

COORDINATION NUMBER

- Also known as ligancy of the metal atom/ion
- CN of ~~the metal atom/ion~~ is defined as - the no. of donor atoms of the ligands which are attached directly to the metal atom/ion in coordination sphere.
- Ligands are - e^- ions or neutral molecules which are attached to the central metal atom, it donates e^- pair to form coordination bond.
Depending on the no. of atoms of the ligands which donate e^- pair to metal atom, the ligand are said to be
 - monodentate \rightarrow if Only one donor atom is there
 - bidentate \rightarrow 2 ($\text{CN}, \text{S}, \text{O}$)
 - tridentate \rightarrow 3
 - tetridentate \rightarrow 4
 - Pentadentate \rightarrow 5
 - Hexadentate \rightarrow 6 & so on.

e.g. CN of Ag^+ ion in $[\text{Ag}(\text{CN})_2]^-$ is 2
as CN^- ion is a monodentate

CN of Cr^{3+} in $[\text{Cr}(\text{en})_3]^{3+}$ is 6 en - ethylene diaminine.
as en is bidentate ligand.

→ Coordination no. varies from 2 to 9

" The spatial arrangement of ligands around the central metal atom/ion in coordination sphere which are directly attached to the central metal atom/ion is called Coordination polyhedron / geometries around the central metal atom/ion.



OPPO F19S

Geometry:

The ligand present in the complex adopt a definite geometry around the central metal atom.
The geometry adopted by ligand is the geometry of complex compound.

- Geometry depends upon the coordination no. of central metal atom/ion.
- Generally observed geometries are tetrahedral, square planar, octahedral, square pyramidal & trigonal bipyramidal.

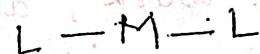
Geometry of complex $\equiv \text{CN} = 2$

→ 1 central atom (M)

→ 2 ligand (L)

→ lying in same plane

→ $L-M-L$ angle $= 180^\circ$



Linear

→ Linear geometry

e.g. $[\text{Cu}(\text{Cl}_2)]^-$, $[\text{Au}(\text{CN})_2]^-$, $[\text{Ag}(\text{NH}_3)_2]^{2+}$, $[\text{Hg}(\text{CN})_2]^-$

Geometry of complex $\equiv \text{CN} = 3$

→ 3 ligand

→ ML_3 type complex

→ trigonal planar geometry (most common)
T-shaped, trigonal pyramidal

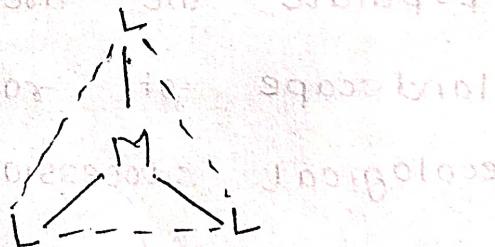
→ In this geometry, central metal

atom (M) lies at the centre of

equilateral triangle & three ligands are at the vertices

of the triangle

→ $L-M-L$ angle $= 120^\circ$ | e.g. $[\text{HgI}_3]^-$



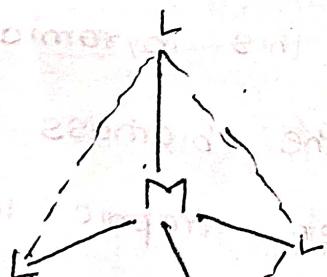
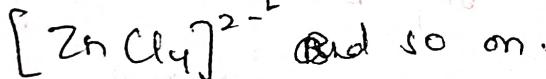
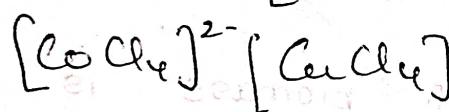
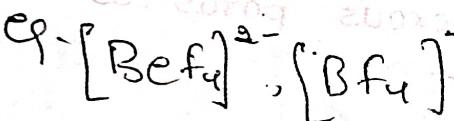
Trigonal planar

Geometry with CN = 4

N₄ type complexes

Tetrahedral

- has 4 vertices (corners)
4 triangular faces & 6 edges.
- 4 ligands are at 4 corners
surrounding a regular tetrahedron
& central M-atom lies at the centre.
- Complexes have weak donor ligands.
- L-M-L angle around $\approx 109^\circ$



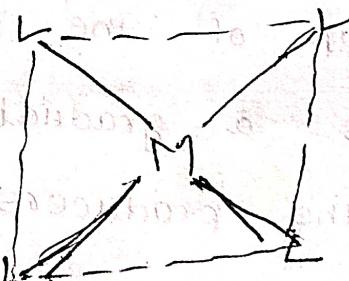
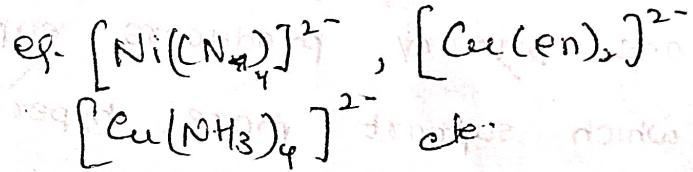
Tetrahedral

tetrahedral geometry

Square planar geometry

Square planar

- 4 ligands are at 4 corners of the square & M lies at the centre
- Complexes have strong donor ligands.
- L-M-L angle 90°



Square planar

Geometry & CN = 5

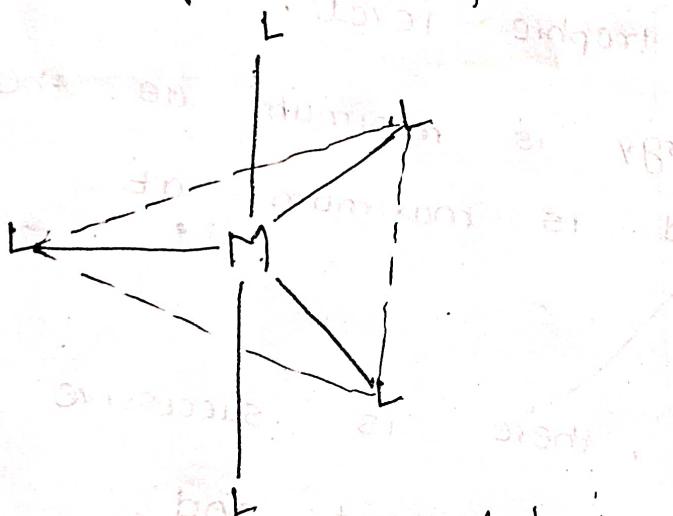
ML₅ type complex

Trigonal Pyramidal geometry

Square pyramidal geometry.

Trigonal Bipyramidal (D_{3h})

- Central Metal atom lies at the centre of triangular/trigonal base & 5 ligands lie at the 5 vertices
- 3 Ligand at 3 corners of the triangular base & 2 ligand occupy the axial position



Trigonal bipyramidal structure

e.g. $\text{Fe}(\text{CO})_5$, $[\text{Mo}(\text{Cl})_5]^-$

$[\text{Cu}(\text{Cl}_5)]^-$, $[\text{Sn}(\text{Cl}_5)]^-$

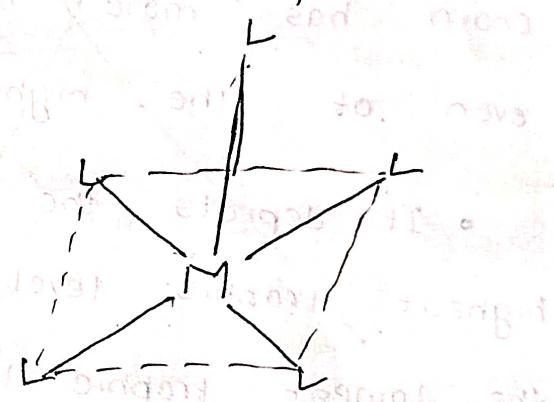
$[\text{Cu}^{\text{II}} \text{I}(\text{bpy})_2]^+$

Iodo bis(bipyridine) copper

Iodo bis(bipyridine) iodide

Square pyramidal (C_{4v})

- Central Metal atom at the centre of the square base & 5 ligand at 5 vertices.
- 4 L are at 4 corners of square and one ligand occupy axial position.



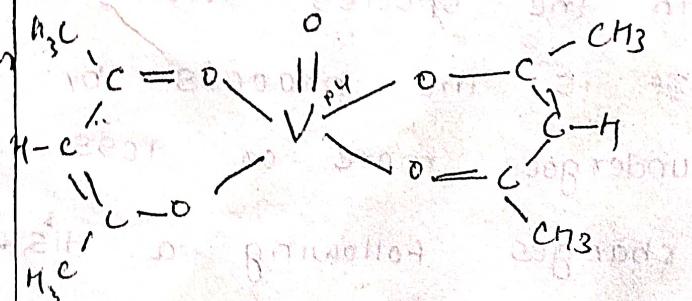
Square pyramidal structure

e.g. $[\text{SbF}_6]^{2-}$

$[\text{VO}(\text{acac})_2]^+$

bis(acetylacetonato)

oxovanadium (IV)



Geometry C ($CN = 6$)

ML₆ type

Octahedral

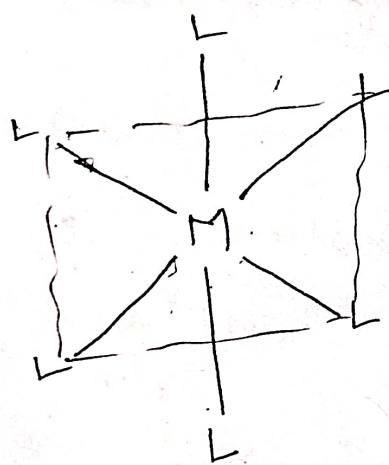
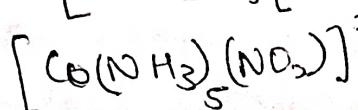
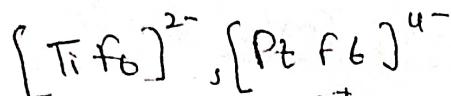
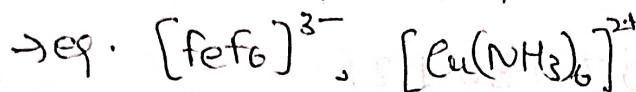
Distorted Octahedral

Trigonal prism

Octahedral (O_h)

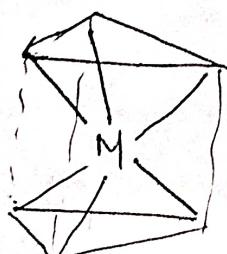
→ all M-L bond lengths are equal / same.

→ M at centre of the square base & 4 ligands at the corner of square base & two occupy axial position



Octahedral structure

Trigonal prism



Distorted Octahedral

→ this geometry is obtained due to the distortion in octahedral geometry bcs of Jahn-Teller effect
Depending upon ligand, distortion is of two type

Tetragonal elongation

→ Two trans Ligand are pulled away from M

∴ all M-L bond

length are not equal in both cases.



elongation



compression

Tetragonal compression

→ Two trans Ligand are pulled away from M.

Geometry \hat{c} CN = 7

ML_7 -type

Pentagonal bipyramidal $[ZrF_7]^{3-}$

Capped trigonal prism $[TaF_7]^{2-}$

Capped octahedral geometry. e.g. $[MoF_7]$

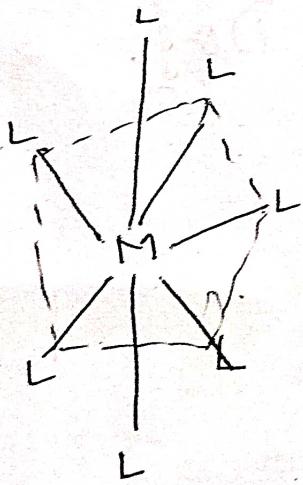
Pentagonal \rightarrow 5 ligands occupy 5 corners of the pentagon & two occupy axial position \hat{c}

Central M-atom at the centre of pentagon.

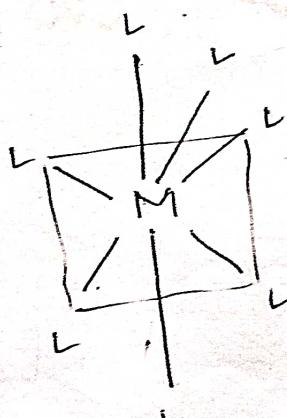
e.g. $[UF_7]^{3-}$, $[ZrF_7]^{3-}$, $[VO_2F_5]^{3-}$

Capped octahedral geometry \rightarrow This geometry is obtld when an additional 7th ligand is placed at the centre of top triangular face of octahedron. e.g. $[NbOF_6]^{3-}$

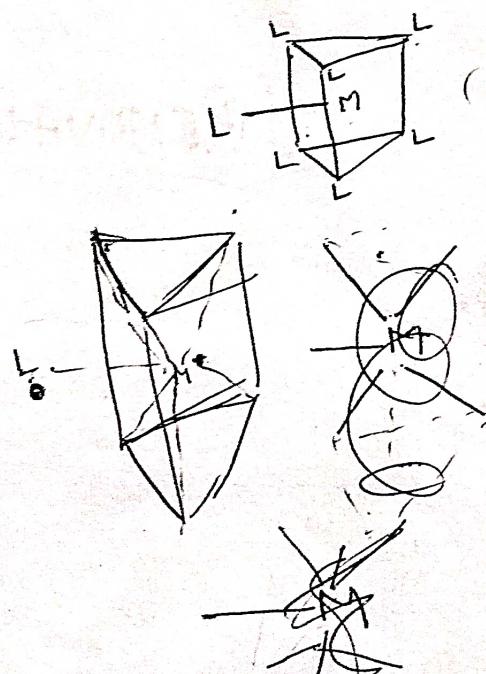
Capped trigonal prism \therefore obtld when an oddⁿ 7th ligand is placed above the centre of rectangular face of a trigonal prism. e.g. $[NbF_7]^{2-}$, $[TaF_7]^{2-}$



Pentagonal bipyramidal geometry.



Capped octahedral geometry



Capped trigonal prism geometry

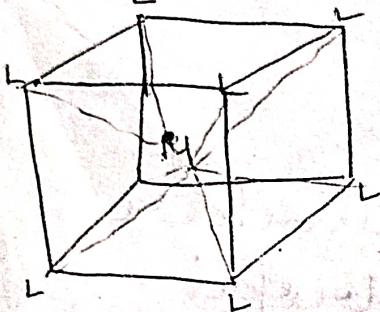
Geometry ē CN-8

ML₈ types, usually formed by lanthanides &

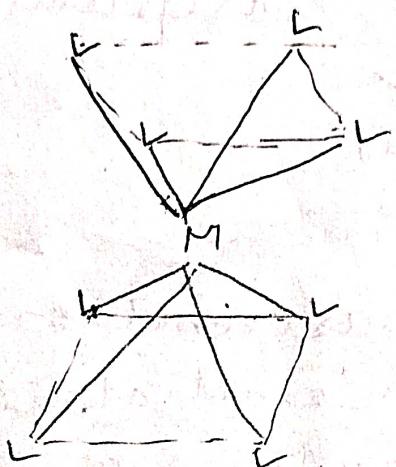
Actinoids

ML₈ → Cubic geometry $[UF_8]^{3-}$
 | → Square antiprism geometry $[TaF_8]^{-3}$
 | → Dodecahedral geometry $[Mo(CN)_8]^{4-}$

Cubic



Square antiprism



Sq

Dodecahedral

