation: According to Werner's theory, secondary valences are non-ionizable and are satisfied by neutral molecules or negative ions. Secondary valence is equal to the coordination number and is fixed for a metal.

15. **(a)** Geometrical isomerism

Explanation: The given complex is of type $[MX_3Y_3]$ and such complexes exhibit geometrical isomerism. If three donor atoms of the same ligands occupy adjacent positions at the corners of the octahedral face, then we have the facial (fac) isomer. When the positions are around the meridian of the octahedron, we have the meridional (mer) isomer.



fac-isomer



mer-isomer

16. **(a)** 6

Explanation: Oxalate i.e. $C_2O_4^{2-}$ is a didentate ligand as it can bind through 2 O atoms. In given complex there are 3 oxalate ligands bound to Fe. So that means Fe has a coordination number 6.

17. **(a)** 6

Explanation: Coordination number is the number of ligands joined to the central metal ion or atom. Since ethylenediamine is a bidentate ligand, Co has coordination number of 6.

18. **(a)** NO_2

Explanation: ambidentate ligands can attach to the central atom in two places. A good example of this is thiocyanate SCN, which can attach at either the sulfur atom or the nitrogen atom. Such compounds give rise to linkage isomerism. Polyfunctional ligands, see especially proteins, can bond to a metal center through different ligand atoms to form various isomers. For example -NO_2

19. **(a)** Solvate isomerism

Explanation: The given compounds have a different number of water molecules inside and outside the coordinate sphere therefore it is solvate isomers.

20.

(d) Coordination isomerism

Explanation: $[Co(NH_3)_6]$ $[Cr(CN)_6]$ and $[Cr(NH_3)_6]$ $[Co(CN)_6]$ show Coordination isomerism

21. **(a)** $[Co(en)_3]^{3+}$

Explanation: Geometrical isomerism arises in heteroleptic complexes due to different possible geometric arrangements of the ligands. In $[Co(en)_3]^{3+}$ all ligands are same i.e. ethane-1,2-diamine. It is symmetrical so it does not show geometrical isomerism.

22. **(a)** Diamminedichloridoplatinum (II)

Explanation: Diamminedichloridoplatinum (II)

23.

(b) 8,000 cm^{-1}

Explanation: Crystal field splitting energy for tetrahedral is 4/9 times that for octahedral

$$\Delta t = \frac{4}{9}\Delta_o$$

$$\Delta t = \frac{4}{9} \times 18,000cm^{-1} = 8,000cm^{-1}$$

24.

(c) NH_4^+

Explanation: NH_4^+ ion does not have a lone pair of electrons which it can donate to central metal ion. Hence it cannot behave as a ligand.

25.

(b) $[Co(en)_3]^{3+}$

Explanation: $[Co(en)_3]^{3+}$

26.

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

Explanation: $[Fe(C_2O_4)_3]^{3-}$

27.

(b) $[Co(NH_3)_5NO_2](NO_3)_2$

Explanation: $[Co(NH_3)_5NO_2](NO_3)_2$ will exhibit linkage isomerism as it contains nitrite ligand which have the same composition differing with the connectivity of the metal to a ligand.It can bind from N as well as from O side.

28.

(d) Ionisation

Explanation: Ionisation

29.

(b) Are satisfied by negative ions

Explanation: Primary valence of the central metal atom/ion is ionisable and is satisfied by negative ions.

30.

(c) +3

Explanation: +3

31. **(a)** $K^+[PtCl_3(C_2H_4)]^-$

Explanation: Potassium trichloro(ethylene)platinate(II) i.e. $K[PtCl_3(C_2H_4)]$ is zeise's salt.

32.

(d) 3

Explanation: The given complex can be written as $Co(NH_3)_6Cl_2$.Thus, $[Co(NH_3)_6]^{2+}$ along with two Cl^- ions are produced in solution which is a total of 3 ions.

33.

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

Explanation: Complexes in which the central metal is bound to only one kind of donor groups are called homoleptic complexes. $[Cu(NH_3)_6]^{+2}$ is a homoleptic complex because in this only ammonia group is the donor group bound to Cu^{+2}.

34.

(b) $C_2O_4^{2-}$

Explanation: $C_2O_4^{2-}$

35.

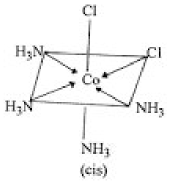
(c) Tetraamminecopper(II) nitrate

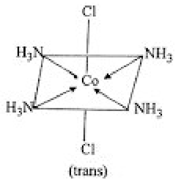
Explanation: In an ionic compound, the cation is named first and then the anion. If cation is the complex then ligands are named first in alphabetical order and then the central metal atom/ion with its oxidation state in parenthesis in roman numerals. Here, NH_3 (ammine) is the neutral ligand and there are 4 NH_3 bound to Cu (copper). Nitrate NO_3^- is the anion there are two NO_3^- outside the square bracket, each carries -1 charge so there is a total of -2 charge on anions and thus the complex carries a total of +2 charge. Since ammine is a neutral ligand so Cu has +2 oxidation state. So, $[Cu(NH_3)_4](NO_3)_2$ is tetraamminecopper(II) nitrate.

36.

(b) $[Co(NH_3)_4Cl_2]^+$

Explanation: In octahedral complexes of formula $[MX_2L_4]$ in which the two ligands X may be oriented adjacent or opposite to each other, cis and trans isomers are possible. Thus, $[Co(NH_3)_4Cl_2]^+$ exists as cis and trans isomers.





37. **(a)** Ammonium ferrous sulphate hexahydrate

Explanation: This is a double salt so its IUPAC name is written in alphabetical order and the number of the molecules of water of crystallisation is mentioned in the end. So the name is ammonium ferrous sulphate hexahydrate.

38.

(b) Cis – Platin

Explanation: Cis-platin (cis – $[Pt(NH_3)_2(Cl)_2]$) is a coordination compound used in the treatment of cancer. It inhibits the growth of tumors.

39.

(b) $[Cr(NH_3)_6][Co(CN)_6]$

Explanation: Coordination isomerism arises from the interchange of ligands between cationic and anionic entities of different metal ions present in a complex. Here interchange of CN^- and NH_3 ligands is possible between Cr and Co to give $[Co(NH_3)_6][Cr(CN)_6]$. So this complex can exhibit coordination isomerism.

40.

(b) Aluminium potassium sulphate dodecahydrate

Explanation: This is a double salt so its name is written in alphabetical order and the number of molecules of water of crystallisation is mentioned in the end. So the name is aluminium potassium sulphate dodecahydrate.

41.

(b) 3

Explanation: The given compound will dissociate to give $[Co(NH_3)_6]^{2+}$ and 2 Cl^- ions in solution i.e. a total of 3 ions. The two Cl^- ions satisfy the primary ionisable valence of Co^{2+} whereas the 6 NH_3 molecules satisfy the non ionisable secondary valence of Co^{2+}.

42. **(a)** Lewis acid

Explanation: The central metal atom/ion behaves as a Lewis acid while the ligand acts as a Lewis base. The ligand can be a negatively charged ion or a neutral molecule that donates its electron pair to the central metal atom/ion which acts as an electron pair acceptor (Lewis acid).

43.

(d) Lithium tetrahydridoaluminate is represented as: $Li[AlH_4]$

Explanation: The cation is named first and then the anion. When the anion is the complex then the -ate is added to the name of the central metal. Here there are 4 hydride ligands represented as H^- each carries a charge of -1 and hence a total of -4 charge on the ligands. Lithium-ion is represented by Li^+ and carries a +1 charge which means the charge on the complex is -1. In the complex, central metal atom/ion is written followed by the ligands in alphabetical order.
Lithium tetrahydridoaluminate(III) is $Li[AlH_4]$.

44. **(a)** 3

Explanation: 3

45.

(b) $\frac{4}{9}\Delta_0$

Explanation: Since splitting in tetrahedral complex is 23rd of octahedral complex ,so for one legand splitting in OH
$\frac{4}{9}\Delta_0$

46.

(b) 1

Explanation: The complex $[PtCl_3(NH_3)_3]Cl$ has only one ionizable chlorine

47.

(c) $[Cr(H_2O)_4 Cl_2]^+$

Explanation: $[Cr(H_2O)_4 Cl_2]^+$ shows geometrical (cis-trans) isomerism. In cis isomer, two ClCl ligands are adjacent to each other. In trans isomer, two ClCl ligands are opposite to each other. Complexes of type MA_4B_2 shows geometrical isomerism.

48.

(b) Geometrical isomerism

Explanation: Geometrical isomerism

49.

(d) Dodecacarbonyltrimanganese(0)

Explanation: In the nomenclature of coordination compounds, the ligands are named first followed by the name of central metal atom/ion followed by the oxidation state of the metal in parenthesis. Here CO is the carbonyl ligand, there are 12 CO ligands and they are attached to 3 Mn i.e. Manganese metal atoms. CO is a neutral ligand and carries no charge and hence the oxidation state of Mn is 0. So the IUPAC name is Dodecacarbonyltrimanaganese(0).

50. **(a)** $Cu^{2+} + 4CN^- \rightleftharpoons [Cu(CN)_4]^{2-}$; Log K = 27.3

Explanation: $Cu^{2+} + 4CN^- \rightleftharpoons [Cu(CN)_4]^{2-}$; Log K = 27.3

K is called the equilibrium constant(or binding constant) and tells us how strongly the ligands bind to the metal centre. So, the higher the value of K, the greater the stability of the complex formed.

$$K = \frac{[Cu(CN)_4]}{[Cu]^{2+}[CN]^{-4}}$$

Greater the value of K, the equilibrium is favoured more towards the side of the formation of complex, which is possible only if it is very stable.

51.

(d) sp^3d^2

Explanation: Given complex can be written as $K_3[CoF_6]$. There are 3 Potassium ions K^+ means an overall +3 charge on cations

and so the charge on the complex anion is -3. Each F^- ligand has -1 charge so there is a total of -6 charge on ligands. Let oxidation state of Co (Z=27) be x
$x + (-6) = -3$
$x = -3 + 6 = +3$

So, the oxidation state of Co=+3 and its electronic configuration is $1s^2 2s^2 2p^6 3s^2 3p^6 3d^6$. Since its, a high spin complex means there is no pairing of electrons in 3d subshell. The coordination number of Co is 6 as there are 6 ligands bound to it, so this octahedral complex has hybridization sp^3d^2.

52. **(a)** ionization isomerism
Explanation: The isomers which form different ions in solution, although, they have same the composition, are called ionization isomers.

53. **(a)** hexadentate ligand
Explanation: Ethylenediaminetetraacetate ion is a hexadentate ligand as it can bind to the central metal atom/ion through 6 donor atoms i.e. 2 N and 4 O atoms.

54. **(a)** Cyanocobalamine
Explanation: Vitamin B_{12}, cyanocobalamine, the antipernicious anaemia factor is a coordination compound of Cobalt.

55.

(c) $[Ni(NH_3)_4]^{2+}$

Explanation: Ni has atomic number 28, so Ni^{2+} has electronic configuration $1s^2 2s^2 2p^6 3s^2 3p^6 3d^8$. NH_3 is a weak field ligand and hence two electrons are unpaired and hence this complex is paramagnetic.

56. **(a)** $KCl.MgCl_2.6H_2O$

Explanation: The given option is correct because it is a double salt (a double salt dissociates into simple ions completely when dissolved in water) whereas others are complexes which don't dissociate completely into solution.

57. **(a)** Cyclopentadienyl

Explanation: $C_5H_5^-$ is a cyclopentadienyl anion and it is a negatively charged ligand.

58.

(c) 3

Explanation: The complex $[Co(NH_3)_6]Cl_2$ ionize to give 3 ions .i.e., $[Co(NH_3)_6]^+$ along with two Cl^- ion.

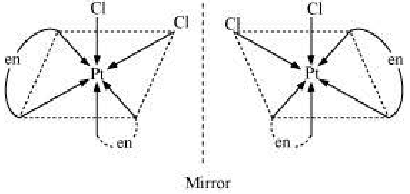
59.

(b) 2
Explanation: In given complex both H_2O and NH_3 are weak field ligands and are neutral. So Ni has oxidation state +2. Its electronic configuration is $1s^2 2s^2 2p^6 3s^2 3p^6 3d^8$. So the number of unpaired electrons are 2.

60.

(c) cis-isomer

Explanation:



We can see that in the cis isomer the mirror images are non-superimposable whereas in trans-isomer the mirror images will be superimposable and hence will not show optical activity.

61. **(a)** Titration with EDTA

Explanation: Hardness of water is because of presence of Ca^{2+} and Mg^{2+} ions which can form stable complexes with EDTA. So by simple titration with EDTA, hardness of water can be estimated. The selective estimation of these ions can be done due to difference in the stability constants of their complexes with EDTA.

62.

(d) Bis(cyclopentadienyl)iron(II)

Explanation: $C_5H_5^-$ is cyclopentadienyl ligand. The name of the ligand is written first followed by the name of the central metal and its oxidation state in parenthesis in roman numerals. $C_5H_5^-$ carries -1 charge and there are two such ligands. The overall charge on the complex is 0 so to balance the -2 charge of the ligands iron must be in +2 oxidation state. Hence, the IUPAC name of the complex is Bis(cyclopentadienyl)iron(II).

63. **(a)** dsp^2

Explanation: Tetraaminecopper(II) ion is square planar. Square planar complexes have dsp^2 hybridization. So hybridization is dsp^2.

64.

(d) Linkage isomers

Explanation: Ambidentate ligand SCN^- ion has donor atoms N and S. It links to the metal as either M-SCN or M-NCS. Complexes containing ambidentate ligands shows linkage isomerism.

65. **(a)** Solvate isomerism

Explanation: Solvate / Hydrate isomerism

Solvate or hydrate isomers have the same composition but differ with respect to the number of solvent ligand molecules as well as the counter ion in the crystal lattice.

Step I: $[Cr(H_2O)_6]Cl_3$ and $[Cr(H_2O)_5CI]Cl_2 \cdot H_2O$ have same composition.

Step II: In$[Cr(H_2O)_6]Cl_3$, the number of water molecules inside the co-ordination sphere is six and the number of water molecules outside the co-ordination sphere is 0.

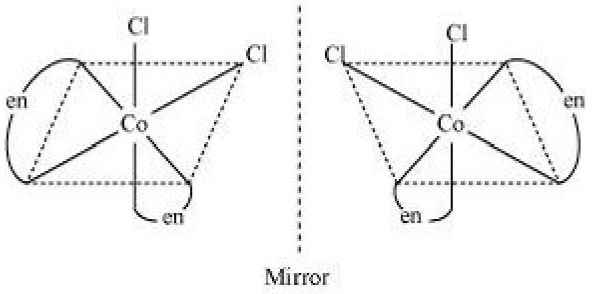
Step III: In $[Cr(H_2O)_5Cl]Cl_2 \cdot H_2O$ the number of water molecules inside the co-ordination sphere is five and the number of water molecules outside the co-ordination sphere is one.

66.

(c) Cis - $[Co(en)_2Cl_2]^+$

Explanation:

Cis - $[Co(en)_2Cl_2]^+$ has non superimposable mirror images as shown.



Hence, it shows optical isomerism and can form d (dextrorotatory) and l (laevorotatory) isomers.

67.

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

Explanation: 3 mol of AgCl means 3Cl are given in the solution, hence, the formula of the complex will be $[Cr(H_2O)_6]Cl_3$

68.

(b) Optical isomerism

Explanation: Optical isomerism

69.

(b) $EDTA^{4-}$

Explanation: $EDTA^{4-}$ having six donor atoms comes under polydentate ligand category.

70.

(d) both σ and π character

Explanation: The metal-carbon bond in metal carbonyls possesses both σ and π character. The M–C σ bond is formed by the donation of lone pair of electrons on the carbonyl carbon into a vacant orbital of the metal. The M–C π bond is formed by the donation of a pair of electrons from a filled d orbital of metal into the vacant antibonding π^* orbital of carbon monoxide. The metal to ligand bonding creates a synergic effect which strengthens the bond between CO and the metal.

71.

(d) Thiosulphate

Explanation: Thiosulphate or $(S_2\ O_3)^{2-}$ is not a chelating agent. Since it is a monodentate ligand.

72.

(c) $KFe[Fe(CN)_6]$

Explanation: This is a confirmatory test to detect Fe^{+3} ion in unknown sample. Ferric chloride combines with potassium ferrocyanide solution to give blue precipitate of potassium ferri ferrocyanide.
$FeCl_3(aq) + K_4[Fe(CN)_6]\ (aq) \rightarrow KFe[Fe(CN)_6](s) + 3KCl(aq)$

73. **(a)** Ionization isomerism

Explanation: Ionization isomerism- One isomer is $[Co(NH_3)_4Cl_2]NO_2$, where NO_2 ions is outside the complex and another isomer is $[Co(NH_3)_4Cl_2NO_2]Cl$ where Cl^- ion is outside the complex.

74. **(a)** Pentacarbonyliron (0)

Explanation: Iron (Z=26) has an electronic configuration $1s^2 2s^2 2p^6 3s^2 3p^6 3d^6 4s^2$. CO being a strong field ligand, causes pairing of electrons in the d orbital and shifting of 4s electrons to 3d orbital. With a coordination number 5 it results in sp^3d hybridisation and hence a trigonal bipyramidal geometry.

75.

(c) Co^{3+}

Explanation: Co^{3+}