
IOC Mega Revision
Live at 8:00 PM
1st March - 13th March
Get Top Ranks in IIT-JEE/NEET with eSaral APP
Get it on
Google Play

Free MEGA Seminar on
How To Crack
JEE 2021
For JEE Target - 2021
Students
on
2 March, 2021- 8 PM
Get Top Ranks in IIT-JEE/NEET with eSaral APP
Get it on
Google Play

Faculty of the Series

Prateek Gupta Sir
eSaral Chemistry Faculty

- **IIT Bombay,** Metallurgy
- **Online** Creativity & Visualization Expert
- **Mentored** Lakhs of Students

Master Planners & Faculties

Phy
Mega Revision

Saransh Gupta Sir

eSaral Physics HoD

- **IIT Bombay**, CS
- **AIR-41** IIT-JEE
- **Air-71** AIEEE (JEE Main)
- **AIR-4** NSO
- **1%** In Top INPHO
- **8+** Years of Teaching Experience
- **Mentored** Lakhs of Students

Master Planners & Faculties

N.K. Gupta Sir

eSaral Math Faculty & Master Planner

- **IIT Kanpur**, Mechanical
- Ex **Vice President & Academic Head**, Allen, Kota
- Mentored many of **Rank 1** & **Top 100** Students
- **30+ years** of Teaching Experience
- **Mentored** over 3,00,000 Students

Master Planners & Faculties

Dr. Anshuman Agarwal

eSaral Biology Faculty

- **MBBS, MD, FIPM**
- **AIR-196**, AIPMT(NEET)
- **ARR-46**, RPMT
- **NTSE Scholar**
- **Ex HoD Biology**, Resonance, Kota
- **10+ years** of Teaching Experience
- **Mentored** over thousands of doctors

Master Planners & Faculties

Dr. Kushika Taneja

eSaral Biology Faculty

- **Ex-HoD Biology,** Pace IIT and Medical, Indore
- Biology faculty at Rao Academy, Kota
- **7+ years** of Teaching Experience
- **Mentored** over thousands of doctors


Chemistry
1
Samjho, dekho & yaad karo
2
3

Why Bonding?

× Octet rule
× Overlaping
× Hybridisation

M ← L

BF_3

SO_3

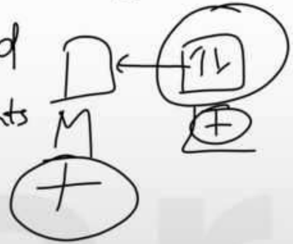
$\frac{K q_1 q_2}{r}$

+ve > −ve

What is a Coordination Compound ?

Coordinate Bond

d-block elements



(A) Double Salts

Break down into simpler ions.

(B) Coordination Compounds

Retain their identity in solution.

(I) Perfect Complexes

(II) Imperfect Complexes

Classification of Ligands

(A) Based on charge

en
tn
pn
bn
ox
EDTA

ML_6

(i) Neutral ligands

H_2O, NO, CO, C_6H_6 etc.

(ii) Positive ligands NO^+, $N_2H^+_5$

(iii) Negative ligands

Cl^-, NO^-_2, CN^-, OH^-

(B) Based on denticity

→ teeth/claws

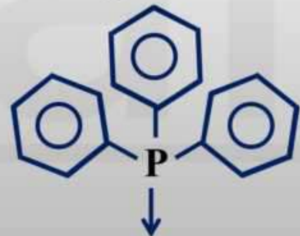
The number of electron pairs donated to central metal by ligands is known as DENTICITY. Depending on number of electron pairs donated, these are classified in following categories.

(a) Unidentate/monodentate ligands

Ligands which donate one pair of electron to the central metal are called unidentate ligands.

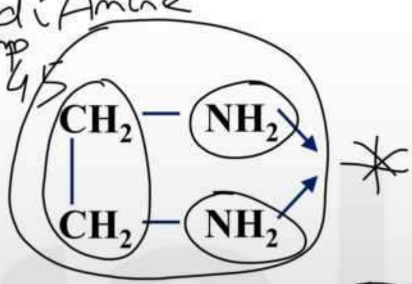
X^-, CN^-, NO_2^-, NH_3, Pyridine, OH^-, NO_3^-, H_2O, SO_3^{-2}, CO, NO, OH^-, O^{-2}, $(C_6H_5)_3P$, CH_3CO^- etc.

Pyridine (Py)



Triphenyl phosphine (PPh_3)

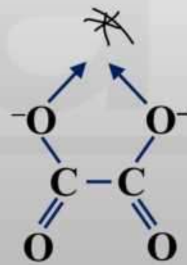
(b) Bidentate ligands



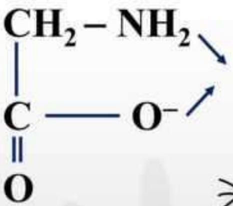
Ethylenediamine (en)

Ligands which have two donor atoms and have the ability to link with central metal ion at two positions are called bidentate ligands.

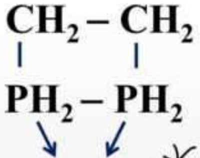
1, 10-Phenanthroline
(O-phen)



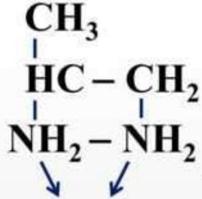
Oxalate (ox)



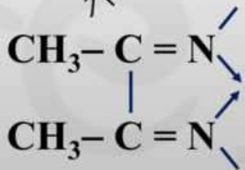
Glycinato (Gly)



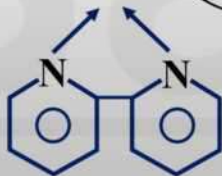
ethylene diphosphene (diphos)



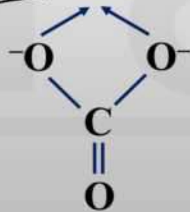
Propyline diamine or 1,2- diamino propane (pn)



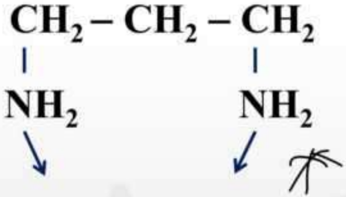
Dimethyl glyoximion (DMG)



2, 2'-Dipyridyl (Dipy)



Carbonate



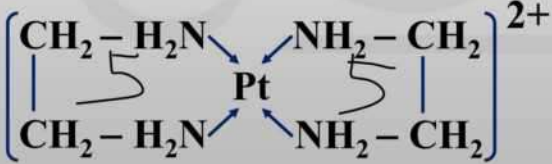
1,3 diamino propane

or

trimethylene diamine

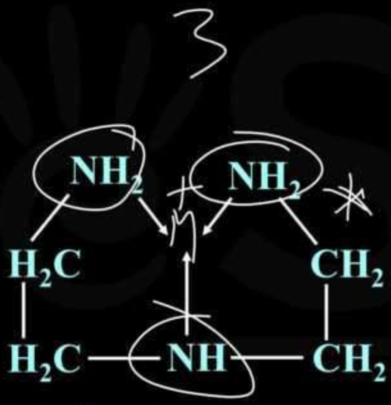
(tn)

Chelation



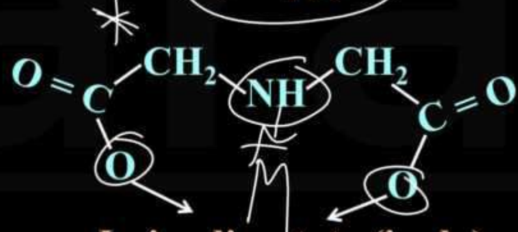
Superstable

(c) Tridentate ligands



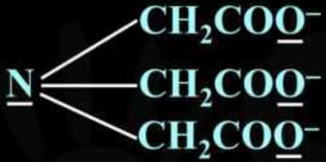
Diethylene triamine (Dien)

2,2',2"-Terpyridine (Terpy)

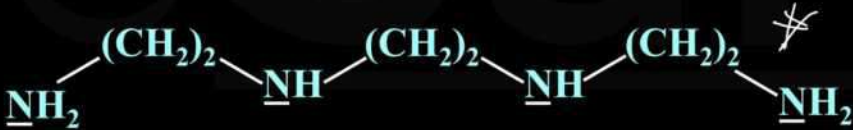


Iminodiacetato (imda)

(d) Tetradentate ligands



Nitrilotriacetato (nta^{3-})

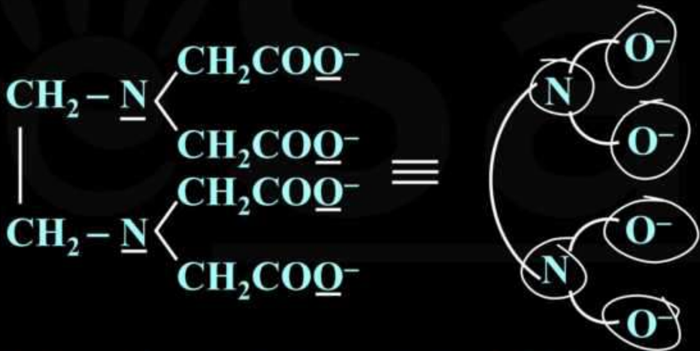


Triethylene tetra amine
(trien)

(f) Hexadentate ligands

Super stable

Most Important Ligand



5 membered Rings
6 "

Ethylenediaminetetraacetato (EDTA)$^{-4}$

(h) Ambidentate ligands

1 site only
1 lp
No imaan dharm

Ligands which can ligate through two different atoms present in it are called ambidentate ligands. At a time only one atom can donate.

$\left[\begin{matrix}CN^- \\ NC^-\end{matrix}\right.$ $\left[\begin{matrix}NO_2^- \\ ONO^-\end{matrix}\right.$ $\left[\begin{matrix}SCN^- \\ NCS^-\end{matrix}\right.$ $\left[\begin{matrix}CNO^- \\ NCO^-\end{matrix}\right.$ $\left[\begin{matrix}S_2O_3^{2-} \\ OSO_2S^{2-}\end{matrix}\right.$

(C) Based upon bonding interaction between the ligand and the central atom.

(i) Classical or simple ligand

These ligands only donate the lone pair of electrons to the central atom.

Ex. O^{2-}, OH^-, F^- etc.

(ii) Non classical or π-acid or π -acceptor ligand

These ligand not only donate the lone pair of electrons to central metal but also accept the electron cloud from central atom.

On the basis of nature of donating electron cloud these ligands are following types.

Trick

σ donor

π-donor

(a) σ donor π acceptor

Ex. CO, CN^-, NO^+, PF_3, PR_3 etc.

Non-classical ligand

(b) π donor π acceptor

Aromatic, Anti-Aromatic Can never be σ accep

Ex. C_2H_4, C_6H_6, $C_5H_5^-$ etc.

1 lp
2 lp rxn rate ↑↓ $\Delta G = \Delta H - T\Delta S$
3 lp → flexidentate ΔS↑ no of molecules↑

$$[Ni(H_2O)_6]^{2+} + 6NH_3 \rightleftharpoons [Ni(NH_3)_6]^{2+} + 6H_2O(l) \quad (1) \quad K_f = 4\times10^{8}$$

$$[Ni(H_2O)_6]^{2+} + 3en \rightleftharpoons [Ni(en)_3]^{2+} + 6H_2O(l) \quad (2) \quad K_f = 2\times10^{18}$$

Sidgwick Theory or Effective Atomic Number Concept (EAN)

Polynuclear CC

no of e⁻ in the molecule

Noble gas

no of e⁻ no of e⁻ lost

EAN = (atomic number of the metal – oxidation state of central metal) + number of electrons gained from the donor atoms of the ligands.

Q) Determine the effective atomic number of the metal atom in the following

Complex	oxidation state of the metal	Effective atomic number (EAN)
$[Co(NH_3)_6]Cl_3$	+3	(27 – 3) + (6 × 2) = 36 (kr)
$K_4[Fe(CN)_6]$	+2	(26 – 2) + (6 × 2) = 36 (kr)

Q) Find value of x

$[Mn_2(CO)_x]$ Mn–Mn linkage is present and no bridge ligand is present.

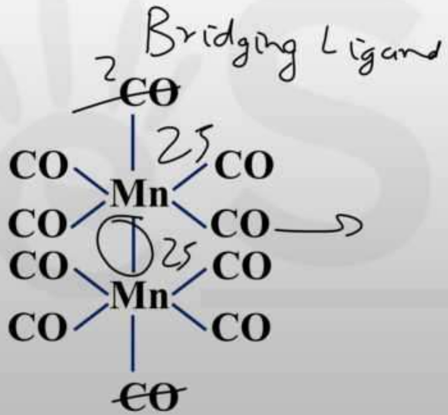
$Mn_2(CO)_{10}$ Mn

Sol.

$\frac{72}{2} = 36$

to

$\frac{68}{2}$ 34



Werner's Co-ordination Theory

Q)

	Old	New	No. of Cl^- Ions precipitate	Total No. of ions
(i)	$CoCl_3 \cdot 6NH_3$	$[Co(NH_3)_6]Cl_3$	3	4
(ii)	$CoCl_3 \cdot 5NH_3$	$[Co(NH_3)_5Cl]Cl_2$	2	3
(iii)	$CoCl_3 \cdot 4NH_3$	$[Co(NH_3)_4Cl_2]Cl$	1	2

Sol. Order of electrical conductivity of aq. solution. (i) > (ii) > (iii)

Synergic Bonding

CO

V Imp

$M(CO)_5$

Classical

$M \rightleftarrows CO$

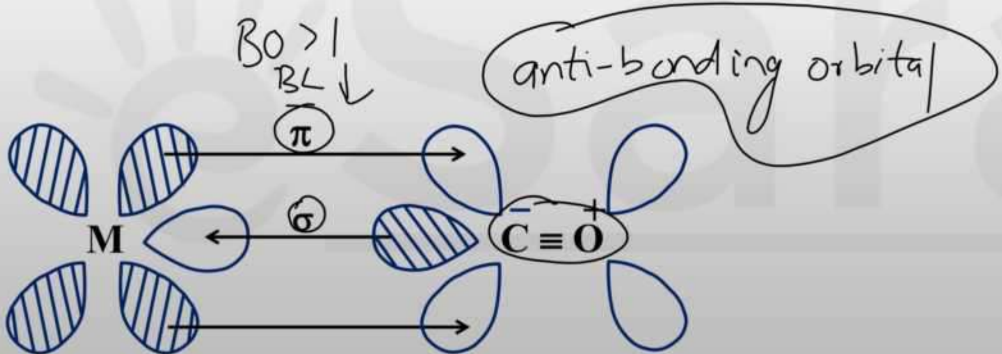
BO=1

BO>1

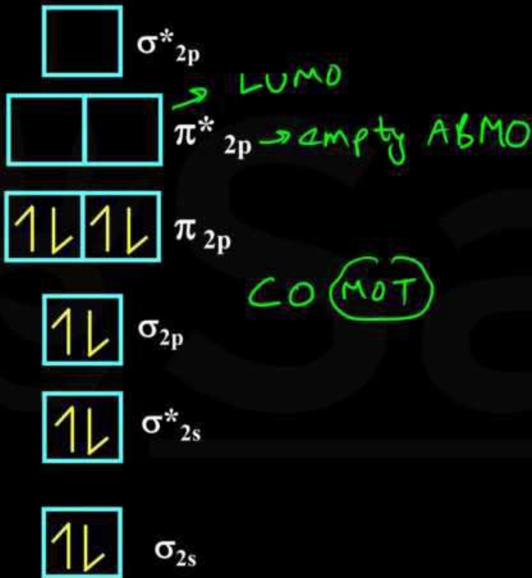
Due to presence of π acceptor ligands special type of bonding takes place in coordination compounds. It is known as synergic bonding.

1. Bonding in metal carbonyl

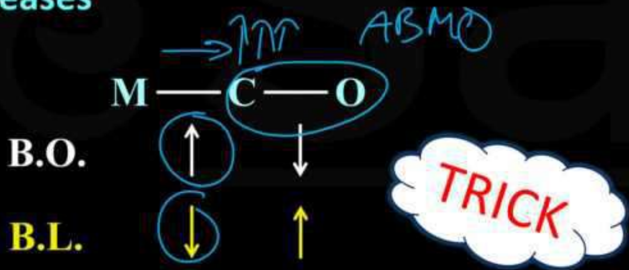
Ex. $[Fe(CO)_5]$; $[Ni(CO)_4]$; $[Cr(CO)_6]$



σ - donor , π - acceptor


σ*2p
LUMO
π*2p → empty ABMO
π2p
CO MOT
σ2p
σ*2s
σ2s

As Bond order increases, bond length decreases

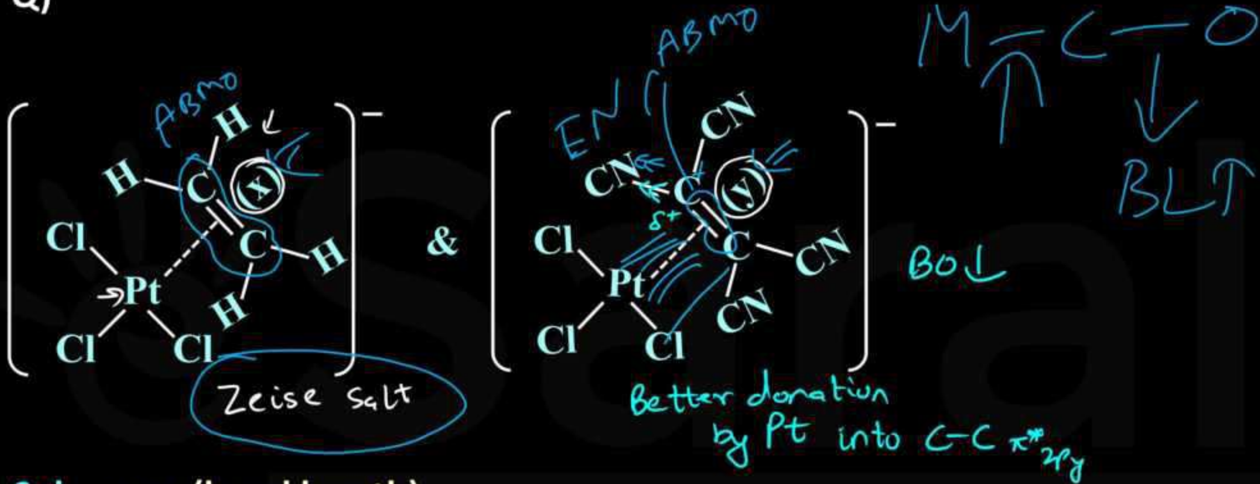


Q) Order of carbon oxygen bond order in following metal carbonyls.

(a) $[Mn(CO)_6]^+ > [Cr(CO)_6] > [V(CO)_6]^-$

For isoelectronic species as negative charge on center metal atom/ion increases extent of back bonding increases.

Q)



Sol. y > x (bond length)


WORK HARDER
1 minute motivation


JEE 2021
eSaral
मैं भी
Bounce Back
करेगा!
with eSaral Crash Course 2021
APURV PRINCE
FIRST ROUND
39%le
SECOND ROUND
99%le
Get Top Ranks in IIT-JEE/NEET with eSaral APP
Get it on
Google Play

IUPAC nomenclature of coordination compounds

Imp Part

(a) Like simple salts, the positive part of the coordination compound is named first.

Ex. $K_4[Fe(CN)_6]$ the naming of this complex starts with potassium.

$[Cr(NH_3)_6]Cl_3$ the naming of this complex starts with name of complex ion.

(b) Naming of coordination sphere

The names of ligands along with their numerical prefixes (to represent their no.) are written first, followed by the name of central metal.

(c) The ligands can be neutral, anionic or cationic.

(i) The neutral ligands are named as the molecule

C_5H_5N [pyridine]

$(C_6H_5)_3P$ [Triphenyl phosphine]

$H_2N-CH_2-CH_2-NH_2$ [ethylene diamine]

CH_3NH_2 [methyl amine]

Me_2O [diemthyl ether]

The neutral ligands which are not named as the molecule are

CO [carbonyl]

CS [thiocarbonyl]

NO [nitrosyl]

H_2O [aqua]

NH_3 [ammine]

o / ido

chloride

Symbol	Name as ligand	Symbol	Name as ligand
Cl^-	Chloro/Chlorido	N^{3-}	Nitrido
Br^-	Bromo/Bromido	O_2^{2-}	Peroxo/Peroxido
CN^-	Cyano/Cyanido	O_2H^-	Perhydroxo/Perhydroxido
O^{2-}	Oxo/Oxido	S^{2-}	Sulphido
OH^-	Hydroxo/Hydroxido	NH^{2-}	Imido
H^-	Hydrido	NH_2^-	Amido

Symbol	Name as ligand	Symbol	Name as ligand
CO_3^{2-}	Carbonato	SO_3^{2-}	Sulphito
$C_2O_4^{2-}$	Oxalato	CH_3COO^-	Acetato
SO_4^{2-}	Sulphato	ClO_3^-	Chlorate
NO_3^-	Nitrato		
$S_2O_3^{-2}$	Thiousulphate		

(iii) Positive ligand naming ends in 'ium'

$NH_2 - NH_3^+$ [Hydrazinium]

NO_2^+ [nitronium]

NO^+ [nitrosonium/nitrosylium]

(iv) Ambidentate ligands

NO_2^- [nitro, nitrito-N]

ONO^- [nitrito-O]

CN^- [cyano/cynido]

(v) π-donor and π-acceptor ligands

Prefix of Greek letter η^x (ita) is repeated before the name of each different kind of π- donor, π- acceptor ligand.

Where x is the number of carbon atoms to which donated electron cloud is bounded. x is known as heptacity of ligand.

				no. of donated e^-
(i)	π-C_2H_4		η^2-ethylene	2
(ii)	π-$C_5H_5^-$		η^5-cyclopentadienyl	6

Alphabetical

(d) If ligands are present more than once, then their number is indicated by prefixes like di, tri, tetra etc.

Cationic

Roman numerals

Ex: $[Cr(H_2O)_4Cl_2]Cl$

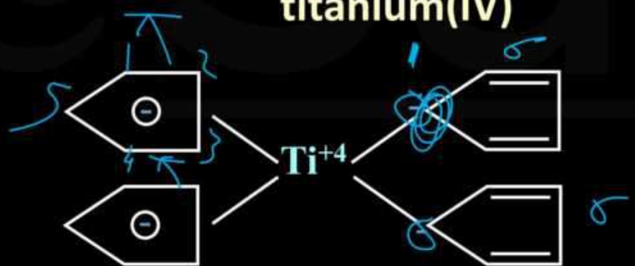
Tetraaquadichlorochromium(III) Chloride

(e) If words like di, tri, tetra are already used in the naming of ligand, or if it is polydented ligand or organic ligand, the prefixes bis–, tris– tetrakis–, pentakis– etc. are used to specify their number.

Example

$Ti(\sigma\text{-}C_5H_5)_2(\pi\text{-}C_5H_5)_2$

Bis(η^1-cyclopentadienyl)bis(η^5-cyclopentadienyl) titanium(IV)



If the complex is the part of anion then some of center metal atom/ion is named as

Al – aluminate

Pt – Platinate

Mo – Molybdate

Ni – Nickelate

Fe – Ferrate

Mn – Manganate

Q) The naming of some of the complexes is done as follows (as per IUPAC)

Complex Compounds	IUPAC Name
(i) $K_4[Fe(CN)_6]$ (anionic complex) so suffix 'ate' is added with metal name	Potassium hexacyanoferrate(II)
(ii) $K_2[Pt\,Cl_6]$	Potassium hexachloroplatinate(IV)
(iii) $[Co(NH_3)_6]\,Cl_3$ (Cationic complex) so metal is without any suffix	Hexamminecobalt (III) Chloride

20. Which of the following name formula combinations is not correct?

[J-MAIN–2014, Online]

Formula	Name
(1) $K[Cr(NH_3)_2Cl_4]$	Potassium diammine Tetrachlorochromate (III)
(2) $[Co(NH_3)_4(H_2O)I]SO_4$	Tetraammine aquaiodo cobalt (III) sulphate
(3) $[Mn(CN)_5]^{2-}$	Pentacyanomagnate (II) ion
(4) $K_2[Pt(CN)_4]$	Potassium tetracyanoplatinate(II)

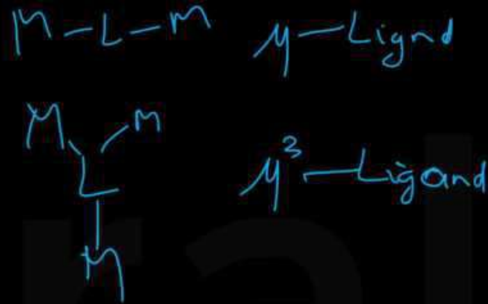
+3

Ans 3

(i) If a complex ion has two metal atoms then it is termed polynuclear.

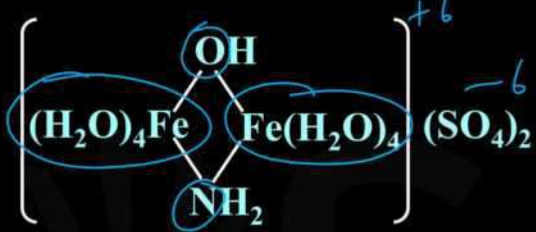
The ligand which connects the two metal ions is called as Bridging ligand or Bridge group.

A prefix of Greek letter μ^{x} is repeated before the name of each different kind of bridging group.



Where x is number of center metal atom/ion joined by one bridge ligand.The value of x is only mentioned when it is more than two.

Q)

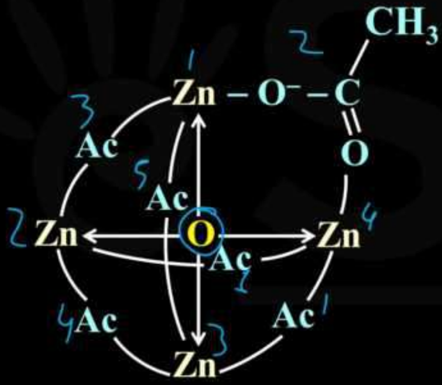


Ans. Tetraaquairon(III)-μ-amido-μ-hydroxotetraaquairon(III)sulphate

Q) $[Zn_4O(CH_3COO)_6]$

$-2-6+4(os)=0$

Sol. Hexa-μ–acetato – μ^4– oxido –tetrazinc(II)



Ac : CH_3COO^-


WORK HARDER
eSaral
1 minute motivation
Get Top Ranks in IIT-JEE/NEET with eSaral APP
Get it on
Google Play

Classification of Isomerism

Type of isomerism

- **Structural isomerism**
  - Ionization
  - Hydrate
  - Coordination
  - Linkage
  - Ligand
- **Stereo isomerism**
  - Geometrical
  - optical

(A) Structural Isomerism

It arises due to the difference in the type of chemical linkages and distribution of ligands within and outside the coordination sphere.

(a) Ionisation isomerism

Q) Find the ionisation isomers of the following

(1) $Co(NH_3)_4Br_2SO_4$

Sol.

$Co(NH_3)_4Br_2SO_4$ can be represented as:-

$[Co(NH_3)_4Br_2]SO_4$ (red violet)
and $[Co(NH_3)_4SO_4]Br_2$ (red)
These complexes give sulphate ion and bromide ion respectively

(b) Hydrate isomerism

Q) Find the hydrate/solvate isomers of $Cr(H_2O)_6Cl_3$ Compound.

Water of hydration

Sol. $Cr(H_2O)_6Cl_3$ has four possible structures

(i) $[Cr(H_2O)_6]Cl_3$ violet

(ii) $[Cr(H_2O)_5Cl]Cl_2.H_2O$ green

(iii) $[Cr(H_2O)_4Cl_2]Cl.2H_2O$ dark green

(iv) $[Cr(H_2O)_3Cl_3].3H_2O$ dark green

(c) Linkage isomerism

(i) This type of isomerism arises due to presence of ambidentate ligands like NO_2^-, CN^- and SCN^-

1. Which of the following pairs represents linkage isomers ? [AIEEE – 2009]

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

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

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

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

+4

Sol. 4

(d) Coordination isomerism

(i) This type of isomerism is exhibited when the complex has two complex ions in it - 'Cationic and anionic'.

Q) Find total number of Coordination isomers of the following

(a) $[Cu(NH_3)_4][PtCl_4]$

Ans. 4

(b) $[Fe^{III}(NH_3)_4][Co(NO_3)_6]$

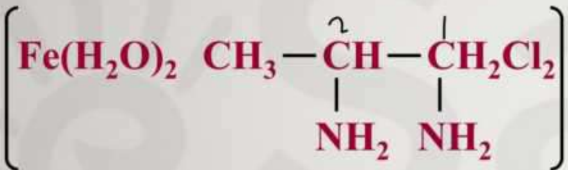
Ans. 6

(e) Ligand isomerism

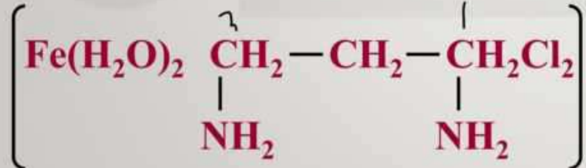
It is arising due to possible isomerism within a particular ligand.

Q) Find the ligand isomers of $[Fe(H_2O)_2C_3H_6(NH_2)_2Cl_2]$

Sol. It has two different ligand structures



and



(f) Co-ordination Position Isomerisation

It is shown by polynuclear complexes, due to interchange of ligands between the different metal nuclei.

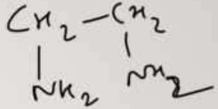
(B) Stereo Isomerism

They have same molecular formula, same constitution, they differ only with respect to the spatial orientation of ligands in space around the metal ion.

(a) Geometrical Isomerism

(i) The ligands occupy different positions around the central metal ion.

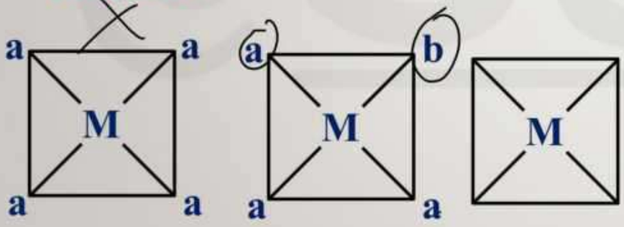
Geometrical isomers with coordination number = 4 (Square planar complexes)



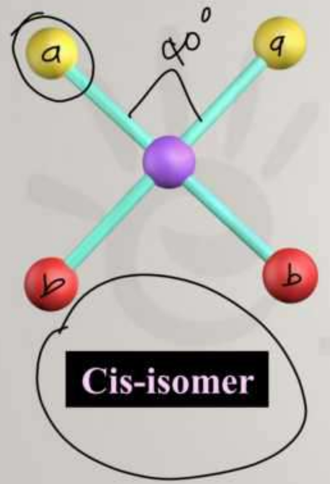
AA

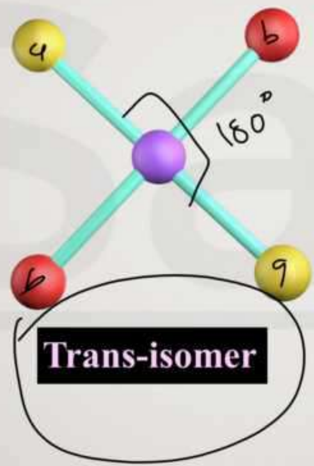
a, b → monodentate

(i) Ma_4, Ma_3b, $M(AA)_2$, $M(AA)a_2$, $M(AA)ab$, $M(AB)a_2$, $M(AA)(AB)$, $M(AA)(BB)$ can't show GI.



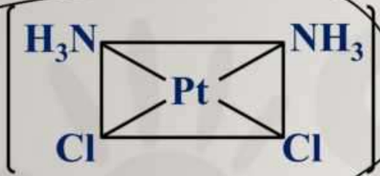
(i) Complexes with general formula, Ma_2b_2 (where both a and b are monodentate) can have Cis-and trans isomers.





Complex Ma_2b_2

$[Pt(NH_3)_2Cl_2]$

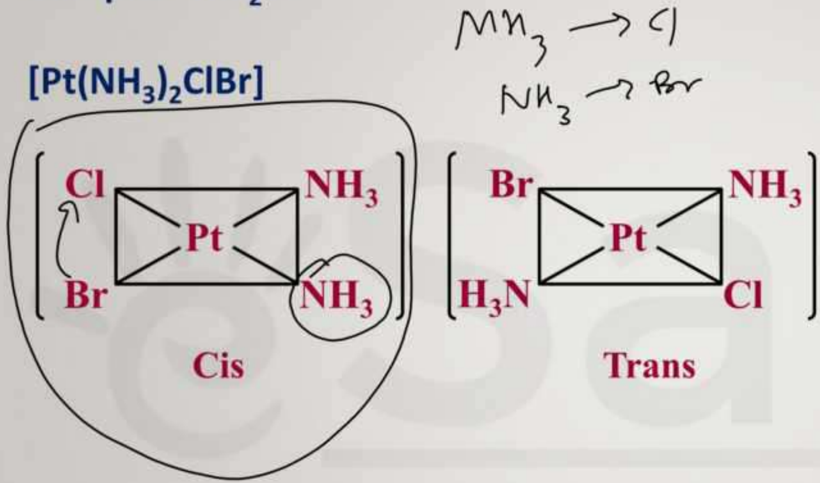


Cis(Cis-platin) anti cancer

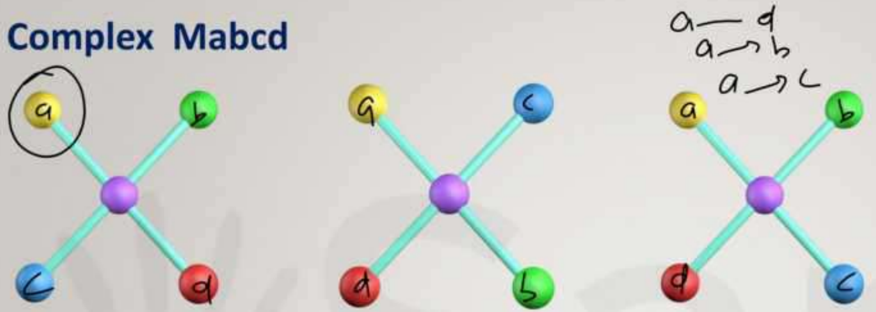
Trans

Complex Ma_2bc

$[Pt(NH_3)_2ClBr]$



Complex Mabcd



3

10. The complex ion

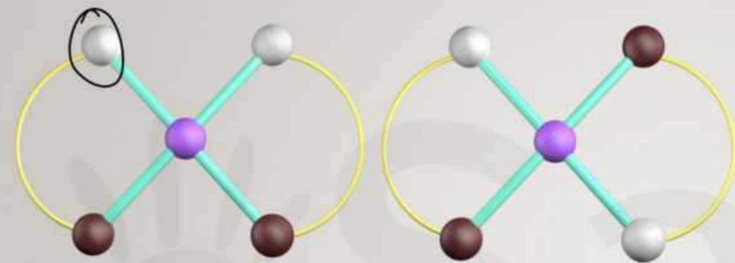
$[Pt(NO_2)(Py)(NH_3)(NH_2OH)]^+$ will give :- **[J-MAIN–2012, Online]**

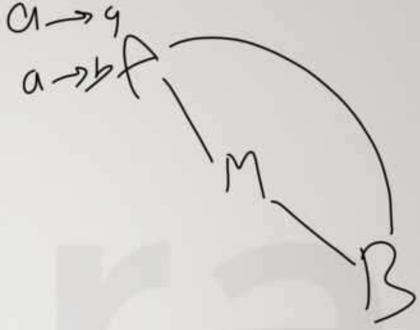
(1) 4 isomers (Geometrical)
(2) 2 isomers (Geometrical)
(3) 3 isomers (Geometrical)
(4) 6 isomers (Geometrical)

Mabcd

Sol. 3

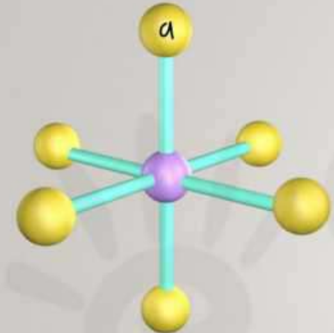
$M(AB)_2$



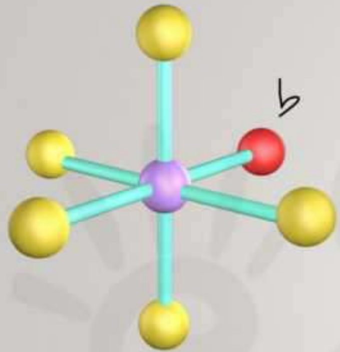


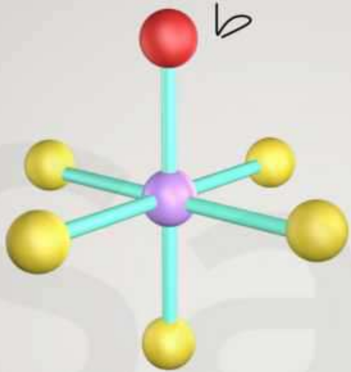
Stereoisomerism In Octahedral Complexes

Ma_6



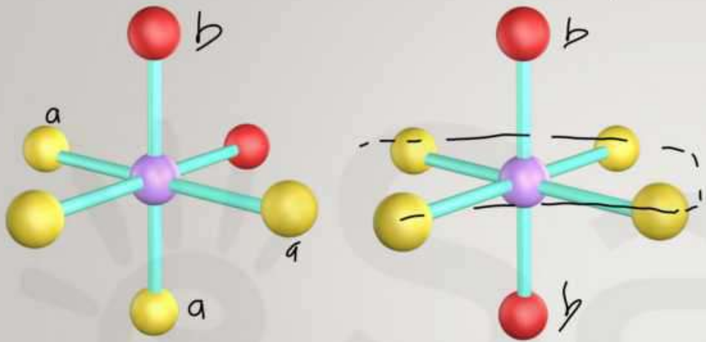
Ma_5b





no isomerism

Ma_4b_2

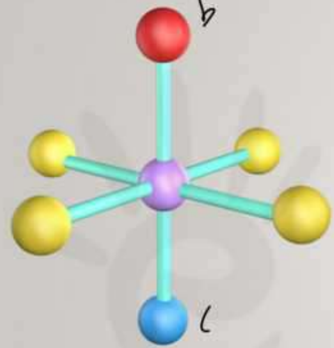


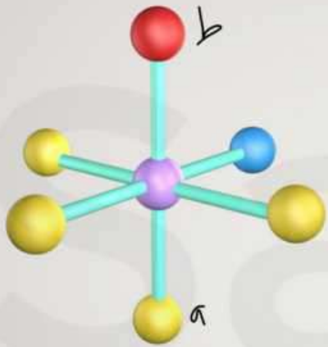
For Octahedral
2 isomers

2 same species
in trans position

no OI

Ma_4bc

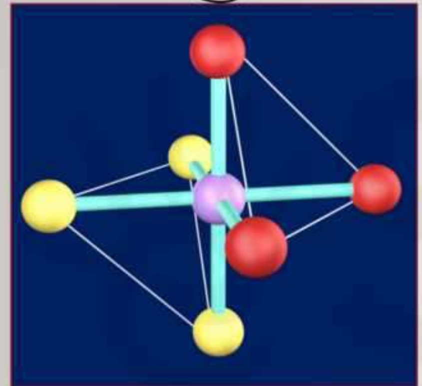




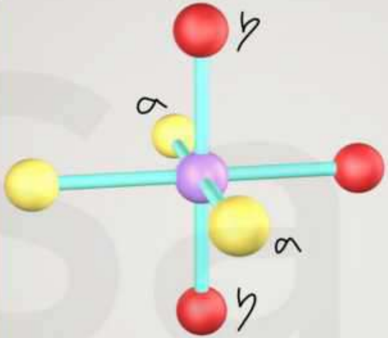
2 Isomers

Ma_3b_3

fac



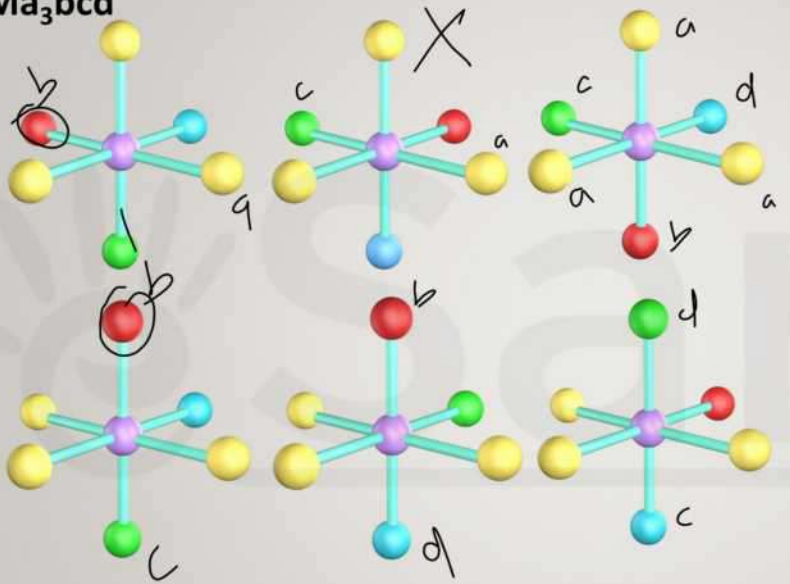
mer



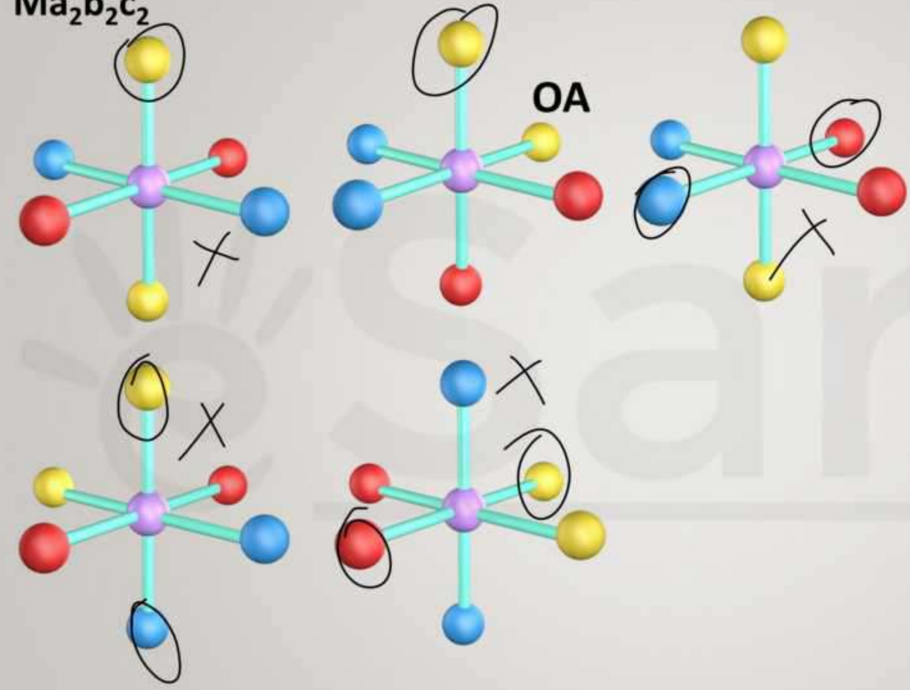
2 Isomers

Ma_3bcd

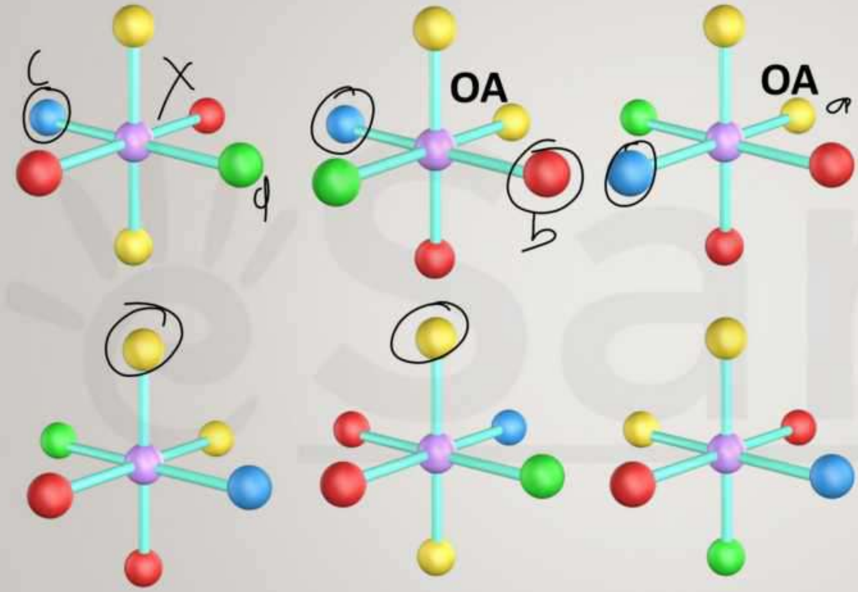
OA



$Ma_2b_2c_2$



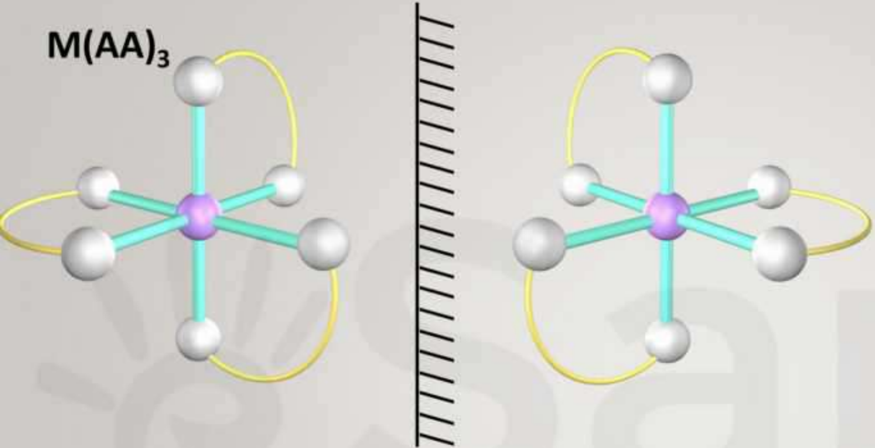
Ma_2b_2cd

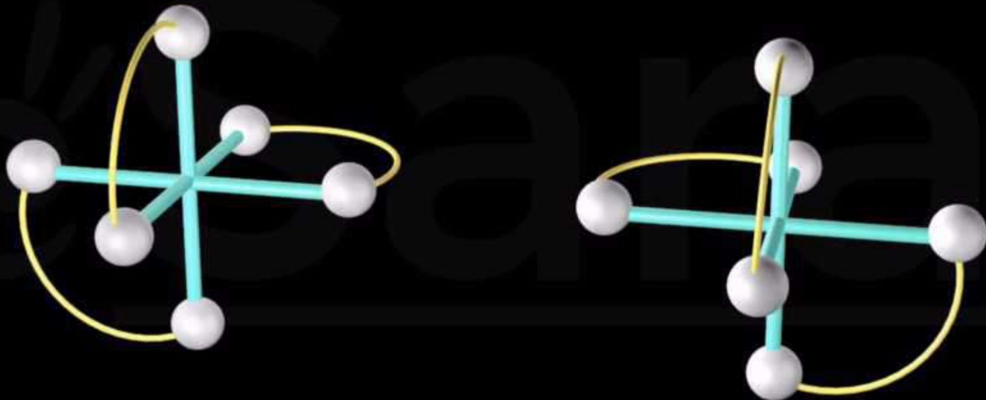


EP
2

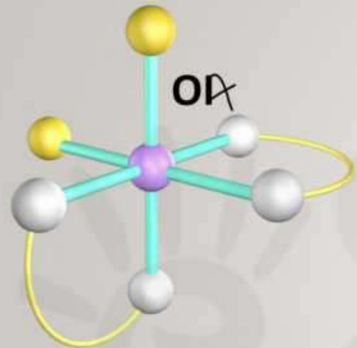
General formula	GI	Pairs of Enantiomers	Total
Ma_6	1	0	1
Ma_5b	1	0	1
Ma_4b_2	2	0	2
Ma_4bc	2	0	2
Ma_3b_3	2	0	2
Ma_3b_2c	3	0	3
Ma_3bcd	4	1	5
$Ma_2b_2c_2$	5	1	6
Ma_2b_2cd	6	2	8
Ma_2bcde	9	6	15
Mabcdef	15	15	30

$M(AA)_3$

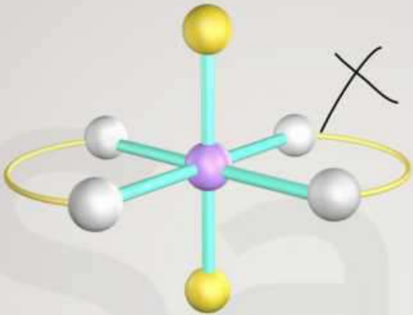




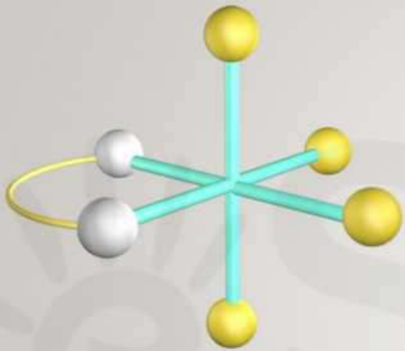
$M(AA)_2a_2$



OA

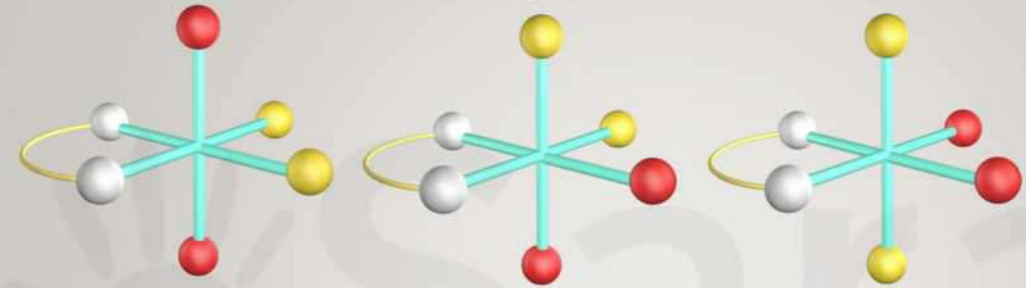


$M(AA)a_4$



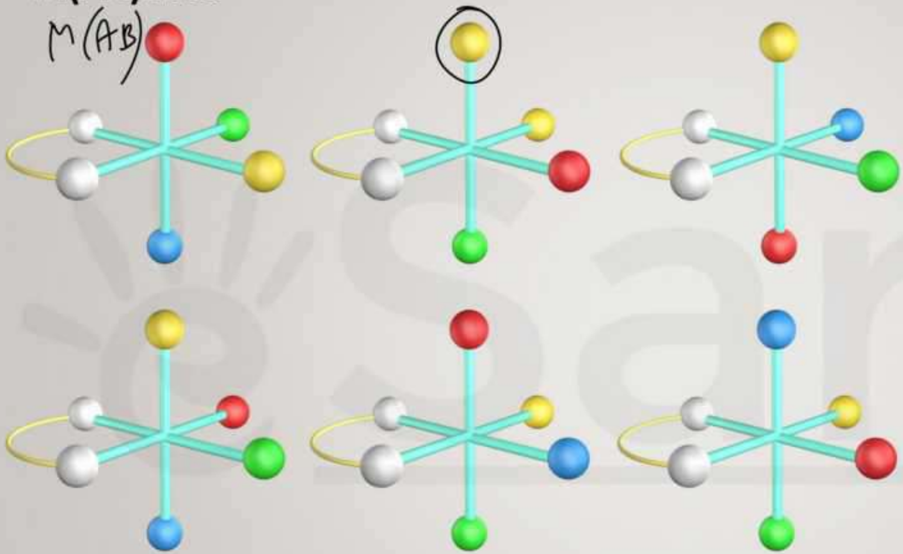
M(AA)a_2b_2

OA

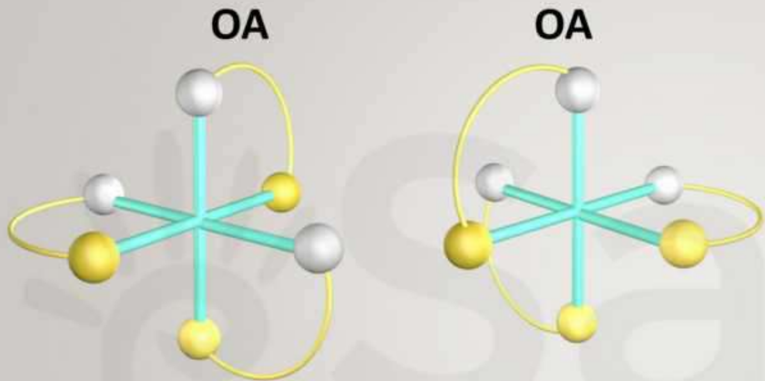


M(AA)abcd

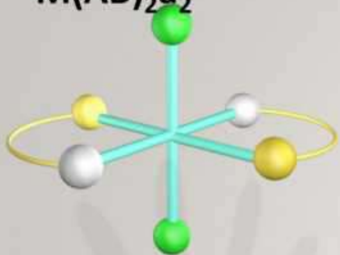
M(AB)

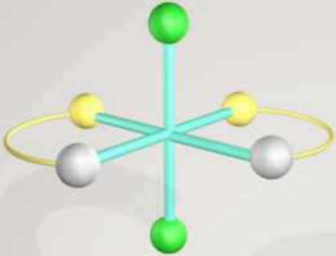


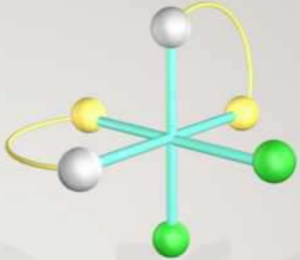
$M(AB)_3$



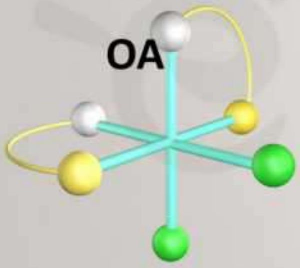
$M(AB)_2a_2$



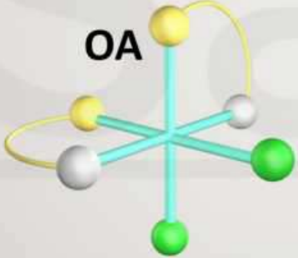




OA

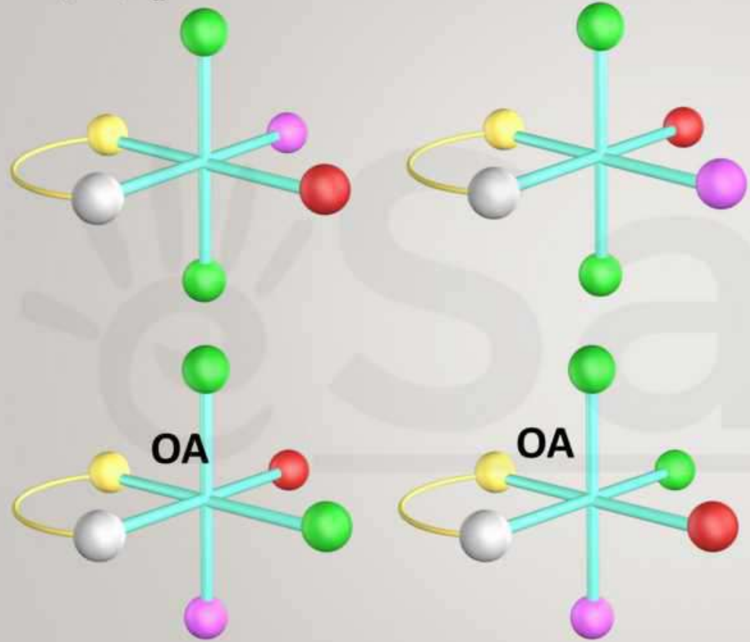


OA

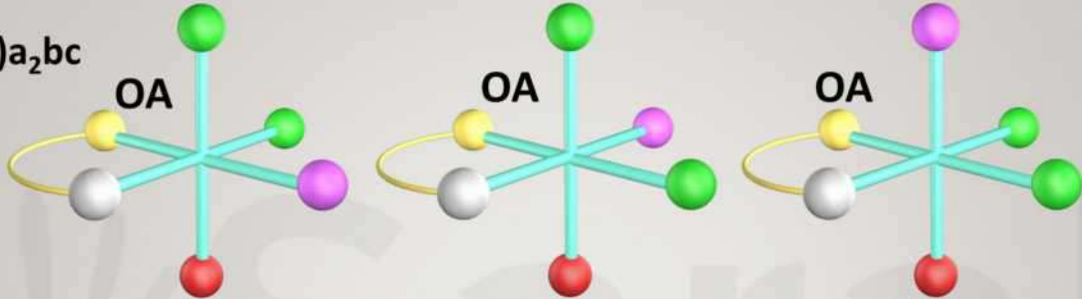


OA

$M(AB)a_2bc$



$M(AB)a_2bc$



11. Which of the following complex ions will exhibit optical isomerism? (en = 1, 2-diamine ethane)

(1) $[Co(en)_2Cl_2]^+$ ✓

(2) $[Zn(en)_2]^{2+}$ ✗

(3) $[Co(NH_3)_4Cl_2]^+$ ✗

(4) $[Cr(NH_3)_2Cl_2]^+$ ✗

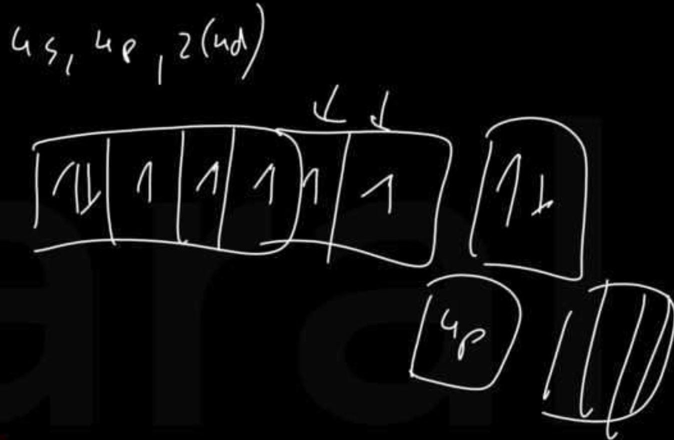
Ma_4b_2

$M(AA)_2b_2$


WORK HARDER
1 minute motivation

Valence Bond Theory

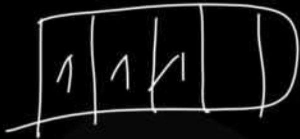
(a) The metal ion under the influence of ligands can use its vacant d(n-1), ns, np, nd orbitals for hybridisation.

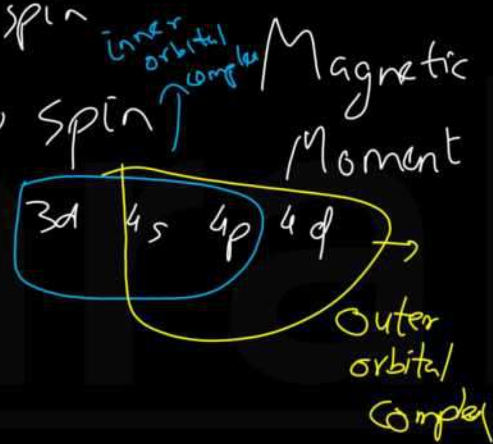


In the formation of $[Fe(NH_3)_6]^{3+}$, Fe^{+3} ion provides six vacant orbitals.

In $[Cu(NH_3)_4]^{2+}$, Cu^{+2} ion provides four vacant orbitals.

Points To Remember In VBT



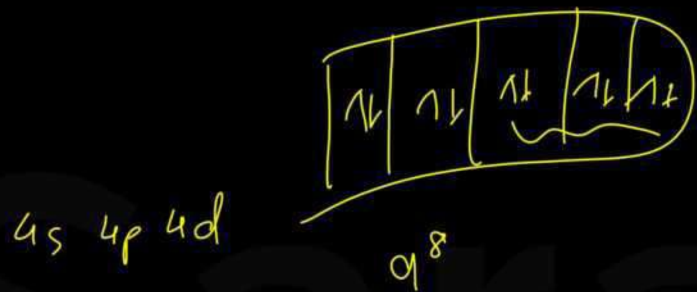


(i) In octahedral complexes with CM having d^0, d^1, d^2, d^3 configuration, pairing of e^- don't take place, no matter what the ligand is.

And all such complexes are inner orbital complexes with $\mu = 0, \sqrt{3}, \sqrt{8}, \sqrt{15}$ respectively (d^2sp^3 configuration)

d^0 **Diamagnetic**

d^1, d^2, d^3 **Paramagnetic**



(ii) In octahedral complexes with CM having d^8, d^9, d^{10} configuration pairing of e^- doesn't take place, whatever be the ligand, and all such complexes are outer orbital complex (sp^3d^2) with $\mu = \sqrt{8}, \sqrt{3}, 0$ BM respectively.

(iv) All the octahedral complex of Co^{3+} are inner orbital complexes (d^2sp^3) irrespective of nature of ligands and all such complex are diamagnetic except $[CoF_6]^{3-}$ and $[Co(H_2O)_3F_3]$ are outer orbital complex, sp^3d^2, $\mu = \sqrt{24}$ BM

(v) All the above points are written considering that ligand is not paramegnetic. (important)

Example

$$\overset{II}{K_4[Fe(CN)_5(O_2)]}$$

is parameganetic due to parameganetic nature of O_2^- (superoxido)

$\phi \rightarrow$ poor shielding

(vi) In all the octahedral complexes of 4d and 5d series metal ions with configuration d^4, d^5, d^6 and d^7, pairing of e^- takes place whatever may be the ligand.

Q) For $[Fe(H_2O)5 NO]SO_4$ (Brown ring complex), $\mu = \sqrt{15}$ B. M. Select the correct statement(s)

NO^+

Learn

(A) oxidation state of Fe is +1

(B) geometry is octahedral

(C) hybirdisation of Fe is sp^3d^2

(D) NO is neutral ligand

Ans. A, B, C

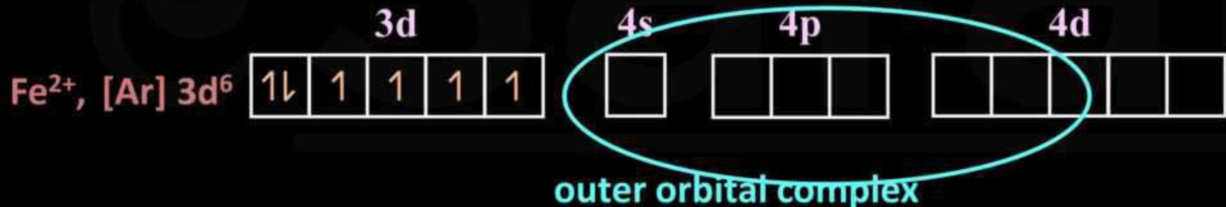
Q) $[Fe(H_2O)_6]^{2+}$ is paramagnetic while $[Fe(CN)_6]^{4-}$ is diamagnetic.

VBTX

$d^4 - d^7$

Ligand strength

Sol. $[Fe(H_2O)_6]^{3-}$ involves sp^3d^2 hybridization.

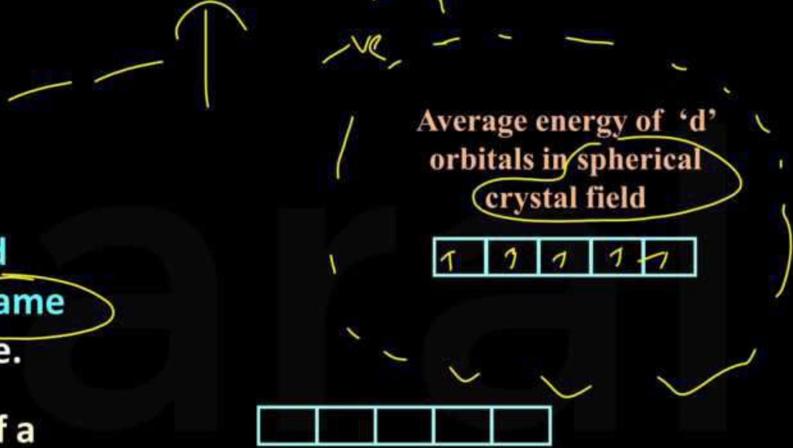


Crystal Field Theory

Most Important

The five d-orbitals in an isolated gaseous metal atom/ion have same energy, i.e., they are degenerate.

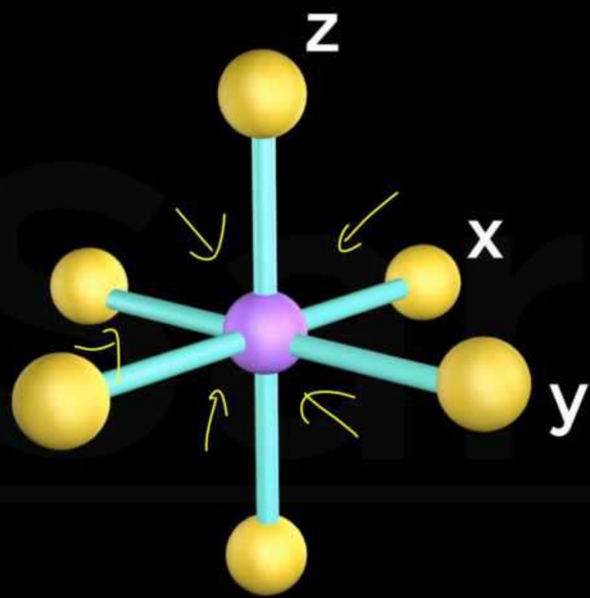
This degeneracy is maintained if a spherically symmetrical field of negative charges surrounds the metal atom/ion.



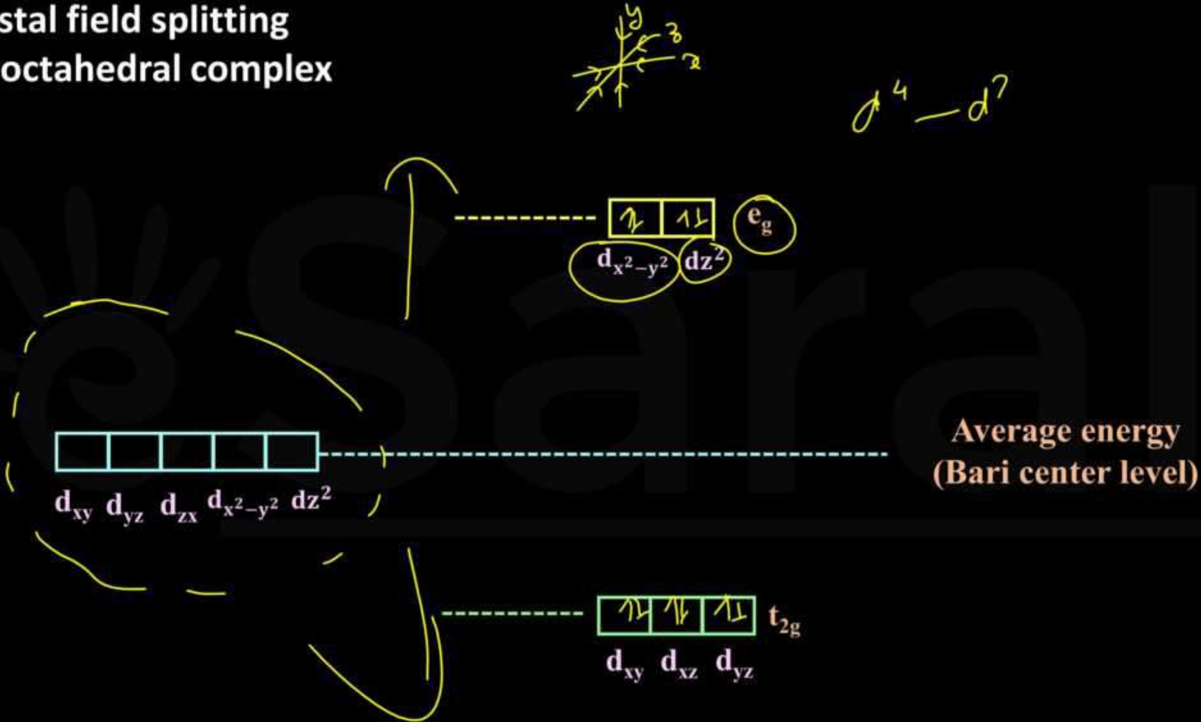
Five degenerate d-orbitals on the free central metal cation

However, when this negative field is due to ligands in a complex, it becomes asymmetrical and the degeneracy of the d orbitals is lost.

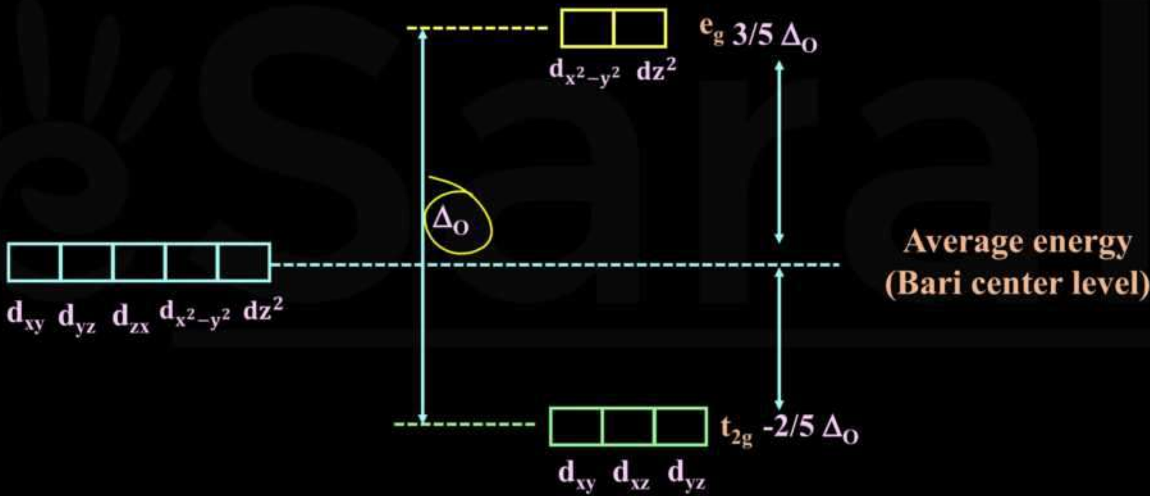
It results in splitting of the d orbitals.


z
x
y

Crystal field splitting for octahedral complex



Crystal field splitting
for octahedral complex

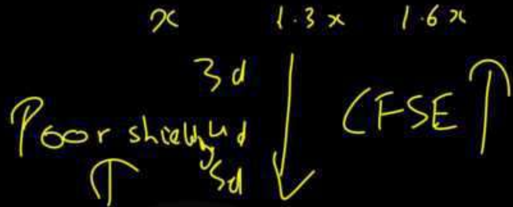


CFSE depends upon the following factors

+ve charge ↑

CFSE ↑

1. Higher the charge on the metal ion higher will be CFSE.



2. It depends upon the nature of metal ion, that is the metal ion is of which transition series.

It has been observed that as we go down from first transition state to second to third CFSE increases by 30% at each step.

LS↑ Δ_o↑

***

3. It depends upon the nature of ligand.

Some ligands are able to produce strong fields in which case, the splitting will be large whereas others produce weak fields and consequently result in small splitting of d orbitals.

CFSE depends upon the following factors

1. Higher the charge on the metal ion higher will be CFSE.

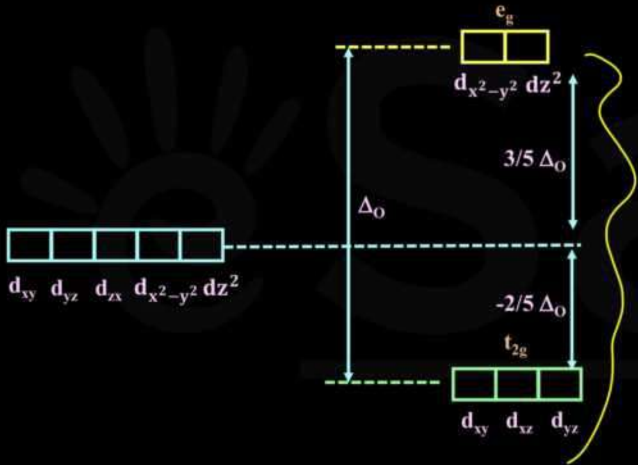
2. It depends upon the nature of metal ion, that is the metal ion is of which transition series.

It has been observed that as we go down from first transition state to second to third CFSE increases by 30% at each step.

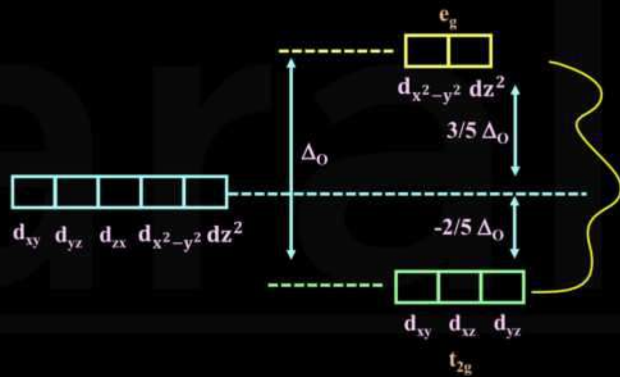
3. It depends upon the nature of ligand.

Some ligands are able to produce strong fields in which case, the splitting will be large whereas others produce weak fields and consequently result in small splitting of d orbitals.

SFL


e_g
$d_{x^2-y^2}$ dz^2
3/5 Δ_O
Δ_O
d_{xy} d_{yz} d_{zx} $d_{x^2-y^2}$ dz^2
-2/5 Δ_O
t_{2g}
d_{xy} d_{xz} d_{yz}

WFL


e_g
$d_{x^2-y^2}$ dz^2
3/5 Δ_O
Δ_O
d_{xy} d_{yz} d_{zx} $d_{x^2-y^2}$ dz^2
-2/5 Δ_O
d_{xy} d_{xz} d_{yz}
t_{2g}

C, N → SFL

O, X → WFL

In general, ligands can be arranged in a series in the order of increasing field strength as given below

$I^- < Br^- < SCN^- < Cl^- < S^{2-} < F^- < OH^- < C_2O_4^{2-} < H_2O < NCS^- < EDTA^{4-} < NH_3 < en < NO_2^- < CN^- < CO$

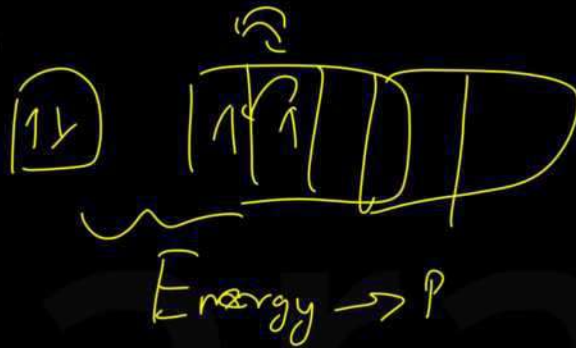
3. It depends upon geometry.

$\Delta_{sp} > \Delta_O > \Delta_t$

$\Delta_{sp} > 1.3\Delta_O$

$\Delta_t > 4/9\Delta_O$

Mean pairing energy (P)



It is the energy required for electron pairing in a single orbital. And it is defined per pair.

The two possibilites are-

(i) If $\Delta_O < P$, the fourth electron enters in one of the e_g orbitals giving the configuration $t^3_{2g}e_g^1$.

(ii) Ligands for which $\Delta_O < P$ are known as weak field ligands and form high spin complexes.

SFL Pairing ✓
WFL " ✗

(ii) If $\Delta_o > P$, it becomes energetically more favourable for the fourth electron to occupy a t_{2g} orbital with configuration $t_{2g}^4 e_g^0$.

Ligands which produce this effect are known as **strong field ligands** and form low spin complexes.

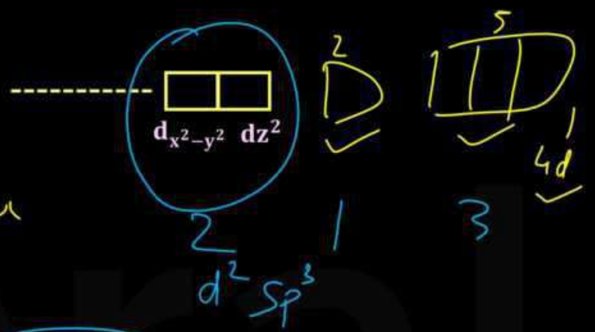
SFL → d^2sp^3

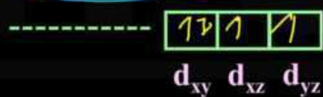
WFL → sp^3d^2

d^4, d^5, d^6, d^7

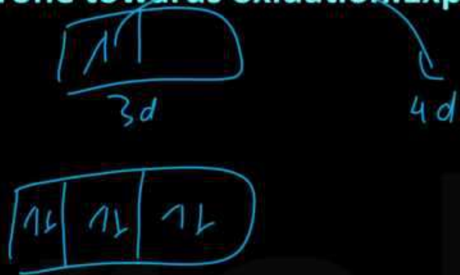
- **WFL** → ~~d^2sp^3~~ sp^3d^2 — outer orbital complex
- **SFL** → ~~sp^3d^2~~ d^2sp^3 — inner orbital complex

  d^7 will shift its 7^{th} e- to the higher energy level
- **WFL + SFL** → **Can't be predicted unless the relationship b/w Δ_o & P is directly or indirectly given.**





Q) $[CO(NH_3)_6]^{2+}$ & $[CO(NO_2)_6]^{4-}$ are very much prone towards oxidation.Explain.



$\left.\begin{array}{l} NH_3 \\ NO_2 \end{array}\right\}$ SFL | Can shift an e^- to the higher energetic level

$\Rightarrow$ t_2g^6 eg^1

$$[Co(NH_3)_6]^{2+} \longrightarrow [Co(NH_3)_6]^{3+} + e^-$$

Since the last e^- is already in the higher energy status. Room temp or visible light is sufficient to remove it oxidation.

WFL → high spin

	No. of upe
d^4	4
d^5	5
d^6	4
d^7	3

d^4–d^7 with WFL → high spin

	No. of upe	
d^4	2	Low Spin
d^5	1	
d^6	0	
d^7	1	

SFL →

Crystal Field Stabilising Energy In Octahedral Field (CFSE)

not important

Formula

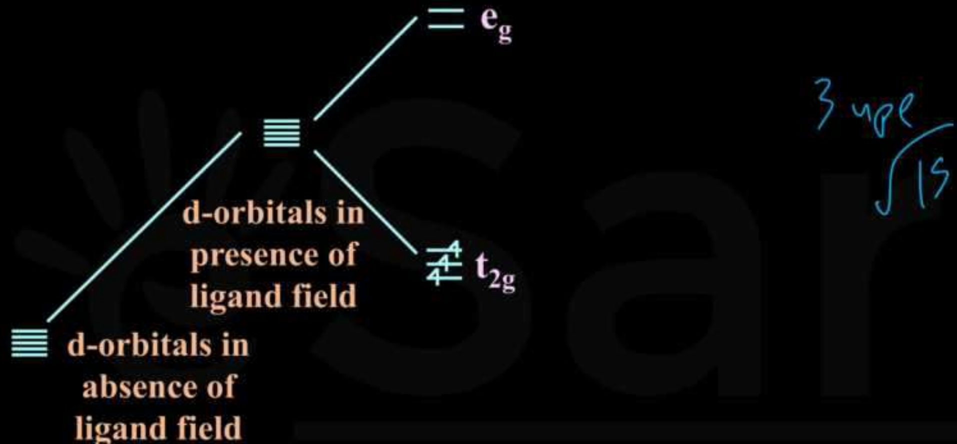
$$CFSE = [-0.4\,(n)\,t_{2g} + 0.6\,(n')\,e_g]\,\Delta_0 + {*}mP.$$

where n & n' are number of electron(s) in t_{2g} & e_g orbitals respectively and Δ_0 crystal field splitting energy for octahedral complex *m represents the number of electron pairs formed.

Q) For each of the following complexes, draw a crystal field energy-level diagram, assign the electrons to orbitals, and predict the number of unpaired electrons

(i) $[CrF_6]^{3-}$

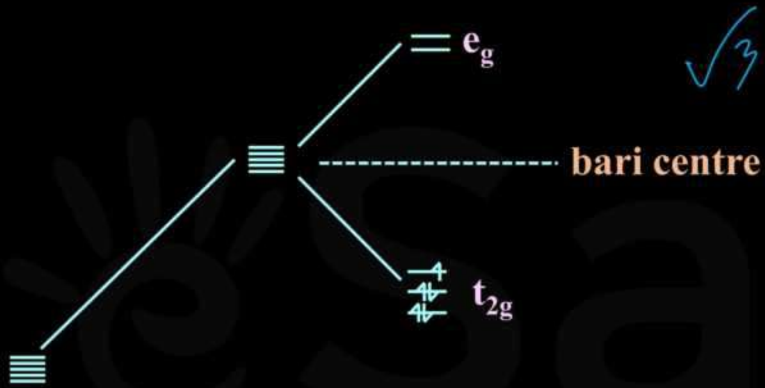
Ans. F^- is weak field ligand. Cr^{3+}, $3d^3$



So number of unpaired electrons = 3

(iii) $[Fe(CN)_6]^{3-}$

Ans. CN^- is strong field ligand. Fe^{3+}, $3d^5$



So number of unpaired electron = 1.

Q) $[Cr(H_2O)_6]Cl_3$ has a magnetic moment of 3.83 B.M. The correct distribution of 3d electrons in Chromium is?

(A) $3d_{xy}^1, 3d_{yz}^1, 3d_{z^2}^1$

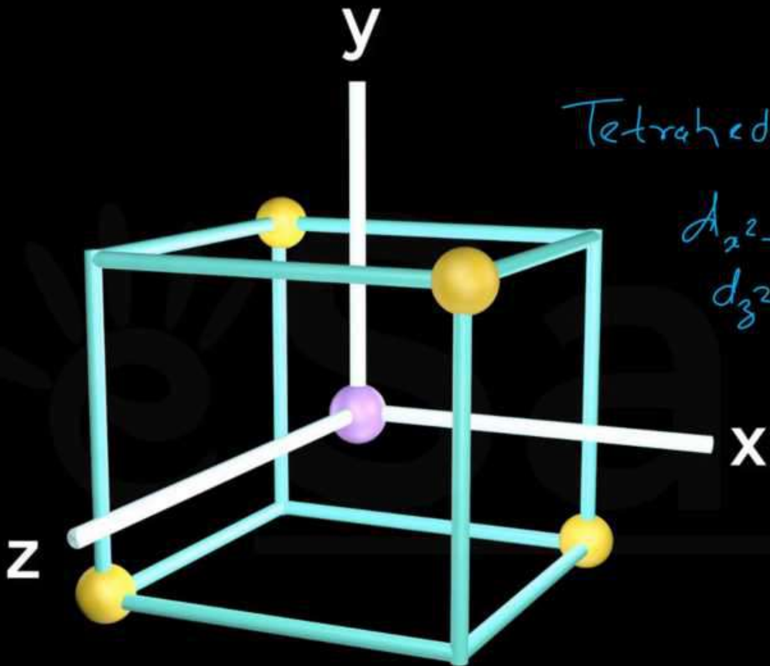
(B) $\left(3d_{x^2-y^2}\right)^1, 3d_{z^2}^1, 3d_{xz}^1$

(C) $3d_{xz}^1 \left(3d_{x^2-y^2}\right)^1, 3d_{yz}^1$

(D) $3d_{xy}^1, 3d_{yz}^1, 3d_{xz}^1$

Ans. (D)

Crystal Field Splitting In Tetrahedral Coordination Entities

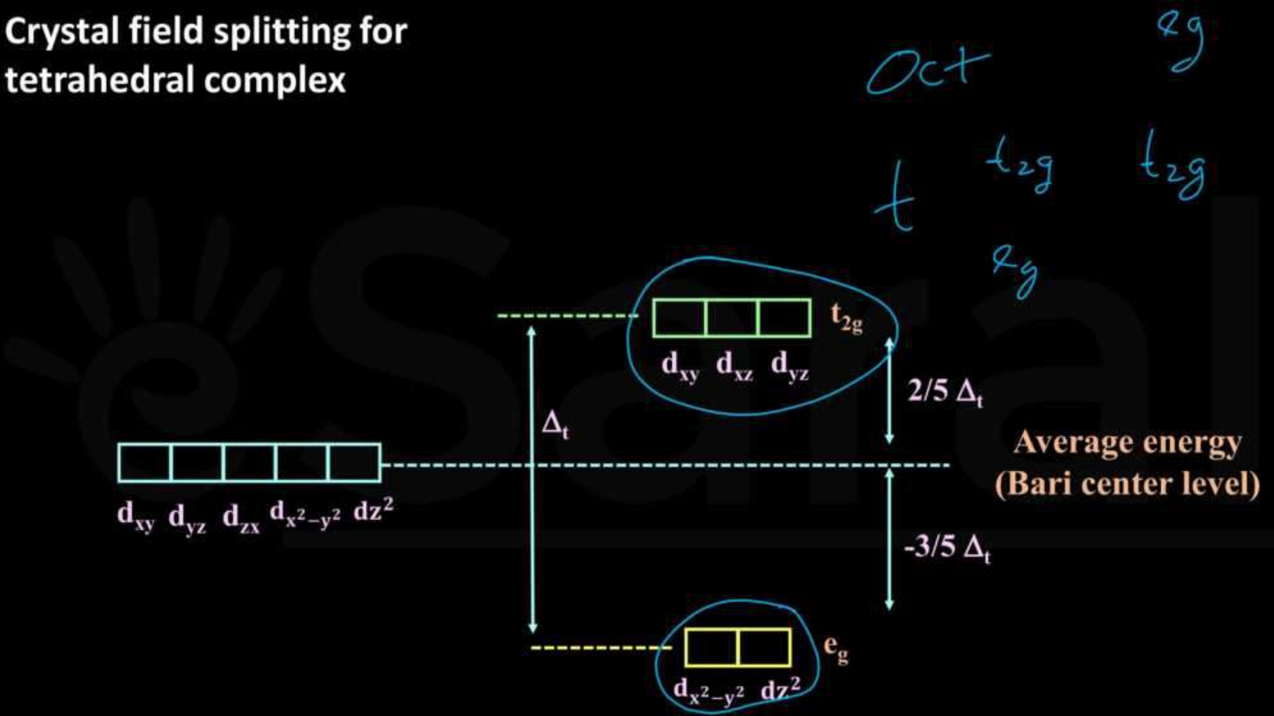


Tetrahedral

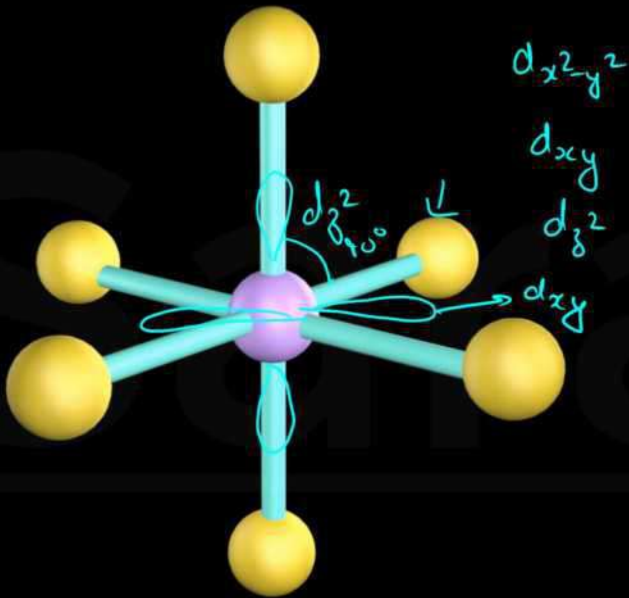
$d_{x^2-y^2}$, d_{z^2} ↓

d_{xy} d_{yz} d_{xz} ↑

Crystal field splitting for tetrahedral complex

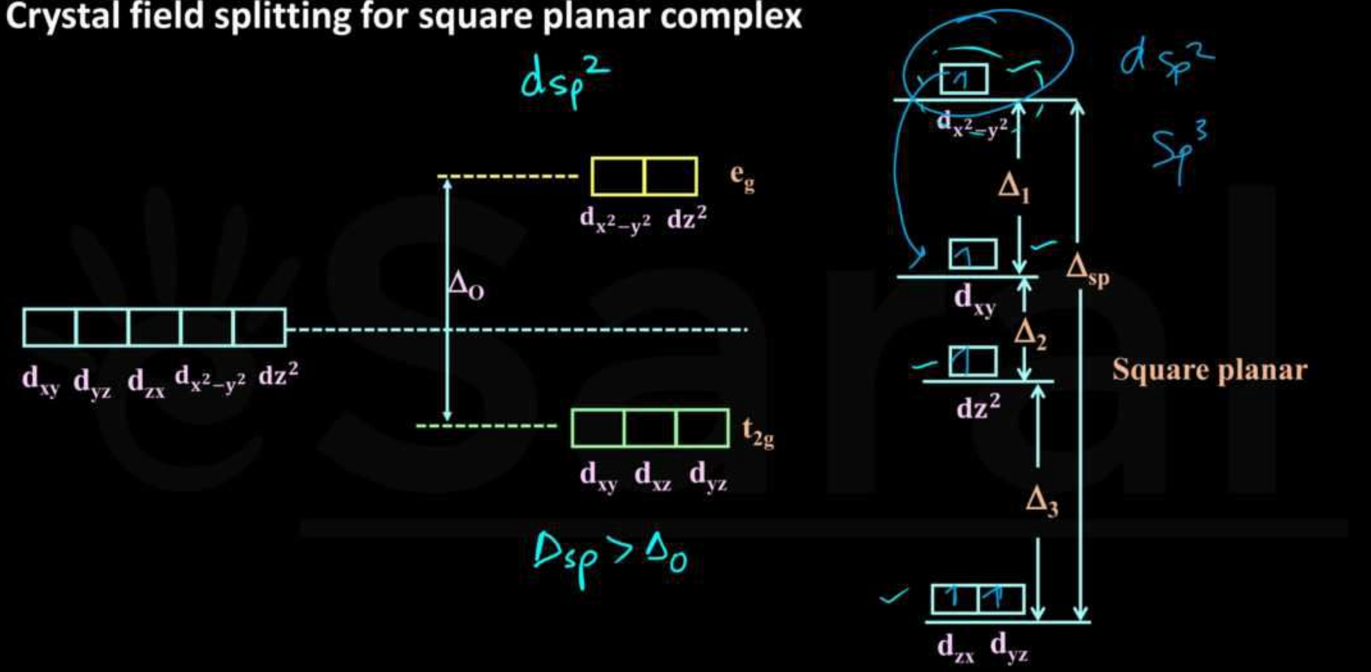


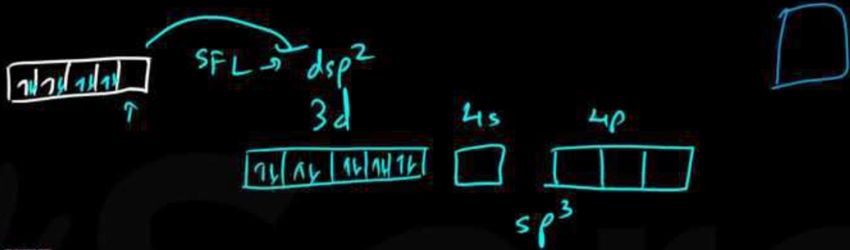
Crystal Field Splitting in Square Planar Coordination Entities



$d_{x^2-y^2}$
d_{xy}
d_{z^2}
d_{z^2}
$90°$
d_{xy}

Crystal field splitting for square planar complex





CN = 4

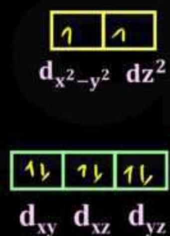
- WFL → sp^3 (outer orbital complex)
- SFL → dsp^2 (inner orbital complex)

Not valid for d^{10}

Q) Which of the following are expected to have non sp^3 hybridisation but tetrahedral geometry?

(A) $[Ni(CO)_4]$ (B) $[PtCl_4]^{2-}$ (C) $[CrO_4^{2-}]$ (D) NH_3

Sol. Since this is a d^0 system.



Ans. (C)

Q) The magnetic moments of following, arranged in increasing order will be (atomic number of Co = 27) Reversion

(1) Co^{3+} (octahedral complex with a strong field ligand) $d^6 \to 0$ upe LS

(2) Co^{3+} (octahedral complex with a weak field ligand, F^-) $d^6 \to 4$ upe HS

(3) Co^{2+} (tetrahedral complex) $d^7 \to 3$ upe WFL

(4) Co^{2+} (square planar complex) 2 upe SFL

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

Ans is B

* $[Mn(NH_3)_6]^{2+}$ → WFL

* $[Fe(NH_3)_6]^{2+}$ → WFL

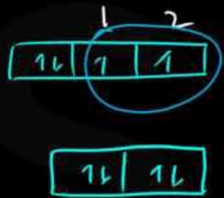
* $[Co(H_2O)_6]^{3+}$ → SFL

* $[NiF_6]^{2-}$ → SFL

Q) The magnetic moment of $[NiCl_4]^{2-}$ is?

(A) 2.82 BM (B) 1.41 BM (C) 1.82 BM (D) 5.46 BM

Ans A



(F) Factors Influencing the Magnitude of CFSE

Stability Factors

1. Higher the CFSE value higher will be the stability of complex

Strong Ligand ↑ Stability ↑

+3

a) $[Fe(H_2O)_6]^{3+} > [Fe(H_2O)_6]^{2+}$

b) $[CoCl_6]^{3-} < [Co(C_2O_4)_3]^{3-} < [Co(CN)_6]^{3-}$

c) $[ML_4]^{n\pm} > [ML_6]^{n\pm} > [ML_4]^{n\pm}$
tet oct sp

d) $[Co(NH_3)_6]^{3+} < [Rh(NH_3)_6]^{3+} < [Ir(NH_3)_6]^{3+}$
3d 4d 5d

2. Chelated complexes are more stable than non-chelated complexes given the donor atoms are same

$[Ni(NH_3)_6]^{2+} + 3en \rightarrow [Ni(en)_3]^{2+} + 6\ NH_3$

$[Co(NH_3)_6]^{3+} + EDTA \rightarrow [Co(EDTA)]^{-} + 6NH_3$

$[Ni(NH_3)_6]^{2+} < [Ni(en)_3]^{2+}$

$[Co(NH_3)_6]^{3+} < [Co(EDTA)]^{-}$

no of rings ↑ stability ↑

(ii) $[Pd(en)_2]Cl_2$ < $[Pd(trien)]Cl_2$

2 rings 3 rings

(iii) $[Fe(ox)_3]^{3-}$ < $[Fe(CN)_6]^{3-}$

3. Same charges on the cation but the number of d-electrons is different

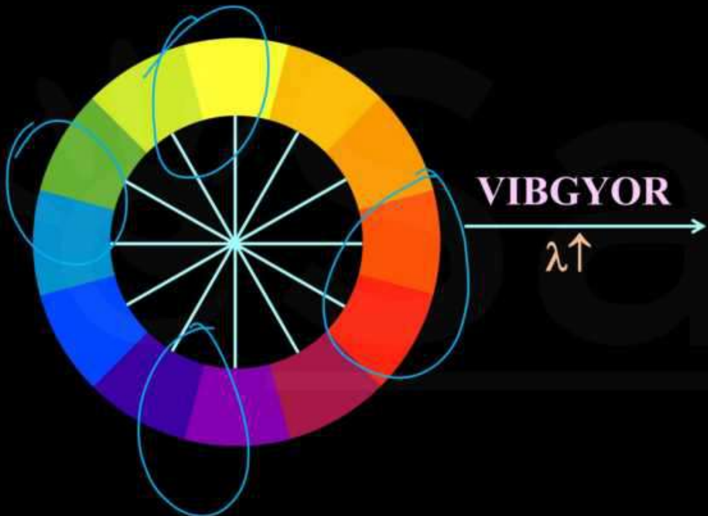
The magnitude of CFSE increases with the increase of the number of d-electrons.

e.g., $[Co(H_2O)_6]^{2+} < [Ni(H_2O)_6]^{2+}$

Colour In Coordination Compounds

According to the crystal field theory the colour of coordination compound is due to d-d transition of electron

Colour wheel



Q) The correct order for the wavelength of absorption in the visible resion is

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

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

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

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

Ans. (A)

The octahedral complex of a metal ion M^{3+} with four monodentate ligands L_1, L_2, L_3 and L_4 absorb wavelength in the region of red, green, yellow and blue, respectively. The increasing order of ligand strength of the four ligands is: **[J-MAIN–2014]**

(1) $L_3 < L_2 < L_4 < L_1$

(2) $L_1 < L_2 < L_4 < L_3$

(3) $L_4 < L_3 < L_2 < L_1$

(4) $L_1 < L_3 < L_2 < L_4$

VIBGYOR → $\lambda \uparrow$

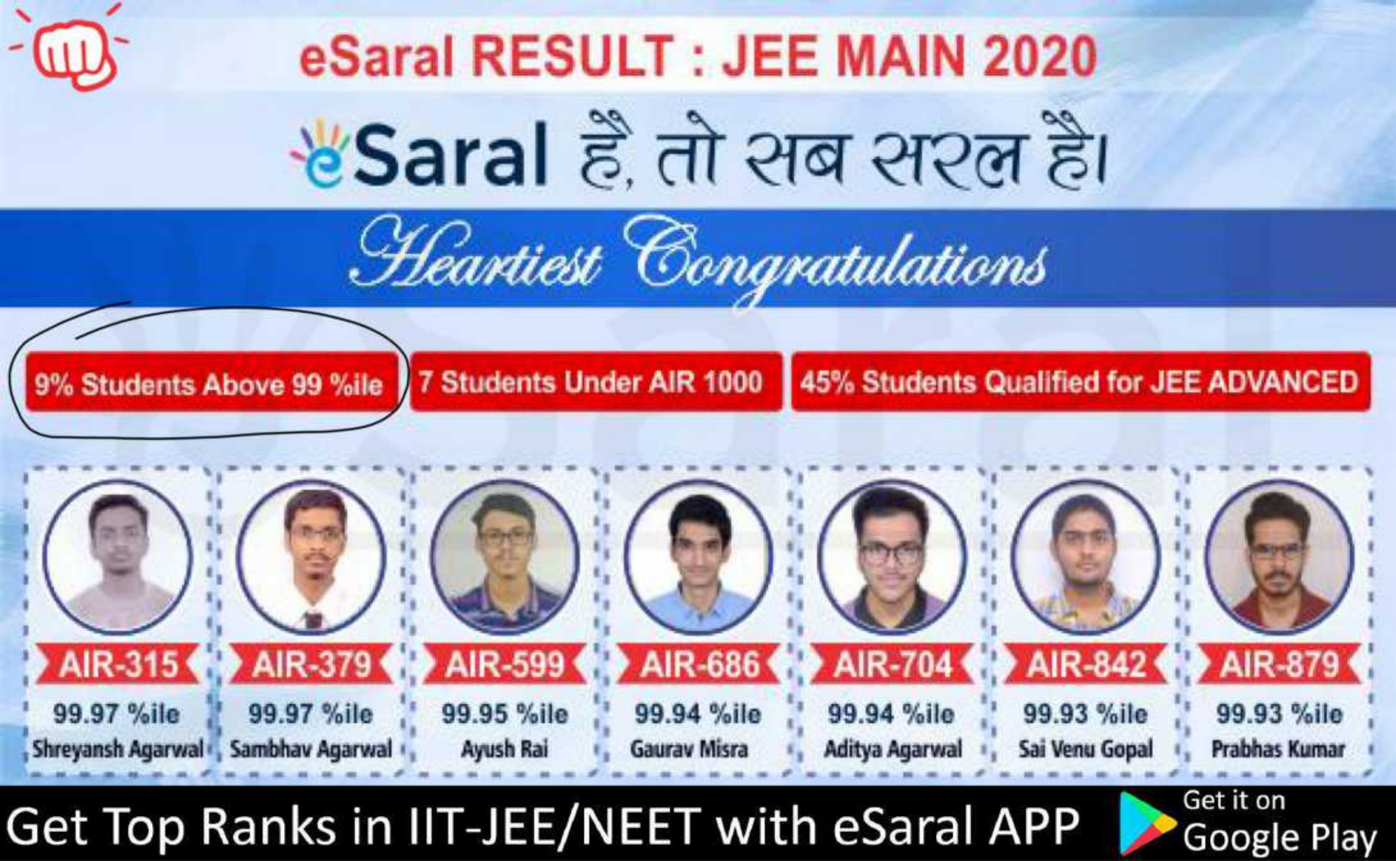
$E \downarrow$

L_4, L_2, L_3, L_1

Ans. 4

What you get inside the course?

- Study from Kota's **Top IITian Faculties**
- **650+ Hours of PCM Videos** Lectures with best Visualisation
- **30000+** Solved Qs
- Personalised date wise Time-table
- Live **4-Layered Doubt Solving** System
- Personalised 3-Layered **One to One Mentorship**
- **115** Fully Solved Topic wise segregated **Practice Sheets** with **homework index & video solutions**
- Solved **Prev 10 years Chapterwise Qs**
- Quick Revision Video Lectures and **90+ Mind Maps**
- **97 JEE Main** and **94 JEE advanced** 1hr Topic wise **Tests**
- 3 Hour Regular Review tests and Test Series
- Instant Test Analysis Report
- Regular Motivation and Strategy Sessions


eSaral RESULT : JEE MAIN 2020
eSaral है, तो सब सरल है।
Heartiest Congratulations
9% Students Above 99 %ile
7 Students Under AIR 1000
45% Students Qualified for JEE ADVANCED
AIR-315
99.97 %ile
Shreyansh Agarwal
AIR-379
99.97 %ile
Sambhav Agarwal
AIR-599
99.95 %ile
Ayush Rai
AIR-686
99.94 %ile
Gaurav Misra
AIR-704
99.94 %ile
Aditya Agarwal
AIR-842
99.93 %ile
Sai Venu Gopal
AIR-879
99.93 %ile
Prabhas Kumar
Get Top Ranks in IIT-JEE/NEET with eSaral APP
Get it on
Google Play

Outstanding eSaral RESULT in JEE ADVANCED 2020
eSaralites in Top 1000
CRL
AIR-468 Amogh v. Agarwal
AIR-932 Shreyansh Agarwal
AIR-966 Gaurav Misra
EWS
AIR-175 Prabhas Kumar
AIR-190 Apoorv Bansal
AIR-211 Vivek Kumar Singhal
AIR-240 Shiva Ganesh Reddy
AIR-295 Shikhar Gupta
AIR-635 Chitraansh Pandey
AIR-669 Harsh Vijayvargiya
AIR-782 Param Shah
AIR-802
OBC
AIR-263 Abhay Saini
AIR-323 Gaurav Kumawat
AIR-541 Divy Soni
AIR-821 Siddhant Sekhar
AIR-909 Salman Hussain
eSaralites in Top 5000 (CRL)
AIR-1033 Aditya Agarwal
AIR-1224 Ashish Anand
AIR-1289 Pranav Jain
AIR-1330 Ayush Rai
AIR-1662 Vardan Jain
AIR-1670 Akshat Jain
AIR-1738
AIR-2430 Aditya Anand
AIR-2577
AIR-3377
AIR-3390
AIR-3537 Brijesh kumar
AIR-3622
AIR-3733 Priyam Goenka
AIR-4000 Vishnu Bhagawat
AIR-4906
AIR-5000


RESULT : NEET 2020
eSaral
First Online Platform Delivering Outstanding Results Possible Only with
Best Faculty
Best System
Personalised Mentorship
eSaralite with Outstanding Performance
Heartiest Congratulations
Himachal
Rank - 1
AIR-400
685
720
Bhavya Sharma
eSaral है, तो सब सरल है।
Download eSaral App
Google Play
Visit : www.esaral.com
+91-6376 440 597
+91-9024 464 479
KOTA

Shoutout