

9.0 INTRODUCTION

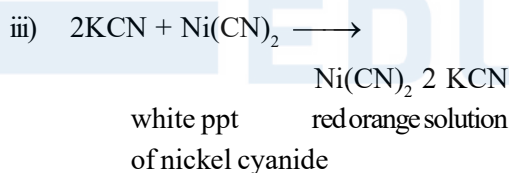
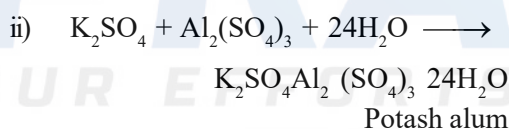
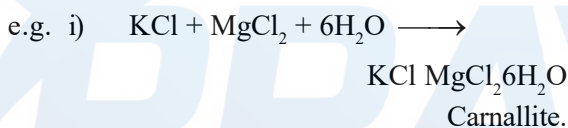
The concept of coordination compounds arise from complex forming tendency of transition elements (d-block elements).

Transition elements have good tendency to form complex compounds because of small atomic size, highly charged ions and vacant low energy orbitals to accept lone pair of electrons from ligands (lone pair donor).

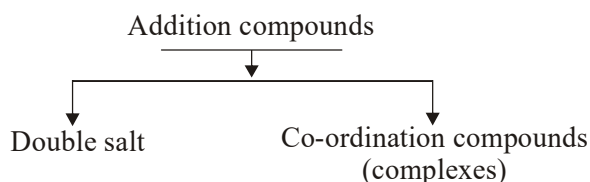
9.1 ADDITION COMPOUNDS OR MOLECULAR COMPOUNDS

Definition:

Compounds which are formed from two or more stable compounds in simple molecular proportions (stoichiometric ratio) are known as addition compounds.



Addition compounds are divided in to two types.

**Double Salt :**

These are addition compounds exist only in solid state (crystal lattice) and lose their identity when dissolve in water or dissociate completely in water.

- i) When potash alum is dissolved in water gives test

of K^+ , Al^{3+} , SO_4^{--}

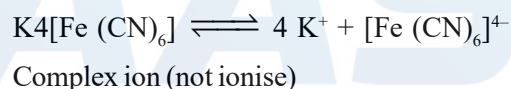
- ii) Carnallite ($\text{KCl} \cdot \text{MgCl}_2 \cdot 6\text{H}_2\text{O}$). When carnallite is dissolved in water gives test of K^+ , Mg^{2+} , Cl^-
- iii) Mohr's salt ($\text{FeSO}_4 \cdot (\text{NH}_4)_2 \text{SO}_4 \cdot 6\text{H}_2\text{O}$). When Mohr's salt is dissolved in water gives test of Fe^{2+} , NH_4^+ , SO_4^{--}

9.2 COORDINATION COMPOUNDS OR COMPLEX COMPOUNDS

Definition:

The addition compounds does not lose their identity when dissolve in water or solution are known as coordination compounds or complex compounds.

e.g. When potassium ferrocyanide $\text{K}_4[\text{Fe}(\text{CN})_6]$ is dissolved in water it does not give a test for Fe^{2+} , CN^- ions because these two ions are present in new ions called complex ion (ferrocyanide) and does not ionise in to Fe^{2+} and CN^-



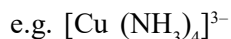
9.3 TERMS USED IN COORDINATION COMPOUNDS

1. **Complex ion or coordinate ion or coordinate entity or coordinate sphere:**

It contain, central atom or ion which is attached to ligands, are collectively known as coordination sphere.

It may be positively charged, or negatively charged or neutral.

This part of the complex behave as one unit generally kept in [] bracket and non-ionisable.



In the complex ion Cu^{2+} ion is linked to four NH_3 ligands by coordinate bond

2. **Central atom or central ion or centre of coordination:**

Definition: In complex ion, the metal atom or cation is attached to number of ions or groups (ligands) through coordinate bond in a definite

geometrical arrangement is known as central atom or ion.

e.g. $[\text{Ni}(\text{NH}_3)_6]^{2+}$, $[\text{Fe}(\text{CN})_6]^{3-}$, $[\text{NiCl}_2(\text{H}_2\text{O})_4]$, $[\text{Co}(\text{NH}_3)_5\text{Cl}]^{2+}$.

In these complex ion Ni^{2+} , Fe^{3+} , Ni^{2+} , CO^{3+} are central atoms or ions respectively and known as Lewis acids (electron pair acceptor).

3. Counter ion:

- Counter ion may be positive or negative.
- The positive ion is always kept at left side of complex ion. Then complex ion is negative.

e.g. $\text{K}_4[\text{Fe}(\text{CN})_6]$

The counter ion is K^+ and complex ion $[\text{Fe}(\text{CN})_6]^{4-}$.

- The negative counter ion is always kept at right side of complex ion. Then complex ion is positive.

e.g. $[\text{Co}(\text{NH}_3)_6]\text{Cl}_3$

The counter ion is Cl^- and complex ion $[\text{Co}(\text{NH}_3)_6]^{3+}$.

4. Ligands (Lewis bases) :

Definition : These are atoms or ions or neutral molecule having tendency to donate lone pair of electrons to the formation of coordinate bonds are known as ligands.

Ligands may be positive, negative or neutral molecules.

- Positive ligands :** They have positive charge.
e.g. NO^+ (nitrosylium or nitrosonium), NO_2^+

a) Neutral monodentate ligands :

Common names	IUPAC name	No special ending	Formula
Hydroxyl amine	Hydroxyl amine		NH_2OH
Ammonia	Ammine		NH_3
Methyl amine	Methanamine		CH_3NH_2
Water	Aqua or aquo		H_2O
Carbonyl	Carbonyl		CO

b) Positive monodentate ligands (They ends with "ium")

NO_2^+ Nitronium
 NO^+ Nitrosylium or nitrosonium
 $\text{NH}_2 - \text{NH}_3^+$ Hydrazinium

(nitronium), $\text{NH}_2 - \text{NH}_3^+$ or N_2H_5^+ (hydrazinium), NH_4^+ (ammonium) etc.

- Negative ligands :** They have negative charge.
e.g. Cl^- , NO_2^- , OH^- , X^- , CN^- , O_2^- (oxide) etc.

- Neutralligands:** They have no charge
e.g. $\text{H}_2\text{N}-\text{CH}_2-\text{CH}_2-\text{NH}_2$ (ethylene diammine), CO (carbonyl), NH_3 , H_2O , NH_2-OH , $\text{R}-\text{NH}_2$, $\text{R}-\text{OR}$, $\text{R}-\text{OH}$, SH , CH_3 , CO_2 etc.

9.4 CLASSIFICATION OF LIGANDS

I] Classification based on contribution of number of electron pair to the central atom or ion. (When these ligands are considered as neutral molecules)

- Molecules having one lone pair of electron is considered as two electron donor.

e.g. $\ddot{\text{N}}\text{H}_3$, $\ddot{\text{P}}\text{X}_3$, $\text{R}-\ddot{\text{N}}\text{H}_2$, $\text{R}_2\ddot{\text{N}}\text{H}$, $\text{R}_3\ddot{\text{N}}$ etc.

- Molecules having two lone pair of electrons are considered as four electron donor.

e.g. $\text{H}_2\ddot{\text{N}} - \text{CH}_2 - \text{CH}_2 - \ddot{\text{N}}\text{H}_2$ ethylene diamine.

II] Classification based on number of point of attachment to the central atom or ion:

- Monodentate or unidentate ligands :** They have only one point of attachment to the central atom, they may be neutral, cationic (+ve), anionic (-ve) ligands.

c) Negative monodentate ligands (They end with 'ido' or 'o')

Common names	IUPAC names	Formula
Fluoro	fluorido	F^-
Chloro	chlorido	Cl^-
Bromo	bromido	Br^-
Iodo	iodido	I^-
Cyano	Cyanido-C (C-bonded)	CN^-
Isocyano	Isocyanido - N (N-bonded)	NC^-
Thiocyano	Thiocyanato - S (S-bonded)	SCN^-
Isothiocyano	Isothiocyanato-N (N-bonded)	NCS^-
Cyanate	Cyanato - O (O - bonded)	OCN^-
Isocyanate	Isocyanato - N (N-bonded)	NCO^-
Hydroxy	Hydroxido	OH^-
Nitro	Nitrito-N(N-bonded)	NO_2^-
Nitrite	Nitrito - O (O-bonded)	ONO^-
Nitrate	Nitrato	NO_3^-
Amido	Amido	NH_2^-

III) Poly dentate (neutral and negative) ligands : They have more than one point of attachment to metal cation are known as polydentate ligands. They may be neutral or negative. These are classified as bidentate, tridentate, tetrad entate, pentadentate and hexadentate ligands.

Formula	Point of attachment	Common name	IUPAC name	Notation
O^{2-}	Bidentate	Oxide	Oxido	--
$C_2O_4^{2-}$	Bidentate	Oxalate	Oxalato	ox^{2-}
$NH_2-CH_2-CH_2-NH_2$ (neutral)	Bidentate	Ethylene diamine	Ethane 1, 2- diamine	en
CO_3^{2-}	Bidentate	Carbonato	Carbonato	--
CO_2 (neutral)	Bidentate	Carbon dioxide	Carbon dioxide	--
$NH_2-CH_2-CH_2-NH_2$	Tridentate	Diethylene	N - (2-amino ethyl)	dien
$NH-CH_2-CH_2-NH_2$ (neutral)	Triammine	Triammine	1, 2- ethane diamine or diethylene triammine	
$NH_2-CH_2-CH_2-NH-CH_2-CH_2-NH_2$ (neutral)	Tetradentate	Triethylene	Triethylene	trien
$NH-CH_2-CH_2-NH-CH_2-CH_2-NH_2$ (neutral)	Tetrammine	Tetrammine	tetrammine	
$NH_2-CH_2-COO^-$ Unsymmetrical	Bidentate	Clycinate	Clycinato	gly
$HO-N=C-C=N-OH$ CH_3CH_3 (Neutral)	Bidentate	Dimethyl glyoximate	Dimethyl glyoximato	dmg
$\begin{array}{c} -OOC-H_2C \\ -OOC-H_2C \end{array} \begin{array}{c} \diagup \\ \diagdown \end{array} \ddot{N}CH_2-CH_2-\ddot{N} \begin{array}{c} \diagdown \\ \diagup \end{array} \begin{array}{c} CH_2-COO^- \\ CH_2-COO^- \end{array}$	Hexadentate	Ethylene diamine tetra acetate		$[EDTA]^{4-}$

IV] Chelating ligands OR chelate ligands :

Definition: The polydentate ligands which form ring structure with central metal ion are known as chelate ligands.

The complex formed from such ligands have a ring structure are known as chelates and process is known as chelation.

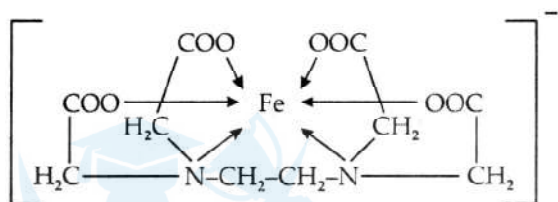
The number of such ligating groups is known as denticity of ligands.

Chelate ring may have many number of atoms, the most common contains five or six atoms including the metal ion.

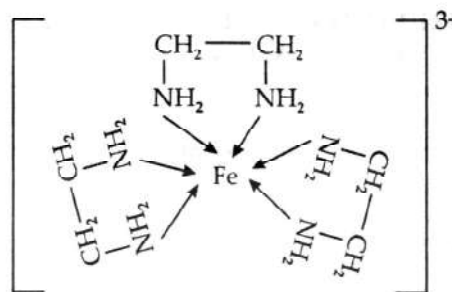
The chelate complex are more stable than similar complex containing unidentate ligands. The greater stability of chelate complex than normal complex is called as chelate effect.

In chelate complex number of rings increases stability increases.

e.g. $[\text{Fe}(\text{EDTA})]^-$ has five-six membered rings is more stable than $[\text{Fe}(\text{en})_3]^{3+}$ has three- five membered rings.



$[\text{Fe}(\text{EDTA})]^-$ has five- six membered ring
(more stable)



$[\text{Fe}(\text{en})_3]^{3+}$ has three-five membered rings
(less stable)

V] Ambidentate ligands :

Definition: They have two or more different donor atoms in same ligands and giving rise to linkage isomerism.

- e.g. 1) $\text{M} \leftarrow \text{NO}_2$ $\text{M} \leftarrow \text{O} - \text{N} = \text{O}$
 nitro – N nitro – O
- 2) $\text{M} \leftarrow \text{C} = \text{N}$ $\text{M} \leftarrow \text{NC}$
 cyano isocyano
- 3) $\text{M} \leftarrow \text{SCN}$ $\text{M} \leftarrow \text{NCS}$
 thiocyanate isothiocyanate
- 4) $\text{M} \leftarrow \text{OCN}$ $\text{M} \leftarrow \text{NCO}$
 Cyanate–O Isocyanate – N

9.5 COORDINATION NUMBER OF CENTRAL METAL ION (CN.) OR LIGANCY**Definition:**

Total number of attachment of ligands to central metal ion in complex is known as coordination number.

C.N. = Number of ligands X Total number of attachments to the central metal cation.

- e.g. 1) $[\text{Pt}(\text{Cl})_6]^{2-}$ = 6 Cl unidentate ligands are attached to Pt. Hence coordination number of Pt^{4+} is 6.
- 2) $[\text{Ni}(\text{NH}_3)_4]^{2+}$ = Four NH_3 neutral unidentate ligands are attached to nickel. Hence coordination of number of Ni^{2+} is four.
- 3) $[\text{Fe}(\text{C}_2\text{O}_4)_3]^{3-}$ = Three didentate ligands (C_2O_4) are attached to Fe. Hence coordination number of Fe^{3+} is six.
- 4) $[\text{Co}(\text{en})_3]^{3+}$ = Three didentate ligands (thylene diamine) attached to cobalt. Hence coordination number of Co^{3+} is six.
- 5) $\text{K}_3[\text{Fe}(\text{CN})_6]$ = Six unidentate ligands are attached to Fe^{3+} . Hence C.N. of Fe^{3+} is six.

9.6 COORDINATION POLYHEDRON OR GEOMETRY OF COORDINATION COMPOUNDS

Geometry of coordination compounds depends up on coordination number.

Definition:

The spatial arrangement of ligands around the central atom or ion is known as coordination polyhedron.

9.7 OXIDATION STATE OR OXIDATION NUMBER OF CENTRAL ATOM

It represents the total charge of a central atom in a coordination compounds. The oxidation state is represented by Roman numericals.

Counter ion

e.g. $\overset{\uparrow}{K}_4[Fe(CN)_6] \rightarrow$ complex ion

The complex compound has four monovalent counter cation (K). Hence complex ion must carry four negative charge i.e. $[Fe(CN)_6]^{4-}$

The six univalent uninegative ligands (CN^-) attached to central atom Fe. Hence the coordination number of Fe is six.

Oxidation state of Fe is



$$x + (-1 \times 6) = -4$$

$$x - 6 = -4$$

$$x = -4 + 6$$

$$x = +2$$

Thus iron is +2 oxidation state i.e. Fe(II)

9.8 HOMOLEPTIC AND HETEROLEPTIC COMPLEXES

- Complex compound in which a metal atom or ion is co-ordinately bonded with only one kind of ligands are known as homoleptic complexes.
e.g. $[Co(NH_3)_6]^{3+}$
- Complex compound in which a metal atom or ion is co-ordinately bonded with more than one kind of ligands are known as heteroleptic complexes.
e.g. $[Co(NH_3)_4Cl_2]^+$

9.9 TYPES OF COMPLEXES

Complex ion may be positive or negative or neutral.

- Positively charged (cationic) complex:**
 $[Co(NH_3)_6]^{3+}$, $[Ni(NH_3)_2]^{2+}$, $[Co(NH_3)_4Cl_2]^+$, $[Fe(H_2O)_6]Cl_3$
- Negatively charged (anionic) complex:**
 $[Fe(CN)_6]^{4-}$, $[Fe(C_2O_4)_3]^{3-}$, $[Ag(OH)_2]^-$, $K_4[Fe(CN)_6]$, $K[Ag(CN)_2]$, $K_2[AgI_4]$.
- Neutral complex (no charge complex) :**
 $[Ni(CO)_4]$, $[Pt(NH_3)_2Cl_2]$, $[Co(NH_3)_3Cl_2]$

9.10 CHARGE NUMBER OF COMPLEX ION

The net charge carried by complex ion is called as charge number. It is equal to algebraic

sum of the charges carried out by the central metal ion and ligands attached to it.

e.g. i) Charge number of $[Fe(CN)_6]^{4-}$ is -4

It can be calculated as,

$$\begin{aligned} [Fe(CN)_6]^{4-} &= \text{charge on } Fe^{2+} + 6 \\ &\quad \times \text{charge on } CN^- \text{ ion} \\ &= +2 + 6(-1) \\ &= -4 \end{aligned}$$

ii) Charge number of $[Fe(EDTA)]^-$ is -1

It can be calculated as,

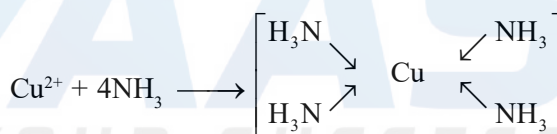
$$\begin{aligned} [Fe(EDTA)]^- &= \text{charge on } Fe^{3+} + 1 \\ &\quad \times \text{charge on EDTA ion} \\ &= +3 + 1 \times (-4) \\ &= -1 \end{aligned}$$

9.11 SIDGWICK ELECTRONIC THEORY

Sidgwick in 1927 extend the electronic Lewis theory for the formation of coordinate compounds.

According to Sidgwick, ligands donate electron pair(s) to the central metal ion to form number of coordinate bonds.

e.g. Cuprammonium ion is formed by the donation of four electrons pair by four ammonia molecule to cupric ion



9.12 EFFECTIVE ATOMIC NUMBER (EAN)

Definition:

Total number of electron around the central metal ion present in complex is known as effective atomic number.

Effective atomic number is valid for central metal cation possess equal number of electrons with rare gas.

EAN can be calculate as,

$$EAN = Z - X + Y \quad \text{OR}$$

$$EAN = \text{At.no. of central metal} - \text{O.S} + (2 \times \text{C.N})$$

Z = Atomic number of metal.

X = Number of electron lost by metal i.e. oxidation state.

Y = Total number of electron donated by ligands. (one lone pair = 2 electrons) or $2 \times \text{C.N}$

e.g. $[\text{Fe}(\text{CN})_6]^{4-}$

Effective atomic number can be calculated as

- In above example oxidation state of Fe = + 2, hence it loses 2 electron.
- Atomic number of Fe = 26
- CN^- is unidentate ligand. Each CN donate one pair i.e. 2 electron
EAN = $26 - 2 + 12 = 24 + 12 = 36$ electron

Note:

- EAN rule is useful to find the number of possible ligands around the metal ion.
- There are few complex compounds which violates EAN rule. A few complex shows EAN which is different from the atomic number of next rare gas.

Metal	Complex	Z	X	Y	EAN
Fe	$[\text{Fe}(\text{CN})_6]^{3-}$	26	3	12	35
Cu	$[\text{Cu}(\text{NH}_3)_4]^{2+}$	29	2	8	35
Pt	$[\text{Pt}(\text{NH}_3)_4]^{2+}$	78	2	8	84

9.13 NOMENCLATURE OF COORDINATION COMPOUNDS

The systematic nomenclature system of coordination compounds is based upon IUPAC recommendation, called IUPAC system. The latest rule (1990) are given below.

- Write name of positive counter ion (generally metals) before the complex ion, while name of negative counter ion after the complex ion. Never to indicate number of counter ions.
- In complex ion, the ligands are named in alphabetical order first followed by name of metal ion.
e.g. $[\text{Pt Br Cl}(\text{NO}_2)\text{NH}_3]^-$
Aminebromidochloridonitrito – N–platinate (II).
- In IUPAC nomenclature,
The negative ligands will be ends with 'ido' or '– o'.
The positive ligands will be ends with 'ium'.
Neutral ligands have no special ending.
- When similar ligands appears more than ones then prefixes di, tri, tetra are used.
If the names of the ligands include a numerical prefix or creates some confusion i.e. dipyrldyl, triphenyl phosphine, ethylene diamine etc. In such cases following prefix is used.

Name of such ligands are kept in bracket to avoid confusion. Bis for di, tris for tri, tetrakis for tetra etc.

e.g. $[\text{Pt Cl}_2(\text{H}_2\text{N} - \text{CH}_2 - \text{CH}_2 - \text{NH}_2)_2](\text{NO}_2)_2$
Dichloridobis (1,2–ethane diamine) platinum (IV) nitrite.

- If the complex is cation (+ve) or neutral the metal is named as element. For example; Co in complex cation is called cobalt and Pt is called platinum.
 - If the complex ion is anion (– ve) the name of metal ends with suffix 'ate'. For example, Co in complex anion is called cobaltate.
 - In negative complex, some metals are named by Latin names.

Iron (Fe) = Ferrate

Silver (Ag) = Argenate

Gold (Au) = Aurate

Lead (Pb) = Plumbate

Tin (Sn) = Stannate

e.g. i) $[\text{Co}(\text{NH}_3)_4\text{Cl}_2]^+$

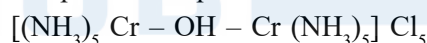
Tetraamminedichlorido cobalt (III)

ii) $(\text{NH}_4)_2[\text{Co}(\text{SCN})_4]$

Ammoniumtetrathiocyanato – S–cobaltate (II)

- Complex contain bridge:** In bridge complexes, the bridge forming ligands are indicated by prefix μ .

a) If complex compound is symmetrical at both side of bridge, then write the name of complex at one place.

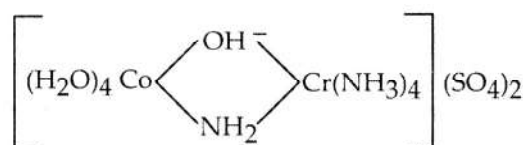


μ -hydroxido bispentaammine dichromium (III) chloride. or

Pentaammine chromium (III)

μ -hydroxidopentaammine chromium (III) chloride.

- If complex compound is unsymmetrical at both sides of the bridge. The name can be written in this way,
one side bridge $\rightarrow \mu$ (name of ligands) \rightarrow second side of bridge.



Tetraaquacobalt (III) – μ – amido – μ – hydroxide tetraammine chromium (III) sulphate.

- The oxidation state of central metal atom is shown by Roman numbers in bracket after the name of metals.
- There is a no space between name of ligands, name of metal and counter ion.

e.g.



Sodium pentacyanonitrosonium ferrate (II) or sodium nitroprusside (diamagnetic)

Explanation: Square bracket contain complex ion, which is a anion. The cation is sodium, named first. The ligands are named alphabetically. Since there are sodium ion (counter ion) in the complex. Hence charge on complex must be -2 .

From charge on the complex ion and charge on ligand oxidation state of metal can be calculated (CN is negative unidentate ligand and NO is positive unidentate ligand).

Hence oxidation state of Fe in $[\text{Fe}(\text{CN})_5 \text{N O}]^{2-}$

$$x + (-1 \times 5) + (1 \times 1) = -2$$

$$x - 5 + 1 = -2$$

$$x - 4 = -2$$

$$x = -2 + 4 = +2$$

9.14 RULES FOR WRITING THE FORMULA OF CO-ORDINATION COMPOUNDS

- The central atom or ion is placed first.
- The ligands are placed in alphabetical order. The placement of a ligand in the list does not depends on its charge.
- The neutral and positive ligands are kept in bracket.
- The coordination complex is enclosed in square bracket [].
- When formulae is charged, coordination complex is written without the counter ion.
- The charge is indicated outside the square bracket with number before sign
e.g. i) $[\text{Co}(\text{NH}_3)_6]^{3-}$
ii) $[\text{Cr}(\text{H}_2\text{O})_6]^{3+}$
- The charge of cation is balanced by charge on anion.

Examples:

- Diaquaethenedioxomolybdenate(II) – $[\text{Mo}(\text{O})_2 (\text{C}_2\text{H}_4) (\text{H}_2\text{O})_2]^{2-}$
- Potassiumtetrahydroxidozincate (II) – $\text{K}_2 [\text{Zn} (\text{OH})_4]$

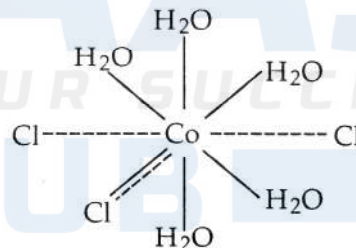
9.15 WERNER'S THEORY OF CO-ORDINATION COMPOUNDS

In 1893 German chemist Alfered Werner's put this theory to explain nature of bonding in complex compounds. He concluded that in complex compounds, metal shows two types of valencies i.e. primary valency and secondary valency.

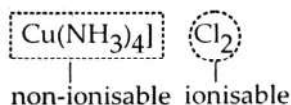
Basic postulates of Werner's Theory :

- Primary valency:** It is oxidation state of metal ion. This is also called as principal or ionisable or ionic valency. It is satisfied by positive or negative counter ions and its attachment with central metal ion is shown by dotted lines. It is non directional.
- Secondary valency or auxiliary valency:** It is coordination number (CN) of central metal ion. It is satisfied by neutral ligands or positive ligands or negative ligands. It is represented by both thick and dotted lines.

e.g. $[\text{Co Cl} (\text{H}_2\text{O})_5] \text{Cl}_2$



- Primary valencies are ionisable and satisfied by negative ions.
 $[\text{Cu}(\text{NH}_3)_4] \text{Cl}_2 \xrightarrow{\text{ionise}} [\text{Cu}(\text{NH}_3)_4]^{2+} + 2 \text{Cl}^-$
Primary valency or O. S of Cu = +2
- Secondary valencies are non-ionisable.
 $[\text{Cu}(\text{NH}_3)_4]^{2+}$ non – ionisable. Thus C. N or secondary valency of Cu = 4.
- Secondary valencies are directional and so complex has a particular shape.
e.g. i) C.N = 6 = octahedral.
- To distinguish between two types of valencies, Werner's introduced a square bracket []. Atoms present in square bracket are non-ionisable while portion out side the square bracket is ionisable.



e.g. On the basis of above explanation, Werner's formulated the coordination compounds of cobalt (III) chloride (CoCl_3) and NH_3 .

It was found that complex compound formed from CoCl_3 and NH_3 with AgNO_3 . Some of the chloride ions are precipitated as AgCl , while some of chloride ions not precipitated or remains in solution.

Sr.No.	Complex	Ionisable Cl	No. of ions	Molar conductance
1.	$\text{CoCl}_3 \cdot 6\text{NH}_3 \xrightarrow{3\text{AgNO}_3}$ 1mole	3	4	$390 \text{ ohm}^{-1} \text{ mol}^{-1}$
2.	$\text{CoCl}_3 \cdot 5\text{NH}_3 \xrightarrow{2\text{AgNO}_3}$ 1mole	2	3	$261 \text{ ohm}^{-1} \text{ mol}^{-1}$
3.	$\text{CoCl}_3 \cdot 4\text{NH}_3 \xrightarrow{1\text{AgNO}_3}$ 1mole	1	2	$102 \text{ ohm}^{-1} \text{ mol}^{-1}$
4.	$\text{CoCl}_3 \cdot 3\text{NH}_3 \xrightarrow{0\text{AgNO}_3}$ 1mole	0	0	$0.0 \text{ ohm}^{-1} \text{ mol}^{-1}$

Note: The $\text{CoCl}_3 \cdot 3\text{NH}_3$ does not react with AgNO_3 because three chloride ions are non-ionisable will not produces AgCl and it is nonconductor of electricity.

On the basis of conductivity measurement Werner's formulated cobalt (III) chloride and ammonia complex.

Modern formula and colour	Sol ⁿ conductivity and total ions	Ionisation	No. of Ions	2° valency (C.N)
$[\text{Co}(\text{NH}_3)_6] \text{Cl}_3$ Yellow	1 : 3 electrolyte and 4 moles of ions	$[\text{Co}(\text{NH}_3)_6]^{3+} + 3\text{Cl}^-$	4	6
$[\text{Co}(\text{NH}_3)_5 \text{Cl}] \text{Cl}_2$ purple	1 : 2 electrolyte and 3 moles of ions	$[\text{Co}(\text{NH}_3)_5]^{2+} + 2\text{Cl}^-$	3	6
$[\text{Co}(\text{NH}_3)_4 \text{Cl}_2] \text{Cl}$ Green	1 : 1 electrolyte and 2 moles of ions	$[\text{Co}(\text{NH}_3)_4 \text{Cl}_2]^+ + \text{Cl}^-$	2	6
$[\text{Co}(\text{NH}_3)_3 \text{Cl}_3]$ Violet	No electrolyte and a moles of ions	Not ionise	0	6

Note: From above table it is clear that the solution conductivity of complexes is $\text{CoCl}_3 \cdot 3\text{NH}_3 < \text{CoCl}_3 \cdot 4\text{NH}_3 < \text{CoCl}_3 \cdot 5\text{NH}_3 < \text{CoCl}_3 \cdot 6\text{NH}_3$

9.16 BONDING IN CO-ORDINATION COMPOUNDS

Werener's describe the bonding in coordination compounds. But this theory cannot answer some basic questions like.

1. Why only certain elements have the property to form coordination compounds.
2. Why the bonding in coordination compound has directional property.
3. Why coordination compounds have magnetic and optical property. To answer the above question, some theories are put forth viz. valency bond theory (VBT), crystal field theory (CFT), ligand field theory (LFT) and molecular orbital theory (MOT). We shall focus on only VBT and CFT.

9.17 VALENCE BOND THEORY (VBT)

Valence bond theory was developed by Linus Pauling in 1931.

Before studying the VBT we must know the shape of s, p, d and f orbitals and their orientations.
s-orbitals – Spherical shape – No orientation.

p-orbitals – Dumbel shape

– Oriented as P_x , P_y , P_z axis

d-orbitals – Double dum bel shape

– Oriented as d (x y), d (x z), d (y z), d ($x^2 y^2$), dz^2 .

9.18 POSTULATES OF VBT OR SALIENT FEATURE OF VBT

1. Metal atoms or ions, under the influence of ligands can use its (n – 1) d, ns, np or ns, np, nd orbitals for hybridization. The complexes formed in two ways are called low spin complexes or high spin complexes respectively.
2. Low spin complexes are also known as inner orbital complexes or spin paired complexes or (n – 1) d, ns, np orbital complexes.
3. High spin complexes are also known as outer orbital complex or spin free complex or ns, np, nd orbital complexes.
4. In the presence of weak ligand, electrons presents in inner orbitals does not take part in hybridisation. Hence electrons are grouped according to Hunds rule.
5. However in the presence of strong ligands like CO , CN^- , NO_2^- , en, NH_3 . The electrons can be forced to pair up against Hunds rule.
The decreasing order of strength of ligands according to spectrochemical series is, $\text{CO} > \text{CN}^- > \text{NO}_2^- > \text{en} > \text{NH}_3 > \text{EDTA}_4^- > \text{NCS}^- > \text{H}_2\text{O} > \text{C}_2\text{O}_4^{2-} > \text{OH}^- > \text{F}^- > \text{S}^{2-} > \text{Cl}^- > \text{SCN}^- > \text{Br}^- > \text{I}^-$
Note: $\text{CO} > \text{CN}^- > \text{NO}_2^- > \text{en} > \text{NH}_3$ are strong ligands. NH_3 act as strong as well as weak ligand.
6. When central metal of complex compound contain one or more unpaired electrons shows paramagnetic property. If no unpaired electrons, such complex shows diamagnetic property.

Following table provides the types of hybridisation with different coordination number.

C. N. of metal	Type of hybridisation	Shape of complex
4 (high spin)	sp^3	Tetrahedral
4 (low spin)	dsp^2	Square planer
6 (high spin)	sp^3d^2	Octahedral
6 (low spin)	$d^2 sp^3$	Octahedral

9.19 GEOMETRY OF COORDINATION COMPOUNDS

9.19.1 Tetrahedral complexes (C. N. 4)

e.g. $[\text{NiCl}_4]^{2-}$

Atomic number of Ni = 28

Oxidation state of Ni = + 2

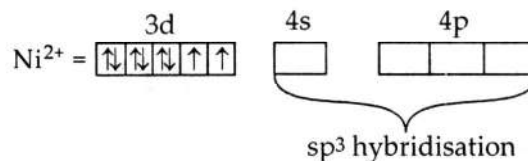
Ligand = Cl (weak)

Electronic configuration of Ni and Ni^{2+}

$_{28}\text{Ni} = 1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 3d^8, 4s^2, 4p^0$

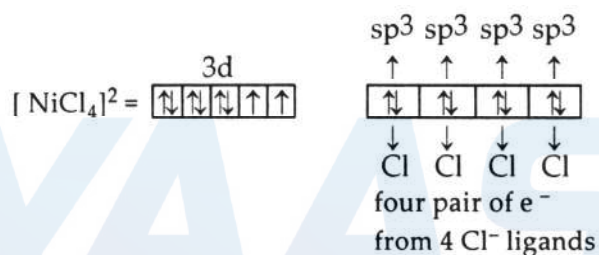
$\text{Ni}^{2+} = 1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 3d^8, 4s^0, 4p^0$

As shown below



Nickel undergoes sp^3 hybridisation by mixing of one 4s orbital and three 4p orbitals to form four sp^3 hybrid orbitals.

Each sp^3 hybrid orbitals takes lone pair of electrons from four Cl^- ligands to form $[\text{NiCl}_4]^{2-}$



Since, complex is formed by sp^3 hybridisation, it is tetrahedral and paramagnetic because of presence of two unpaired electrons in 3d orbitals. It is high spin complex because metal can use its 4s, 4p orbitals (higher) for bonding.

9.19.2. Square planer complexes (C. N. 4)

Square planer complexes are formed by dsp hybridisation. These complexes are formed when the central ion has only one d-orbital available in inner shell.

e.g. $[\text{Ni}(\text{CN})_4]^{2-}$ Tetracyanonickelate (II)

Atomic number of Ni = 28

Oxidation state of Ni = + 2

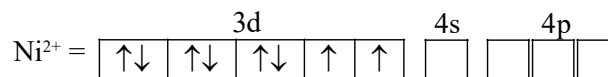
Ligands = four CN (strong).

Electronic configuration of Ni and Ni^{2+}

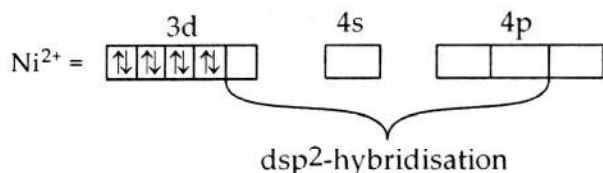
$_{28}\text{Ni} = 1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 3d^8, 4s^2, 4p^0$

$\text{Ni}^{2+} = 1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 3d^8, 4s^0, 4p^0$

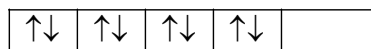
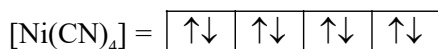
It is shown as follows,



In the presence of strong ligand like CN, 3d electrons are re – arranged against Hunds rule.



Each dsp^2 hybrid orbitals takes lone pair electrons from four CN^- ligands to form $[Ni(CN)_4]^{2-}$



Four pair of electron
from four CN ligands

Since, complex is formed by dsp^2 hybridisation. It is square planer and diamagnetic.

It is low spin complex because metal atom used its $(n-1)d$ ns, np orbitals.

9.19.3 Octahedral complexes (C.N. 6)

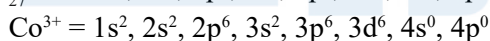
These complexes are formed from d^2sp^3 (low spin complex) and sp^3d^2 (high spin complex) hybridisation.

A] Low spin complexes or inner orbital complexes:

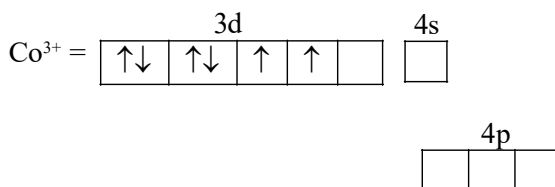
e.g. Formation of $[Co(NH_3)_6]^{3+}$

Atomic number of Co = 27
Oxidation state of Co = +3
Ligands = NH_3 (strong)

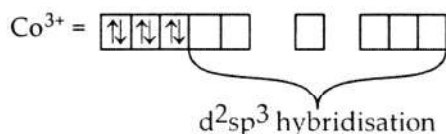
Electronic configuration of Co and Co^{3+} .



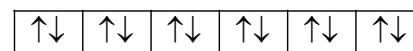
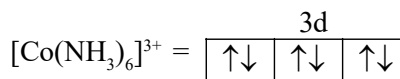
It is shown as follows,



In the presence of strong ligand like NH_3 . The 3d electrons are rearranged against Hunds rule.



Each d^2sp^3 hybrid orbitals take lone pair of electron from ammonia to form $[Co(NH_3)_6]^{3+}$.



Six paired electron
from six NH_3 ligands.

Since, the complex is formed by d^2sp^3 hybrid orbitals. It is octahedral and diamagnetic.

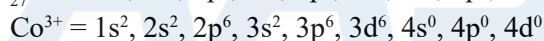
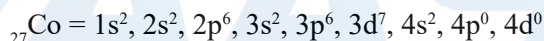
B] Outer orbital complexes or high spin complex: (sp^3d^2 hybridisation).

These complexes are formed by the use of 4d – orbitals. These complexes are paramagnetic and high spin complexes. The outer orbital complexes have greater number of unpaired electrons hence they have strong paramagnetic property than inner orbital complexes.

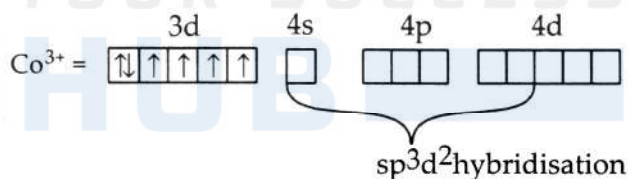
Such types of complexes are formed by weak ligands like F, Cl, H_2O and NH_3 (mild strong) etc.

e.g. Formation of $[CoF_6]^{3-}$

Atomic number of Co = 27
Oxidation state of Co = +3
Ligand = F (weak)
Electronic configuration of Co and Co^{3+}

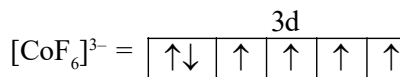


It is shown as follows,



Note that no 3d orbital involved in hybridisation because F^- is weak ligand can not force the pairing up electrons against Hunds rule.

Each sp^3d^2 hybrid orbitals takes lone pair of electrons from six F ligands to form $[CoF_6]^{3-}$.



Six pair of electrons
from six F^- ligands.

Since the complex is formed from sp^3d^2 hybridisation. It is octahedral and paramagnetic.

9.20 LIMITATION OF VBT

Valence bond theory explain the formation of complex, structure of complex and magnetic property.

But suffer from following drawbacks.

1. It does not give quantitative interpretation of magnetic data.
2. It does not explain colour shown by complex compounds.
3. It does not explain why magnetic property vary with temperature.
4. It does not make exact prediction regarding tetrahedral and square planer complexes of $C.N = 4$.
5. It does not distinguish between weak and strong ligands.
6. It does not give explanation about thermodynamic and kinetic stability of coordination compounds.
7. It does not give explanation about inner orbital and outer orbital complexes

The limitation of V.B.T. considerable remove by crystal field theory (CFT).

9.21 CRYSTAL FIELD THEORY (CFT)

The crystal field theory was originally proposed by Bethe in 1929, to explain the nature of bonding in ionic crystal and magnetic and spectroscopic property of complex compound. Later on the theory was applied by Schlapp and Penny in 1932 and also by Van Vleck in 1932.

9.22 POSTULATES OR SALIENT FEATURES OF C.F.T.

1. In the complex, central metal ion is surrounded by various atoms or groups called ligands.
2. Ligands acts as point charge $M \leftarrow L$
3. Ligands may be positive, negative or neutral.
4. According to crystal field theory, when ligands come closer to metal atom or ion, a field is created.
5. Attraction between metal atom and ligand is purely electrostatic (Ignore covalent bonds).
6. The pattern of splitting of d-orbitals in metal cation depends upon nature of crystal field i.e. geometry of complex compounds.
7. d-orbitals has five orientations with same energy. i.e. d_{xy} , d_{xz} , d_{yz} , $d_{x^2-y^2}$, d_{z^2} .
8. When ligands approaches towards metal, the d-orbitals split in two groups.

d-orbitals (d_{xy} , d_{xz} , d_{yz} , $d_{x^2-y^2}$, d_{z^2})

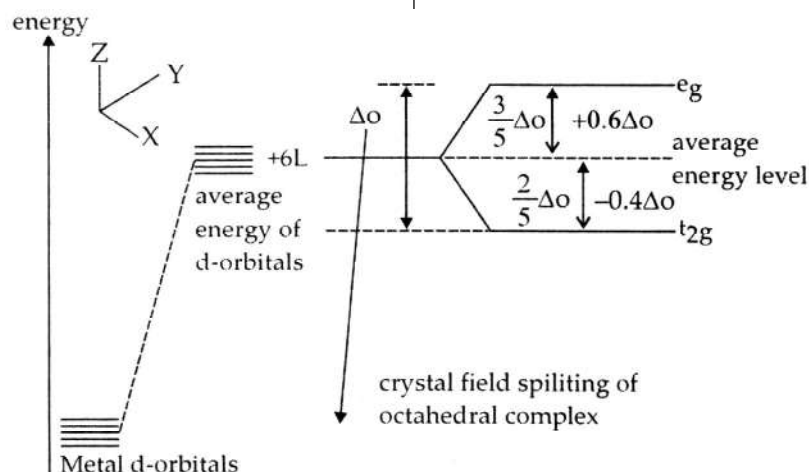


9. The difference of energy between ' t_{2g} ' and ' eg ' orbitals is called crystal field splitting energy and represented as Δ . This is taken as $10 Dq$ or 10Δ . called bari centre.
10. The stability of complex ion can be known by crystal field stability energy (CFSE).
11. Crystal field stability energy (CFSE) is actually the gain energy achieved by preferential filling of orbitals by electrons. It is always negative quantity. The value zero of CFSE indicate that the complex is not stable.
12. Splitting of d-orbitals depends upon nature of ligands and charge on metal cation (O.S). Higher the oxidation state of central metal cation higher the crystal field splitting of d-orbital and higher the crystal field stability energy (CFSE).

9.23 CRYSTAL FIELD SPLITTING OF d-ORBITALS IN OCTAHEDRAL COMPLEXES (C.N.6)

1. In octahedral complexes $[ML_6]$, when six energy ligands approaches towards metal, the energy of ' eg ' orbital increases and energy of ' t_{2g} ' orbital decreases relative to average energy level (Bari centre).
2. It is observe that energy of ' eg ' orbital is $+0.6 \Delta_o$ or $6 Dq$ while energy of ' t_{2g} ' orbital is $-0.4 \Delta_o$ or $4 Dq$.
3. The energy difference between ' eg ' and ' t_{2g} ' orbital in octahedral complex is denoted by Δ_o , (where o-for octahedral complexes).
4. Distribution of electron in ' eg ' and ' t_{2g} ' orbitals depends upon strength of ligands (magnitude of

Δ_o). The decreasing order of strength of ligands according to spectrochemical series is, $\text{CO} > \text{CN}^- > \text{NO}_2^- > \text{en} > \text{NH}_3 > \text{EDTA}_4^- > \text{NSC}^- > \text{H}_2\text{O} > \text{C}_2\text{O}_4^{2-} > \text{OH}^- > \text{F}^- > \text{S}^{2-} > \text{Cl}^- > \text{SCN}^- > \text{Br}^- > \text{I}^-$



- a) **Weak field ligands** : Ligands which causes small degree of splitting is called weak field ligands. i.e. $\Delta_o < P$. (P = energy required for pairing of electron in single orbital). In the presence of weak field ligands electrons are not paired in low energy ' t_{2g} ' orbital and arranged according to Hund's rule. Thus high spin complex. is formed.
- b) **Strong field ligands** : Ligands which causes large degree of splitting is called strong field ligands. i.e. $\Delta_o > P$. In the presence of strong field ligands electron are paired in low energy ' t_{2g} ' orbital against Hund's rule. Thus low spin complex. is formed
5. Calculation shown that, when electron entering into lower energy i.e. t_{2g} orbital. The complex is stabilized by $0.4 \Delta_o$ or $4 Dq$. While electron entering into higher energy i.e. ' eg ' orbital. The complex is destabilized by $0.6 \Delta_o$ or $6 Dq$.

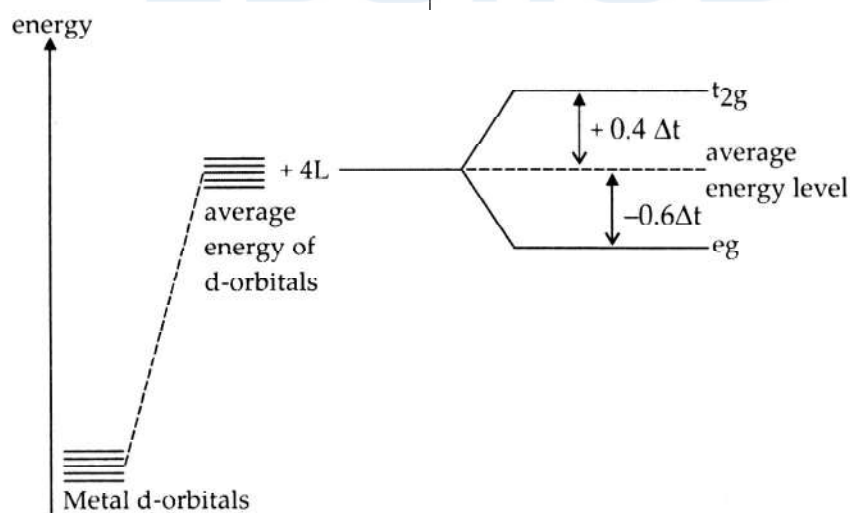
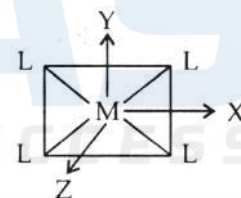
Distribution of electron among d-orbital that result in low and high spin in octahedral complex.

Electrons in d-orbitals	Weak ligands $\Delta_o < P$ (High spin complexes)	spin	Strong ligands $\Delta_o > P$ (Low spin complexes)	spin
d^1	eg dx^2y^2 dz^2 t_{2g} dxy dxz dyz	$\frac{1}{2}$	eg t_{2g}	$\frac{1}{2}$
d^2	eg t_{2g}	1	eg t_{2g}	1
d^3	eg t_{2g}	$\frac{3}{2}$	eg t_{2g}	$\frac{3}{2}$
d^4	eg t_{2g}	2	eg t_{2g}	1

d^5	eg \uparrow \uparrow t_{2g} \uparrow \uparrow \uparrow	$\frac{5}{2}$	eg \circ \circ t_{2g} $\uparrow\downarrow$ $\uparrow\downarrow$ \uparrow	$\frac{1}{2}$
d^6	eg \uparrow \uparrow t_{2g} $\uparrow\downarrow$ \uparrow \uparrow	2	eg \circ \circ t_{2g} $\uparrow\downarrow$ $\uparrow\downarrow$ $\uparrow\downarrow$	0
d^7	eg \uparrow \uparrow t_{2g} $\uparrow\downarrow$ $\uparrow\downarrow$ \uparrow	$\frac{3}{2}$	eg \uparrow \circ t_{2g} $\uparrow\downarrow$ $\uparrow\downarrow$ $\uparrow\downarrow$	$\frac{1}{2}$
d^8	eg \uparrow \uparrow t_{2g} $\uparrow\downarrow$ $\uparrow\downarrow$ $\uparrow\downarrow$	1	eg \uparrow \uparrow t_{2g} $\uparrow\downarrow$ $\uparrow\downarrow$ $\uparrow\downarrow$	1
d^9	eg $\uparrow\downarrow$ \uparrow t_{2g} $\uparrow\downarrow$ $\uparrow\downarrow$ $\uparrow\downarrow$	$\frac{1}{2}$	eg $\uparrow\downarrow$ \uparrow t_{2g} $\uparrow\downarrow$ $\uparrow\downarrow$ $\uparrow\downarrow$	$\frac{1}{2}$
d^{10}	eg $\uparrow\downarrow$ $\uparrow\downarrow$ t_{2g} $\uparrow\downarrow$ $\uparrow\downarrow$ $\uparrow\downarrow$	0	eg $\uparrow\downarrow$ $\uparrow\downarrow$ t_{2g} $\uparrow\downarrow$ $\uparrow\downarrow$ $\uparrow\downarrow$	0

9.24. CRYSTAL FIELD SPLITTING OF d-ORBITALS IN TETRAHEDRAL COMPLEXES (C.N. 4)

1. In tetrahedral complexes the four ligands are placed at four corner of regular tetrahedron with metal placed at centre.
2. In tetrahedral complexes $[ML_4]$, when four ligands approaches towards metal, the energy of ' t_{2g} ' orbital increases and energy of ' eg ' orbital decreases relative to average energy level (Bary centre). The splitting of d-orbital is inverted and smaller than octahedral complexes i.e. $\Delta_t < \Delta_o$



Crystal field splitting of d-orbitals in tetrahedral complex.

3. It is observed that energy of ' t_{2g} ' orbital is $+0.4 \Delta t$ or $4 Dq$ while energy of ' e_g ' orbital is $-0.6 \Delta t$ or $6 Dq$.
4. The energy difference between ' t_{2g} ' and ' e_g ' orbital in tetrahedral complex is denoted by Δt . (where t —for tetrahedral complexes).
5. Distribution of electron in ' e_g ' and ' t_{2g} ' orbitals depends upon strength of ligands (magnitude of Δt). i.e. spectrochemical series
 - a) **Weak field ligands** : Ligands which causes small degree of splitting is called weak field ligands. i.e. $\Delta t < P$. In the presence of weak field ligands electrons are not paired in low energy ' e_g ' orbital and arranged according

to Hund's rule. Thus high spin complex is formed.

- b) **Strong field ligands** : The ligands which causes large degree of splitting is called strong field ligands. i.e. $\Delta t > P$.

In the presence of strong field ligands electrons are paired in low energy ' e_g ' orbital against Hund's rule. Thus low spin complex is formed.

6. Calculation shown that, when electron entering into higher energy i.e. ' t_{2g} ' orbital. The complex is destabilized by $+0.4 \Delta t$ or $4 Dq$. While electron entering into lower energy i.e. ' e_g ' orbital. The complex is stabilized by $-0.6 \Delta t$ or $6 Dq$.

Distribution of electron among d-orbitals that results in low and high spin in tetrahedral complexes.

Electrons in d-orbitals	Weak ligands $\Delta t < P$. (High spin complexes)	spin	Strong ligands $\Delta t > P$. (Low spin complexes)	spin
d^1	t_{2g} $\begin{array}{ccc} d_{xy} & d_{xz} & d_{yz} \\ \circ & \circ & \circ \end{array}$ e_g $\begin{array}{cc} \uparrow & \circ \\ d_{x^2-y^2} & d_{z^2} \end{array}$	$\frac{1}{2}$	t_{2g} $\begin{array}{ccc} \circ & \circ & \circ \end{array}$ e_g $\begin{array}{cc} \uparrow & \circ \end{array}$	$\frac{1}{2}$
d^2	t_{2g} $\begin{array}{ccc} \circ & \circ & \circ \end{array}$ e_g $\begin{array}{cc} \uparrow & \uparrow \end{array}$	1	t_{2g} $\begin{array}{ccc} \circ & \circ & \circ \end{array}$ e_g $\begin{array}{cc} \uparrow & \uparrow \end{array}$	1
d^3	t_{2g} $\begin{array}{ccc} \uparrow & \circ & \circ \end{array}$ e_g $\begin{array}{cc} \uparrow & \uparrow \end{array}$	$\frac{3}{2}$	t_{2g} $\begin{array}{ccc} \circ & \circ & \circ \end{array}$ e_g $\begin{array}{cc} \downarrow\uparrow & \uparrow \end{array}$	$\frac{1}{2}$
d^4	t_{2g} $\begin{array}{ccc} \uparrow & \uparrow & \circ \end{array}$ e_g $\begin{array}{cc} \uparrow & \uparrow \end{array}$	2	t_{2g} $\begin{array}{ccc} \circ & \circ & \circ \end{array}$ e_g $\begin{array}{cc} \downarrow\uparrow & \downarrow\uparrow \end{array}$	0
d^5	t_{2g} $\begin{array}{ccc} \uparrow & \uparrow & \uparrow \end{array}$ e_g $\begin{array}{cc} \uparrow & \uparrow \end{array}$	$2\frac{1}{2}$	t_{2g} $\begin{array}{ccc} \uparrow & \circ & \circ \end{array}$ e_g $\begin{array}{cc} \downarrow\uparrow & \downarrow\uparrow \end{array}$	$\frac{1}{2}$
d^6	t_{2g} $\begin{array}{ccc} \uparrow & \uparrow & \uparrow \end{array}$ e_g $\begin{array}{cc} \downarrow\uparrow & \uparrow \end{array}$	2	t_{2g} $\begin{array}{ccc} \uparrow & \uparrow & \circ \end{array}$ e_g $\begin{array}{cc} \downarrow\uparrow & \downarrow\uparrow \end{array}$	$\frac{1}{2}$

d^7	t_{2g} \uparrow \uparrow \uparrow eg $\downarrow\uparrow$ $\downarrow\uparrow$	$\frac{3}{2}$	t_{2g} \uparrow \uparrow \uparrow eg $\downarrow\uparrow$ $\downarrow\uparrow$	$\frac{3}{2}$
d^8	t_{2g} $\downarrow\uparrow$ \uparrow \uparrow eg $\downarrow\uparrow$ $\downarrow\uparrow$	1	t_{2g} $\downarrow\uparrow$ \uparrow \uparrow eg $\downarrow\uparrow$ $\downarrow\uparrow$	1
d^9	t_{2g} $\downarrow\uparrow$ $\downarrow\uparrow$ \uparrow eg $\downarrow\uparrow$ $\downarrow\uparrow$	$\frac{1}{2}$	t_{2g} $\downarrow\uparrow$ $\downarrow\uparrow$ \uparrow eg $\downarrow\uparrow$ $\downarrow\uparrow$	$\frac{1}{2}$
d^{10}	t_{2g} $\downarrow\uparrow$ $\downarrow\uparrow$ $\downarrow\uparrow$ eg $\downarrow\uparrow$ $\downarrow\uparrow$	0	t_{2g} $\downarrow\uparrow$ $\downarrow\uparrow$ $\downarrow\uparrow$ eg $\downarrow\uparrow$ $\downarrow\uparrow$	0

9.25 LIMITATION OF CRYSTAL FIELD THEORY

The crystal field theory is successful to explain the structure, colour and magnetic properties of coordination compounds in large extent, but it has some limitations

Limitations:

1. It considers metals only in d-orbitals and no consideration for other orbitals i.e s, px, py, pz orbitals.
2. It is unable to explain the relative strength of ligands for examples why H_2O is stronger ligand than OH^- in the spectrochemical series.
3. According to this theory metal-ligand bond is ionic, but can't explain partly covalent nature of metal-ligand bond.
4. It cannot account for the π -bonding in complexes.

Superiority of CFT over VBT :

1. CFT explain the magnetic property of complexes and variation with temperature, which are not explain by VBT.
2. CFT explain the stability of complexes on the basis of its geometry. VBT does not explain stability of complexes.
3. CFT explain kinetic and thermodynamic properties of some complexes. Which is not explain by VBT.
4. CFT explain colour of the complex on the basis of d-d transition. VBT does not explain colour of the complexes.

9.26. MAGNETIC PROPERTY OF COORDINATION COMPOUNDS

In complex central metal cation contain unpaired electrons are paramagnetic while all electrons are paired the complex is diamagnetic.

It may be noted that complex compound containing more number of unpaired electrons are strongly paramagnetic while less number of unpaired electrons are weakly paramagnetic.

Magnetic moment can be calculated by formula. This relationship is known as spin only.

$$\text{Magnetic moment } \mu_{\text{eff}} = \sqrt{n(n+2)} \text{ Bm.}$$

n = number of unpaired electrons.

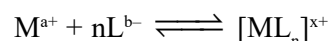
e.g. Complex $[Fe(H_2O)]^{3+}$ is paramagnetic containing d^5 electrons.

$$\therefore \mu_{\text{eff}} = \sqrt{5(5+2)} = \sqrt{5(7)} = \sqrt{35} = 5.9 \text{ B.m.}$$

9.27 STABILITY OF COMPLEX COMPOUNDS

The stability of complex compounds depends upon interaction of metal ion and ligands. If the interaction is strong the complex formed will be more stable.

The reaction between metal ion and ligand can be consider as acid-base reaction. Metal act as Lewis acid (e^- pair acceptor) while ligand act as Lewis base (e^- pair donor). The metal ion and ligand reaction can be shown by following equilibrium reaction.



Where a, b, x are charge on metal, ligand and complex respectively. The equilibrium constant for above reaction is termed as stability constant and it is represented by K.

$$K = \frac{[ML_n]^{x+}}{[M^{a+}][L^{b-}]^n}$$

More the value 'K' more stable will be the complex (less dissociation) and vice versa. Therefore dissociation constant or instability constant of coordination compound can be define as "It is a reciprocal of formation constant".

More the formation constant less will be dissociation and vice versa.

Factors affecting the stability of complex compounds:

- The charge on central metal cation:** If the central metal cation has high charge i.e high O.S. The complex formed is more stable.
e.g. +3 charged ions are more stable than +2 charged ions.
- Size of the central metal cation:** If metals have similar charge. The stability of complex depends upon size of the ions. If ions have smaller size, the complex formed is more stable.
e.g. The magnitude of positive charge on Cu^{2+} and Co^{2+} ions is same but the ionic radius of Cu^{2+} ion (72 pm) is less than that of Co^{2+} ion (76pm). Hence charge density of Cu^{2+} ion greater than Co^{2+} . Thus complex formed from Cu^{2+} ions are more stable than Co^{2+} ion.

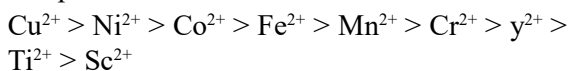
$$K \text{ for } [Cu(NH_3)_4]^{2+} = 4.5 \times 10^{11}$$

$$K \text{ for } [Co(NH_3)_4]^{2+} = 1.3 \times 10^7$$

Ionic radius of some divalent and trivalent ions are given below.

Elements	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn
M^{2+} ion (in pm)	-	90	88	84	80	76	76	72	72	74
M^{3+} ion (in pm)	81	76	74	64	66	64	63	60	-	-

Therefore with same ligand, the stability of complex of these ions follows the order.



This order of stability is also known as Irving William stability order of M^{2+} ions.

- The nature of the ligands :** If the ligands has smaller size; and high charge. The complex formed will be more stable. e.g. $F^- > Cl^- > Br^- > I^-$
 F^- forms stable complex because smaller size and

high charge.

- Basicity of ligands:** If the ligands are more basic i.e. it has more tendency to donate lone pair of electrons to central ions. The complex formed is more stable. e.g. CN^- is more basic than NH_3 . Therefore cyano complexes of metal ion are more stable than amine complexes.
 $K \text{ for } [Ag(CN)_2]^{2-} = 5.5 \times 10^{18}$
 $K \text{ for } [Ag(NH_3)_2]^+ = 1.6 \times 10^7$
- The chelated effect:** The chelated complex are more stable than non-chelated complex.
- Chelate ring size:** If the complex has more number of chelating rings. The complex is more stable. The chelate effect is maximum for 6 membered ring which provides greater stability for complex.
- Steric effect:** In the bulky ligands, due the greater repulsion between metal ligand bond, less stable complex will be formed.

9.28 COLOUR OF THE COORDINATION COMPOUNDS

Colour of the coordination compounds in their solid or solution form, depends upon excitation of electrons from lower d-orbital to higher d-orbital i.e. d-d transition.

When visible light falls on metal complexes, the some part of the visible light is absorbed and remaining part of light is transmitted.

The colour of the transmittted complementary colour of absorbed light.

The complementary colour was shown by Munshell colour wheel. The energy of red light is less than that of violet light. So the energy order is Red < Yellow < Green < Blue. The complex absorb lower energy light will have lower strength. Strong ligand can absorb light of more energy. e.g. CN is strong ligand can absorb violet light.

The colour of co-ordinate compounds can be explain on the basis of CFT.

Explanation: For example $[Ti(H_2O)_6]^{3+}$ is purple.

The Ti has d¹ configuration and present in lower set of orbitals (t_{2g}). When light passes through complexes the electron gets excited to higher set of orbital (e_g) by absorbing light equal to Δo . The transition metal absorb blue/ green light from visible light and looks purple.

Note:

- a) On the absence of ligand crystal field splitting does not occur and substance become colourless e.g. $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ is blue colour while anhydrous CuSO_4 is colourless.
- b) Colour of the complexes depends upon nature of ligands.

e.g. Consider three complexes.

$[\text{Co}(\text{H}_2\text{O})_6]^{3+}$, $[\text{Co}(\text{NH}_3)_6]^{3+}$, $[\text{Co}(\text{CN})_6]^{3-}$
According to spectrochemical series the crystal field splitting energy will be in the order of $\text{CN} > \text{NH}_3 > \text{H}_2\text{O}$.

Therefore in $[\text{Co}(\text{CN})_6]^{3-}$. CN ligand can absorb light of more energy i.e violet colour and looks yellow.

While in $[\text{Co}(\text{H}_2\text{O})_6]^{3+}$. H_2O ligand can absorb light of less energy i.e orange colour and looks blue

9.29 METAL CARBONYLS**Definition:**

Compounds formed by combination of CO(carbonyl) molecule and transition metals are known as metal carbonyls. These are represented by MCO.

These are another type of organic metallic compounds in which metal atoms have zero valency and CO molecule acts as ligands.

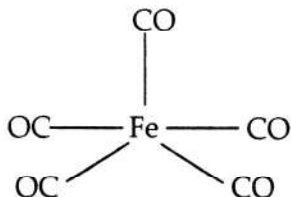
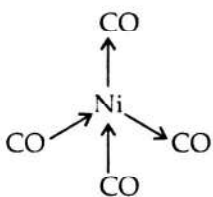
All metal carbonyls are crystalline solid except $\text{Ni}(\text{CO})_4$, $\text{Fe}(\text{CO})_5$, $\text{Ru}(\text{CO})_5$, $\text{Os}(\text{CO})_5$.

All metal carbonyls are diamagnetic except $\text{V}(\text{CO})_6$ which is paramagnetic.

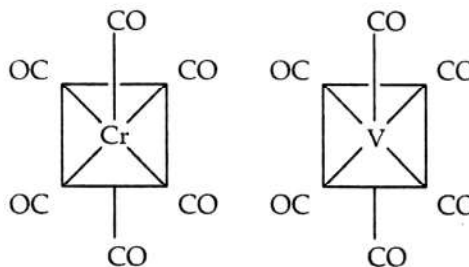
Metal carbonyls are divided into two types:

- a) **Monomeric metal carbonyls** : They contain only one metal atom per molecule are called as monomeric metal carbonyl.

- e.g. 1) $\text{Ni}(\text{CO})_4$:
Tetrahedral sp^3 hybridisation
- 2) $\text{Fe}(\text{CO})_5$:
Trigonalbipyramidal sp^3 hybridisation.

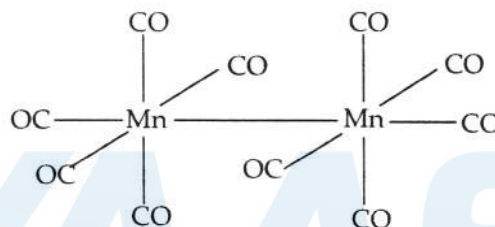


- 3) $\text{Cr}(\text{CO})_6$ and $\text{V}(\text{CO})_6$:
Octahedral $d^2\text{sp}^3$ hybridization

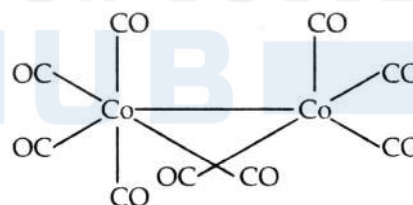


- b) **Polymeric metal carbonyls** : They contain two or more metal atoms per molecule and they have metal – metal bonds are known as polymeric metal carbonyls.

e.g. 1) Decacarbonyl manganese $[\text{Mn}_2(\text{CO})_{10}]$. It is made up of two square pyramidal $\text{Mn}(\text{CO})_5$ units joined by Mn – Mn bond.

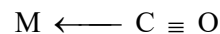


- 2) $[(\text{Co})_2(\text{CO})_8]$ octacarbonyl cobalt. It has Co-Co bond bridge by two CO (carbonyl) groups.

**Bonding in metal carbonyls :**

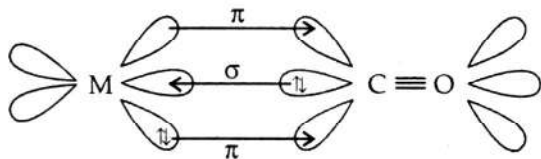
It can be best explained on the basis of molecular orbital theory.

The carbon monoxide [CO] ligand bind metal through the carbon atom



Carbon monoxide is weak Lewis base, which form weak sigma bond to metal atom. But CO is also an electron acceptor ligand and form π – bond with metal. This unique property of CO is known as back bonding (synergic bonding), which increase the strength of M–CO bond. Thus metal–

carbon bond in metal carbonyls possess both σ - and π -character.



Back bonding (synergic bonding) in a carbonyl complex.

9.30 ISOMERISM IN COORPINATION COMPOUNDS

Isomers are two or more compounds that have same chemical formula (molecular formula) but different arrangements of atoms or groups (configuration). Because of different configuration, they differs in one or more physical and chemical properties.

Coordination compounds show two main types of isomerism –

- 1) Structural isomerism and
- 2) Stereoisomerism.

9.30.1 Structural isomerism

They have same molecular formula but different in bonds (structural formula). They have also different physical and chemical properties. It is divided into four types.

1. Linkage isomerism
2. Coordinate isomerism
3. Ionisation isomerism
4. Solvate or hydrate isomerism

1. **Linkage isomerism:** Scientist Jorgensen discovered such type of isomerism in complex.

It is present in complex compound containing ambidentate ligands like CN^- , SCN^- , OCN^- , NO_2^- etc.

e.g. i) NO_2 group and nitrite ion (NO_2^-) is bonded through nitrogen atom or oxygen atom. When it is bonded through nitrogen act as nitro ligand ($\text{M} \leftarrow \text{NO}_2$).

When it is bonded through oxygen act as nitrito ligand ($\text{M} \leftarrow \text{O} - \text{N} = \text{O}$)



ii) $\text{M} \leftarrow \text{SCN} \quad \text{M} \leftarrow \text{NCS}$
S-thiocyanato N-isothiocyanato

through (S) through (N)

iii) $\text{M} \leftarrow \text{CN} \quad \text{M} \leftarrow \text{NC}$

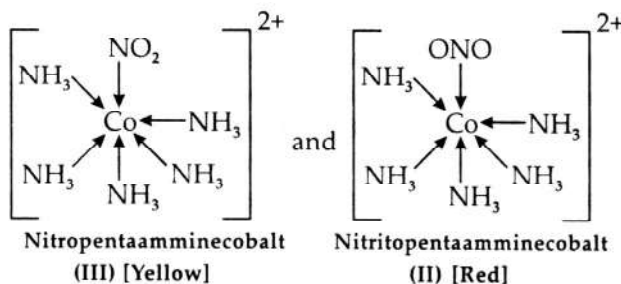
cyano

isocyano

through (C)

through (N)

$[\text{Co}(\text{NH}_3)_5\text{NO}_2]\text{Cl}_2$, which is obtained in yellow form in nitro ligand ($\text{M} \leftarrow \text{NO}_2$) and red form in nitrite ligand ($\text{M} \leftarrow \text{O} - \text{N} = \text{O}$) and



2. Coordination isomerism:

It is present in such coordination compounds in which positive and negative ions are complex.

It arises due to interchange of ligands between positive and negative ions. Such isomers have different physical and chemical properties.

- e.g. i) $[\text{Co}(\text{NH}_3)_6]^{3+} [\text{Cr}(\text{CN})_6]^{3-}$ and $[\text{Co}(\text{CN})_6]^{3-} [\text{Cr}(\text{NH}_3)_6]^{3+}$
 ii) $[\text{Cu}(\text{NH}_3)_4]^{2+} [\text{PtCl}_4]^{2-}$ and $[\text{CuCl}_4]^{2-} [\text{Pt}(\text{NH}_3)_4]^{2+}$
 iii) $[\text{Cr}(\text{NH}_3)_6]^{3+} [\text{Cr}(\text{CN})_6]^{3-}$ and $[\text{Cr}(\text{NH}_3)_4(\text{CN})_2]^+ [\text{Cr}(\text{NH}_3)_2(\text{CN})_4]^-$
 iv) $[\text{Pt}(\text{NH}_3)_4]^{2+} [\text{PtCl}_4]^{2-}$ and $[\text{Pt}(\text{NH}_3)_3\text{Cl}]^{2+} [\text{Pt}(\text{NH}_3)\text{Cl}_3]^{2-}$

3. Ionisation isomers (ion-ion exchange isomerism): Definition:

Coordination compound having same molecular formula but give different ions in solution is known as ionisation isomers.

This type of isomerism occurs when the negative counter ion itself is potential ligand, which can displace ligand from complex ion.

e.g. Compound of formula $\text{Co}(\text{NH}_3)_5\text{BrSO}_4$ = It has two isomers.

- a) $[\text{Co}(\text{NH}_3)_5\text{Br}]\text{SO}_4^{--}$: It is red violet and give white precipitate with BaCl_2 or $\text{Ba}(\text{NO}_3)_2$ indicating that SO_4^{--} (sulphate ion) is outside the coordination sphere.
 b) $[\text{Co}(\text{NH}_3)_5\text{SO}_4]\text{Br}$: It is red colour and give yellow precipitate with AgNO_3

indicating that Br^- ion is outside the coordination sphere. It does not give white precipitate with BaCl_2 or $\text{Ba}(\text{NO}_3)_2$.

4. **Solvate or hydrate isomers:** It is a special form of ionisation isomerism.

It arises due to exchange of water molecules inside and outside the coordination sphere.

Solvate isomers have same M.P but differs by water molecules outside and inside the co-ordination sphere. e.g. $\text{CrCl}_3 \cdot 6\text{H}_2\text{O}$. It has four isomers. On dehydration by using conc. H_2SO_4 and precipitation of chlorine by AgNO_3 . They have been given following formulae.

Complex	Colour	Number of AgCl pptd.	No. of water lost by conc. H_2SO_4 (dehydration)
$[\text{Cr}(\text{H}_2\text{O})_6]\text{Cl}_3$	Violet	3	No reaction or no water molecule is lost
$[\text{Cr}(\text{H}_2\text{O})_5\text{Cl}]\text{Cl}_2 \cdot \text{H}_2\text{O}$	Blue Green	2	One mole of water is lost per mole of compound
$[\text{Cr}(\text{H}_2\text{O})_4\text{Cl}_2]\text{Cl} \cdot 2\text{H}_2\text{O}$	Dark Green	1	Two moles of water are lost per mole of compound
$[\text{Cr}(\text{H}_2\text{O})_3\text{Cl}_3] \cdot 3\text{H}_2\text{O}$	-----	0	Three moles of water are lost per mole of compound

9.30.2 STEREOISOMERISM

Coordinate compound having same molecular formula, same structural formula but different in arrangement around the central atom (different configuration) is known as stereoisomerism. It is divided into two types –

A) Geometrical isomerism B) Optical isomerism

Notation of ligands :

Where, a and b = Neutral monodentate ligands like H_2O , NH_3 , CO , NO , $\text{C}_5\text{H}_5\text{N}$ etc.

c and d = Positive monodentate ligands like NO_2^+ , NO^+ etc

x and y = Negative monodentate ligands like X^- , NO_2^- , CN^- , SCN^- etc.

(aa) = Symmetrical bidentate ligands like 'en', 'ox' etc

(ab) = Unsymmetrical bidentate ligands like 'gly' etc

A] **GEOMETRICAL ISOMERISM:** This type of isomerism present in heteroleptic complex. It arises due to different position of ligands around the central atom or ion. When same ligands are at same position is known as cis isomer. When same ligands are at opposite position known as trans isomer.

Note: Geometrical isomerism is most common in compound with coordination number 4, 6.

a) **Geometrical isomerism in coordination number four:** Complex with coordination

number four have square planar and tetrahedral geometry.

Geometrical isomerism is present in only square planar complex not in tetrahedral complex, because all four ligands are equidistant to one another.

Cis and trans position in square planar complex:



Cis positions = 1–2, 2–3, 3–4, 1–4

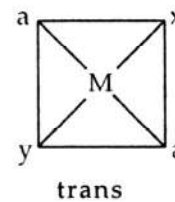
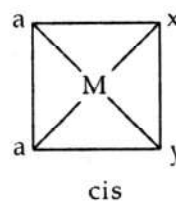
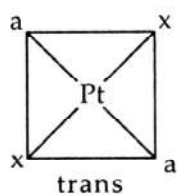
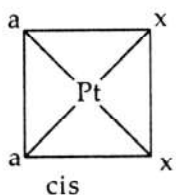
Trans positions 1–3, 2–4

Following type of complexes shows geometrical isomerism

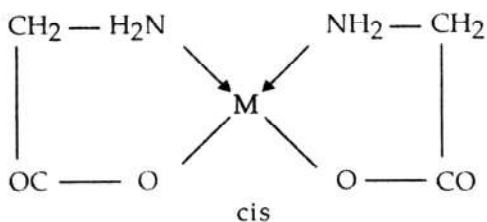
Sr. No.	Types	No. of geometrical isomers	Examples
1	Ma_2x_2	2	$[\text{Pt}(\text{NH}_3)_2\text{Cl}_2]^+$ $[\text{Pt}(\text{H}_2\text{O})_2(\text{NO}_2)_2]^+$
2	Ma_2xy	2	$[\text{Pt}(\text{py})_2\text{ClNO}_2]^+$
3	Ma_2bx	2	$[\text{Pt}(\text{H}_2\text{O})_2\text{NH}_3\text{Cl}]^{2+}$
4	Mabx_2	2	$[\text{Pt}(\text{NH}_3)_2\text{H}_2\text{OCl}_2]^+$
5	$\text{M}(\text{ab})_2$	2	$[\text{Pt}(\text{Gly})_2]$
6	Mabcd	3	$[\text{Pt}(\text{NH}_3)(\text{H}_2\text{O})(\text{NH}_2\text{OH})(\text{Py})]^{3+}$
7	Mabxy	3	$[\text{Pt}(\text{NH}_3)(\text{H}_2\text{O})\text{Cl}, \text{Br}]^+$

Structures:

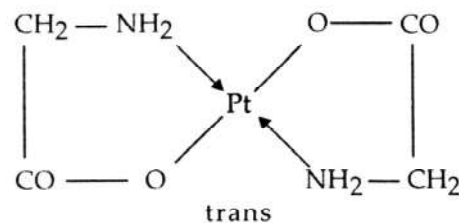
Type 1 ,2,3,4 :



Type 5 :

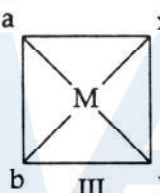
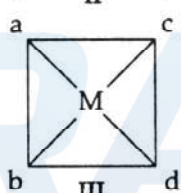
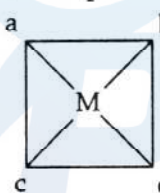
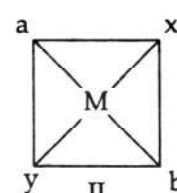
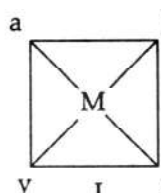
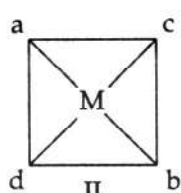
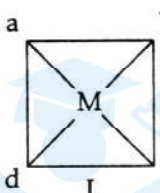


and



Diglycinatoplatinum (II)

Type 6 :



Type 7:

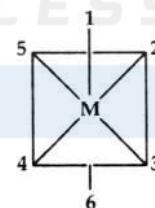
b) Geometrical isomerism in octahedral complexes with coordination number six:

Positions in octahedral complexes,

Cis positions : 1-2, 2-3, 3-6, 6-4, 4-5, 5-1, 1-3, 1-4

Trans positions 1-6, 2-4, 3-5

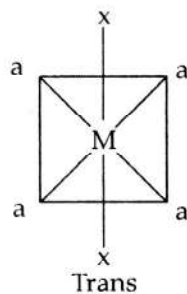
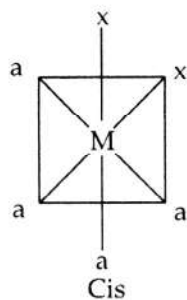
Following type of complexes shows geometrical isomerism



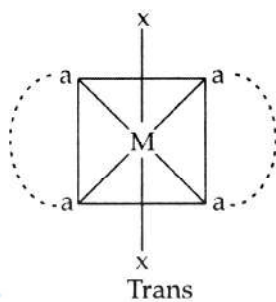
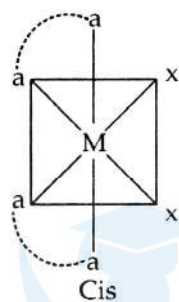
Sr. No.	Types	No. of geometrical isomers	Examples
1	Ma_2x_4	2	$[\text{Pt}(\text{NH}_3)_2\text{Cl}_4]^-$, $[\text{Pt}(\text{H}_2\text{O})_2(\text{CN})_4]^-$
2	Ma_4x_2	2	$[\text{Co}(\text{NH}_3)_4\text{Cl}_2]^+$
3	Ma_4xy	2	$[\text{Co}(\text{NH}_3)_4\text{ClNO}_2]^+$
4	$\text{M}(\text{aa})_2\text{x}_2$	2	$[\text{Co}(\text{en})_2\text{Cl}_2]^+$, $[\text{Co}(\text{en})_2\text{Cl}_2]^+$, $[\text{Cr}(\text{en})_2\text{Cl}_2]^+$
5	$\text{M}(\text{aa})_2\text{xy}$	2	$[\text{Cr}(\text{en})_2\text{ClBr}]^+$, $[\text{Co}(\text{en})_2\text{ClBr}]^+$
6	$\text{M}(\text{aa})\text{x}_3\text{y}$	2	$[\text{Cr}(\text{en})\text{Cl}_3\text{NO}_2]^-$
7	$\text{M}(\text{ab})_3$	2	$[\text{Ni}(\text{Gly})_3]$
8	$\text{Ma}_3\text{b}_3 / \text{Ma}_3\text{x}_3$	2	$[\text{Co}(\text{NH}_3)_3(\text{NO}_2)_3]$
9	$\text{M}(\text{aa})\text{x}_2\text{y}_2$	3	$[\text{Ni}(\text{en})\text{Cl}_2(\text{NO}_2)_2]^-$

Structures:

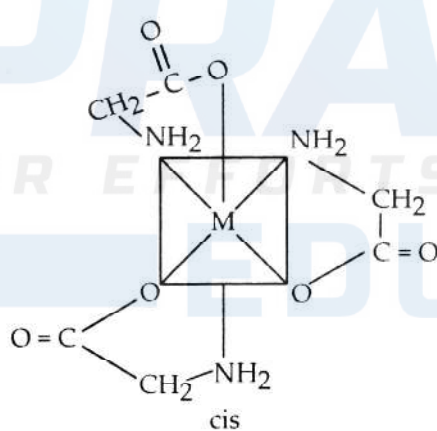
Type 1, 2, 3 :



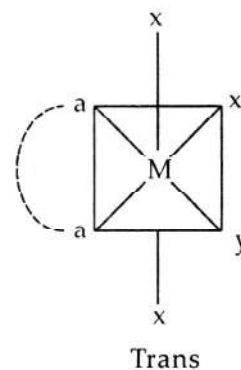
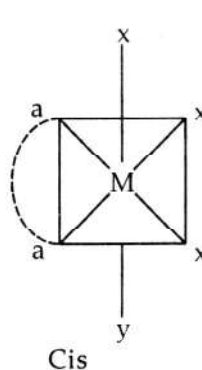
Type 4, 5 :



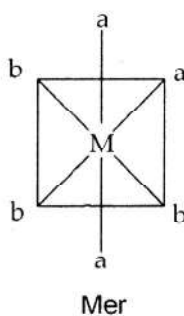
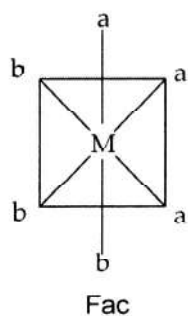
Type 7 :



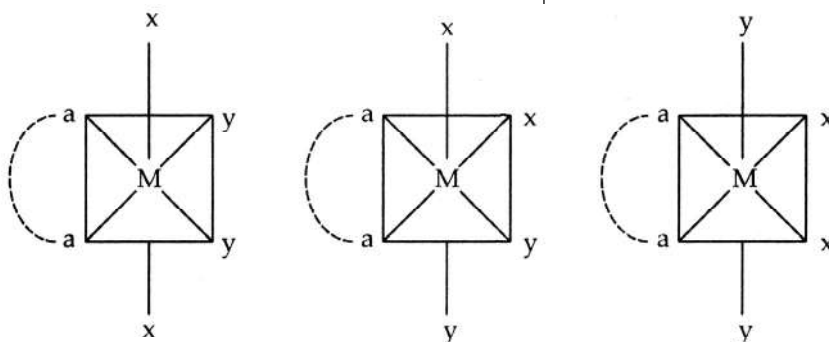
Type 6 :



Type 8 :



Type 9 :



Note: $[M(en)_3]$, $[M(ox)_3]$ do not show geometrical isomerism because 'en' and 'ox' are symmetrical bidentate ligands.

B) OPTICAL ISOMERISM:

Definition: Compound having same molecular formula, same structural formula, non-superimposable mirror image and opposite action on plane polarised light are known as optical isomers and phenomenon is known as optical isomerism.

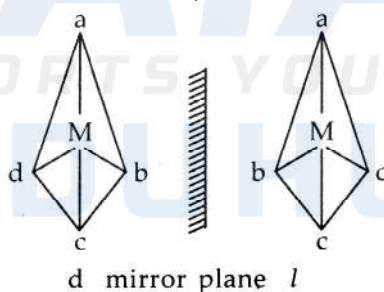
Optical isomers are d and l isomers. The equimolar mixture of d and l isomer is known as racemic mixture which is optically inactive due to external compensation.

Optical activity is mostly observed in complex compound having coordination number 4 and 6.

1. **Optical isomerism in complex compound having coordination number four:**

The complex compound having coordination number four having square planer and tetrahedral geometry. Optical isomerism present in only tetrahedral geometry. Square planer geometry do not show optical isomers because they have plane of symmetry.

e.g. Tetrahedral complex of the type $[M a b c d]$, $[M a b x y]$, $[M c d x y]$ shows optical isomerism.
 $[As(III)(CH_3)(C_2H_5)(S)(C_6H_4COO)]^{2+}$ shows optical isomerism

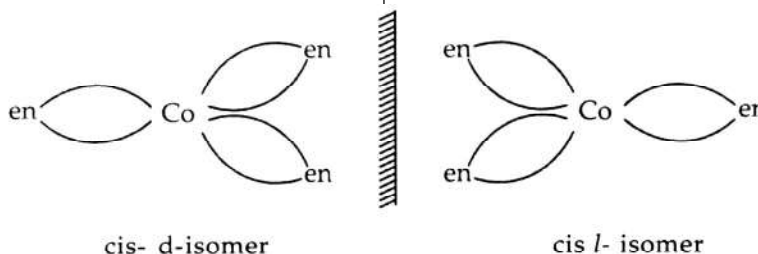
2. **Optical isomerism in coordination number six (octahedral complexes):**

Octahedral complexes containing all monodentate ligand are not resolved (not show optical isomerism).

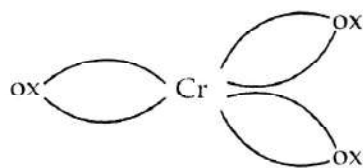
Optical isomerism is most common in cis octahedral complexes involving didentate ligands such as en, ox
 Octahedral complex of the type $[M(aa)_3]$, $[M(aa)_2x_2]$, $[M(aa)_2xy]$ shows optical isomerism

i) **Type $[M(aa)_3]$ where 'aa' is bidentate ligand**

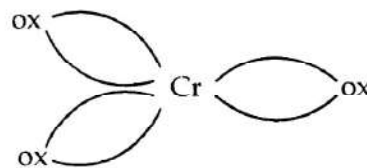
a) $[Co(en)_3]^{3+}$ tris(ethane 1, 2-diamine) cobalt (III)



b) $[\text{Cr}(\text{C}_2\text{O}_4)_3]^{3-}$ OR $[\text{Cr}(\text{ox})_3]^{3-}$ Trisoxalatochromate (III)

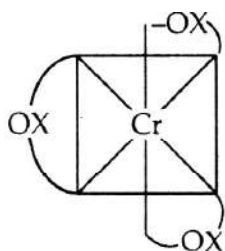


cis- d-isomer

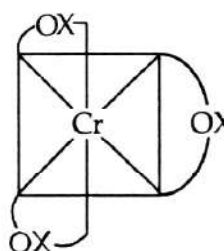


cis- l-isomer

OR



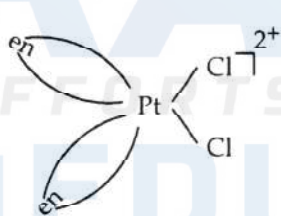
d-form



l-form

ii) Type $[\text{M}(\text{aa})_2\text{x}_2]$

a) $[\text{Pt}(\text{en})_2\text{Cl}_2]^{2+}$ dichlorobis (ethane 1, 2-diamine) platinum (IV)

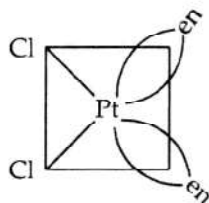


cis-d- isomer

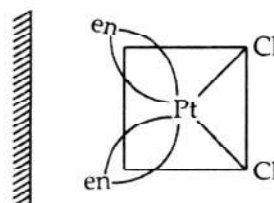


cis- l- isomer

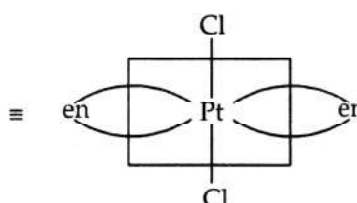
OR



cis-d-isomer

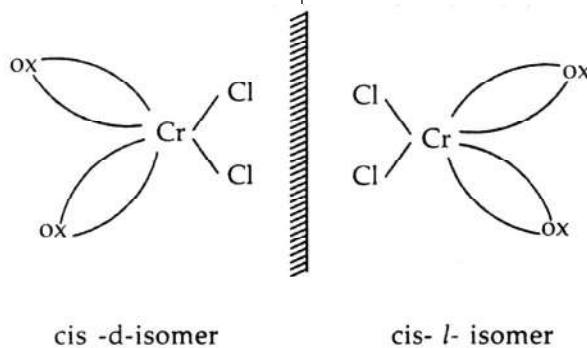


cis-l-isomer



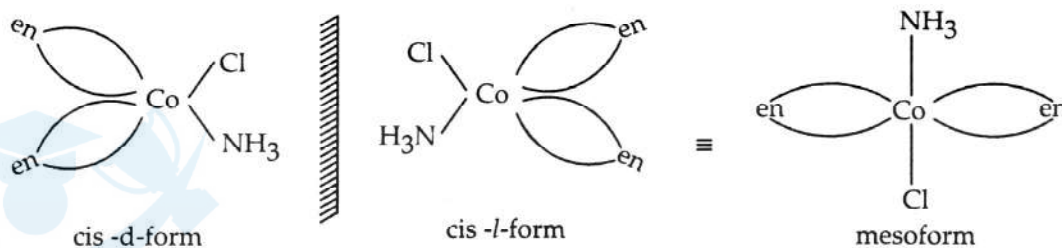
optically inactive trans form

b) $[\text{Cr}(\text{ox})_2\text{Cl}_2]^{3-}$ dichlorodioxalatochromate (III)



iii) **Type $[\text{M}(\text{aa})_2\text{xy}]$** where 'aa' is symmetrical bidentate chelate ligand. x and y are monodentate ligand.

a) $[\text{Co}(\text{en})_2\text{ClNH}_3]^{2+}$



MULTIPLE CHOICE QUESTIONS

- Which of the following ligands is a bidentate ligand?
 - EDTA
 - Ethylenediamine
 - Acetate ion
 - Pyridine
- Which of the following is a bidentate (or didentate) ligand?
 - Pyridine
 - Ethylenediamine
 - Sulphate ion
 - Both (b) and (c).
- The oxidation state of platinum in $\text{Na} [\text{PtBrCl} (\text{NO}_2)(\text{NH}_3)]$ is
 - +2
 - +4
 - +6
 - 0
- The oxidation state of oxygen in $\text{O}_2[\text{PtF}_6]$ is
 - Zero
 - +1/2
 - +1
 - 1/2
- Which response gives the correct coordination number (C.N.) and oxidation number (O.N.) of the transition metal atom in $[\text{Co}(\text{NH}_3)_2(\text{H}_2\text{O})_2\text{Cl}_2]^+$?
 - C.N. = 3; O.N. = +1
 - C.N. = 4; O.N. = +2
 - C.N. = 6; O.N. = +1
 - C.N. = 6; O.N. = +3
- In $\text{K}_4\text{Fe}(\text{CN})_6$
 - (CN) are linked with primary valency
 - (CN) are linked with secondary valency
 - K are linked with secondary valency
 - K are linked with non-ionic valency
- In $\text{K}_4[\text{Fe}(\text{CN})_6]$, the number of 3d- electrons in the iron atom is
 - 3
 - 4
 - 5
 - 6
- Which one of the following is the correct arrangement of the ligands in terms of the Dq values of their complexes with any particular "hard" metal ion?
 - $\text{Cl}^- < \text{F}^- < \text{NCS}^- < \text{NH}_3 < \text{CN}^-$
 - $\text{NH}_3 < \text{F}^- < \text{Cl}^- < \text{NCS}^- < \text{CN}^-$
 - $\text{Cl}^- < \text{F}^- < \text{NCS}^- < \text{CN}^- < \text{NH}_3$
 - $\text{NH}_3 < \text{CN}^- < \text{NCS}^- < \text{Cl}^- < \text{F}^-$
- The IUPAC name of the complex compounds, $[\text{Cr}(\text{NH}_3)_5(\text{CO}_3)]\text{Cl}$ is
 - carbonatopentaamminechromium (III) chloride
 - pentaamminecarbonatochromium (III) chloride
 - pentaamminecarbonatechromate (III) chloride
 - pentaamminetricarbonylchromium (III) chloride
- The correct IUPAC name of the complex compound, $\text{K}_3[\text{Cr}(\text{CN})_6]$ is
 - potassium hexacyanochromate (III)
 - potassium hexacyanochromium (III)
 - potassium chromium (III) hexacyanide
 - potassium chromic (III) hexacyanide.
- The correct formula of the complex, tetraamineaquathiocyanato-N-cobalt (III) chloride is
 - $[\text{Co}(\text{NH}_3)_4(\text{H}_2\text{O})(\text{NCS})]\text{Cl}_2$
 - $[\text{Co}(\text{H}_2\text{O})(\text{NH}_3)_4(\text{NCS})]\text{Cl}_2$
 - $[\text{Co}(\text{NCS})(\text{H}_2\text{O})(\text{NH}_3)_4]\text{Cl}_2$
 - $[\text{Co}(\text{NCS})(\text{NH}_3)_4(\text{H}_2\text{O})]\text{Cl}_2$.
- NH_3 group in a coordination compound is named as
 - Ammonium
 - Ammine
 - Amine
 - Ammonia
- The formula of tetrachlorodiamine platinum (IV) is
 - $[\text{Pt}(\text{NH}_3)_2\text{Cl}_2]\text{Cl}_2$
 - $\text{K}_4[\text{Pt}(\text{NH}_3)_2\text{Cl}_4]$
 - $[\text{Pt}(\text{NH}_3)_2]\text{Cl}_4$
 - $[\text{Pt}(\text{NH}_3)_2\text{Cl}_4]$
- Match list I with list II and select the correct answer using the codes given below the lists.

List I	List II
(Pair of isomers)	(Type of isomerism)
<ol style="list-style-type: none"> $(\text{I}) [\text{Co}(\text{NH}_3)_6][\text{Cr}(\text{CN})_6]$ $(\text{II}) [\text{Cr}(\text{NH}_3)_6][\text{Co}(\text{CN})_6]$ $(\text{III}) [\text{PtCl}_2(\text{NH}_3)_4]\text{Br}_2$ $(\text{IV}) [\text{PtBr}_2(\text{NH}_3)_4]\text{Cl}_2$ $(\text{V}) [\text{Co}(\text{SCN})(\text{NH}_3)_5]\text{Cl}_2$ $(\text{VI}) [\text{Co}(\text{NCS})(\text{NH}_3)_5]\text{Cl}_2$ $(\text{VII}) [\text{Cr}(\text{H}_2\text{O})_6]\text{Cl}_3$ $(\text{VIII}) [\text{CrCl}_2(\text{H}_2\text{O})_4]\text{Cl} \cdot 2\text{H}_2\text{O}$ 	<ol style="list-style-type: none"> Ionization (H) Hydrate (IV) Coordination (VI) Geometrical Linkage isomerism

Codes: (a) (b) (c) (d)

- | | | | |
|------|---|---|---|
| a) 4 | 1 | 5 | 2 |
| b) 1 | 3 | 2 | 5 |
| c) 3 | 1 | 5 | 2 |
| d) 1 | 3 | 5 | 2 |

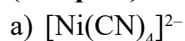
15. The complex ion $[\text{Co}(\text{en})_2\text{Cl}_2]$ exhibits
 a) cis-trans isomerism only
 b) cis-trans isomerism and linkage isomerism
 c) cis-trans isomerism and optical isomerism
 d) optical isomerism and linkage isomerism.
16. Which one of the following can show optical isomerism?
 a) $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$ b) $\text{K}_3[\text{Cr}(\text{C}_2\text{O}_4)_3]$
 c) $\text{K}_3[\text{Fe}(\text{CN})_6]$ d) $\text{Cr}[(\text{NH}_3)_6]\text{Cl}_3$
17. The complex salt having the molecular composition, $[\text{Co}(\text{NO}_2)(\text{SCN})(\text{en})_2]\text{Br}$ exhibits
 a) cis-trans isomerism only
 b) linkage isomerism only
 c) ionization isomerism only
 d) all the above.
18. The possible number of isomers for the complex $[\text{MBr}_2\text{Cl}_2]\text{SO}_4$ is
 a) 2 b) 4
 c) 5 d) 7
19. The complexes of nickel (II) can be
 a) square planar, tetrahedral and octahedral
 b) square planar and tetrahedral
 c) tetrahedral and octahedral
 d) square planar only.
20. The ion $[\text{Co}(\text{NH}_3)_6]^{2+}$ is octahedral and high spin. This complex is
 a) paramagnetic, with 1 unpaired electrons
 b) paramagnetic, with 3 unpaired electrons
 c) paramagnetic, with 4 unpaired electrons
 d) paramagnetic, with 5 unpaired electrons.
21. The hybridization scheme involved in $[\text{Cu}(\text{NH}_3)_4]^{2+}$ is
 a) sp^3 b) dsp^2
 c) d^3s d) none of the above.
22. In $\text{K}_4[\text{Fe}(\text{CN})_6]$, Fe is the form of
 a) An atom b) An ion
 c) Cationic complex d) Anionic complex
23. The number of neutral molecules or negative groups attached to the central metal atom in a complex ion is called
 a) Atomic number
 b) Effective atomic number
 c) Coordination number
 d) Primary valency
24. Match list I with list II and select the correct answer using the codes given below the lists.

List I

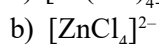
List II

(complex)

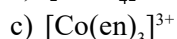
(Geometry)



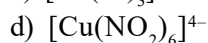
1. Tetrahedral



2. Tetragonal distortion



3. Square planar



4. Square pyramid

5. Octahedral

Codes: (a) (b) (c) (d)

a) 1 2 3 4

b) 3 1 5 2

c) 2 3 4 5

d) 1 3 5 4

a) 1, 2 and 4

b) 1, 3, and 4

c) 2 and 3

d) 1 and 4

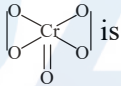
32. The solution of $K_4[Fe(CN)_6]$ in water will
 a) give a test of K^+
 b) give a test of Fe^{2+}
 c) give a test of CN^-
 d) give a test of $[Fe(CN)_6]^{4-}$
33. Which is the correct statement about Ligands are?
 a) negative ions only
 b) neutral molecules only capable of donating the electron pair(s)
 c) negative or very rarely positive ions or neutral molecules
 d) never positive ions.
34. EDTA is a ligand.
 a) monodentate b) bidentate
 c) Hexadentate d) tetradentate.
35. The donor atoms in EDTA are
 a) two N and two O b) two N and four O
 c) four N and two O d) three N and three O.
36. The coordination number of Pt in $K_2[PtCl_6]$ is
 a) 2 b) 4
 c) 6 d) 0.
37. The oxidation state of Co in $[Co(CO)_4]^{2-}$ is
 a) + 2 b) -2
 c) + 4 d) -4.
38. The oxidation state of Co in $[Co(NH_3)_5Cl]Cl_2$
 a) + 2 b) -2
 c) + 5 d) + 3.
39. $C_2O_4^{2-}$ is a ligand.
 a) monodentate b) didentate
 c) tridentate d) polydenate.
40. The brown ring complex compound is formulated as $[Fe(H_2O)_5NO^+][SO_4]$. The oxidation state of iron in it is
 a) + 1 b) + 2
 c) + 3 d) 0.
41. The oxidation state of platinum in $O_2[PtF_6]$ is
 a) + 8 b) + 5
 c) + 6 d) + 7
42. Which of the following does not form a chelate?
 a) EDTA b) Oxalate
 c) NH_3 d) Ethylenediamine.
43. If solutions of equal concentration are prepared, the one with the highest electrical conductivity will be
 a) $[Pt(NH_3)_2Cl_2]$ b) $[Co(H_2O)_6]SO_4$
 c) $K_3[CoCl_6]$ d) $[Co(NH_3)_4]^{2+}$
44. Which one of the following is a bidentate ligand?
 a) CN^- b) NH_3
 c) CO d) $H_2NCH_2CH_2NH_2$
45. In which compound synergic effect is present
 a) $[Ni(CO)_4]$ b) $[NiCl_4]^{2-}$
 c) $[CuCl_4]^{2-}$ d) $[Mn(H_2O)_6]^{2+}$
46. In the complex ion, $[Fe(CN)_6]^{4-}$, the oxidation number of Fe is
 a) + 1 b) + 2
 c) + 3 d) - 4
47. In the complex ion, $[Co(en)_2Br_2]^+$, the oxidation number of Co is
 a) + 1 b) + 2
 c) + 3 d) - 2
48. In the complex ion, $[Cr(C_2O_4)_2(H_2O)_2]^-$, the oxidation number of Cr is
 a) + 1 b) + 2
 c) + 3 d) - 2
49. The number of primary and secondary valencies (or linkages) in the complex ion $[Cr(C_2O_4)_2(H_2O)_2]^-$ are
 a) Primary linkages = 2, secondary linkages = 2
 b) primary linkages = 1, secondary linkages = 4
 c) primary linkages = 3; secondary linkages = 6
 d) primary linkages = 2; secondary linkages = 6
50. In which of the following complexes oxidation state of metal is zero
 a) $[Pt(NH_3)_2Cl_2]$ b) $[Cr(CO)_6]$
 c) $[Cr(NH_3)_2Cl_3]$ d) $[Cr(en)_2Cl_2]$
51. Pick out the complex compound in which the central metal atom obeys EAN rule strictly
 a) $K_4[Fe(CN)_6]$ b) $K_3[Fe(CN)_6]$
 c) $[Cr(H_2O)_6]Cl_3$ d) $[Cu(NH_3)_4]SO_4$
52. Which of the following is wrong statement
 a) $Ni(CO)_4$ has oxidation number +1 for Ni
 b) $Ni(CO)_4$ has zero oxidation number for Ni
 c) Ni is cationic metal
 d) CO is neutral ligand
53. Match list I with list II and select the correct answer using the codes given below.
- | List I
(Ligand) | List II
(Type of ligand) |
|----------------------------------|-----------------------------|
| a) Methyl amine | 1. Unidentate |
| b) Thiocyanate ion | 2. Didentate |
| c) Ethylenediamine | 3. Tridentate |
| d) Ethylenediaminetetracetateion | 4. Hexadentate |
- Codes: a) b) c) d)

- a) 1 3 2 4
b) 1 2 3 4
c) 1 1 2 4
d) 1 2 4 1
54. Ti^{3+} is purple; while Ti^{4+} is colourless, because
a) there is no crystal field effect in Ti^{4+}
b) The energy difference between e_g and t_{2g} orbitals of Ti^{4+} is quite high and hence, does not fall within the visible region
c) Ti^{4+} had $3d^0$ configuration
d) Ti^{4+} is a very small cation when compared to Ti^{3+} and hence, does not absorb any radiation.
55. The oxidation state of platinum in $[\text{PtCl}(\text{NH}_3)_5]\text{Cl}_3$ is
a) +2 b) +3
c) +4 d) +6.
56. An ambidentate ligand is one which
a) is linked to the metal atom through two donor atoms
b) has two donor atoms, but only one of them has the capacity to form a coordinate bond [or a sigma (σ) bond]
c) has two donor atoms, but either of two can form a coordinate bond
d) forms chelate rings.
57. Which of the following is not an ambident ligand?
a) 5CN^- b) NO_2^-
c) CN^- d) ethylenediamine.
58. The correct name for the coordination compound $[\text{CrCl}_2(\text{H}_2\text{O})_4]\text{NO}_3$ is
a) dichlorotetraquachromium (III) nitrate
b) tetraaquadichlorochromate (III) nitrate
c) tetraaquadichlorochromium (III) nitrate
d) tetraaquodichlorochromium (II) nitrate.
59. The correct IUPAC name for the complex ion $[\text{CoCl}(\text{ONO})(\text{en})_2]$ is
a) chlorodiethyldiaminenitrocobalt (III)
b) chlorodiethyldiaminenitrito-O-cobalt (III)
c) bis(ethylenediamine) chloronitrito-O-cobaltate (III)
d) bis(ethylenediamine) chloronitrito-O-cobalt (III)
60. In the following coordination compound, $[\text{Cr}(\text{NH}_3)_2(\text{en})\text{Cl}_2] \text{Br}$, where en = ethylenediamine, the coordination number (C.N.) and oxidation number (O.N.) of the metal atom, respectively are
a) C.N. = 6; O.N. = 4 b) C.N. = 6; O.N. = 3
c) C.N. = 5; O.N. = 2 d) C.N. = 5; O.N. = 4.
61. In the coordination compound $[\text{Co}(\text{en})_2\text{Cl}_2] \text{Cl}$ (en = ethylenediamine), the coordination number and oxidation number of the central atom are, respectively
a) 4, +3 b) 6, +2
c) 4, +2 d) 6, +3.
62. In the coordination compound $[\text{Pt}(\text{NH}_3)_2\text{Cl}_2]$, the coordination number and oxidation number of the central atom are, respectively.
a) 2, 0 b) 4, +4
c) 6, 0 d) 4, +2.
63. A bidentate ligand always
a) has bonds formed to two metal ions
b) has a charge of +2 or -2
c) forms complex ions with a charge of +2 or -2
d) has two donor atoms forming simultaneously two sigma (σ) bonds.
64. Which one of the following is a monodentate ligand?
a) CN^-
b) EDTA
c) $\text{C}_2\text{O}_4^{2-}$ (oxalate ion)
d) $\text{H}_2\text{NCH}_2\text{CH}_2\text{NH}_2$ (ethylenediamine).
65. The IUPAC name for $\text{K}_4[\text{FeCl}_2(\text{CN})_4]$ is
a) tetra potassium dichlorodicyanoiron (II)
b) potassium dichlorodicyanoiron (II)
c) potassium dichlorodicyanoferrate (III)
d) potassium dichlorodicyanoferrate (II).
66. The IUPAC name for $[\text{Ru}(\text{NH}_3)_2(\text{en})](\text{NO}_3)_2$ is
a) (ethylenediamine) diammineruthenium (II) nitrate
b) diamminebis(ethylenediamine)ruthenium (III) nitrate
c) diammine(ethylenediamine)ruthenium (II) nitrate
d) diammine(ethylenediamine)nitratoruthenium (III).
67. Which of the following square planar complex ions can have cis-trans isomers?
a) $[\text{Pt}(\text{NH}_3)_4]^{2+}$ b) $[\text{Ni}(\text{NH}_3)_4]^{2+}$
c) $[\text{Pt}(\text{NH}_3)_2\text{Cl}_2]$ d) $[\text{Pt}(\text{NH}_3)\text{Cl}_3]^-$
68. Cis-trans isomerism is exhibited by which one of the following?
a) $[\text{Pd}(\text{NH}_3)_2\text{Cl}_2]$ b) $[\text{Co}(\text{NH}_3)_5\text{Cl}]^{2+}$
c) $[\text{Fe}(\text{CN})_6]^{3-}$ d) None of these.

69. The numbers of geometrical and optical isomers of the complex ion, $[\text{Co}(\text{en})_2]^{3+}$ (en ethylenediamine) are, respectively
 a) 2 and 2 b) 1 and 1
 c) 3 and 2 d) 1 and 2.
70. Match list I with list II and select the correct answer using the codes given below the lists.
- | | List I | List II |
|----|---|----------------------------|
| | (Pair of isomers) | (Type of isomerism) |
| A) | $(\text{I}) [\text{Cr}(\text{NH}_3)_6][\text{Cr}(\text{CN})_6]$
$(\text{II}) [\text{Cr}(\text{CN})_2(\text{NH}_3)_4]$
$[\text{Cr}(\text{CN})_4(\text{NH}_3)_2]$ | 1. Ionization |
| B) | $(\text{III}) [\text{Co}(\text{NO}_2)(\text{NH}_3)_5]\text{Cl}_2$
$(\text{IV}) [\text{Co}(\text{ONO})(\text{NH}_3)_5]\text{Cl}_2$ | 2. Optical |
| C) | $(\text{V}) [\text{CoCl}(\text{H}_2\text{O})(\text{en})_2]\text{Cl}_2$
$(\text{VI}) [\text{CoCl}_2(\text{en})_2]\text{Cl} \cdot \text{H}_2\text{O}$ | 3. Hydrate |
| D) | $(\text{VII}) [\text{CoBr}(\text{NH}_3)_5]\text{SO}_4$
$(\text{VIII}) [\text{Co}(\text{SO}_4)(\text{NH}_3)_5]\text{Br}$ | 4. Coordination |
| | | 5. Linkage |
- Codes: (A) (B) (C) (D)**
- | | | | | |
|----|---|---|---|---|
| a) | 1 | 3 | 2 | 4 |
| b) | 4 | 2 | 3 | 1 |
| c) | 1 | 1 | 2 | 4 |
| d) | 4 | 5 | 3 | 1 |
71. $\text{K}_3[\text{Al}(\text{C}_2\text{O}_4)_2]$ is called
 a) potassium aluminoxalate
 b) potassium trioxalatoaluminate (III)
 c) potassium aluminium (III) oxalate
 d) potassium trioxalatoaluminate (III).
72. The complexes $[\text{Co}(\text{OCN})(\text{NH}_3)_5]\text{Cl}_2$ and $[\text{Co}(\text{NCO})(\text{NH}_3)_5]\text{Cl}_2$ are the examples of
 a) geometrical isomers
 b) linkage isomers
 c) ionization isomers
 d) coordination isomers.
73. The number of ions per mole of the complex $\text{CoCl}_3 \cdot 5\text{NH}_3$ in aqueous solution will be
 a) 9 b) 4
 c) 3 d) 2.
74. The complex $\text{CoCl}_3 \cdot 5\text{NH}_3$ is treated with silver nitrate solution. Maximum number of chloride ions that can be precipitated is
 a) 9 b) 4
 c) 3 d) 2.
75. The number of chloride ions that can be precipitated when the complex $\text{PtCl}_4 \cdot 4\text{NH}_3$ is treated with silver nitrate is
 a) 2 b) 3
 c) 4 d) 1.
76. Optical isomerism is not shown by the complex
 a) $[\text{Cr}(\text{ox})_2]^{3-}$ b) $\text{cis}-[\text{Co}(\text{en})_2\text{Cl}_2]^+$
 c) $\text{trans}-[\text{Co}(\text{en})_2\text{Cl}_2]^+$ d) $[\text{Co}(\text{en})(\text{NH}_3)_2\text{Cl}_2]^+$
77. In $[\text{Ag}(\text{CN})_2]^-$, the number of π bonds is
 a) 2 b) 3
 c) 4 d) 6
78. Which of the following coordination entities will show geometrical isomerism?
 a) $[\text{PtCl}_3(\text{NH}_3)]^+$ b) $[\text{PtCl}_2(\text{NH}_3)_2]^0$
 c) $[\text{PtCl}(\text{NH}_3)_5]^{3+}$ d) $[\text{Co}(\text{NH}_3)_6]^{3+}$
79. The complex $\text{CoCl}_3 \cdot 3\text{NH}_3$ ionizes to give
 a) 2 Cl^- ions b) 1 Cl^- ions
 c) 3 Cl^- ions d) no Cl^- ion.
80. Which of the following is polymeric metal carbonyl.
 a) $\text{V}(\text{CO})_6$ b) $\text{Mn}_2(\text{CO})_{10}$
 c) $\text{Cr}(\text{CO})_6$ d) $\text{Ni}(\text{CO})_4$
81. Zeigler-Natta catalyst ($\text{R}_3\text{Al}/\text{TiCl}_4$) is used as a heterogeneous catalyst for
 a) the synthesis of ethanol
 b) polymerization of alkenes
 c) the hydrogenation of alkenes
 d) cracking of hydrocarbons.
82. Which one of following type of isomerism is shown by $[\text{CoCl}_2(\text{en})(\text{NH}_3)_2]\text{Cl}$?
 a) Geometrical isomerism
 b) Optical isomerism
 c) Linkage isomerism
 d) Coordination isomerism.
83. Geometrical isomerism is shown by
 a) $[\text{Co}(\text{NO}_2)(\text{NH}_3)_5]^{2+}$
 b) $[\text{RhCl}_3(\text{CO})_3]^0$
 c) $[\text{CrCl}_3(\text{NH}_3)_3]^0$
 d) both b and c.
84. Which one of the following can show optical isomerism?
 a) $[\text{Cr}(\text{en})_3]\text{Cl}_3$ b) $[\text{Cr}(\text{NH}_3)_6]\text{Cl}_3$
 c) $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$ d) $\text{K}_3[\text{Fe}(\text{CN})_6]$.
85. The complex compounds, $[\text{Pt}(\text{II})(\text{NH}_3)_4]$, $[\text{Pt}(\text{IV})\text{Cl}_6]$ and $[\text{Pt}(\text{IV})\text{Cl}_2(\text{NH}_3)_4]$, $[\text{Pt}(\text{II})\text{Cl}_4]$ are called
 a) linkage isomers b) ionization isomers

- c) coordination isomers d) optical isomers.
86. Which of the following is not optically active?
- trans- $[\text{CoCl}_2(\text{en})_2]$
 - cis- $[\text{CoCl}_2(\text{en})_2]$
 - $[\text{Co}(\text{en})_3]^{3+}$
 - $[\text{Cr}(\text{ox})_3]^{3-}$
87. Number of geometrical isomers shown by the octahedral complex of the type $[\text{MX}_3\text{Y}_3]$ is
- 2
 - 4
 - 6
 - 8.
88. Number of geometrical isomers shown by the octahedral complex of the type $[\text{MX}_2\text{Y}_4]$ is
- 4
 - 6
 - 8
 - 2.
89. The oxidation number of Pt in $[\text{Pt}(\text{H}_2\text{O})\text{Cl}_3]^-$ is
- + 1
 - + 2
 - + 3
 - + 4.
90. Which of the following statement is true?
- The oxidation number of iron in $[\text{Fe}(\text{CN})_6]^{4-}$ is +6
 - In transition metal complexes, the ligands act as Lewis acid
 - The charge on the complex ion in $\text{K}_2[\text{PtCl}_4]$ is + 2
 - The coordination number of Hg in $[\text{Hg}(\text{en})_2]$ is '4' (where en is ethylenediamine).
91. Match list I with list II and select the correct answer using the codes given below the lists.
- | List I | List II |
|--|----------------------------|
| A) $[\text{Hg}(\text{NH}_3)_2]\text{Cl}_2$ | 1. dsp^2 |
| B) $[\text{Cu}(\text{NH}_3)_4]^{2+}$ | 2. sp^3d |
| C) $[\text{CoF}_6]^{3-}$ | 3. sp |
| D) $[\text{Zn}(\text{NH}_3)_4]^{2+}$ | 4. sp^3d^2 |
| | 5. sp^3 |
- Codes: (A) (B) (C) (D)**
- 3 1 4 5
 - 3 1 5 4
 - 1 1 2 4
 - 2 3 4 5
92. Outer orbital complex is
- $[\text{Zn}(\text{NH}_3)_4]^{2+}$
 - $[\text{Co}(\text{NH}_3)_6]^{3+}$
 - $[\text{Cr}(\text{NH}_3)_6]^{3+}$
 - $[\text{CoF}_6]^{3-}$
93. The number of d – electrons in $[\text{Cr}(\text{H}_2\text{O})_6]^{3+}$ is
- 2
 - 3
 - 4
 - 5.
94. Cis – platin used in the treatment of cancer is
- cis – $[\text{Pt}(\text{NH}_3)_2\text{Cl}_2]$
 - trans – $[\text{Pt}(\text{NH}_3)_2\text{Cl}_2]$
 - $[\text{Pt}(\text{NH}_3)\text{Cl}_3]^+$
 - $\text{K}_2[\text{PtCl}_6]^{3-}$
95. The geometry of $[\text{Ag}(\text{NH}_3)_2]^+$ ion is
- trigonal planar
 - tetrahedral
 - linear
 - square planar.
96. The theory of coordination compounds was put forth by
- Pauling
 - Werner
 - Bronsted and Lowry
 - Lewis.
97. The structure of complex cation $[\text{Pt}(\text{NH}_3)_4]^{2+}$ is
- pyramidal
 - tetrahedral
 - square planar
 - none of these.
98. The number of unpaired electrons in $[\text{Ni}(\text{CO})_4]^0$ is
- 2
 - 4
 - 0
 - 3.
99. Which of the following does not have tetrahedral structure?
- CrO_4^{2-}
 - $[\text{Ni}(\text{CN})_4]^{2-}$
 - $[\text{Ni}(\text{CO})_4]\text{O}$
 - $[\text{NiCl}_4]^{2-}$
100. The pair of the compounds in which both the metals are in the highest possible oxidation state is
- $[\text{Fe}(\text{CN})_6]^{3-}$, $[\text{Co}(\text{CN})_6]^{3-}$
 - CrO_2Cl_2 , MnO_4^-
 - TiO_3 , MnO_2
 - $[\text{Co}(\text{CN})_6]^{3-}$, MnO_3
101. In the spectrochemical series, which ligand produces strongest field?
- Cl^-
 - H_2O
 - NO_2
 - CO
102. The IUPAC name of $\text{K}_4[\text{Fe}(\text{CN})_6]$ is
- potassium hexacyanoferrate (III)
 - potassium hexacyanoferrate (II)
 - potassium ferrocyanide
 - potassium ferricyanide
103. Which one of the following has the highest molar conductivity
- Diamminedichloroplatinum (II)
 - Tetraamminedichlorocobalt (III) chloride
 - Potassium hexacyanoferrate (II)
 - Hexaquo chromium (III) bromide

- e) Pentacarbonyliron (0)
104. Which of the following energy diagrams shows the electron distribution according to the crystal field model of the 3d- electrons in $\text{Mn}(\text{H}_2\text{O})_6^{2+}$?
- a) $\uparrow\downarrow \uparrow\downarrow \uparrow\downarrow \uparrow$ b) $\uparrow \uparrow\downarrow \uparrow\downarrow -$
- c) $\uparrow \uparrow \uparrow \uparrow$ d) $\uparrow \uparrow \downarrow \uparrow\downarrow$
105. Which of the following energy diagrams for 3d- electrons corresponds to the low-spin $\text{Fe}(\text{CN})_6^{4-}$ species?
- a) $\uparrow\downarrow \uparrow\downarrow \uparrow\downarrow \uparrow$ b) $\uparrow \uparrow\downarrow \uparrow\downarrow -$
- c) $\uparrow \uparrow \uparrow \uparrow$ d) $\uparrow \uparrow \downarrow \uparrow\downarrow$
106. A complex with the composition $[\text{Ma}_2\text{b}_2]\text{x}_2$ is found to have no geometrical isomers. Both A and B are mono dentate ligands. The structure of the complex is
- a) linear b) square pyramidal
- c) tetrahedral d) octahedral.
107. In the complex ion ML_6^{n+} , M^{n+} has five d- electrons and L is a strong field ligand. According to crystal field theory, the magnetic properties of the complex ion correspond to how many unpaired electrons?
- a) 0 b) 1
- c) 2 d) 3.
108. In the complex ion ML_6^{n+} , M^{n+} has five d- electrons and L is a weak field ligand. According to crystal field theory, the magnetic properties of the complex ion correspond to how many unpaired electrons?
- a) 0 b) 5
- c) 2 d) 3.
109. In the complex ion ML_6^{n+} , M^{n+} has four d- electrons and L is a strong field ligand. According to crystal field theory, the magnetic properties of the complex ion correspond to how many unpaired electrons?
- a) 4 b) 1
- c) 2 d) 3
110. In the complex ion ML_6^{n+} , M^{n+} has four d- electrons and L is a Weak field ligand. According to crystal field theory, the magnetic properties of the complex ion correspond to how many unpaired electrons?
- a) 0 b) 1
- c) 2 d) 4.
111. For ethylenediaminetetraacetic acid (EDTA) correct statement is
- a) not useful as a chelating agent
- b) an effective antidote for heavy metal poisoning (e.g., Pb^{2+} and Hg^{2+})
- c) a mono dentate ligand
- d) form unstable complex ions with Fe^{3+}
112. Cis-platinum complexes are
- a) used in the extraction of silver and gold
- b) effective antidotes for heavy metal poisoning (e.g., Pb^{2+} and Hg^{2+})
- c) used to provide nutrients for plants
- d) effective antitumor agents.
113. How many unpaired electrons does the manganese ion have in $[\text{Mn}(\text{CN})_6]^{4-}$?
- a) 1 unpaired electron
- b) 2 unpaired electrons
- c) 3 unpaired electrons
- d) 5 unpaired electrons
114. The metal ion in complex A has EAN identical to the atomic number of krypton. A is (At. No. of Cr = 24, Fe = 26, Pd = 46)
- a) $[\text{Pd}(\text{NH}_3)_6]\text{Cl}_4$ b) $[\text{Cr}(\text{NH}_3)_5\text{Cl}]\text{SO}_4$
- c) $\text{Na}_4[\text{Fe}(\text{CN})_6]$ d) $\text{K}_3[\text{Fe}(\text{CN})_6]$
115. Which of the following energy shows the electron distribution according to the crystal field model of the 3d- electrons in CoCl_4^{2-}
- a) $\uparrow \uparrow\downarrow \uparrow\downarrow \uparrow\downarrow$ b) $\uparrow \uparrow \uparrow\downarrow \uparrow\downarrow -$
- c) $\uparrow \uparrow \uparrow \uparrow$ d) $\uparrow \uparrow \downarrow \uparrow\downarrow \uparrow$
116. Back bonding is possible in
- a) NH_3 b) en
- c) CN d) CO
117. The number of chloride ion that can be precipitated when the complex $\text{CoCl}_3 \cdot 4\text{NH}_3$ is treated with AgNO_3
- a) 0 b) 1
- c) 2 d) 3
118. How many ions for moles are present in $[\text{Pt}(\text{NH}_3)_2\text{Cl}_4]$?

- a) 0 b) 1
c) 2 d) 4
119. Fac-mer isomerism is possible in
a) $[\text{Co}(\text{NH}_3)_4\text{Cl}_2]^+$ b) $[\text{Fe}(\text{CN})_4(\text{NH}_3)_2]^-$
c) $[\text{Co}(\text{NO}_2)_3(\text{NH}_3)_3]$ d) $[\text{Co}(\text{en})_2\text{Cl}_2]^+$
120. $[\text{Fe}(\text{H}_2\text{O})_6]^{2+}$ is
a) octahedral outer orbital complex
b) octahedral inner orbital complex
c) It is diamagnetic
d) It has hybridization d^2sp^3
121. Which of the following complex is used in silver plating?
a) $\text{K}[\text{Ag}(\text{CN})_2]$ b) AgNO_3
c) $\text{K}[\text{Ag}(\text{H}_2\text{O})]$ d) EDTA
122. Which of the following diapositive cation produces more stable complex?
a) Cd^{2+} b) Ni^{2+}
c) Cu^{2+} d) Mn^{2+}
123. The primary and secondary valencies of chromium in the complex ion, dichlorodioxalatochromium (III), are respectively.
a) 3, 4 b) 4, 3
c) 3, 6 d) 6, 3
124. Oxidation state of chromium in  is
a) + 10 b) + 6
c) + 3 d) + 2
125. The non-existent metal carbonyl among the following is
a) $\text{Cr}(\text{CO})_6$ b) $\text{Mn}(\text{CO})_5$
c) $\text{Ni}(\text{CO})_4$ d) $\text{Fe}(\text{CO})_5$
126. The pair $[\text{Co}(\text{NH}_3)_5\text{NO}_3]\text{SO}_4$ and $[\text{Co}(\text{NH}_3)_5\text{SO}_4]\text{NO}_3$ will show
a) hydrate isomerism
b) linkage isomerism
c) ionization isomerism
d) co-ordinate isomerism
127. Which one of the following co-ordination compounds exhibit ionization isomerism?
a) $[\text{Cr}(\text{NH}_3)_6]\text{Cl}_3$ b) $[\text{Cr}(\text{en})_3]\text{Cl}_3$
c) $[\text{Cr}(\text{en})_3]\text{Cl}_3$ d) $[\text{Co}(\text{NH}_3)_5\text{Br}]\text{SO}_4$
128. If the Effective Atomic Number (EAN) of $[\text{A}(\text{NH}_3)_6]\text{Cl}_3$ is 33, is the atomic number of the element (A) will be
a) 23 b) 27
c) 24 d) 29
129. Tollen's reagent contains
a) AgNO_3 b) AgOH
c) $[\text{Ag}(\text{NH}_3)_2]^+$ d) $[\text{Ag}(\text{NO}_3)_2]^+$
130. Which of the following aquated metal ions 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) $[\text{Zn}(\text{H}_2\text{O})_6]^{2+}$
131. The hybridization states of the central atom in the complex ions $[\text{FeF}_6]^{3-}$, $[\text{Fe}(\text{H}_2\text{O})_6]^{3+}$ and $[\text{Ni}(\text{NH}_3)_6]^{2+}$ are
a) sp^3d^2 , dsp^2 and sp^3 respectively
b) all are dsp^3
c) all are sp^3d^2
d) sp^3d^2 , dsp^3 and d^2sp^3 respectively
132. The formation of the complex ion $[\text{Co}(\text{NH}_3)_6]^{3+}$ involves sp^3d^2 hybridization of Co^{3+} . Hence, the complex ion should possess
a) octahedral geometry
b) tetrahedral geometry
c) square planar geometry
d) tetragonal geometry
133. Which of the following is strong ligand?
a) OH^- b) F^-
c) Cl^- d) NH_3
134. Formula of hexa-aquamanganese (II) phosphate is
a) $[\text{Mn}(\text{H}_2\text{O})_6](\text{PO}_4)$
b) $[\text{Mn}(\text{H}_2\text{O})_6]_3(\text{PO}_4)$
c) $[\text{Mn}(\text{H}_2\text{O})_6]_3(\text{PO}_4)_2$
d) $[\text{Mn}(\text{H}_2\text{O})_6](\text{PO}_4)_3$
135. How many hydrate isomers are possible with the formula $\text{CrCl}_3 \cdot 6\text{H}_2\text{O}$?
a) six b) four
c) three d) two
136. The neutral molecules or ions which co-ordinate with the central atom or ion in a complex ion are called,
a) combinants b) cryptands
c) spherands d) ligands
137. The IUPAC name for $[\text{Pt}(\text{NH}_3)_3(\text{Br})(\text{NO}_2)(\text{Cl})]\text{Cl}$ is
a) triamminechlorobromonitroplatinum (IV) chloride
b) triamminebromochloronitroplatinum (IV) chloride
c) triamminenitrochlorobromoplatinum (IV) chloride
d) triamminenitrochlorobromoplatinum (IV) chloride

- d) triamminechloronitrobromoplatinum (IV) chloride
138. 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 AgNO_3 solution to yield two moles of $\text{AgCl}(\text{s})$. The structure of the complex is
- $[\text{Co}(\text{NH}_3)_4\text{Cl}]\text{Cl}_2 \cdot \text{NH}_3$
 - $[\text{Co}(\text{NH}_3)_5\text{Cl}]\text{Cl}_2$
 - $[\text{Co}(\text{NH}_3)_3\text{Cl}_3] \cdot 2\text{NH}_3$
 - $[\text{Co}(\text{NH}_3)_4\text{Cl}_2]\text{Cl} \cdot \text{NH}_3$
139. Oxidation number of Co in $[\text{Co}(\text{NH}_3)_3(\text{H}_2\text{O})_2\text{Cl}]^+$ is,
- 1
 - 2
 - 3
 - 4
140. Which complex has square planar structure?
- $[\text{Ni}(\text{CO})_4]$
 - $[\text{NiCl}_4]^{2-}$
 - $[\text{Ni}(\text{CN})_4]^{2-}$
 - $[\text{Fe}(\text{CO})_5]$
141. Which of the following complex will not show colour?
- $[\text{Cr}(\text{NH}_3)_6]\text{Cl}_3$
 - $\text{K}[\text{VF}_6]$
 - $[\text{Sc}(\text{H}_2\text{O})]^{3+}$
 - $[\text{NiCl}_4]^{2-}$
142. Coordination compounds are the compounds in which the central metal atom is linked to atoms, ions or molecules by
- Covalent bonds
 - Coordinate bonds
 - Ionic and covalent bonds
 - Both ionic and coordinate bonds
143. Complex compounds are mainly formed by
- p-block elements
 - f-block elements
 - d-block elements
 - s-block elements
144. Which of the following statements is incorrect about coordination compounds?
- All molecular compounds are not coordinate compounds
 - Complexes always give ions in the solution
 - Complexes may or may not give ions in the solution
 - Complex ion does not dissociate into its component parts even in the solution
145. According to Werner's theory, the secondary valencies of a central metal atom correspond to its
- Oxidation state
 - Coordination number
 - Any of the two a and b
 - Neither of the two
146. Mohr's salt is a
- Simple salt
 - Alum
 - Double salt
 - Coordinate compound
147. Which of the following is not a coordination compound?
- $\text{K}_3[\text{Fe}(\text{CN})_6]$
 - $\text{CoCl}_3 \cdot 6\text{NH}_3$
 - $\text{K}_4[\text{Fe}(\text{CN})_6]$
 - Carnallite
148. The number of geometrical isomers of the complex $[\text{Co}(\text{NO}_2)_2(\text{NH}_3)_2]$ is
- 2
 - 3
 - 4
 - 0
149. Ligands are
- neutral molecules only
 - negative ions only
 - never positive ions
 - negative or positive ions or neutral molecules
150. The number of chlorine atoms acting as ligands in the complex $[\text{Co}(\text{en})_2(\text{H}_2\text{O})\text{Cl}]\text{Cl}_2$ is
- 0
 - 1
 - 2
 - 3
151. In the complex $[\text{Co}(\text{NH}_3)_5\text{Cl}]\text{Cl}_2$, the coordination sphere is
- 2Cl^-
 - Co^{3+}
 - $(\text{NH}_3)_5\text{Cl}$
 - $[\text{Co}(\text{NH}_3)_5\text{Cl}]^{2+}$
152. Ethylenediamine is
- Monodentate
 - Bidentate
 - Tridentate
 - Tetradentate
153. O^{2-} is an
- Monodentate ligand
 - Bidentate ligand
 - Tridentate ligand
 - Hexadentate ligand
154. SCN^- is a/an
- Monodentate ligand
 - Bidentate ligand
 - Tridentate ligand
 - Tetradentate ligand
155. Chelating ligand is one which donates to the metal ion
- two lone pair
 - three lone pairs
 - four lone pairs
 - all are correct
156. Which of the following is a chelate complex?

- a) Potassium ferrocyanide
 b) Potassium tetracyanonickelate (II)
 c) $[\text{Co}(\text{en})_3]^{3+}$
 d) $[\text{Co}(\text{NH})_4\text{Cl}_2]\text{Cl}$
157. Which one of the following ligands can act as Hexadentate ligand?
 a) Ethylenediamine b) EDTA
 c) Acetylacetonato d) Dimethyl glyximate
158. Which one of the following acts as a neutral ligand
 a) amine b) Oxalato
 c) fluoro d) Cyano
159. The number of anionic coordinating sites of EDTA are
 a) 2 b) 4
 c) 6 d) 8
160. The most strongest ligand is
 a) Cl^- b) F^-
 c) I^- d) CN^-
161. An example of non ambidentate ligand is
 a) NH_3 b) SCN
 c) CN d) NO_2
162. Chelating ligand among the following is
 a) CO b) CN^-
 c) OH^- d) en
163. The strongest ligand is
 a) Cl^- b) OH^-
 c) CO d) H_2O
164. An example of bidentate ligand is
 a) NH_3 b) OH^-
 c) OX^{2-} d) Cl^-
165. Consider
 1) EDTA – Hexadentate ligand
 2) Ethylene diamine – Bidentate ligand
 3) Diethylene triamine – Tridentate ligand
 4) Chloride – Tridentate ligand
 Which is / are not correctly paired?
 a) 1 and 2 b) 3 and 4
 c) Only 4 d) 1, 2 and 3
166. Which one of the following ligands forms a chelate complex?
 a) Water b) Oxalate
 c) Ammonia d) Cyanide
167. Which ligand is expected to be bidentate?
 a) $\text{C}_2\text{O}_4^{2-}$ b) CH_3NH_2
 c) Br^- d) $\text{CH}_3\text{C} \equiv \text{N}$
168. 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) $[\text{Cu}(\text{NH}_3)_4]\text{SO}_4$
169. Magnetic moment of $[\text{Cu}(\text{NH}_3)_4]^{2+}$ ion is
 a) 1.414 b) 1.73
 c) 2.23 d) 2.38
170. In the compound, lithium tetrahydrido aluminate, the ligand is
 a) H b) H^+
 c) H^- d) Al
171. Which one of the following is NOT a ligand?
 a) PH_3 b) NO^+
 c) Na^+ d) F^-
172. In a coordination complex, the negative groups or neutral molecules attached to the central atom is termed as
 a) charge of metal ion
 b) ligands
 c) coordination number
 d) EAN
173. The coordination number of the central ion may be obtained from
 a) the number of coordinate bonds formed with surrounding atoms
 b) the number of ionic bonds formed with the surrounding ions
 c) the number of ions of opposite charge immediately surrounding the specific ion
 d) none of the above
174. The coordination number of Cr in $[\text{Cr}(\text{NH}_3)_3(\text{H}_2\text{O})_3]\text{Cl}_3$ is
 a) 2 b) 3
 c) 4 d) 6
175. The oxidation number of Fe in $\text{K}_3[\text{Fe}(\text{ox})_3]$ is
 a) 1 b) 2
 c) 3 d) 4
176. The oxidation number of manganese in $[\text{Mn}_2(\text{CO})_{10}]$ is
 a) 0 b) +1
 c) +2 d) +5
177. Which one of the following has oxidation number of transition metal atom four?
 a) KMnO_4 b) $\text{K}_3[\text{PtCl}_4]$
 c) K_2MnO_4 d) $\text{K}_2[\text{PtCl}_6]$
178. Out of the following which one has transition metal atom in the oxidation state +2 ?
 a) $\text{K}_4[\text{Fe}(\text{CN})_6]$ b) $\text{K}_2[\text{Pt}(\text{CN})_6]$

- c) $K_3[Fe(CN)_6]$ d) $[Co(NH_3)_5Br]SO_4$
179. The coordination number of Al in potassium trioxalato aluminate (III) is
a) 3 b) 4
c) 5 d) 6
180. The oxidation state of Al in $LiAlH_4$ is
a) 0 b) 1
c) 2 d) 3
181. The oxidation state of Co in $[Co(en)]^{3+}$ is
a) +3 b) -3
c) +1 d) +2
182. The donor site of CN can be
a) C b) S
c) N d) Both a and c
183. The oxidation state of iron in haemoglobin is
a) 0 b) +1
c) +2 d) +3
184. The coordination number of Ni in the complex $[Ni(CO)_4]$ is
a) 1 b) 2
c) 3 d) 4
185. The oxidation state of Zn in $K_2[Zn(CNS)_4]$ is
a) 0 b) +1
c) +2 d) +3
186. The oxidation state of nickel in the complex $[Ni(CO)_2(H_2O)_2]$ is
a) 0 b) +1
c) +2 d) +4
187. What is true for $[Fe(CN)_6]^{3-}$ and $[FeF_6]^{3-}$
a) Both are paramagnetic
b) Only $[Fe(CN)_6]^{3-}$ is paramagnetic
c) Only $[FeF_6]^{3-}$ is paramagnetic
d) Both are diamagnetic
188. Choose the correct statement.
a) Coordination number has nothing to do with the number of groups or molecules attached to the central atom
b) Coordination number is the number of coordinating sites of all the ligands connected to the central atom or the number of coordinate bonds formed by the metal atom with ligands
c) Werner's coordination theory postulates only one type of valency
d) All are correct
189. The total number of possible isomers for the complex compound $[Cu^{II}(NH_3)_4][Pt^{II}Cl_4]$ are
a) 3 b) 4
- c) 5 d) 6
190. The oxidation state of Fe in $[Fe(H_2O)_5(NH_3)]SO_4$ is
a) +1 b) +2
c) +4 d) +3
191. Coordination number of cobalt in $[Co(ox)_3]^{3-}$ is
a) 2 b) 6
c) 5 d) 4
192. Oxidation number of Co in $[Co(NH_3)_3(H_2O)_2Cl]^+$ is
a) 1 b) 2
c) 3 d) 4
193. The solution of the complex $[Cu(NH_3)_4]SO_4$ in water will
a) give the test of SO_4^{2-} ions
b) give the test of Cu^{2+} ions
c) give the test of NH_3
d) not give the test of any of the above
194. Metal ions which form the most stable complexes have each of the following properties except
a) empty orbitals
b) at least one lone pair of electrons
c) high nuclear charge
d) small size
195. Which of the following will not give tests for free transition metal ion in solution?
a) $K_2[Ni(CN)_4]$
b) $FeSO_4 \cdot K_2SO_4 \cdot 24H_2O$
c) $KCl, MgCl_2, 6H_2O$
d) $FeSO_4, (NH_4)_2SO_4, 6H_2O$
196. The complex $CoCl_3 \cdot 4NH_3$ ionizes to give
a) one Cl^- ion b) two Cl^- ions
c) three Cl^- ions d) no Cl^- ion
197. The number of ions produced from one molecule of $[Pt(NH_3)_5Cl]Cl_3$ in the aqueous solution will be
a) 3 b) 5
c) 4 d) 6
198. Which one has the highest paramagnetism?
a) $Ni(CO)_4$ b) $[Ni(NH_3)_4]Cl_2$
c) $[Ni(NH_3)_6]Cl_2$ d) $[Cu(NH_3)_4]Cl_2$
199. The number of ions furnished by $[Co(NH_3)_5Cl]Cl_2$ in solution are,
a) zero b) 1
c) 2 d) 3
200. Complex forming tendency is more for the metal ion

- a) Ca^{2+} b) Co^{2+}
c) Ce^{2+} d) Li^{+}
201. 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) $[\text{Co}(\text{en})(\text{NH}_3)_2\text{Cl}_2]\text{Cl}$
202. Change in composition of coordination sphere yields which types of isomers
a) Optical b) Geometrical
c) Ionisation d) None of these
203. Which of the following will not give a precipitate with AgNO_3 ?
a) $[\text{Co}(\text{NH}_3)_3\text{Cl}_3]$ b) $[\text{Co}(\text{NH}_3)_4\text{Cl}_2]\text{Cl}$
c) $[\text{Co}(\text{NH}_3)_5\text{Cl}]\text{Cl}_2$ d) $[\text{Co}(\text{NH}_3)_6]\text{Cl}_3$
204. The number of ions formed when $[\text{Cu}(\text{NH}_3)_4\text{SO}_4]$ is dissolved in water is
a) 0 b) 2
c) 4 d) 3
205. The total number of ions furnished by $\text{K}_4[\text{Fe}(\text{CN})_6]$ in solution is
a) 3 b) 4
c) 5 d) 6
206. The number of groups acting only as secondary valencies in the complex $[\text{CoCl}_2(\text{NH}_3)_4]\text{Cl}$ are
a) 4 b) 2
c) 6 d) 1
207. Primary and secondary valency of platinum in the complex $[\text{Pt}(\text{en})_2\text{Cl}_2]$ are
a) 4, 6 b) 6, 2
c) 4, 4 d) 6, 4
208. EAN of Ni in $[\text{Ni}(\text{CO})_4]$ is
a) 35 b) 36
c) 38 d) 40
209. EAN of Pt in $[\text{Pt}(\text{NH}_3)_4]^{2+}$
a) 35 b) 40
c) 80 d) 84
210. The EAN of $[\text{Mn}(\text{Cl})_6]^{4-}$ is
a) 33 b) 34
c) 35 d) 36
211. Consider (At. No. Cr = 24, Ni = 28, Pt = 78, Pd = 46).
Which of the following has correct EAN ?
- | Complex | EAN |
|--------------------------------------|-----|
| a) $[\text{Cr}(\text{CN})_6]^{3-}$ | 52 |
| b) $[\text{Ni}(\text{CO})_4]$ | 86 |
| c) $[\text{Pt}(\text{NH}_3)_6]^{4+}$ | 86 |
| d) $[\text{PdCl}_4]^{2-}$ | 33 |
212. Suffix – o or ido is added to the name of a ligand when the ligand is
a) positively charged
b) neutral (except water)
c) negatively charged
d) all of the above
213. The IUPAC name of $\text{K}_3[\text{Fe}(\text{ox})_3]$ is
a) Potassium ferroxalate
b) Potassium ferrioxalate
c) Potassium trioxalate ferrate (II)
d) Potassium trisoxalato ferrate (III)
214. Diammine silver (I) ion is
a) $[\text{Ag}(\text{NH}_3)_2]^+$ b) $[\text{Ag}(\text{NH}_3)]^{3+}\text{NH}_3$
c) $[\text{Ag}(\text{NH}_3)_2]^{3+}\text{NH}_3$ d) None of these
215. The correct name of the compound $[\text{Cu}(\text{NH}_3)_4](\text{NO}_3)_2$ according to IUPAC system is
a) Cuprammonium nitrate
b) Tetraammine copper (I) nitrate
c) Tetraammine copper (II) nitrate
d) Tetraammine copper (III) nitrate
216. The IUPAC name of $[\text{CoCl}(\text{NH}_3)(\text{en})_2]\text{Cl}_2$ is
a) Chi oro ammine bis (ethylenediamine) cobalt (II) chloride
b) Ammine chlorobis (ethylenediamine) cobalt (II) chloride
c) Ammine chlorobis (ethylenediamine) cobalt (III) chloride
d) Ammine chlorobis (ethylenediamine) cobalt (IV) chloride
217. The complex ions $[\text{Co}(\text{NH}_3)_5(\text{NO}_2)]^{2+}$ and $[\text{Co}(\text{NH}_3)_5(\text{ONO})]^{2+}$ are called
a) Geometrical isomers
b) Linkage isomers
c) Ionization isomers
d) Coordination isomers
218. Geometrical isomerism in complex compounds is exhibited by
a) square planar and tetrahedral complexes
b) square planar and octahedral complexes
c) tetrahedral and octahedral complexes
d) square planar, tetrahedral and octahedral complexes
219. Which one of the following compounds would exhibit coordination isomerism?
a) $[\text{Cr}(\text{H}_2\text{O})_6]\text{Cl}_3$ b) $[\text{Cr}(\text{NH}_3)_6] [\text{Co}(\text{CN})_6]$
c) $[\text{Cr}(\text{en})_3]\text{NO}_2$ d) $\text{K}_4[\text{Fe}(\text{CN})_6]$

220. $[\text{PtII}(\text{NH}_3)_4]$ $[\text{Pt}^{\text{IV}}\text{Cl}_6]$ and $[\text{Pt}^{\text{IV}}(\text{NH}_3)_4\text{Cl}_2]$ $[\text{Pt}^{\text{II}}\text{Cl}_4]$ complexes represent the example of
 a) Linkage isomerism
 b) Ionisation isomerism
 c) Coordination isomerism
 d) Hydrate isomerism
221. Of the following complexes which one will show coordination isomerism?
 a) $[\text{Cu}(\text{en})_2\text{Cl}_2]^+$
 b) $[\text{Co}(\text{en})_2\text{Cl}_2]\text{Cl}$
 c) $[\text{Cr}(\text{NH}_3)_6]$ $[\text{Co}(\text{en})_3]$
 d) $[\text{Cr}(\text{NH}_3)_6]\text{Cl}_2$
222. The octahedral complex $[\text{M}(\text{aa})_2\text{x}_2\text{y}_2]$ gives
 a) two geometrical isomers
 b) two optical isomers
 c) three optical isomers
 d) three geometrical isomers
223. Which of the following complexes can form d and L isomers?
 a) $[\text{Co}(\text{NH}_3)_3\text{Cl}_3]$ b) $[\text{Co}(\text{NH}_3)_4]^{+2}$
 c) Cis $[\text{Co}(\text{en})_2\text{Cl}_2]^+$ d) Trans $[\text{Co}(\text{en})\text{Cl}_2]$
224. Out of the following which will not show geometrical isomerism?
 a) $[\text{Co}(\text{NH}_3)_5\text{NO}_2]\text{Cl}_2$ b) $[\text{Pt}(\text{NH}_3)_2\text{Cl}_2]$
 c) $[\text{Co}(\text{en})_2\text{Cl}_2]\text{Cl}$ d) $[\text{Cr}(\text{NH}_3)_4\text{Cl}_2]\text{Cl}$
225. $\text{K}_3[\text{Fe}(\text{C}_2\text{O}_4)_3]$ exhibits
 a) Ionization isomerism
 b) Geometrical isomerism
 c) Optical isomerism
 d) Coordination isomerism
226. $[\text{Co}(\text{NH}_3)_4\text{Cl}_2]\text{Cl}$ exhibits
 a) Ionization isomerism
 b) Linkage isomerism
 c) Geometrical isomerism
 d) Optical isomerism
227. The number of hydrate isomers of $\text{CrCl}_3 \cdot 6\text{H}_2\text{O}$ are
 a) 1 b) 2
 c) 3 d) 4
228. Geometrical isomerism is shown by
 a) Tetrahedral b) Octahedral
 c) Square planar d) Both b and c
229. Which of the following has metal-metal bond?
 a) $\text{Ni}(\text{CO})_4$ b) $\text{Fe}(\text{CO})_5$
 c) $\text{Cr}(\text{CO})_6$ d) $\text{Mn}_2(\text{CO})_{10}$
230. Cis-trans isomerism is exhibited by which one of the following?
 a) $[\text{Pd}(\text{NH}_3)_3\text{Cl}]^+$ b) $[\text{Co}(\text{NH}_3)_5\text{Cl}]^{2+}$
 c) $[\text{Fe}(\text{CN})_6]^{3-}$ d) $[\text{Pt}(\text{en})_2\text{Cl}_2]^{2+}$
231. Optical isomerism can be shown by the complex
 a) $[\text{Cu}(\text{NH}_3)_4]^{2+}$ b) $[\text{Ni}(\text{H}_2\text{O})_4]^{2+}$
 c) Both (a) and (b) d) Neither (a) or (b)
232. Square planar complex which shows geometrical isomerism is
 a) $\text{M a}_3\text{x}$ b) M a_4
 c) M abcd d) $\text{M a}_3\text{b}$
233. Which of the following types of octahedral complexes does not show optical isomerism?
 a) $\text{M}(\text{aa})_2\text{xy}$ b) $[\text{M}(\text{aa})_3]$
 c) $[\text{M}(\text{aa})_2\text{x}_2]^{n+}$ d) $[\text{M a}_3\text{b}]$
234. A complex with the composition $[\text{M a}_2\text{b}_2]\text{X}_2$ is found to have no geometrical isomers. Both A and B are monodentate weak ligands. The structure of the complex is
 a) Linear b) Tetrahedral
 c) Square planar d) Octahedral
235. The complex ion $[\text{Co}(\text{en})_2\text{Cl}_2]^+$ exhibits
 a) cis-trans isomerism only
 b) cis-trans isomerism and optical isomerism
 c) cis-trans isomerism and linkage isomerism
 d) optical isomerism and linkage isomerism
236. The complex ion $[\text{Cu}(\text{NH}_3)_4]^{2+}$ is
 a) Tetrahedral b) Square planar
 c) Both d) None of these
237. The number of precipitable halide ions in the sample $[\text{Pt}(\text{NH}_3)\text{Cl}_2\text{Br}]\text{Cl}$ will be
 a) 2 b) 3
 c) 4 d) 1
238. Back bonding involves the formation of
 a) a bond b) Coordinate bond
 c) x bond d) None of these
239. Hexafluoroferrate (III) ion is an outer orbital complex. The number of unpaired electrons present in it
 a) 1 b) 4
 c) 5 d) 0
240. A complex involving dsp^2 hybridization has
 a) Square planar geometry
 b) A tetrahedral geometry
 c) An octahedral geometry
 d) Trigonal planar geometry
241. Which of the following complex species involves d^2sp^3 hybridization?

- a) $[\text{Fe}(\text{CN})_6]^{3-}$ b) $[\text{CO}(\text{F})_6]^{3-}$
 c) $[\text{Co}(\text{H}_2\text{O})_6]^{3+}$ d) $[\text{Fe}(\text{F})_6]^{3-}$
242. The ion which has a high spin d6 configuration is
 a) $[\text{Co}(\text{NH}_3)_6]^{2+}$ b) $[\text{CoF}_6]^{4-}$
 c) $[\text{Fe}(\text{CN})_6]^{4-}$ d) $[\text{Co}(\text{H}_2\text{O})_6]^{3+}$
243. Which among the following complexes has square pyramidal geometry?
 a) Tetracarbonyl nickel (0)
 b) Pentacarbonyl iron (0)
 c) Hexamminecobalt (II) nitrate
 d) Tetraaminecopper (II) sulphate
244. An octahedral complex is formed when hybrid orbitals of the following type are involved
 a) sp^3 b) dsp^3
 c) sp^3d d) sp^3d^2
245. Compare
 1) $[\text{Ag}(\text{NH}_3)_2]^+$ Diagonal
 2) $[\text{Cr}(\text{CO})_6]^0$ Tetrahedral
 3) $[\text{Fe}(\text{CN})_6]^{3-}$ Square planar
 4) $[\text{Ni}(\text{CN})_4]^{2-}$ Octahedral
 Which is / are correctly shaped?
 a) 1 and 2 b) 2 and 3
 c) 1 only d) 3 and 4
246. In coordination compound $[\text{Co}(\text{en})_2\text{Cl}_2]\text{Cl}$ which is false
 a) Show geometrical Isomerism
 b) Show optical Isomerism
 c) Show ionic Isomerism
 d) A octahedral complex
247. K_3CoF_6 is high spin complex. What is the hybrid state of Co atom in this complex?
 a) d^2sp^3 b) dsp^2
 c) sp^3d d) sp^3d^2
248. Which complex has square planar structure?
 a) $[\text{Ni}(\text{CO})_4]^{2-}$ b) $[\text{NiCl}_4]^{2-}$
 c) $[\text{Ni}(\text{CN})_4]^{2-}$ d) $[\text{Fe}(\text{CO})_5]$
249. The paramagnetic ion among the following is
 a) $[\text{Ni}(\text{CN})_4]^{2-}$ b) $[\text{Mn}(\text{CN})_6]^{4-}$
 c) $[\text{Zn}(\text{NH}_3)_4]^{2+}$ d) All the above
250. The complex ion $[\text{Cu}(\text{NH}_3)_4]^{2+}$ is
 a) Square planar and diamagnetic
 b) Square planar and paramagnetic
 c) Tetrahedral and diamagnetic
 d) Tetrahedral and paramagnetic
251. Which of the following are diamagnetic?
 1) $\text{K}_4[\text{Fe}(\text{CN})_6]$ 2) $\text{K}_3[\text{Cr}(\text{CN})_6]$
 3) $\text{K}_3[\text{Co}(\text{CN})_6]$ 4) $\text{K}_2[\text{Ni}(\text{CN})_4]$
 Select the correct answer using the codes given below:
 a) 1, 2 and 4 b) 1, 3 and 4
 c) 2 and 3 d) 1 and 4
252. t_{2g} orbitals are proposed in
 a) Crystal field theory b) Pauling theory
 c) Lewis theory d) Sidwick theory
253. eg orbitals consist of
 a) dx^2y^2 , dz^2 b) dxy , dxz , dyz
 c) dxy , dxz , dz^2 d) dz^2
254. Which of the following atomic orbital of the metal cation are considered in CFT ?
 a) s b) p
 c) d d) f
255. Which of the following cannot be explained by CFT?
 a) Electrovalency b) Covalency
 c) Secondary valency d) Oxidation number
256. Which is colourless of the following?
 a) Unhydrous CuSO_4
 b) $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$
 c) $\text{Cu}_2(\text{CH}_3\text{COO})_4 \cdot \text{H}_2\text{O}$
 d) $[\text{Cu}(\text{NH}_3)_4] \text{SO}_4 \cdot 4\text{H}_2\text{O}$
257. The d-electron configuration of Cr^{2+} , Mn^{2+} , Fe^{2+} and Ni^{2+} are 3d^4 , 3d^5 , 3d^6 and 3d^8 respectively. Which one of the following aqua complex will exhibit the minimum paramagnetic behaviour
 a) $[\text{Mn}(\text{H}_2\text{O})_6]^{2+}$ b) $[\text{Fe}(\text{H}_2\text{O})_6]^{2+}$
 c) $[\text{Ni}(\text{H}_2\text{O})_6]^{2+}$ d) $[\text{Cr}(\text{H}_2\text{O})_6]^{2+}$
258. Which of the following complex will not show colour?
 a) $[\text{Cr}(\text{NH}_3)_6]\text{Cl}_3$ b) $\text{K}_3[\text{VF}_6]$
 c) $[\text{Sc}(\text{H}_2\text{O})_6]^{3+}$ d) $[\text{NiCl}_4]^{2-}$
259. Ligand(s) with lone pair of electron(s) with vacant orbital/to receive back the electrons donated to the metal is / are
 a) CO b) H_2O
 c) NH_3 d) F^-
260. The more stable complex among the following is
 a) $[\text{Fe}(\text{H}_2\text{O})_6]^{2+}$ b) $[\text{Mn}(\text{H}_2\text{O})_6]^{2+}$
 c) $[\text{Fe}(\text{H}_2\text{O})_6]^{3+}$ d) None of these.
261. The value of stability constant depends upon
 a) the charge on the central metal ion
 b) nature of the ligand
 c) chelation
 d) all of the above.

262. Which one of the following statements is incorrect?
- Greater the stability constant of a complex ion, greater is its stability
 - Greater the charge on the central metal ion, greater is the stability of the complex
 - Greater the basic character of the ligand, the greater is the stability of the complex
 - Complexes have low stability constants
263. From the stability constants (hypothetical values), given below, predict which one is the strongest ligand?
- $\text{Cu}^{2+} + 4\text{H}_2\text{O} \rightleftharpoons [\text{Cu}(\text{H}_2\text{O})_4]^{2+}$,
 $K = 9.5 \times 10^8$
 - $\text{Cu}^{2+} + 4\text{NH}_3 \rightleftharpoons [\text{Cu}(\text{NH}_3)_4]^{2+}$,
 $K = 4.5 \times 10^{11}$
 - $\text{Cu}^{3+} + 4\text{CN}^- \rightleftharpoons [\text{Cu}(\text{CN})_4]^{2-}$,
 $K = 2.0 \times 10^{27}$
 - $\text{Cu}^{2+} + 2\text{en} \rightleftharpoons [\text{Cu}(\text{en})_2]^{2+}$,
 $K = 3.0 \times 10^{15}$
264. The stability constants of the complexes formed by a metal ion M^{2+} with NH_3 , CN^- , H_2O and en are of the order of 10^{11} , 10^{27} , 10^{15} and 10^{18} respectively. Then,
- CN^- is the strongest ligand
 - en is the strongest ligand
 - these values cannot predict the strength of the ligand
 - all the ligands are equally strong
265. Cyanide process is used for the extraction of
- Sodium
 - Copper
 - Gold
 - Calcium
266. Which of the following complex will give a white precipitate on treatment with BaCl_2 solution?
- $[\text{Cr}(\text{NH}_3)_4\text{SO}_4]\text{Cl}$
 - $[\text{Co}(\text{NH}_3)_4\text{Cl}_2]\text{NO}_2$
 - $[\text{Cr}(\text{NH}_3)_4\text{Cl}_2]\text{SO}_4$
 - Both a and b
267. Complexometric titrations involve use of
- EDTA
 - $\text{K}_2\text{Cr}_2\text{O}_7$
 - KMnO_4
 - NaCl
268. $[\text{Fe}(\text{NO}_2)_3\text{Cl}_3]$ and $[\text{Fe}(\text{O} - \text{NO})_3\text{Cl}_3]$ shows
- Linkage isomerism
 - Geometrical isomerism
 - Optical isomerism
 - None of the above
269. The pair in which both species have same magnetic moment (spin only value) is
- $[\text{Cr}(\text{H}_2\text{O})_6]^{2+}$, $[\text{CoCl}_4]^{2-}$
 - $[\text{Cr}(\text{H}_2\text{O})_6]^{2+}$, $[\text{Fe}(\text{H}_2\text{O})_6]^{2+}$
 - $[\text{Mn}(\text{H}_2\text{O})_6]^{2+}$, $[\text{Cr}(\text{H}_2\text{O})_6]^{2+}$
 - $[\text{CoCl}_4]^{2-}$, $[\text{Fe}(\text{H}_2\text{O})_6]^{3+}$
270. Which of the following can participate in linkage isomerism?
- NO_2^-
 - $\text{H}_2\text{NCH}_2\text{CH}_2\text{NH}_2$
 - H_2O
 - $:\text{NH}_3$
271. The hardness of water is estimated by
- Titration method
 - Conductivity method
 - EDTA method
 - Distillation method
272. When ammonia is added to AgCl , the following is / are correct observations / statements?
- AgCl dissolves
 - AgCl becomes black
 - A complex $[\text{Ag}(\text{NH}_3)_2]\text{Cl}$ is formed
 - Both a and c
273. What will be the theoretical value of magnetic moment (u) when CN^- ligands join Fe^{3+} ion to yield complex
- 2.83 BM
 - 3.87 BM
 - 5.92 BM
 - 1.73 BM
274. Which of the following complex ions is expected to absorb visible light?
- $[\text{Sc}(\text{H}_2\text{O})_3(\text{NH}_3)_3]^{3+}$
 - $[\text{Ti}(\text{en})_2(\text{NH}_3)_2]^{4+}$
 - $[\text{Cr}(\text{NH}_3)_6]^{3+}$
 - $[\text{Zn}(\text{NH}_3)_6]^{2+}$
275. The reaction $[\text{Fe}(\text{CNS})_6]^{3-} \rightarrow [\text{FeF}_6]^{3-}$ takes place with
- Decrease in magnetic moment
 - Increase in magnetic moment
 - Decrease in co-ordination number
 - Increase in co-ordination number
276. An example for a double salt is
- Mohr's salt
 - Potassium ferricyanide
 - Cuprammonium sulphate
 - Cobalthexammine chloride
277. Which of the following facts about the complex $[\text{Cr}(\text{NH}_3)_6]\text{Cl}_3$ is wrong?
- The complex involves d^2sp^3 hybridisation and is octahedral in shape
 - The complex is paramagnetic

- c) The complex is an outer orbital complex
 d) The complex gives white precipitate with silver nitrate
278. $K_4[Fe(CN)_6]$ is a
 a) Complex compound
 b) Double salt
 c) Neutral molecule
 d) None of these
279. Some salts although containing two different metallic elements give test for only one of them in solution. Such salts are
 a) Normal salts b) Complex
 c) Double salts d) None of these
280. The EAN of iron in $[Fe(CN)_6]^{3-}$ is
 a) 34 b) 35
 c) 36 d) 37
281. Coordination number of Ni in $[Ni(C_2O_4)_3]^{4-}$ is
 a) 3 b) 5
 c) 4 d) 6
282. According to Lewis, the ligands are
 a) Acidic in nature
 b) Basic in nature
 c) Neither acidic nor basic
 d) Some are acidic and others are basic
283. According to the postulates of Werner theory coordination compounds
 a) Primary valency is ionizable
 b) Secondary valency is ionizable
 c) Primary and secondary valency are non ionizable
 d) Only primary valency is non-ionizable
284. In $[Co(NH_3)_6]Cl_3$, the number of coordinate bonds are
 a) 18 b) 6
 c) 9 d) 3
285. Chemical formula for iron (III) hexacyanoferrate (II) is
 a) $Fe[Fe(CN)_6]$ b) $Fe_3[Fe(CN)_6]$
 c) $Fe_3[Fe(CN)_6]_4$ d) $Fe_4[Fe(CN)_6]_2$
286. IUPAC name of $Na_3[Co(NO_2)_6]$ is
 a) Sodium cobaltinitrite
 b) Sodium hexanitritocobaltate (III)
 c) Sodium hexanitrocobalt (III)
 d) Hexanitrosodium cobaltate (III)
287. Ligand in a complex salt are
 a) anions linked by coordinate bonds to a central metal atom or ion
 b) cations linked by co-ordinate bonds to a central metal or ion
 c) ions or molecules linked by coordinate bonds to a central atom or ion
 d) only neutral molecules linked by coordinate bonds to a central metal or ion
288. The IUPAC name of $K_3[Ir(C_2O_4)_3]$ is
 a) Potassium trioxalatoiridium (III)
 b) Potassium trioxalatoiridate (II)
 c) Potassium tris (oxalato) iridium (III)
 d) Potassium tris (oxalato) iridate (III)
289. In $[Cr(C_2O_4)_3]^{3-}$, the isomerism shown is
 a) Optical b) Geometrical
 c) Linkage d) Ionization
290. Which of the following complex will show geometrical as well as optical isomerism?
 a) $[Pt(NH_3)Cl_4]$ b) $[Pt(NH_3)_2Cl_2]$
 c) $[Pt(en)_3]^{4+}$ d) $[Pt(en)_2Cl_2]$
291. A co-ordination complex compound of cobalt has molecular formula containing five ammonia molecules, one nitro group and two chlorine atoms for one cobalt atom. One mole of this compound produces three mole ions in an aqueous solution. On reacting this solution, with excess of $AgNO_3$ solution two moles of $AgCl$ get precipitated. The ionic formula of this complex would be
 a) $[Co(NH_3)_4NO_2Cl] [(NH_3)Cl]$
 b) $[Co(NH_3)_5(NO_2)]Cl_2$
 c) $[Co(NH_3)_5] [(NO_2)_2Cl_2]$
 d) $[Co(NH_3)_5Cl] [Cl(NO_2)_2]$
292. The number of isomers exhibited by $[Cr(NH_3)_4Cl_3]$ is
 a) 5 b) 4
 c) 3 d) 2
293. The compounds $[PtCl_2(NH_3)_4]Br_2$ $[PtBr_2(NH_3)_4]Cl_2$ constitutes a pair of
 a) Linkage isomers
 b) Ionization isomers
 c) Co-ordination isomers
 d) Optical isomers
294. A similarity between optical and geometrical isomerism is that
 a) each gives equal number of isomers for a given compound
 b) it in a compound one is present then so is the other
 c) both are included in stereoisomerism

- d) they have no similarity
295. The type of isomerism present in nitropentaamminechromium (III) chloride is
 a) Ionization b) Optical
 c) Linkage d) Polymerization
296. The unpaired electrons in $\text{Ni}(\text{CO})_4$ are
 a) Zero b) One
 c) Three d) Four
297. Which of the following species represent the example of d^2sp^3 hybridisation ?
 a) $[\text{Fe}(\text{CN})_6]^{3-}$ b) $[\text{Ni}(\text{CN})_4]^{2-}$
 c) $[\text{FeF}_6]^{3-}$ d) $[\text{Zn}(\text{NH}_3)_4]^{2+}$
298. The correct structure of $\text{Ni}(\text{CN})_5$ is
 a) Square pyramidal b) Square planar
 c) Octahedral d) Tetrahedral
299. Which one of the following is an example of octahedral complex?
 a) $[\text{Zn}(\text{NH}_3)_4]^{2+}$ b) $[\text{Cu}(\text{NH}_3)_4]^{2+}$
 c) $[\text{MnCl}_6]^{4-}$ d) $[\text{Ni}(\text{CN})_4]^{2-}$
300. Which of the following is paramagnetic?
 a) $[\text{Ni}(\text{CO})_4]$ b) $[\text{Fe}(\text{CN})_6]^{4-}$
 c) $[\text{Ni}(\text{CN})_4]^{2-}$ d) $[\text{Fe}(\text{H}_2\text{O})_6]^{3+}$
301. Which statement is incorrect?
 a) $[\text{Zn}(\text{NH}_3)_4]^{3+}$ Tetrahedral, paramagnetic
 b) $[\text{Ni}(\text{CN})_4]^{2-}$ Square planar, diamagnetic
 c) $[\text{Ni}(\text{CO})_4]$ Tetrahedral, diamagnetic
 d) $[\text{FeCl}_4]^{2-}$ Tetrahedral, paramagnetic
302. Consider the following complex $[\text{Cu}(\text{CN})_4]^{3-}$. The co-ordination number and oxidation number of metal are respectively
 a) 4,1 b) 1,4
 c) 4,2 d) 4,4
303. Which of the following will exhibit maximum ionic conductivity?
 a) $[\text{Co Cl}_3 \cdot 3\text{NH}_3]$ b) $[\text{Co Cl}_3 \cdot 4\text{NH}_3]$
 c) $[\text{Co Cl}_3 \cdot 5\text{NH}_3]$ d) $[\text{Co Cl}_3 \cdot 6\text{NH}_3]$
304. Which of the following complex is diamagnetic?
 a) $[\text{CO}(\text{CN})_6]^{3-}$ b) $[\text{Mn}(\text{H}_2\text{O})_6]^{2+}$
 c) $[\text{Fe}(\text{H}_2\text{O})_6]^{2+}$ d) $[\text{Fe}(\text{H}_2\text{O})_6]^{3+}$
305. In the silver plating of copper, $\text{K} [\text{Ag}(\text{CN})_2]$ is used instead of AgNO_3 . The reason is
 a) More voltage is required
 b) Ag^+ ions are completely removed from solution
 c) A thin layer of Ag is formed on Cu
 d) Less availability of Ag^+ ions, as Cu cannot displace Ag from $[\text{Ag}(\text{CN})_2]^-$ ion
306. Cu^{2+} and Cd^{2+} are separated by
 a) NH_3 ligand b) CN ligand
 c) H_2O ligand d) Cl ligand
307. Molar conductance of complex $\text{M}(\text{NH}_3)_5\text{Br}_4$ is $390 \text{ ohm}^{-1}/\text{mol}^{-1}$. What is the structure of complex?
 a) $[\text{M}(\text{NH}_3)_5 \text{Br}] \text{Br}_3$ b) $[\text{M}(\text{NH}_3)_5 \text{Br}_2] \text{Br}_2$
 c) $[\text{M}(\text{NH}_3)_5 \text{Br}_3] \text{Br}$ d) $[\text{M}(\text{NH}_3)_5 \text{Br}_4]$
308. Molar conductance of complex $\text{Pt} 6\text{NH}_3\text{Cl}_4$ is zero $\text{ohm}^{-1} \text{ mol}^{-1}$. How many total ions are present in solution?
 a) 0 b) 2
 c) 4 d) 5
309. Electronic configuration of Co in $[\text{Co}(\text{ox})_3]^{3-}$ is
 a) $t_{2g} 4, e_g^2$ b) t_{2g}^0, e_g^6
 c) $t_{2g} 3, e_g^3$ d) t_{2g}^3, e_g^3
310. How many unpaired electrons are present in octahedral complexes of d^9 ion when $\Delta_0 > P$.
 a) 0 b) 1
 c) 2 d) 3
311. How many unpaired electrons are present in tetrahedral complexes of d^8 ion when $\Delta_t < P$
 a) 1 b) 3
 c) 4 d) 5
312. On the basis of CFT, what is the electronic configuration of Co^{3+} ion in an octahedral complex for which $\Delta_0 > P$?
 a) $t_{2g} 4, e_g^2$ b) t_{2g}^0, e_g^6
 c) $t_{2g} 3, e_g^3$ d) t_{2g}^3, e_g^3
313. Which of the following complex has large value of Δ_0
 a) $[\text{CO}(\text{CN})_6]^{3-}$ b) $[\text{Co}(\text{NH}_3)_6]^{3+}$
 c) $[\text{CO}(\text{F})_6]^{3-}$ d) $[\text{CO}(\text{Cl})_6]^{3-}$
314. IUPAC name of following complex is

$$(\text{NH}_3)_4\text{Co} \begin{array}{c} \diagup \text{OH} \diagdown \\ \diagdown \text{OH} \diagup \end{array} \text{Co}(\text{en})_2\text{Cl}_4$$

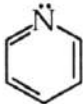
 a) Tetraamminecobalt(III), μ -dihydroxido bis (ethane-1,2-diamine) cobalt(II)chloride
 b) Tetraamminecobalt(III), μ -dihydroxido bis (ethane-1,2-diamine)cobalt(III)chloride
 c) Tetraamminecobalt(III), μ -dihydroxido bis (ethane-1,2-amine)cobalt(III)chloride
 d) Tetraamminecobalt(II), μ -dihydroxido bis (ethane-1,2-diamine)cobalt(II)chloride
315. Which of the following complex give precipitate with barium nitrate?
 a) $[\text{Co} (\text{NH}_3)_5 \text{SO}_4] \text{NO}_2$

- b) $[\text{Co}(\text{NH}_3)_5\text{SO}_4]\text{Br}$
 c) $[\text{Pt}(\text{NH}_3)_4\text{Cl}_2]\text{Br}_2$
 d) $[\text{Co}(\text{NH}_3)_5\text{NO}_2]\text{SO}_4$
316. Complex of formula $\text{CrCl}_3 \cdot 6\text{H}_2\text{O}$ when heated with cone. H_2SO_4 three moles of water are lost. The structure of the complex is
 a) $[\text{Cr}(\text{H}_2\text{O})_6]\text{Cl}_3$
 b) $[\text{Cr}(\text{H}_2\text{O})_5\text{Cl}]\text{Cl}_2\text{H}_2\text{O}$
 c) $[\text{Cr}(\text{H}_2\text{O})_4\text{Cl}_2]\text{Cl}_2\text{H}_2\text{O}$
 d) $[\text{Cr}(\text{H}_2\text{O})_3]\text{Cl}_3 \cdot 3\text{H}_2\text{O}$
317. How many geometrical isomers are possible for $[\text{Ni}(\text{en})\text{Cl}_2(\text{NO}_2)_2]^-$?
 a) 1
 b) 2
 c) 3
 d) 4
318. Which of the following complex does not show linkage isomerism?
 a) $[\text{Co}(\text{en})_3]\text{Cl}_3$
 b) $[\text{Co}(\text{NH}_3)_5\text{NO}_2]\text{Cl}_2$
 c) $[\text{Pt}(\text{NH}_3)_3\text{SCN}]\text{Cl}_2$
 d) $[\text{Co}(\text{NH}_3)_5\text{OCN}]^{2+}$
319. Cobalt (III) chloride forms several octahedral complexes with ammonia. Which of the following will not give test for chloride ions with silver nitrate at 25°C ?
 a) $\text{CoCl}_3 \cdot 3\text{NH}_3$
 b) $\text{CoCl}_3 \cdot 4\text{NH}_3$
 c) $\text{CoCl}_3 \cdot 5\text{NH}_3$
 d) $\text{CoCl}_3 \cdot 6\text{NH}_3$
320. Which of these statements about $[\text{Co}(\text{CN})_6]^{3-}$ is true?
 a) $[\text{Co}(\text{CN})_6]^{3-}$ has unpaired electrons and will be in a low-spin configuration.
 b) $[\text{Co}(\text{CN})_6]^{3-}$ has four unpaired electrons and will be in low-spin configuration.
 c) $[\text{Co}(\text{CN})_6]^{3-}$ has four unpaired electrons and will be in low-spin configuration.
 d) $[\text{Co}(\text{CN})_6]^{3-}$ has no unpaired electron and will be in high-spin configuration.

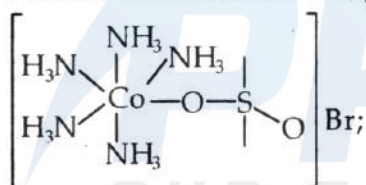
○○○

1. b)	2. d)	3. a)	4. b)	5. d)	6. b)	7. d)	8. a)	9. b)	10. a)
11. c)	12. b)	13. d)	14. c)	15. c)	16. b)	17. d)	18. c)	19. a)	20. b)
21. b)	22. b)	23. c)	24. b)	25. c)	26. b)	27. d)	28. c)	29. c)	30. c)
31. d)	32. a)	33. c)	34. c)	35. b)	36. c)	37. b)	38. d)	39. b)	40. a)
41. b)	42. c)	43. c)	44. d)	45. a)	46. b)	47. c)	48. c)	49. c)	50. b)
51. a)	52. a)	53. c)	54. c)	55. c)	56. c)	57. d)	58. c)	59. d)	60. b)
61. d)	62. d)	63. d)	64. a)	65. d)	66. c)	67. c)	68. d)	69. d)	70. d)
71. b)	72. b)	73. c)	74. d)	75. a)	76. c)	77. c)	78. b)	79. d)	80. b)
81. b)	82. b)	83. d)	84. a)	85. c)	86. a)	87. a)	88. d)	89. b)	90. d)
91. a)	92. d)	93. b)	94. a)	95. c)	96. b)	97. c)	98. c)	99. b)	100. b)
101. d)	102. b)	103. c)	104. c)	105. a)	106. c)	107. b)	108. b)	109. c)	110. d)
111. b)	112. d)	113. a)	114. c)	115. d)	116. d)	117. b)	118. a)	119. c)	120. a)
121. a)	122. c)	123. c)	124. b)	125. b)	126. c)	127. d)	128. c)	129. c)	130. b)
131. c)	132. a)	133. d)	134. c)	135. c)	136. d)	137. b)	138. b)	139. b)	140. c)
141. c)	142. b)	143. c)	144. b)	145. b)	146. c)	147. d)	148. a)	149. d)	150. b)
151. d)	152. b)	153. b)	154. a)	155. d)	156. c)	157. b)	158. a)	159. b)	160. d)
161. a)	162. d)	163. c)	164. c)	165. c)	166. b)	167. a)	168. b)	169. b)	170. c)
171. c)	172. b)	173. a)	174. d)	175. c)	176. a)	177. d)	178. a)	179. d)	180. d)
181. a)	182. d)	183. c)	184. d)	185. c)	186. a)	187. a)	188. b)	189. d)	190. b)
191. b)	192. b)	193. a)	194. b)	195. a)	196. a)	197. c)	198. c)	199. d)	200. b)
201. a)	202. c)	203. a)	204. a)	205. c)	206. c)	207. b)	208. b)	209. d)	210. c)
211. c)	212. c)	213. d)	214. a)	215. c)	216. c)	217. b)	218. b)	219. b)	220. c)
221. c)	222. d)	223. c)	224. a)	225. c)	226. c)	227. d)	228. d)	229. d)	230. d)
231. d)	232. c)	233. d)	234. b)	235. b)	236. b)	237. d)	238. c)	239. c)	240. a)
241. a)	242. d)	243. d)	244. d)	245. c)	246. c)	247. d)	248. c)	249. b)	250. b)
251. b)	252. a)	253. a)	254. c)	255. b)	256. a)	257. c)	258. c)	259. a)	260. c)
261. d)	262. d)	263. c)	264. a)	265. c)	266. c)	267. a)	268. a)	269. b)	270. a)
271. c)	272. d)	273. d)	274. c)	275. b)	276. a)	277. c)	278. a)	279. b)	280. b)
281. d)	282. b)	283. a)	284. b)	285. d)	286. b)	287. c)	288. d)	289. a)	290. d)
291. b)	292. d)	293. b)	294. c)	295. c)	296. a)	297. a)	298. a)	299. c)	300. d)
301. a)	302. a)	303. d)	304. a)	305. d)	306. b)	307. a)	308. a)	309. a)	310. b)
311. d)	312. b)	313. a)	314. b)	315. d)	316. d)	317. c)	318. a)	319. a)	320. a)

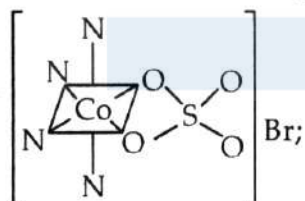
1. b)

Ligand	Number of sigma bond (s) formed by the ligand	Type of ligand
$ \begin{array}{c} \text{O}=\text{OCH}_2\text{C} \quad \quad \quad \text{CH}_2\text{COO}^- \\ \quad \quad \quad \diagdown \quad \quad \quad \diagup \\ \quad \quad \quad \text{N}-\text{CH}_2-\text{CH}_2-\text{N} \\ \quad \quad \quad \diagup \quad \quad \quad \diagdown \\ \text{O}=\text{OCH}_2\text{C} \quad \quad \quad \text{CH}_2\text{COO}^- \\ \text{(EDTA)} \end{array} $	6	Hexadenate
$\text{H}_2\ddot{\text{N}}-\text{CH}_2-\text{CH}_2-\ddot{\text{N}}\text{H}_2$	2	Bidentate (or didenate)
CH_3COO^-	1	Unidentate
	1	Unidentate

2. d) Ethylenediamine is always a didentate ligand, but SO_4^{2-} ion can act both as monodentate as well as didentate ligand. This is clear from the following example:



SO_4^{2-} as monodentate ligand



SO_4^{2-} as didentate ligand

3. a) $\text{Na}[\text{PtBrCl}(\text{NO}_2)(\text{NH}_3)]$

Let x = oxidation state of Pt.

$$\therefore 1(+1) + x + 1(-1) + 1(-1) + 1(-1) + 1(0) = 0 \quad \text{or} \quad x = +2$$

4. b) $\text{O}_2[\text{PtF}_6]$ can be written as $\text{O}_2^+[\text{PtF}_6]^-$. The oxidation state of Pt in this compound is +5. Let x = oxidation state of oxygen. Here oxidation state of F = -1.

$$2x + 5 + 6(-1) = 0$$

$$x = +1/2$$

5. d) Coordination number of the central is equal the number of sigma (s) bond formed by the ligands with the central metal atom. Since all the ligands are monodentate (or Unidentate),

therefore, the coordination number is equal to the number of ligands surrounding the central metal. Here the C.N. 6.

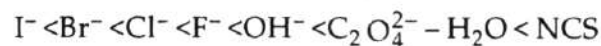
Let x = O.N. (or oxidation number) of central Co ion.

$$x + 1(0) + 2(0) + 2(-1) = +1 \quad \text{or} \quad x = +3$$

6. b) (CN) are linked with secondary valency.
7. d) The oxidation state of central metal is +2. The electronic configuration of Fe^{2+} (atomic number = 26) is



8. a) A list of ligands arranged in the order of increasing value of Dq (i.e., in the order of their abilities to split the d-orbital energies) is:



Halide ions and OH^- are weak- field ligands, because they split the d-orbitals to a lesser extent.

9. b) NH_3 is a neutral ligand ; CO_3^{2-} ion has a charge of -2; Cl^- ion also has a charge of -1, so the oxidation of chromium is +3.

$$x + 5(0) + 1(-2) + 1(-1) = 0 \quad \text{or} \quad x = +3$$

The cation is named before the anion. Within a complex ion, the ligands are named first in alphabetical order, irrespective of the nature of ligands. The name of anionic ligands ends in the letter 'o'. Special names are given to NH_3

A numerical prefix 'penta' is used to indicate five molecules of NH_3 . Numerical prefixes do not determine the alphabetical order of ligands. The oxidation state of the metal is written in Roman numerals, following the name of metal and is enclosed in parenthesis. Hence, the name of this coordination compound is pentaamminecarbonatochromium (III) chloride.

10. a) Each potassium ion has a charge of +1. There are six CN^- ions as ligands. So the oxidation state of chromium is +3 or $x = +3$.

A Greek prefix "hexa" is used to indicate six CN^- ligands. Since the anion is complex, the name of complex anion ends in -ate. The suffix '-ate' is often added to the Latin stem. Therefore, the name of this complex compound is, potassium hexacyanochromate (III).

11. c) The complex cation has central metal, Co with an oxidation state of +3. This complex cation consists of four neutral NH_3 groups, one neutral H_2O molecule, and one NCS^- ion.

Let x = charge on the complex cation.

$$\therefore x = 3 + 4(0) + 1(0) + 1(-1) = -2.$$

This indicates that there must be two Cl^- as anions. Hence, the formula of this complex compound is $[\text{Co}(\text{NCS})(\text{H}_2\text{O})(\text{NH}_3)_4]\text{Cl}_2$.

Note : Since NH_3 and H_2O are cited respectively at N and H, so H_2O comes before NH_3 in the formula. Hence, $[\text{Co}(\text{NCS})(\text{NH}_3)_4(\text{H}_2\text{O})]\text{Cl}_2$ is not the correct formula for the above compound.

12. b) NH_3 (Ammine) is a neutral ligand with zero charge and named "ammine."

13. d) The coordination entity has four chloride ions, each having a charge of -1, two neutral NH_3 groups, and platinum metal with an oxidation state of +4.

Let x = charge on coordination entity.

$$\therefore 4(-1) + 2(0) + 4 = x \quad \text{or} \quad x = 0$$

This shows that the coordination entity is not an ion and hence, the formula of the tetrachlorodiammine platinum (IV) is $[\text{Pt}(\text{NH}_3)_2\text{Cl}_4]$.

Note : In the formula of a coordination entity, the symbol of the central atom(s) is placed first, followed by ionic ligands and then the neutral ligands. The order of citation of central atoms is decided by the use of alphabetical order of the element symbols. Ligands are cited alphabetically with in each

recommendations 1990. Therefore, the formula of above compound should be written as $[\text{PtCl}_4(\text{NH}_3)_2]$ and not as $[\text{Pt}(\text{NH}_3)_2\text{Cl}_4]$.

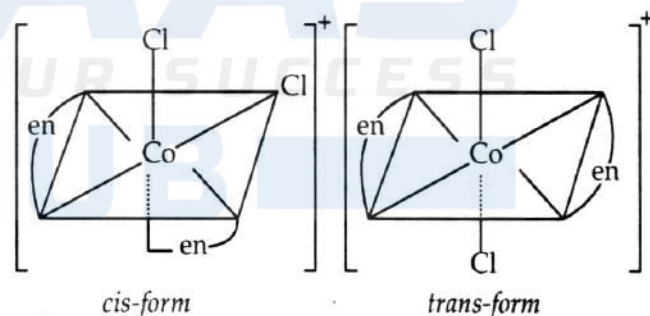
14. c) Compounds (I) and (II) both contain complex cation and anion, so they show coordination isomerism.

Compounds (III) and (IV) are obtained by the interchange of groups outside the coordination sphere and the ligands within the coordination sphere. Therefore, they give different ions in the solution. Hence, they show ionization isomerism.

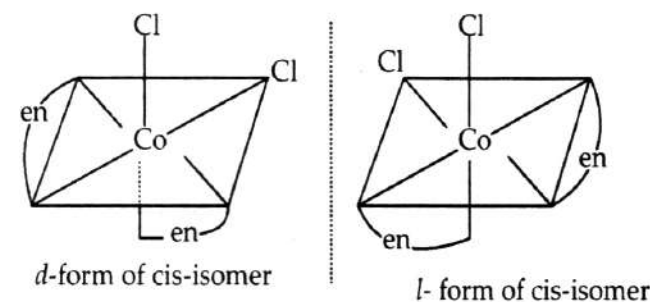
Compounds (V) and (VI) are linkage isomers, because the ambident ligand, SCN has two donor atoms, i.e., it has two possibilities of attachment (SCN and NCS) with the central metal. Hence, they show linkage isomerism.

Compounds (VII) and (VIII) are obtained by the replacement of a coordinated group such as Cl^- by water of hydration. Hence, they show hydrate isomerism.

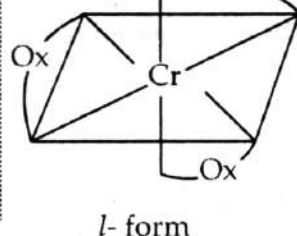
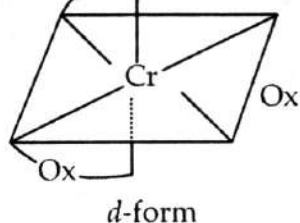
15. c) Octahedral complexes of the type $[\text{M}(\text{aa})_2 \text{x}_2]$ (where x = monodentate ligand and (aa) = didentate ligand) exhibit both cis-trans isomerism and optical isomerism.



Since cis-form has non-superimposable mirror image, so it also show optical isomerism.



16. b) The anion of the compound (B) is $[\text{Cr}(\text{C}_2\text{O}_4)_3]^{3-}$ or $[\text{Cr}(\text{ox})_3]^{3-}$, where $\text{ox} = \text{C}_2\text{O}_4^{2-}$. Since such octahedral complexes have non-superimposable mirror images, so they show optical isomerism.



[Ni(H₂O)₄(NH₃)₂]²⁺.

d⁸ arrangement in Ni (II) compounds with strong field ligands also form square planar complexes such as [Ni(CN)₄]²⁻.

Several tetrahedral Ni (II) complexes are known containing, generally, halide ligands such [Ni(Cl₄)]²⁻.

17. d) [Co(NO₂)(SCN)(en)₂]Br is an octahedral complex of the type [Mxy (aa)₂]. This type of octahedral complexes show geometrical isomerism.

Since the group Br⁻ outside the coordination can be interchanged with the ligands, so it gives different ions in the solution and hence, this compound will also show ionization isomerism.

Since the coordination sphere of the complex ion has ambident ligands such as SCN and NO₂, therefore, the compound would also show linkage isomerism.

18. c) The complex ion [MBr₂Cl₂]²⁺ shows geometrical isomerism. The geometrical isomers are :

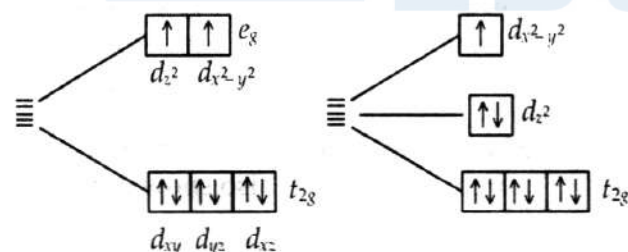
- i) cis - [MBr₂Cl₂]SO₄
- ii) trans- [MBr₂Cl₂]SO₄

The compound also shows ionization isomerism. The ionization isomers are :

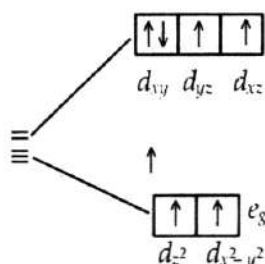
- i) [MBr₂(SO₄)]Cl₂
- ii) [MCl₂(SO₄)]Br₂
- iii) [MBrCl(SO₄)] BrCl

Thus, a total of five isomers are formed.

19. a) In Ni (II) compounds, Ni has configuration of 3d⁸ 4s⁰.



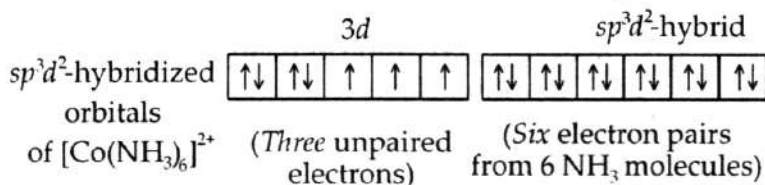
(d⁸ arrangement in weak and strong octahedral field)



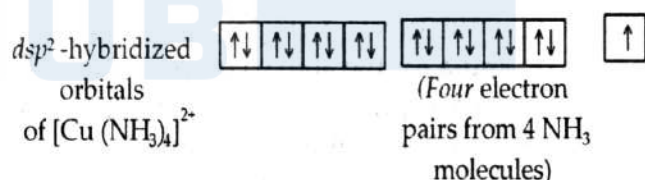
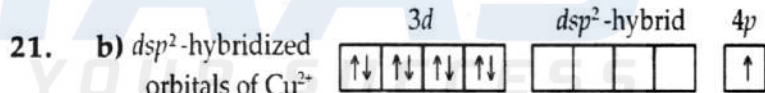
(d⁸ arrangement in tetrahedral field)

d⁸ arrangement in Ni (II) compounds with weak octahedral field forms octahedral

20. b) The complex ion is high spin, i.e., the electrons are arranged so that they remain unpaired as much as possible. This can be possible, if the d-orbitals involved are from higher energy shell than from ns and np-orbitals. In other words, in a high spin complex, (n - 1) d-orbitals are not involved in the hybridization.



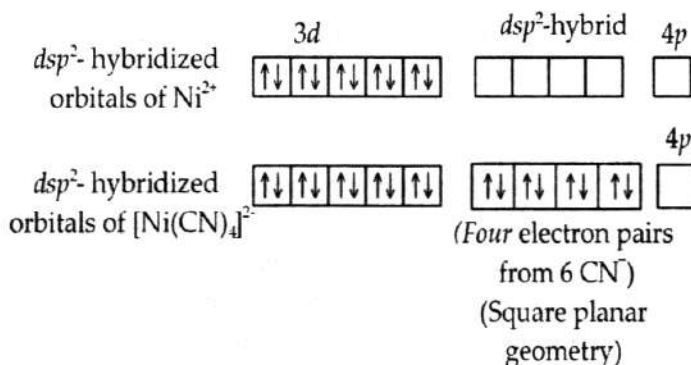
High spin complexes always have more magnetic moment than low spin complexes. On the other hand, [Co(CN)₆]³⁻ is referred to as low spin complex, because the electrons are arranged so that they remain paired as much as possible. In this case, d-orbitals involved in hybridization scheme are from lower energy shell than ns and np-orbitals.



22. d) K₄[Fe(CN)₆] → 4K⁺ + [Fe(CN)₆]⁴⁻
Complex has negative charge so it is anionic complex.

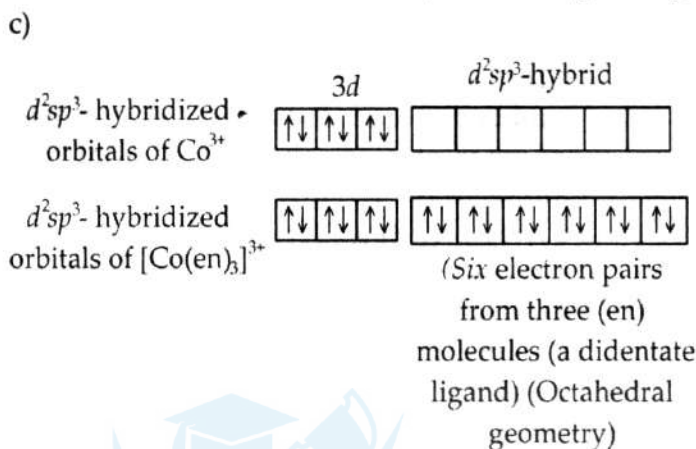
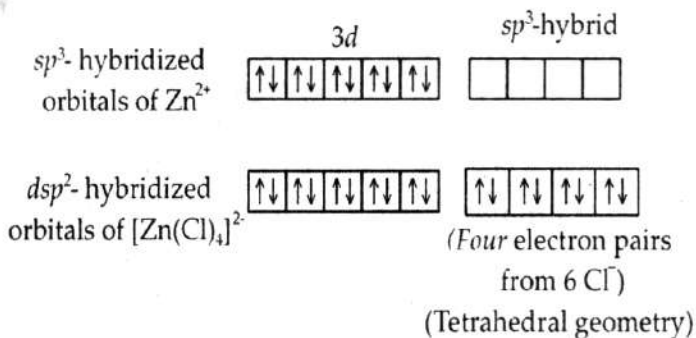
23. c) Number of ligand bonded with central metal ion known as coordination number.

24. b)
a)

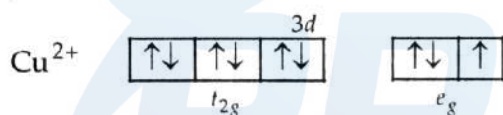


energy. Hence, electrons are paired in lower energy d-orbitals.

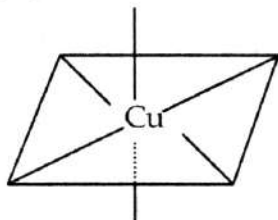
Complex salt	Oxidation state of central metal ion
$K_4[Fe(CN)_6]$	+ 2
$K_3[Cr(CN)_6]$	+ 3
$K_3[Co(CN)_6]$	+ 3
$K_2[Ni(CN)_4]$	+ 2



d) In $[Cu(NO_2)_6]^{4-}$ ion, copper is present as Cu^{2+} . The electronic configuration of Cu^{2+} ion is

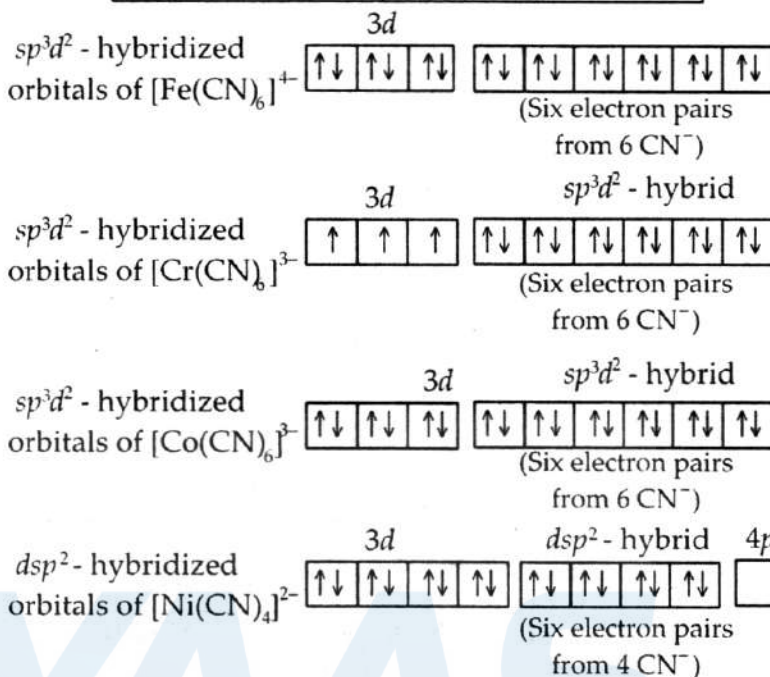


The two e_g orbitals are normally degenerate. However, if they are asymmetrically filled, then this degeneracy is destroyed, and two e_g orbitals are no longer equal in energy. As a result, e_g level would suffer John-Teller tetragonal distortion, because the d_{z^2} orbital contains two electrons (d_{z^2} , $d_{x^2-y^2}$), the ligands approaching along the +z and -z directions are prevented from coming as close to the copper as those approaching along +x, -x, +y and -y. As a result, tetragonally distorted octahedral complex, $[Cu(NO_2)_6]^{4-}$ has four short bonds in a square planar rearrangement, and two trans bonds.



25. c) Number of donor atoms (N) in $N(CH_2CH_2NH_2)_3$ is four. So, $N(CH_2CH_2NH_2)_3$ is a tetradentate ligand.

26. b) In all these complexes, CN^- is a strong-field ligand and therefore, the crystal field splitting [D] is much larger than spin-pairing

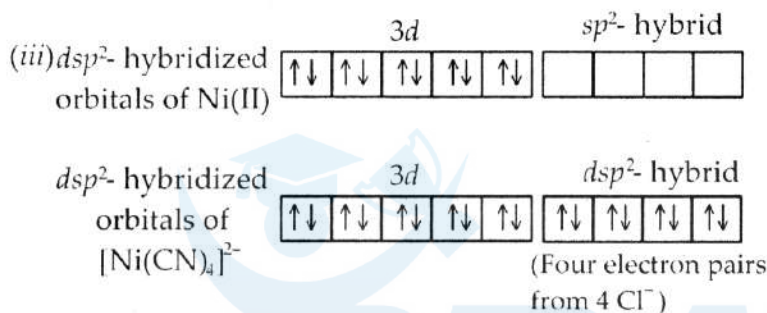
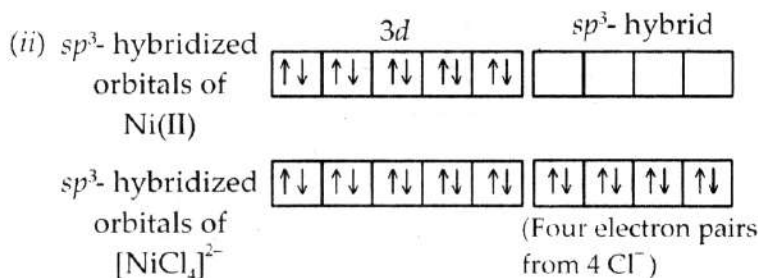
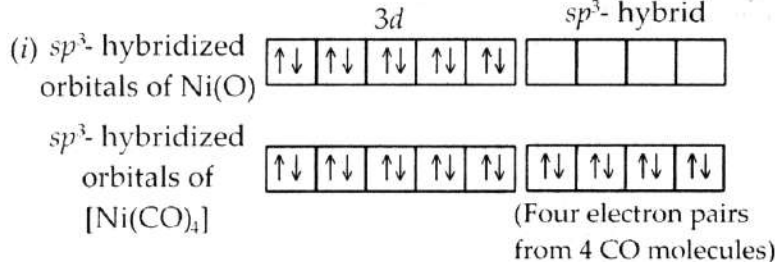


	Complex salt	Number of unpaired electrons	Magnetic character
1.	$K_4[Fe(CN)_6]$	0	Diamagnetic
2.	$K_3[Cr(CN)_6]$	3	Paramagnetic
3.	$K_3[Co(CN)_6]$	0	Diamagnetic
4.	$K_2[Ni(CN)_4]$	0	Diamagnetic

27. d) Water is a weak-field ligand, so the crystal field splitting (Δ) is smaller than spin-pairing energy. Hence, electrons are not paired in lower energy d-orbitals (i.e., no pairing of electrons in d-orbitals occurs against the Hund's rule).

	Species	O.S of metal	E.C of No. of unpaired	
			metal ion	electrons
a)	$[Cr(H_2O)_6]^{3+}$	+ 3	$Cr^{3+} (3d^3)$	3
b)	$[Fe(H_2O)_6]^{2+}$	+ 2	$Fe^{2+} (3d^6)$	4
c)	$[Cu(H_2O)_6]^{2+}$	+ 2	$Cu^{2+} (3d^9)$	1
d)	$[Zn(H_2O)_6]^{2+}$	+ 2	$Zn^{2+} (3d^{10})$	0

The more the number of unpaired electrons, the higher is the paramagnetic character of the metal ion. As a result, $[Fe(H_2O)_6]^{2+}$ has the highest paramagnetism.



Complex salt	Number of unpaired electrons	Magnetic character
i. $[\text{Ni}(\text{CO})_4]^0$	0	Diamagnetic
ii. $[\text{NiCl}_4]^{2-}$	2	Paramagnetic
iii. $[\text{Ni}(\text{CN})_4]^{2-}$	0	Diamagnetic

29. c) In octahedral complexes, the central metal may involve either inner $(n-1)$ d-orbitals or outer nd-orbitals for hybridization. If the complex formed uses inner d-orbitals [i.e., $(n-1)$ d-orbitals] for hybridization (written as d^2sp^3 , it is called inner orbital complex. On the other hand, if the complex formed uses outer d-orbitals for hybridization (written as sp^3d^2), it is called an outer orbital complex.

45. a) In π acid ligand back bonding also take place which in value filled orbitals of metal and vacant orbitals of ligand this is synergic effect.

50. b) The oxidation state of metal in metal carbonyl is zero.

51. a) In complex $\text{K}_4[\text{Fe}(\text{CN})_6]$ the Fe obey EAN rule strictly. [EAN = 36(Kr)]

52. a) $\text{Ni}(\text{CO})_4$ has O.N. zero for Ni.

77. c) Both cyanide ions have two π bonds.

100. b) $\text{CrO}_2\text{Cl}_2, \text{MnO}_4^-$.

conductivity also increases.

1 mole of $[\text{Pt}(\text{NH}_3)_2\text{Cl}_2]$ gives one mole of ions

1 mole of $[\text{Co}(\text{NH}_3)_4\text{Cl}_2]\text{Cl}$ gives two mole of ions

1 mole of $\text{K}_4[\text{Fe}(\text{CN})_6]$ gives five moles of ions

1 mole of $[\text{Fe}(\text{CO})_5]$ gives zero moles of ions

(because it is a neutral molecule)

Hence $\text{K}_4[\text{Fe}(\text{CN})_6]$ has the highest molar conductivity.

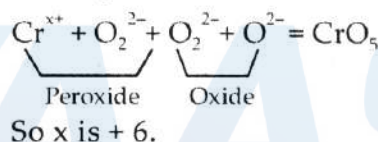
114. c) Atomic number of krypton = 36

Effective atomic number (EAN) = atomic number of electrons lost in ion formation + number of electrons gained from the donor atoms of the ligands.

EAN of $\text{Na}_4[\text{Fe}(\text{CN})_6] = 26 - 2 + 12 = 36$

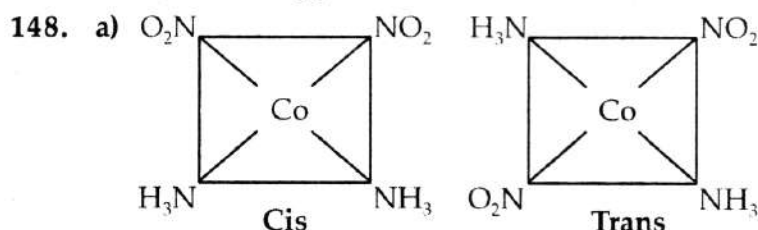
123. c) Primary valency corresponds to oxidation number and secondary valency represents the coordination number of the metal in a coordination compound. Therefore in complex dichlorodioxalatochromium (III), the primary valency is 3 and secondary valency is 6.

124. b) It comprises of the following things.



125. b) By applying the EAN rule, the stability of metal carbonyls can be predicted. All the given metal carbonyls except $\text{Mn}(\text{CO})_5$ follow the EAN rule and thus, it exists as dimer $\text{Mn}_2(\text{CO})_{10}$.

128. c) $Z - 3 + 12 = 33 \Rightarrow Z = 24$



168. b) Because it will not give any ions in solution.

169. b) Magnetic moment of $[\text{Cu}(\text{NH}_3)_4]^{2+}$ ion is 1.73 due to the presence of one unpaired electron.

187. a) Due to the presence of one unpaired electron, both are slightly paramagnetic.

189. d) 1. $[\text{Cu}(\text{NH}_3)_4] \cdot [\text{PtCl}_4]$
 2. $[\text{Cu}(\text{NH}_3)_3\text{Cl}] \cdot [\text{PtCl}_3(\text{NH}_3)]$
 3. $[\text{Cu}(\text{NH}_3)_2\text{Cl}_2] \cdot [\text{PtCl}_2(\text{NH}_3)_2]\text{cis}$
 4. $[\text{Cu}(\text{NH}_3)_2\text{Cl}_2] \cdot [\text{PtCl}_2(\text{NH}_3)_2]\text{Trans}$
 5. $[\text{Cu}(\text{NH}_3)_3\text{Cl}] \cdot [\text{PtCl}(\text{NH}_3)_3]$
 6. $[\text{Pt}(\text{NH}_3)_4\text{Cl}] \cdot [\text{CuCl}_4]$

201. a) $[\text{Co}(\text{NH}_3)_3\text{Cl}_3]$ does not have optical isomers because it is of formula MA_3B_3 which does not show optical isomerism.

202. c) Change in composition of co-ordination sphere yield ionisation isomers.

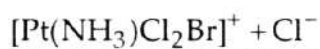


203. a) As $[\text{Co}(\text{NH}_3)_3\text{Cl}_3]$ does not lose any Cl^- ions in the solution so it will not give ppt. with AgNO_3 .

227. d) It has four solvate isomers

1. $[\text{Cr}(\text{H}_2\text{O})_6]\text{Cl}_3$
2. $[\text{Cr}(\text{H}_2\text{O})_5\text{Cl}]\text{Cl}_2 \cdot \text{H}_2\text{O}$
3. $[\text{Cr}(\text{H}_2\text{O})_4\text{Cl}_2]\text{Cl} \cdot 2\text{H}_2\text{O}$
4. $[\text{Cr}(\text{H}_2\text{O})_3\text{Cl}_3] \cdot 3\text{H}_2\text{O}$

237. d) $[\text{Pt}(\text{NH}_3)\text{Cl}_2\text{Br}]\text{Cl} \rightleftharpoons$



Cl^- ion is precipitable.

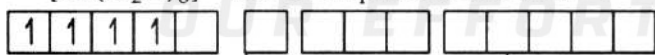
246. c) When coordinate compounds give different ions in solution then it produces ionic isomerism while this situation is not present in $[\text{Co}(\text{en})_2\text{Cl}_2]\text{Cl}$

257. c) $[\text{Fe}(\text{H}_2\text{O})_6]^{2+}$ no. of unpaired electron = 4



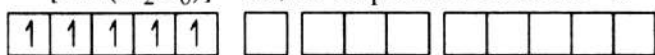
sp^3d^2

$[\text{Cr}(\text{H}_2\text{O})_6]^{2+}$ no. of unpaired electron = 4



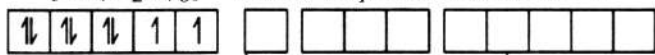
sp^3d^2

$[\text{Mn}(\text{H}_2\text{O})_6]^{2+}$ no. of unpaired electron = 5



sp^3d^2

$[\text{Ni}(\text{H}_2\text{O})_6]^{2+}$ no. of unpaired electron = 2



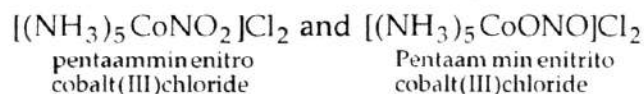
sp^3d^2

Paramagnetic behaviour will be minimum if no. of unpaired electron will be minimum.

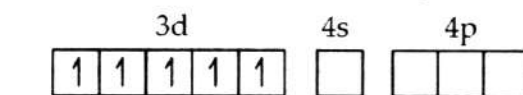
268. a) $[\text{Fe}(\text{NO}_2)_3\text{Cl}_3]$ and $[\text{Fe}(\text{ONO})_3\text{Cl}_3]$ show linkage isomerism. This type of isomerism is shown by the complexes in which an ambidentate ligand is present.

NO_2^- , SCN^- , CN^- etc. are ambidentate ligand as each of them contain more than one donor sites. In the linkage isomerism, at a time only one donor atom of ligand is bonded to metal atom and hence arises linkage isomerism.

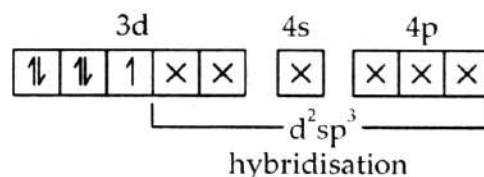
270. a) NO_2^- may be bonded to metal through nitrogen (nitro) or through oxygen (nitrito). Hence NO_2^- can participate in linkage isomerism.



273. d) Valence shell electronic configuration of Fe^{3+} :



$[\text{Fe}(\text{CN})_6]^{2-}$:



CN^- is a strong field ligand, so it forms low spin complexes after pairing of electrons within 3d level.

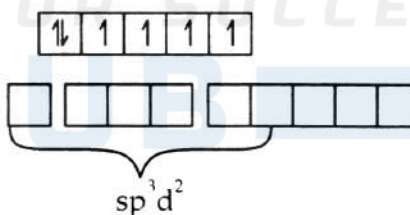
$$\text{Magnetic moment} = \sqrt{n(n+2)} \text{ B.M.}$$

$$= \sqrt{1(1+2)} \text{ B.M.}$$

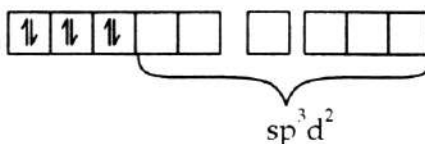
$$= 1.73 \text{ B.M.}$$

274. c) Cr^{3+} in the complex has unpaired electrons in the d orbital.

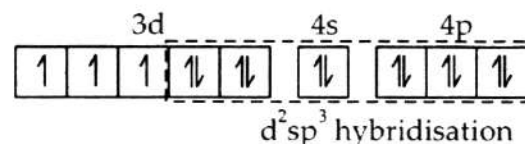
275. b) F^- is a weak-field ligand and $[\text{FeF}_6]^{3-}$ is an outer-orbital complex.



CNS^- is a strong-field ligand and $[\text{Fe}(\text{CNS})_6]^{3-}$ is an inner-orbital complex.



277. c) In case of d^3 configuration, the number of unpaired electrons remains 3 whether the ligand is strong field or weak field. The hybridisation scheme can be shown as follow $[\text{Cr}(\text{NH}_3)_3]^{3+} =$



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

