

COORDINATION COMPOUNDS

↳ TARGET 100
↳ these notes have been verified by top faculties of India & CBSE Science Toppers 2020

↳ As per the latest syllabus
↳ Previous year Qs have been Integrated

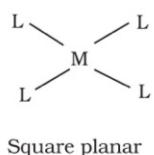
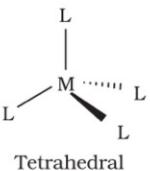
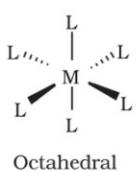
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Raman Shattaud

Flow Chart

IUPAC Nomenclature



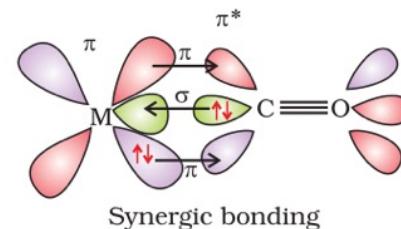
Addition Comp.

Double comp.

Complex comp.

Terminology related to Coordination Compounds

Coordination entity	Wavelength of light absorbed (nm)	Colour of light absorbed	Colour of coordination entity
$[\text{CoCl}(\text{NH}_3)_5]^{2+}$	535	Yellow	Violet
$[\text{Co}(\text{NH}_3)_5(\text{H}_2\text{O})]^{3+}$	500	Blue Green	Red
$[\text{Co}(\text{NH}_3)_6]^{3+}$	475	Blue	Yellow Orange
$[\text{Co}(\text{CN})_6]^{3-}$	310	Ultraviolet	Pale Yellow
$[\text{Cu}(\text{H}_2\text{O})]^{2+}$	600	Red	Blue
$[\text{Ti}(\text{H}_2\text{O})_6]^{3+}$	498	Blue Green	Purple



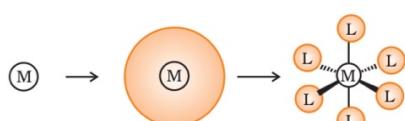
Coordination Compounds

Bonding in Coordination compounds

Werner's Theory

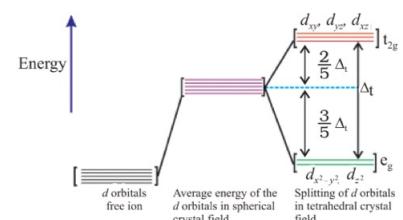
Bonding in Metal Carbonyl

Valence Bond Theory



Crystal Field Theory

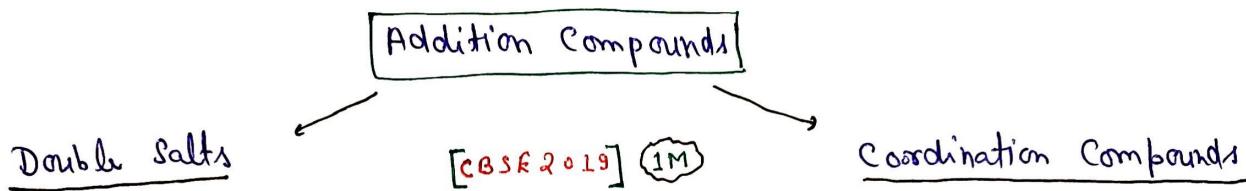
Octahedral Complex



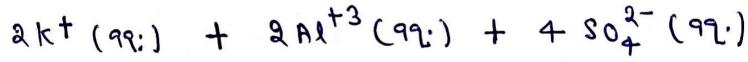
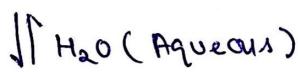
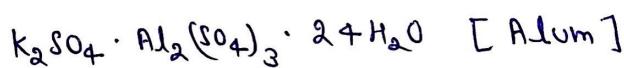
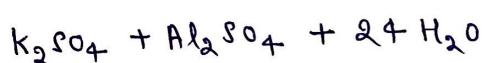
Tetrahedral Complex

Co-ordination Compounds

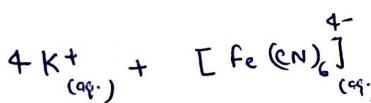
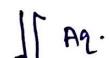
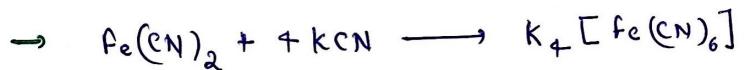
Addition Compounds :- They are formed by the combination of two or more stable compounds in stoichiometric ratio.



Compounds which lose their identity in solution are called double salts.



→ Compounds which does not lose their identity in solution are called coordination compound.



Terminology related to Co-ordination Compounds :-

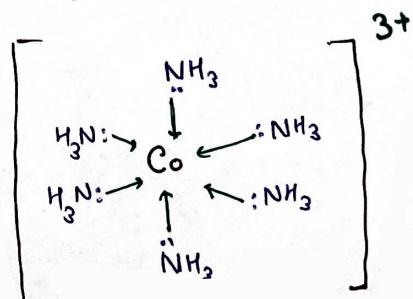
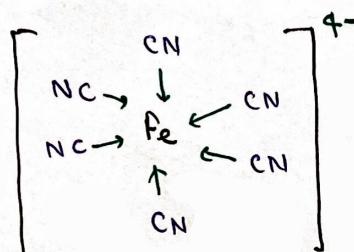
9.) Co-ordination Entity :- The central atom/ion and the ligands attached to it are enclosed in square brackets are collectively known as co-ordination entity or co-ordination sphere.

Ligand :- The donor atoms, ions or molecules which donate a pair of electrons to the central metal atom/ion are called ligands.

For example → $[Fe(CN)_6]^{4-}$, $[Co(NH_3)_6]^{3+}$

Here Fe is a central metal and CN^- is a ligand.

Here Co is central metal and NH_3 is a ligand.

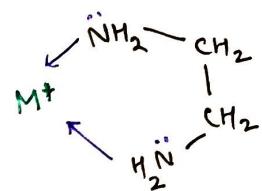


b.) Denticity :— The no. of donor atoms present in a ligand, is called denticity of ligand.

→ Unidentate :— Only one donor atom [Cl^- | NH_3 | H_2O etc.]

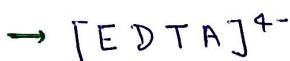
→ Bidentate / didentate -: When a ligand can bind through two donor atoms

For example → Ethane-1,2-diamine $\left[\text{NH}_2-\overset{1}{\text{CH}_2}-\overset{2}{\text{CH}_2}-\text{NH}_2 \right]$
 or
 Ethylenediamine [en]



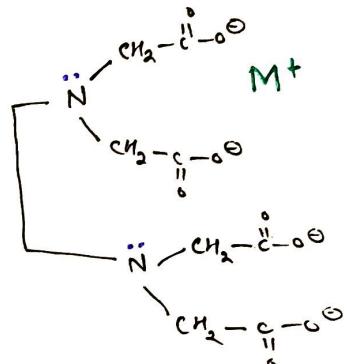
→ Polydentate : More than two donor atoms.

for example → Ethylene diamine tetra - acetate ion



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→ It can bind through two nitrogen and four oxygen atoms to a central metal ion.



c.) Ambidentate Ligand :- Unidentate ligands containing more than one co-ordinating atoms are ambidentate ligands.

For example → $M \leftarrow N\overset{O}{=}$
nitrito- N

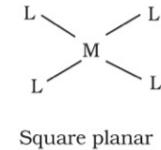
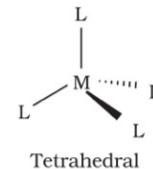
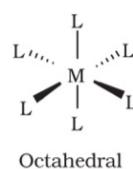
$$M \leftarrow O-N^{\ddagger\ddagger} ; \quad M \leftarrow SCN \quad M \leftarrow Ncs$$

nitrito- O thiocyanato isothiocyanato

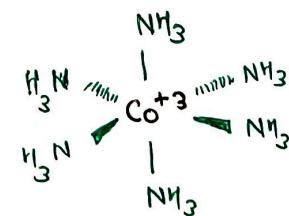
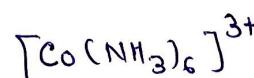
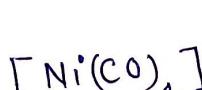
d.) Co-ordination Number :- The no. of ligand donor atoms to which the metal is directly bonded.

for example $\rightarrow [PtCl_6]^{2-}$: C.N. \Rightarrow 6

$$[\text{Ni}(\text{NH}_3)_4]^{2+} : \text{C.N.} \Rightarrow 4$$



e.) Co-ordination Polyhedron :- The spatial arrangement of the ligand atoms which are directly attached to the central atom/ion defines a co-ordination polyhedron about the central atom.



f.) Homoleptic and Heteroleptic Complexes :-

→ Complexes in which a metal is bound to only one kind of donor groups are known as homoleptic.

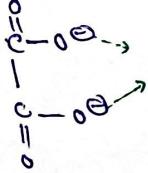
For example → $[\text{Co}(\text{NH}_3)_6]^{3+}$

→ Complexes in which a metal is bound to more than one kind of donor groups are known as heteroleptic complex.

For example → $[\text{Co}(\text{NH}_3)_4\text{Cl}_2]^+$

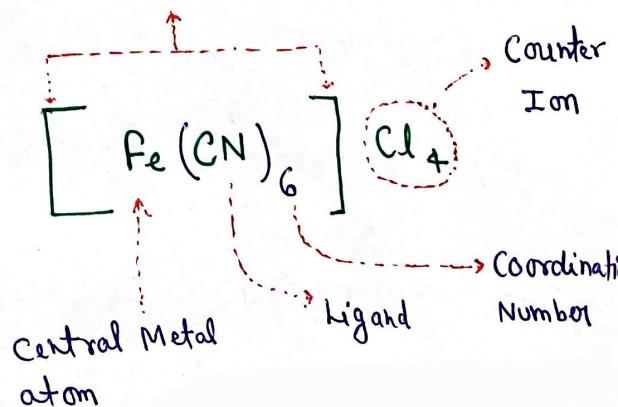
Abhi Koksha

→ Formula IUPAC Name

 or $\text{C}_5\text{H}_5\text{N}$	Pyridine	No	Nitrosyl
NH_3	Amine	NO_2^-	Nitro
H_2O	Aqua	ONO^-	Nitrito-o
CO	Carbonyl	NH_2^-	Amido
$\text{R}-\text{NH}_2$	Alkylamine		Oxalato [OX]
Cl^-	Chlorido		Hydroxo.
Br^-	bromido	OH^-	
CN^-	cyanido / Cyano	Coordination sphere / entity	
CO_3^-	Carbonato	Counter Ion	
SCN^-	Thiocyanato	Central Metal atom	
NCS^-	Isothiocyanato	Ligand	

g.) Oxidation No. of central atom :-

Oxidation no. of CA + sum of charge on total ligands = charge on co-ordination sphere



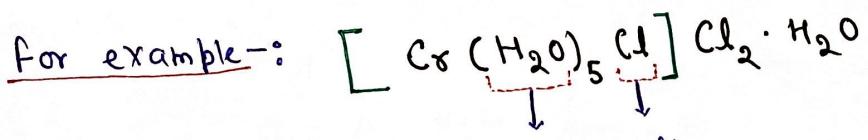
→ $[\text{Cu}(\text{NH}_3)_4]^{2+}$: oxidation no. of Cu ??

$$x + + (\text{charge on } \text{NH}_3) = 2$$

$$x + 4 \times 0 = 2 \text{ then } x = +2$$

Nomenclature of Co-ordination Compounds

- Rules for writing formula of mononuclear co-ordination complexes :-
- Formula of Cation [simple or complex] is written first.
 - Co-ordination entity is enclosed in square bracket.
 - In coordination sphere, metal atom is written first, followed by ligands in alphabetical order of their names.
 - In abbreviated ligands [like en, ox] → first letter of abbreviation is considered.
 - When ligands are polyatomic, their formulas are enclosed in parenthesis.
for example → (SCN) , (PPh_3) etc.
 - There should be no space between the ligands and the metal.
 - For charged coordination entity - : charge is indicated outside the square brackets as a right superscript with the no. before the sign.
for example → $[\text{Co}(\text{CN})_6]^{3-}$, $[\text{Cr}(\text{H}_2\text{O})_6]^{3+}$ etc.
 - The charge of the cation is balanced by the charge of anion.



Alphabetical order :
Aqua > Chloro

Rules for naming of mononuclear co-ordination compounds →

- a.) Complex cation is named first followed by anion (if present).
- b.) The ligands are named in alphabetical order before the name of metal atom/ion.
- c.) Names of anionic ligands end in -o. [for example → cyano | chlorido].
Neutral ligands have no special ending [$\text{H}_2\text{O} \rightarrow \text{Aqua}$, $\text{NH}_3 \rightarrow \text{ammine}$].
Positive ligands end in -ium. [$\text{NO}^+ : \text{Nitrosonium}$]

- d.) Prefixes mono, di, tri... are used to indicate the number of the individual ligands.

→ When the names of ligands include a numerical prefix, then terms, bis, tris, tetrakis are used, the ligand to which they refer being placed in parenthesis.

- e.) Oxidation state of metal is indicated by Roman numerical in parenthesis.

f.) If complex ion is a cation, the metal is named same as the element.

→ If complex ion is an anion, the name of the metal ends with suffix -ate.

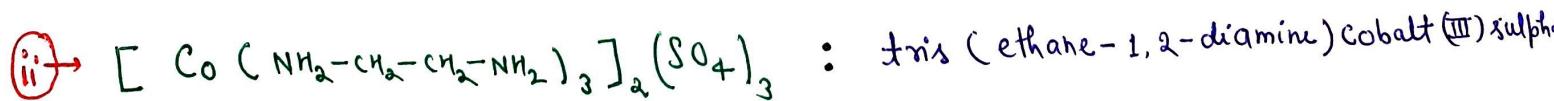
→ The neutral complex molecule is named similar to that of the complex cation.



$$\text{Oxidation no. of Cr} + 3(\text{charge on } \text{NH}_3) + 3(\text{charge on } \text{H}_2\text{O}) + 3(\text{charge on Cl}) = 0$$

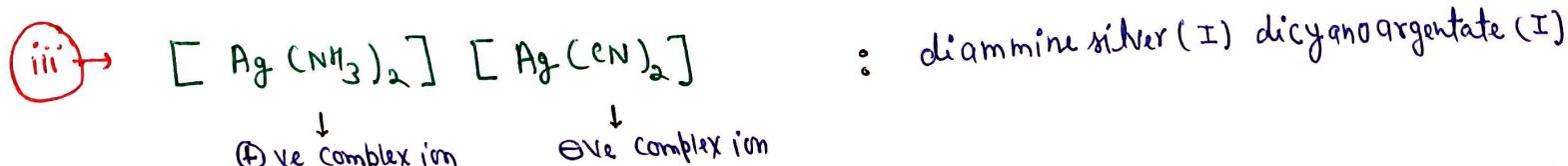
$$\rightarrow \text{Oxidation no. of Cr} + 3 \times 0 + 3 \times 0 + 3 \times -1 = 0$$

$$\rightarrow \text{Oxidation no. of Cr} = +3$$



$$\rightarrow 2(x + 3 \times 0) + 3(-2) = 0$$

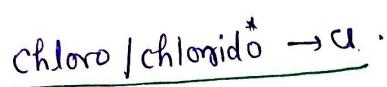
$$\rightarrow \boxed{x = +3}$$





$$\rightarrow x + 4(0) = 0 \text{ then } x = 0$$

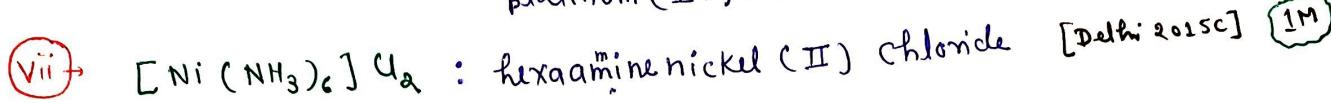
Potassium hexacyanoferrate (II).



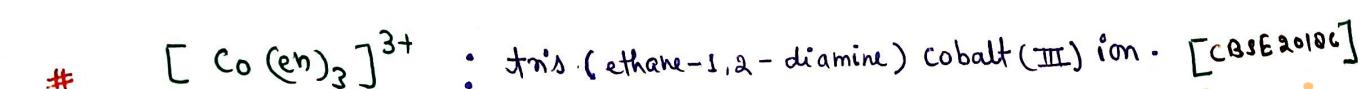
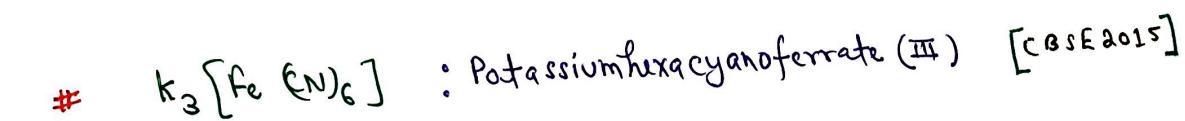
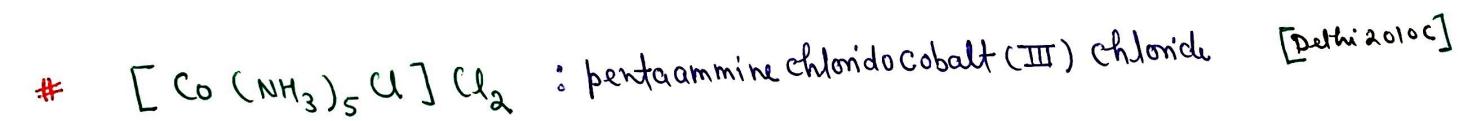
[CBSE 2015] 1M

$$4(+1) + x + 6(-1) = 0$$

$$\text{then } x = +2$$



[Delhi 2011C]



$[\text{Co}(\text{NH}_3)_5(\text{NO}_2)]^{2+}$: Pentaammine nitro-N cobalt (III) ion.

$[\text{Pt}(\text{NH}_3)_2\text{U}_2]$: Diammine dichlorido platinum (II).

→ co-ordination No → 4

→ oxidation state → +2

$[\text{Co}(\text{COO}^-)_3]^{3-}$: Trioxalato cobaltate (III) ion.

$[\text{Cr}(\text{CO})_6]$: Hexacarbonyl chromium (0).

$[\text{PtCl}_3(\text{C}_2\text{H}_4)]$: Trichlorido ethene platinum (IV)

$[\text{CoBr}_2(\text{en})_2]^+$: Dibromido bis(ethane-1,2-diamine) Cobalt (III) ion. [Delhi 2013]

$\text{K}_3[\text{Fe}(\text{C}_2\text{O}_4)_3]$: Potassium trioxalato ferrate (III) ion. [Delhi 2013C]

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$[\text{Pt}(\text{NH}_3)_6]\text{U}_4$: Hexaamine platinum (IV) chloride. [Delhi 2013C]

$[\text{Cr}(\text{C}_2\text{O}_4)_3]^{3-}$: Trioxalato chromate (III) ion

$[\text{Co}(\text{en})_2\text{U}_2]^+$: Dichlorido bis(ethane-1,2-diamine) Cobalt (III) ion

→ Hexaamine cobalt (III) sulphate : $[\text{Co}(\text{NH}_3)_6]_2(\text{SO}_4)_3$

Potassium trioxalato chromate (III) : $\text{K}_3[\text{Cr}(\text{C}_2\text{O}_4)_3]$

Potassium trioxalato aluminate (III) : $\text{K}_3[\text{Al}(\text{C}_2\text{O}_4)_3]$

Dichlorido bis(ethane-1,2-diamine) cobalt (III) ion : $[\text{CoCl}_2(\text{en})_2]^+$

→ [CBSE 2014] 3M

→ [Delhi 2019] 2M

→ [CBSE 2017] 2M

→ Pentaaminenitrito-o-Cobalt (III) ion : $[\text{Co}(\text{NH}_3)_5(\text{ONO})]^{2+}$

Delhi 2015

(1M)

→ Sodiumdicyanidoaurate(I) : $\text{Na}[\text{Au}(\text{CN})_2]$

Delhi 2017

2M

→ Tetraamminechloridonitrito-N - platinum (IV) sulphate : $[\text{Pt}(\text{NH}_3)_4\text{U}(\text{NO}_2)]\text{SO}_4$

→ Mercury tetrathiocyanatocobaltate (III) : $\text{Hg}[\text{Co}(\text{SCN})_4]$

→ Potassium trioxalato aluminate (III) : $\text{K}_3[\text{Al}(\text{C}_2\text{O}_4)_3]$

→ Potassium tetrahydroxozincate (II) : $\text{K}_2[\text{Zn}(\text{OH})_4]$

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Bonding in Co-ordination Compounds

Werner's Theory

Valence Bond Theory

Crystal Field Theory

Werner's Theory :— Werner was the first to formulate his idea about the structures of co-ordination compounds. The main postulates are →

- i) In coordination compounds metals show two types of valency → primary and secondary.
- ii) The primary valences are normally ionisable and are satisfied by negative ions.
- iii) The secondary valences are non-ionisable. These are satisfied by neutral molecules or negative ions.
- iv) The ions/groups bound by secondary valency to metal have spatial arrangements corresponding to different coordination numbers.

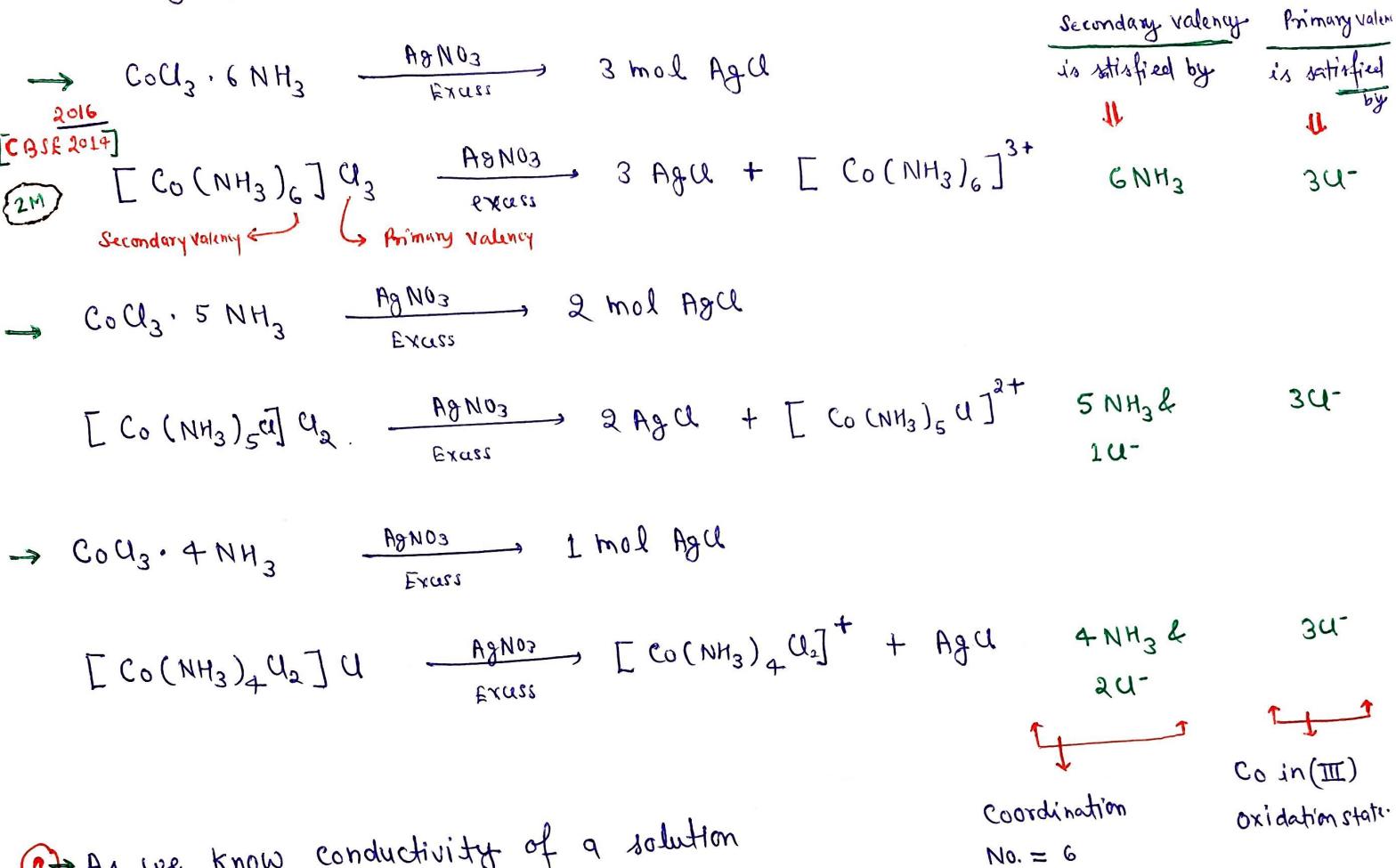
NOTE :— In modern formulation —: Primary valency corresponds to oxidation state of metal.

→ Secondary Valency corresponds to Coordination No. of central metal.

→ Spatial arrangements are called coordination polyhedra.

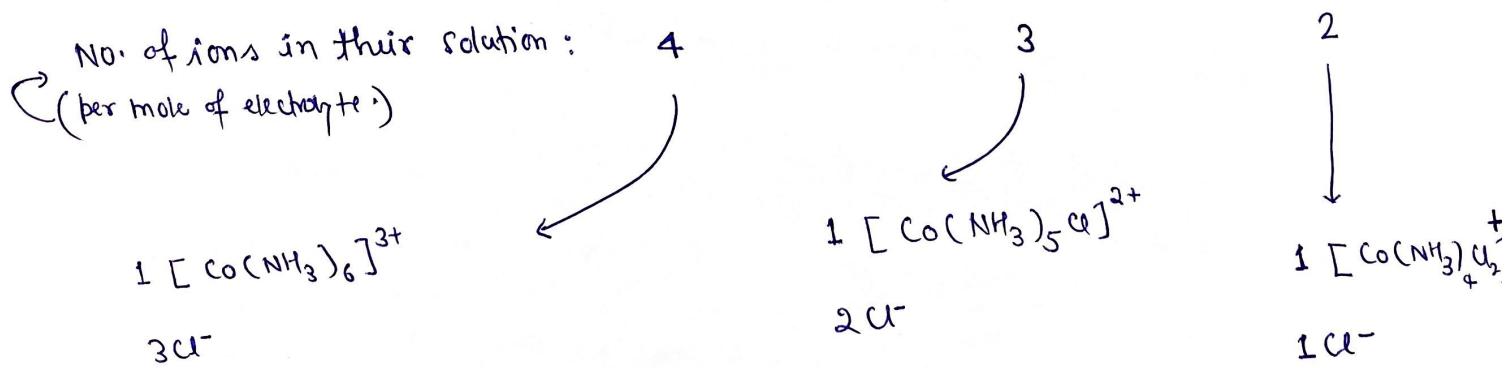
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Experiments -: ① In a series of compounds of cobalt (III) chloride with ammonia, it was found that some of chloride ions could be precipitated as AgCl on adding excess AgNO_3 solution but some remained in solution.



② As we know conductivity of a solution depends on no. of ions present in solution.

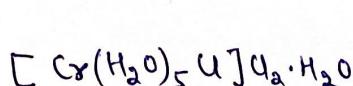
Experimental order of conductivity : $\text{CoCl}_3 \cdot 6 \text{NH}_3 > \text{CoCl}_3 \cdot 5 \text{NH}_3 > \text{CoCl}_3 \cdot 4 \text{NH}_3$



→ When a coordination compound $\text{CrCl}_3 \cdot 6 \text{H}_2\text{O}$ is mixed with AgNO_3 , 2 moles of AgU are precipitated per mole of compound.

i) Write structural formula :- $\text{CrCl}_3 \cdot 6 \text{H}_2\text{O} \xrightarrow{\text{AgNO}_3} 2 \text{AgU} \downarrow$: means that 2U^- is ionisable.

[Delhi 2014/2016]
[CBSE 2019] [1M]

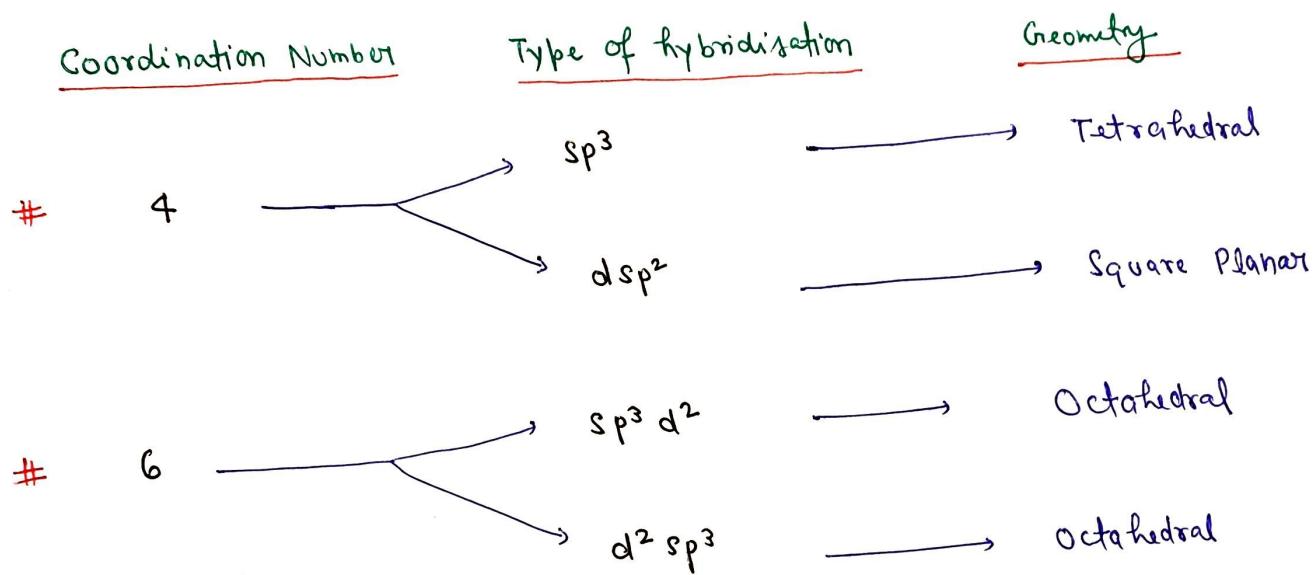


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ii) IUPAC Name of complex :- Pentaquacloridochromium(III) chloride [Delhi 2014] 1M

Valence Bond Theory

- According to this theory, the metal ion or atom under the influence of ligand can use its $(n-1)d$, ns , np / ns , np , nd orbitals for hybridisation to give a set of equivalent orbitals of definite geometry.
- These hybridised orbitals are allowed to overlap with ligand orbitals that can donate electron pairs for bonding.



- It is possible to predict the geometry of a complex from the knowledge of its magnetic behaviour on the basis of NBT.
- Magnetic moment of a complex depends on no. of unpaired electrons.

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$$\text{Magnetic moment } \mu = \sqrt{n(n+2)}$$

$n = \text{No. of unpaired electron}$.

Example :- i) $[\text{Co}(\text{NH}_3)_6]^{3+}$: Diamagnetic in nature.

→ Co^{+3} Ion :
($3d^6$)

[CBSE 2010] 2M

Diamagnetic
Electrons are paired.

→ Hybridisation :
 d^2sp^3 : Inner orbital complex
Inner d orbital

:
6 ligands : octahedral

NH_3 NH_3 NH_3 NH_3 NH_3 NH_3

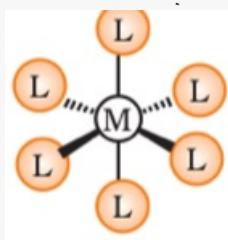
→ Inner Orbital Complex : d^2sp^3 : Low spin complex : spin paired complex.

→ Outer orbital Complex : sp^3d^2 : High spin complex : spin free complex.

ii) $[CoF_6]^{3-}$: Paramagnetic Octahedral complex.

CBSE 2018
[CBSE 2014C]
[Delhi 2010]

Presence of unpaired electrons.



Co^{+3} Ion : $\begin{array}{|c|c|c|c|c|} \hline 1L & 1 & 1 & 1 & 1 \\ \hline \end{array}$ $\begin{array}{|c|} \hline \end{array}$ $\begin{array}{|c|c|c|} \hline \end{array}$ $\begin{array}{|c|c|c|c|c|} \hline \end{array}$

($3d^6$) $3d$ $4s$ $4p$ $4d$

Hybridisation : $\begin{array}{|c|c|c|c|c|} \hline 1L & 1 & 1 & 1 & 1 \\ \hline \end{array}$ $\begin{array}{|c|c|c|c|c|} \hline \end{array}$ $\begin{array}{|c|c|} \hline \end{array}$

sp^3d^2 Hybrid

$[CoF_6]^{3-}$: $\begin{array}{|c|c|c|c|c|c|} \hline 1L & 1 & 1 & 1 & 1 & 1 \\ \hline \end{array}$ $\begin{array}{|c|c|c|c|c|c|} \hline 1L & 1L & 1L & 1L & 1L & 1L \\ \hline \end{array}$ $\begin{array}{|c|c|} \hline \end{array}$

[outer orbital complex]

F^- F^- F^- F^- F^- F^-

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iii) $[NiCl_4]^{2-}$: paramagnetic in nature. ← [CBSE 2017]

Ni^{2+} Ion : $\begin{array}{|c|c|c|c|c|} \hline 1L & 1L & 1 & 1 & 1 \\ \hline \end{array}$ $\begin{array}{|c|} \hline \end{array}$ $\begin{array}{|c|c|c|} \hline \end{array}$

($3d^8$) $3d$ $4s$ $4p$

Hybridisation : $\begin{array}{|c|c|c|c|c|} \hline 1L & 1L & 1 & 1 & 1 \\ \hline \end{array}$ $\begin{array}{|c|c|c|c|c|} \hline \end{array}$ sp^3 Hybrid → Tetrahedral

$[NiCl_4]^{2-}$: $\begin{array}{|c|c|c|c|c|} \hline 1L & 1L & 1L & 1L \\ \hline \end{array}$ $\begin{array}{|c|c|c|c|c|} \hline \end{array}$

Cl^- Cl^- Cl^- Cl^-

iv) $Ni(CO)_4$: diamagnetic in nature.

[Delhi 2012]

$Ni(0)$: $\begin{array}{|c|c|c|c|c|} \hline 1L & 1L & 1L & 1 & 1 \\ \hline \end{array}$ $\begin{array}{|c|} \hline \end{array}$ $\begin{array}{|c|c|} \hline \end{array}$

($3d^9 4s^2$) $3d$ $4s$ $4p$

APNI KAKSHA

Hybridisation : $\begin{array}{|c|c|c|c|c|} \hline 1L & 1L & 1L & 1L & 1L \\ \hline \end{array}$ $\begin{array}{|c|} \hline \end{array}$ $\begin{array}{|c|c|c|} \hline \end{array}$

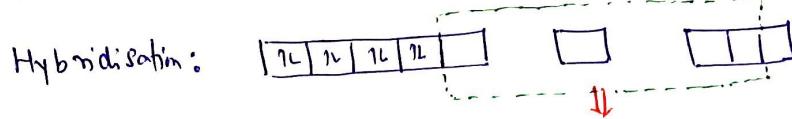
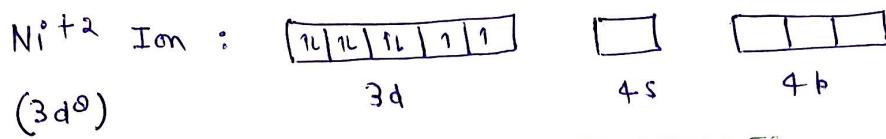
$3d$

CO CO CO CO CO sp^3 Hybrid → Tetrahedral

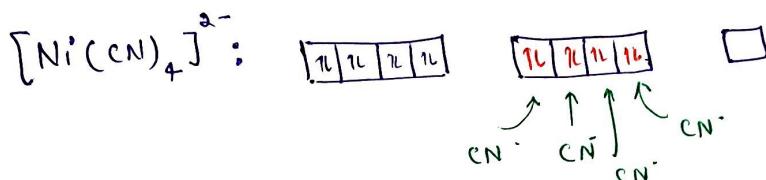
$Ni(CO)_4$: $\begin{array}{|c|c|c|c|c|} \hline 1L & 1L & 1L & 1L & 1L \\ \hline \end{array}$

14) $[\text{Ni}(\text{CN})_4]^{2-}$: Square Planar Complex : Diamagnetic.

Delhi 2010
C.B.S.E 2019
2011



$d^2 \text{sp}^2$: Square Planar



NOTE - :

$d^1 \quad d^2 \quad d^3$

$d^4 \quad d^5 \quad d^6$

$d^7 \quad d^8 \quad d^9 \quad d^{10}$

Always sp^3d^2

Because inner d orbitals are not available.

for octahedral complex :

1 Always d^2sp^3
 2 Inner d orbitals are always available for hybridisation.

$\text{d}^2\text{sp}^3 \mid \text{sp}^3\text{d}^2$

both are possible. It can be determined by value of magnetic moment.

$\Rightarrow [\text{Mn}(\text{CN})_6]^{3-}$: Magnetic moment of 2 electrons : d^2sp^3 : Paramagnetic [C.B.S.E 2014]

$[\text{MnCl}_6]^{3-}$: Magnetic moment of 4 electrons : sp^3d^2

$\rightarrow [\text{Fe}(\text{CN})_6]^{3-}$: $M = \sqrt{n(n+2)} = \sqrt{1(1+2)} = 1$ unpaired electron : d^2sp^3

$[\text{FeF}_6]^{3-}$: $M = \sqrt{5(5+2)} = 5$ unpaired electrons : High spin complex $[\text{sp}^3\text{d}^2]$

$\rightarrow [\text{Co}(\text{C}_2\text{O}_4)_6]^{3-}$: diamagnetic : d^2sp^3 : Inner orbital complex. [Delhi 2017]

$[\text{CoF}_6]^{3-}$: paramagnetic with four unpaired electron : sp^3d^2

Limitation of VBT - : i) It involves no. of assumptions.

ii) It does not explain colour of coordination compounds.

iii) It does not give explanation of kinetic and thermodynamic stabilities of complex.

iv) It does not distinguish between weak and strong ligands.

Crystal Field Theory

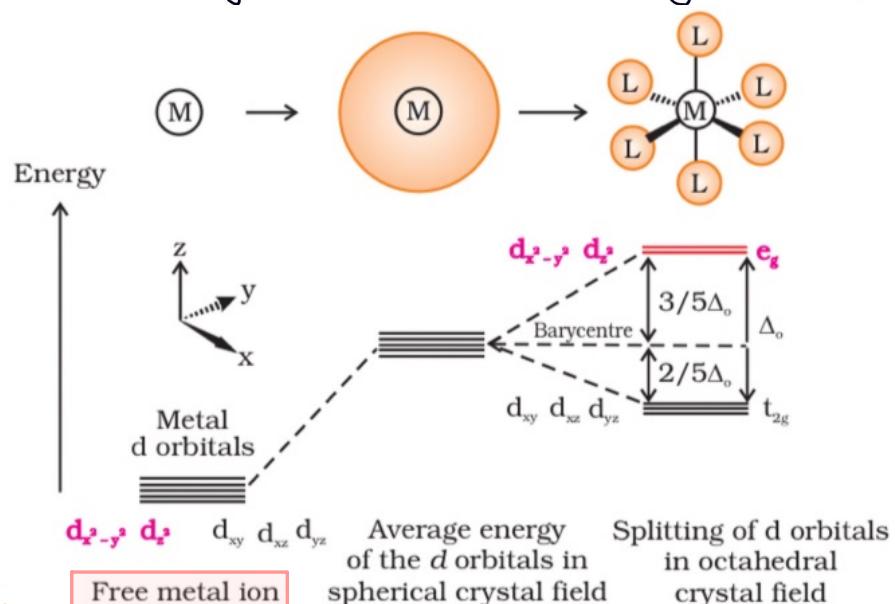
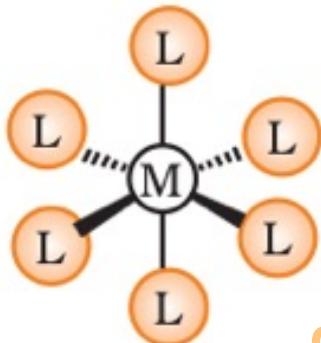
- CFT is an electrostatic model which considers the metal-ligand bond to be ionic, arising purely from electrostatic interactions between the metal ion and ligand.
- Ligands are treated as point charges in case of anions or dipoles in case of neutral molecules. (H_2O , NH_3 etc.)

\downarrow
 $[\text{Cl}^-, \text{Br}^-, \text{OH}^- \text{ etc.}]$

Crystal field Splitting in Octahedral complexes :-

- Under the influence of 6 ligands field, degeneracy of d orbitals has been removed due to ligand-metal electron repulsions in octahedral complex.
- Removal of degeneracy gives three orbitals [d_{xy} , d_{yz} , d_{zx}] of lower energy (t_{ag}) and two orbitals of higher energy [d_{z^2} , $d_{x^2-y^2} = e_g$ set].
- $d_{x^2-y^2}$ and d_{z^2} orbitals point towards the axes along the direction of the ligand, will experience more repulsion and will raise in energy.
- d_{xy} , d_{yz} , d_{zx} orbitals are directed between axes, will be lowered in energy relative to average energy (in the spherical crystal field).
- splitting of degenerate levels due to the presence of ligands in a definite geometry is called Crystal field splitting and the energy separation is denoted by Δ_o [crystal field splitting energy].

[Delhi 2011C/1M]



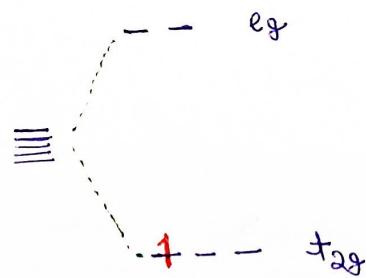
Abni Kaksha :)

d orbital splitting in an octahedral crystal field

→ The extent of splitting depends upon the field produced by ligand and charge on metal ion.

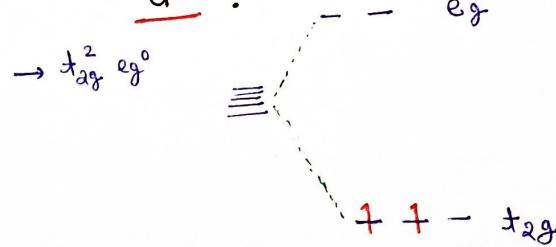
→ d^1 :-

→ $t_{2g}^1 e_g^0$



d^2 :-

→ $t_{2g}^2 e_g^0$



d^3 :-

→ $t_{2g}^3 e_g^0$

eg

+ + + t_{2g}

Spectrochemical Series :-

→ If ligands are arranged in a series in the order of increasing field strength, then that series is called spectrochemical series.

→ halogen donors < oxygen donors
< Nitrogen donors < Carbon donors

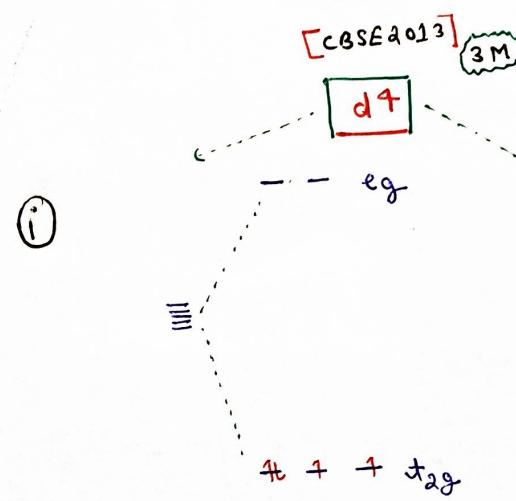
→ $I^- < Br^- < SCN^- < Cl^- < S^{2-} < F^- < OH^- < C_2O_4^{2-} < H_2O < NCS^- < EDTA^{4-} < NH_3$
< en < CN^- < CO

→ Generally, CN^- & CO are SFL with M^{+2} and rest ligands are WFL.

→ CN^- , CO , en , NH_3 & H_2O are SFL with M^{+3} .

Quesn'tm :- ① $[CoF_6]^{3-}$

→ F^- as WFL.



(i)

If $\Delta_o > P$

Now 4th electron enters into t_{2g} orbital and configuration
= $t_{2g}^4 e_g^0$

→ Ligands for which $\Delta_o > P$ are known as strong field ligand.

[SFL]

(ii) If $\Delta_o < P$

Here, 4th electron enters one of eg orbitals giving the configuration $t_{2g}^3 e_g^1$.

→ Ligands for which $\Delta_o < P$, are known as weak field ligand. [WFL]

Abni Kaksha :-

② $[Co(en)]^{3+}$

→ en as SFL

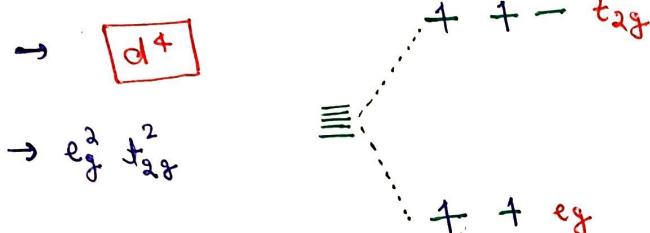
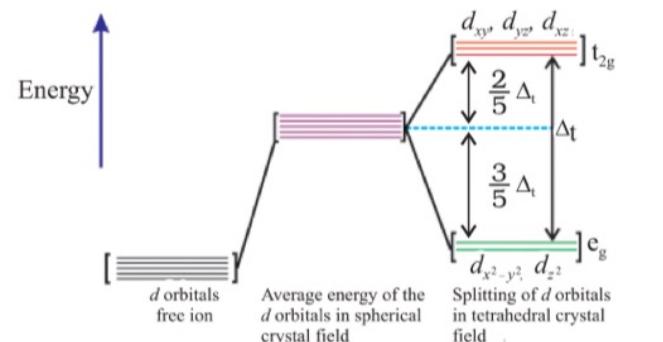
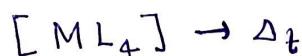
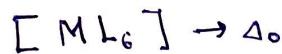
③ $[Co(NH_3)_6]^{3+}$

→ NH_3 as SFL.

Crystal Field Splitting in tetrahedral complexes :-

→ In tetrahedral coordination entity formation the d orbital splitting is inverted and is smaller as compared to the octahedral field splitting.

→ For same metal and ligand : $\Delta_t = \frac{4}{9} \Delta_o$



← For tetrahedral complex : $\Delta_t < P$

Always

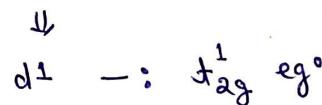
Alpi Kaksha

Colour in Coordination Compounds

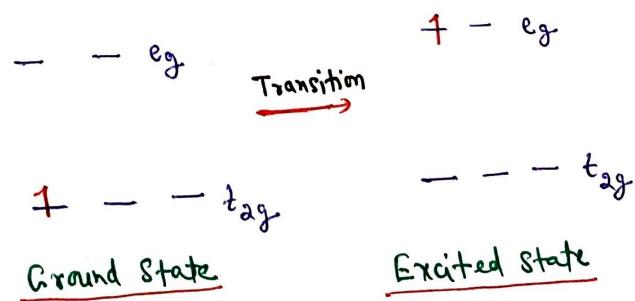
→ When light of certain frequency falls on the complex, it absorbs light from visible range for transition of electrons from lower d-energy level to higher d-energy level. This transition is called d-d transition of electron.

→ Colour of the compound is the complementary colour of absorbed light. For example if green is absorbed by the complex, it appears red.

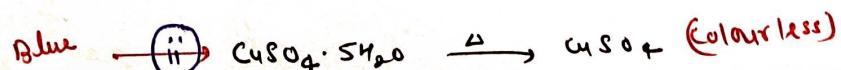
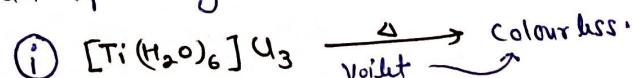
→ $[Ti(H_2O)_6]^{3+}$: violet in colour.



Transition : $t_{2g}^1 e_g^0$ to $t_{2g}^0 e_g^1$

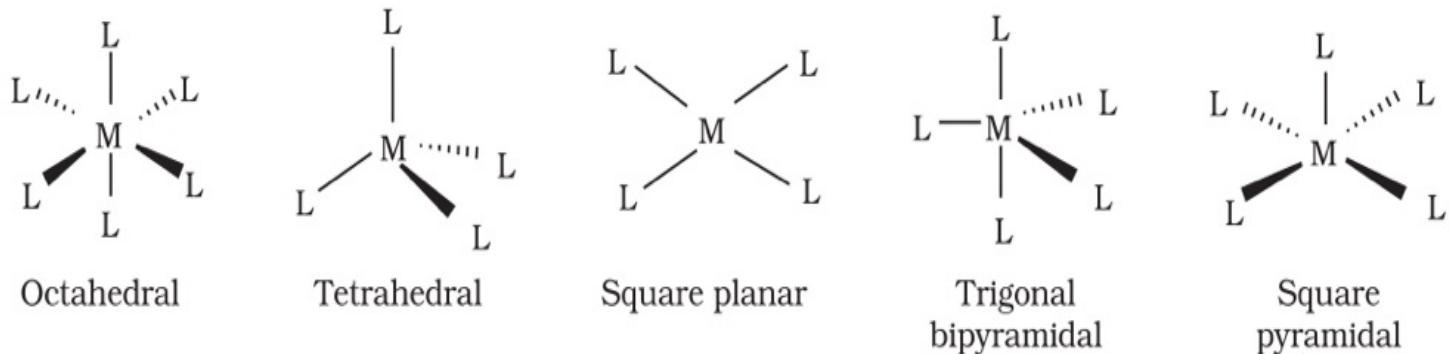


→ In absence of ligand crystal field splitting does not occur and hence the substance is colourless.

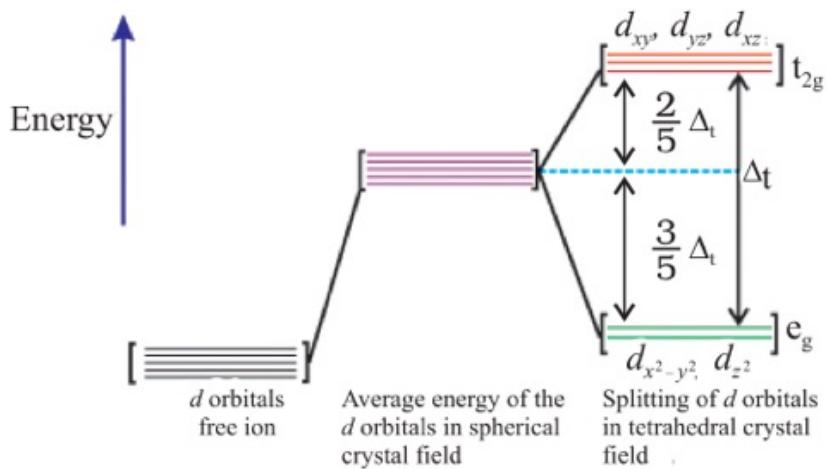


Relationship between the Wavelength of Light absorbed and the Colour observed in some Coordination Entities

Coordination entity	Wavelength of light absorbed (nm)	Colour of light absorbed	Colour of coordination entity
$[\text{CoCl}(\text{NH}_3)_5]^{2+}$	535	Yellow	Violet
$[\text{Co}(\text{NH}_3)_5(\text{H}_2\text{O})]^{3+}$	500	Blue Green	Red
$[\text{Co}(\text{NH}_3)_6]^{3+}$	475	Blue	Yellow Orange
$[\text{Co}(\text{CN})_6]^{3-}$	310	Ultraviolet	Pale Yellow
$[\text{Cu}(\text{H}_2\text{O})_4]^{2+}$	600	Red	Blue
$[\text{Ti}(\text{H}_2\text{O})_6]^{3+}$	498	Blue Green	Purple



Shapes of different coordination polyhedra. M represents the central atom/ion and L, a unidentate ligand.



d orbital splitting in a tetrahedral crystal field.

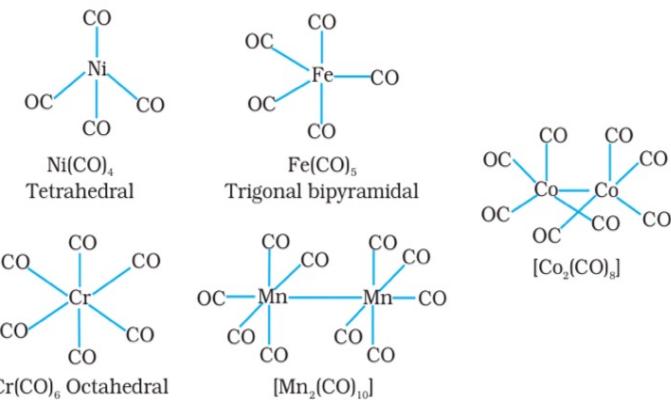
Limitations of CFT :- From the assumptions that the ligands are point charges, it follows that anionic ligands should exert the greatest splitting effect. But it's not true because anionic ligands are found at the low end of spectrochemical series.

Bonding in metal carbonyls

→ Compounds which have atleast one metal - carbon bond are called Organometallic compounds.

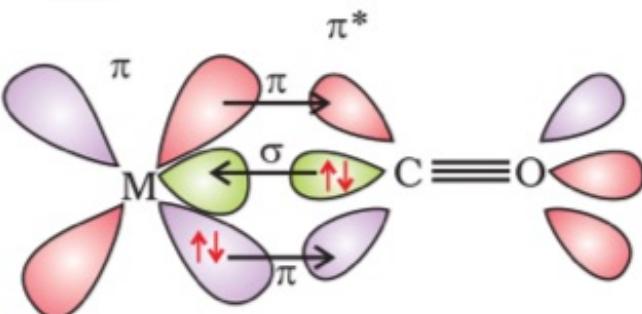
→ The metal carbon bond in metal carbonyls possesses both σ and π character.

→ The M-C σ bond is formed by the donation of lone pair of electrons on the carbonyl carbon into a vacant orbital of metal.



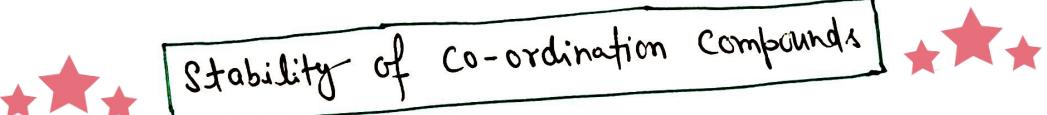
→ The M-C π bond is formed by the donation of a pair of electron from a filled d-orbital of metal into vacant π^* orbital of CO.

→ The metal to ligand bonding creates a **Synergic Effect** which strengthens the bond between CO and the metal.



Synergic bonding

Stability of co-ordination compounds



→ The stability of complex in solution refer to the degree of association between the two species involved in the state of equilibrium.

→ Equilibrium constant for the association expresses the stability.



Value of equilibrium constant $\uparrow \Rightarrow [\text{ML}_4] \uparrow$

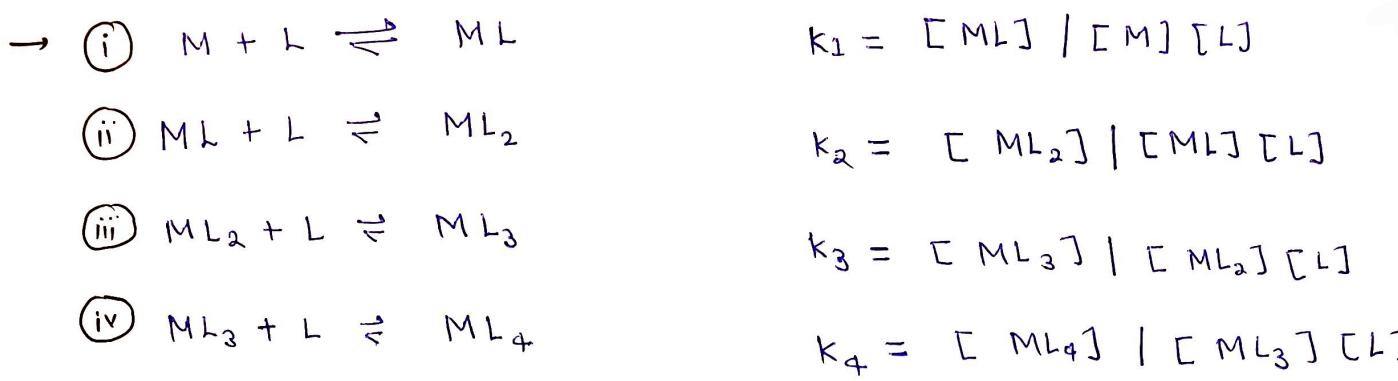
→ Stepwise stability constant :- The equilibrium constant of each step of a complex reaction is called stepwise stability constant. (k_1, k_2, \dots) [CBSE 2011c]

(2M)

→ Overall stability constant :- The equilibrium constant for net reaction.

(β_4)

Apni Kaksha ::

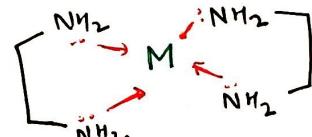


Then $\rightarrow \boxed{\beta_4 = K_1 \cdot K_2 \cdot K_3 \cdot K_4}$

(Aphi Kaksha)

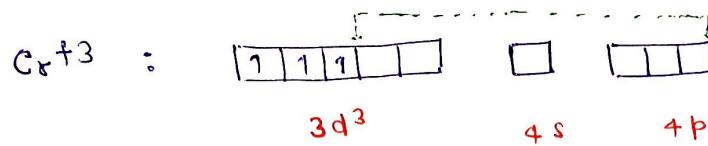
Important Previous Year Questions.

- i) What is meant by chelate effect? [CBSE 2015] 1M
- When a bidentate / polydentate ligand containing donor atoms positioned in such a way that, they coordinate with the central metal ion forming a five or six membered ring. The effect is called chelate effect.
- As a result of chelate effect, the stability of the complex increases.



- # iii) CO is stronger complexing agent than NH₃, Why? [Delhi 2012] 1M
- There exist a back bonding in CO complexes in which CO accepts electron density from the filled d orbitals of metal atom into their π^* orbital. So, there are σ as well as π interaction with metal in case of CO. But NH₃ makes only σ bond with metal. Therefore CO is a stronger complexing agent than NH₃.

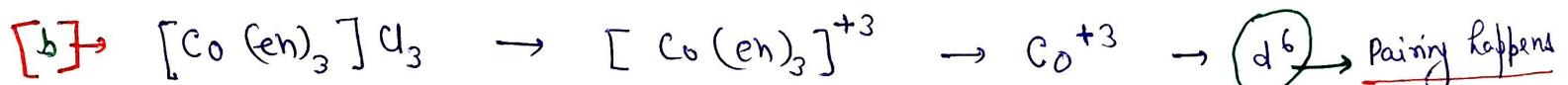
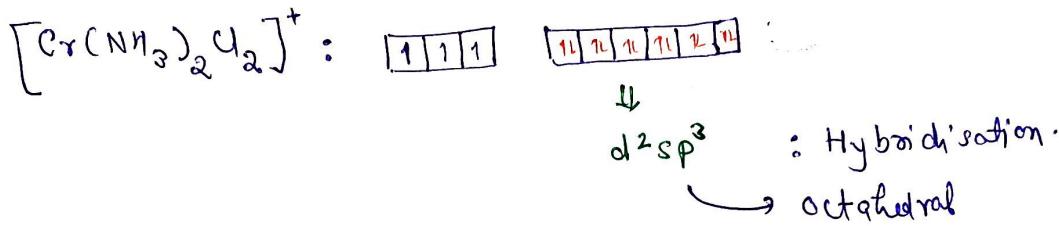
iv) Write the state of hybridisation, the shape and the magnetic behaviour of following complex entities. $[CBSE 2011] \rightarrow 3M$



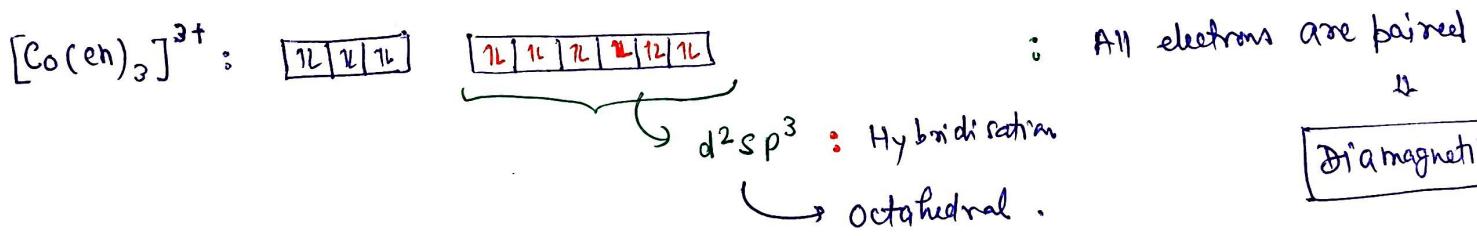
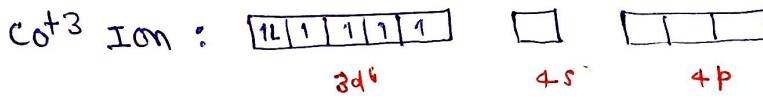
No pairing happens.



paramagnetic
in nature due
to unpaired electrons



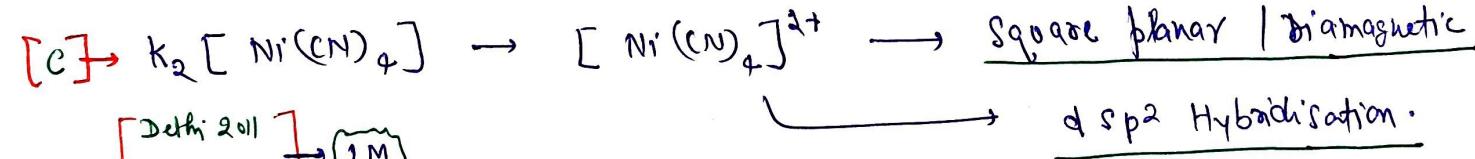
Pairing happens
due to presence of 3F2 (en)



: All electrons are paired

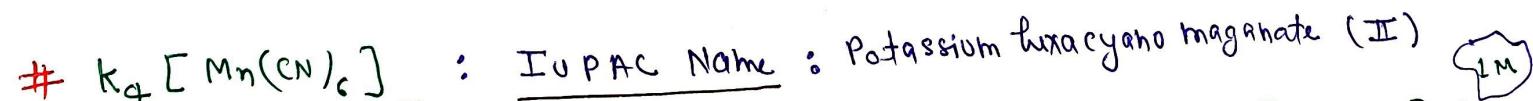


Diamagnetic



[Delhi 2011]
[CBSE 2012] $\rightarrow 1M$

\downarrow
 dsp^2 Hybridisation.



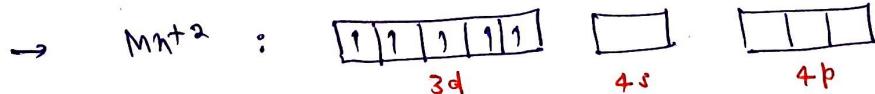
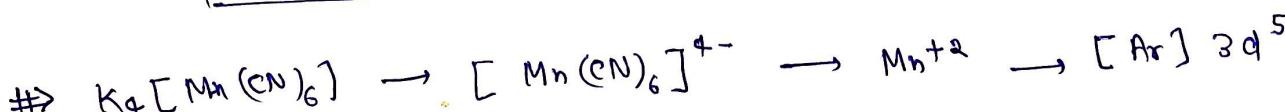
$$4(+1) + x + 6(-1) = 0$$

$$\text{Then } x = +2$$

All the Best! ☺

-[Delhi 2011] \rightarrow

-[CBSE 2010C] $\rightarrow 3M$



d²sp³ : octahedral : one unpaired electron.

Parathalistic ↑