Co - ordination number:

Definition: The maximum number of atoms or groups, which can be co-ordinated with the central metal ion, is known as its co-ordination number (C.N). The co-ordinated groups are called ligands. Each metal has a fixed C.N. Co-ordination number is sometimes called Werner's co-ordination number.

	Metal ion	C.N.
Example :	Zn^{2+}, Cu^{2+}, Pt^{2+}, Cd^{2+}, Ni^{2+}	4
	Fe^{3+}, Fe^{2+}, Co^{3+}, Pt^{4+} Cr^{3+}	6

In $[Fe(CN)_6]^{3-}$ ion, the C.N. of Fe^{3+} is 6.

The co-ordination number of metals varies from 2 to 10, but the most common C.N's are 4 and 6.

Types of Ligands :

The ligands may be classified as monodentate and polydentate ligands according to the number of donor atoms present. If a ligand contains one donor atom, i.e., it is capable of forming only one co-ordinate bond to the central metal atom it is known as monodentate or unidentate ligand.

Example: Cl^-, Br^- CN^-, OH^-, NH_2^- NH_3, H_2O etc.

When a ligand has two or more donor atoms, which may simultaneously co-ordinate to a metal atom, it is known as polydentate or multidentate ligand. Depending upon the number of donor atoms, they are called as bidentate (two donor atoms), tridentate (three donor atoms), tetradentate (four donor atoms) and so on.

Example: Bidentate : ethylene diamine (en)

$$H_2\ddot{N} - CH_2 - CH_2 - \ddot{N}H_2$$

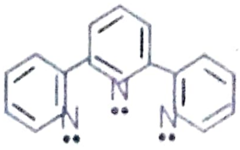
dimethyl glyoxymato (DMG)

$$\begin{array}{c} CH_3 - C - C - CH_3 \\ \quad\ \ \| \quad\ \ \| \\ HO - \underset{\cdot\cdot}{N} - \underset{\cdot\cdot}{N} - OH \end{array}$$

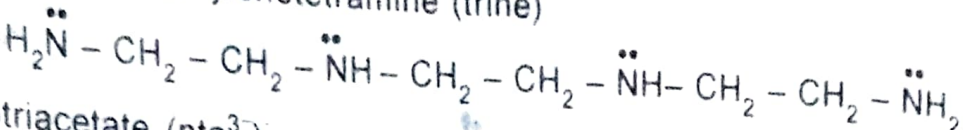
Tridentate: diethylenentriamine [dien]

$$H_2\ddot{N} - CH_2 - CH_2 - \ddot{N}H - CH_2 - CH_2 - \ddot{N}H_2$$

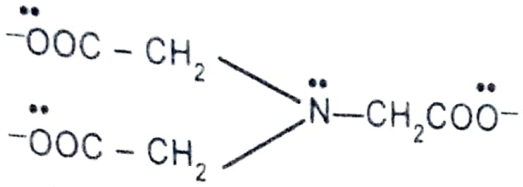
2, 2', 2"-terpyridine (terpy)



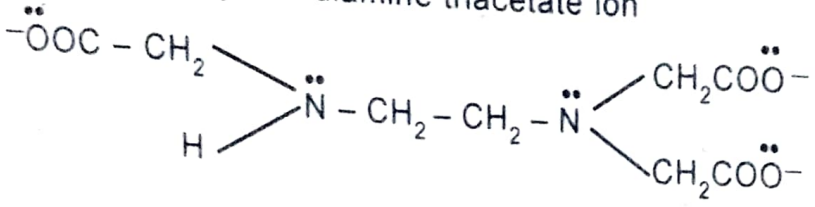
Tetradentate: triethylenetetramine (trine)



Nitribotriacetate (nta^{3-})



Pentadenate : ethylene diamine triacetate ion



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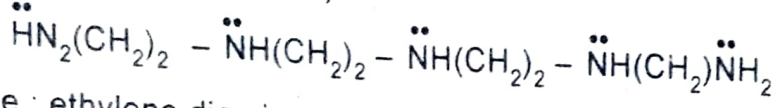
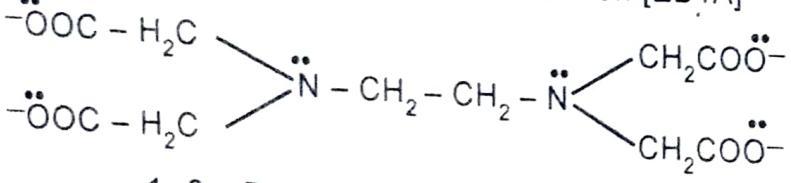
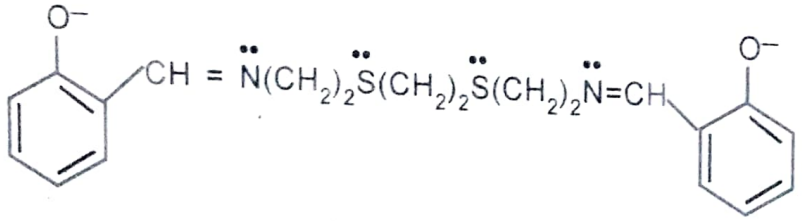
Tetraethylenepentamine (tetraen)



Hexadentate : ethylene diamine tetracetate ion [EDTA]



1, 8 - Bis (salicylideneamino)-3, 6-dithiooctane.

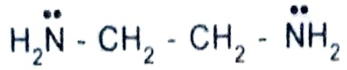


A monodentate ligand may have more than one free electron pairs and may simultaneously co-ordinate with two or more atoms. Thus it may act as a bridge between the metal atoms. Such a ligands is called a bridging ligand and the resulting complex is known as bridged complex:

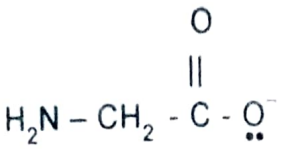
Examples: OH^-, NH_2^-, O^{2-} and Cl^-. SO_4^{2-} etc.

Bidentate ligands may be symmetrical or unsymmetrical. In symmetrical bidentate ligands the two co-ordinating atoms are same while in unsymmetrical bidentate ligands the two co-ordinating atoms are different.

Examples: Symmetrical: Ethylene diamine (en)

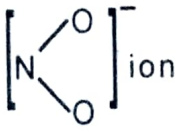


Unsymmetrical : Glycinato (gly)



There are some ligands, which have tow, more donor atoms but form complexes with only one donor atom attached to the metal ion at a given time. Such ligands are called ambidentate ligands.

Examples:



[M-NO_2] Nitro
[M-O-N=O] Nitro

CN^- ion	M-CN Cyano
	M-NC Isocyano
NCS^- ion	MSCN Thiocyanato
	MNCS Isothiocyanato

Complexes, which contain only one metal atom as their central ion are said to be mononuclear complexes and complexes having more than one central ion are termed as polynuclear complexes.

NOMENCLATURE (IUPAC)

The International Union of Pure and Applied Chemists (I.U.P.A.C) published rules for the systematic naming of co-ordination compounds in 1957. The following rules are to be observed in naming the co-ordination compounds.

1. In ionic complexes, the cation is named first and then the anion. Non-ionic or molecular complexes are given a one-word name.
2. Co-ordinated groups are listed in the following order: negative ligands, neutral ligands and then positive ligands.

   [In 1971 this rule has been amended as follows: Ligands are named in alphabetical order regardless of number of each. Only old rule has been followed in this book. Students answering a question on

nomenclature should follow 1971 rule only when specifically asked. Otherwise they are to follow only the old rule]

3. If the name of the ligand ends in 'ide' it is changed into – O.

Examples: Chloride – Chloro; Cyanide – Cyano
Oxide – Oxo ; Hydroxide – Hydroxo

If the name ends in 'ate' or 'ite' then 'a' is changed into 'O'

Examples: Cyanate – Cyanato ; Sulpate – Sulphato
Sulphite – Sulpito ; Acetate – Acetato
Carbonate – Carbonato; Oxalate- Oxalato
Dimethyl glyoximate – Dimethyl glyoximato
Acetylacetonate-Acetylacetonato ($CH_3COCH=COCH_3$)

4. Neutral ligands are named as the molecule. But water is named as aquo and ammonia as ammine or amino.

Positive ligands end in 'ium'
Example: Hydrazinium $H_2N\text{-}NH_3^+$

5. If the complex ion is a cation, the central atom is referred to by its usual name. If it is an anion, the name of the central ion ends in ate. Neutral complexes have no special ending.

6. The ligands so named are followed by the name of the central atom and oxidation state of the central ion is indicated by a Roman numeral in brackets following its name.

7. If the ligands have simple names such as chloro, bromo, nitro, oxalato etc, their number is indicated by prefixes such as di, tri, tetra, penta etc. If the ligands have complex names, their number is indicated by prefixes such as bis, tris, tetrakis, pentakis etc.

8. If the complex contains more than one negative ligands they are named in the increasing order of electronegativity ad also in the order of increasing complexity. When the two ligands have the same number of atoms, the order is that decreasing atomic number of the central atomic species in the ligands.

Example: CrO_4^{2-} first and SO_4^{2-} next.
Neutral organic ligands are named in alphabetical order.

9. If the complex contains two or more metal atoms, it is termed polynuclear. Ligands linking the two metal atoms are called bridge groups and they

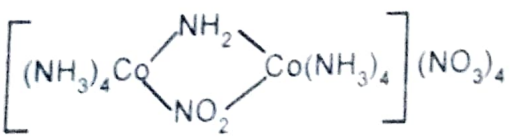
are denoted by the prefix μ, μ is repeated before the name of each different kind of bridging group.

10. Geometrical isomers are named as cis and trans depending upon whether similar groups are on the same side or on the opposite side.

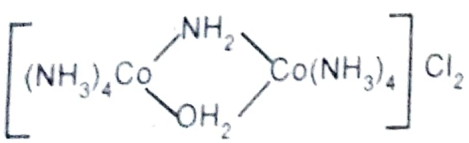
11. The point of attachment of a ligand is designated by placing the symbol of the element attached after the name of the group with separation by hyphen.

Examples : **Cationic complexes**

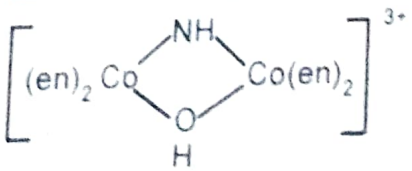
$[Pt(NH_3)_4Cl_2]Br_2$	Dichlorotetrammineplatinum (IV) brominde
$[Pt(NH_3)_4NO_2Cl]CO_3$	Chloronitrotetrammineplatinum (IV) carbonate
$[Pt(NH_3)_4]^{2+}$	Tetrammine platinum (II) ion
$[Co(en)_2Cl_2]^+$	Dichlorobis (ethylenediammine) cobalt (III) ion
$[Co(en)_2Cl_2]NO_3$	Dichloro bis (ethylenediamine) cobalt (III) nitrate
$[Co(en)_2 H_2O\ Cl]SO_4$	Chloroaquobis (ethylenediammine) cobalt (III) sulphate
$[Co(NH_3)_5Cl]^{2+}$	Chloropentamminecobalt (III) ion.
$[Co(ONO)(NH_3)_5]\ SO_4$	Nitritopentammine cobalt (III) sulphate
$[Ag(NH_3)_2]Cl$	Diamminesilver (I) chloride.
$[Cu\ (H_2O)_4]^{2+}$	Tetraaquocopper (II) ion



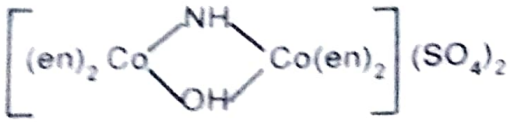
Octaammine μ amido μ nitrodi cobalt (III) nitrate.



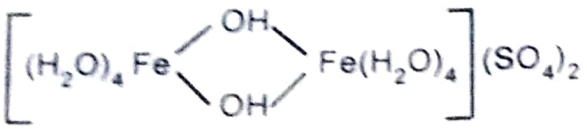
Octaammine μ amido μ aquocobalt (III) chloride



Tetrakis(ethylene diamine) - μ amido- μ - hydroxydicobalt (III) ion



Tetrakis (ethylene diammine) μ - amido - μ -hydroxydicobalt (III) sulphate



Octaaquo - μ - dihydroxodiiron(III) sulphate

$[V(H_2O)_6]Cl_3$ — Hexaaquo vanadium (III)Chloride

$Cr[Cl_2(H_2O)_4]NO_3$ — Dichlorotetra aquochromium (III) nitrate

$[Cr(en)_3]Cl_3$ — Tris (ethylenediamine) chromium (III)chloride

Anionic complexes:

$K_4[Fe(CN)_6]$ — Potassium hexacyanoferrate (II)

$K_3[Fe(CN)_6]$ — Potassium hexacyanoferrate (III)

$Na_2[Fe(CN)_5NO]$ — Sodiumpentacyanonitrosyl ferrate(III)

$K_2[Ni(CN)_4]$ — Potassium tetracyanonickelate (II)

$K[Ag(CN)_2]$ — Potassium dicyanoargentate (I)

$Na_3[Ag(S_2O_3)_2]$ — Sodium dithiosulphatoargentate

$[Pb(OH)_4]^{2-}$ — Tertahydroxoplumbate(II) ion

$[Zn(OH)_4]^{2-}$ — Tertahydroxozincate(II)ion

$K_2[PtCl_6]$ — Pottasium hexachloroplatinate(IV)

$Na_3[Co(NO_2)_6]$ — Sodium hexanitrocobaltate(III)

$K_4[Ni(CN)_4]$ — Pottasium tetracyanonicklate(0)

$Na_3[Co(Co)_4$ — Sodium tetracarbonycobaltate(III)

$H_2[PtCl_6]$ — Hexachloroplatinic acid(IV)

$K_3[Al(C_2O_4)$ — Pottasium trioxalatoaluminate(III)

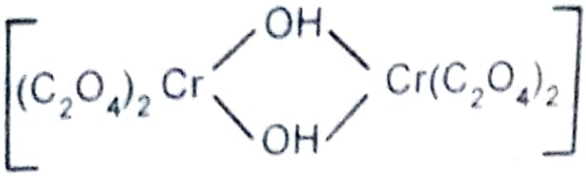
$(NH_4)_3[Cr(NCS)_6]$ — Ammonium hexathiocyanato-N-Chormate (III)

$(NH_4)_2[Pt(SCN)_6]$ — Ammonium hexathiocyanato – S - Platinate(IV)

$[(NH_4)_2\ [Cr(NH_3)_5(NCS)]$ — Ammonium thiocyanato – N - penta ammine chromate(III)

$\{(CH_3)_4N\}_2[Co(NCS)_4]$ — Tetramethylammonium tetra thio cyanato –N- cobaltate (II)

Neutral Complexes

$Fe(CO)_5$	Pentacarbonyliron(0)
$[Pt(NH_3)_2Cl_2]$	Dichlorodiammineplatinium(II)
$[PtCl_4en]$	Tetrachloro ethylene diamine platinum(IV)
$[Cr(H_2O)Cl_3]$	Tricholoro triaquochromium(III)
$[Co(NH_3)_3NO_2(CN)Cl]$	Chlorocyanonirotriammine cobalt(III)
$[Pt(NH_3)Py\ Cl\ Br]$	Bromochloroamminepyridine platinum(II)
	Tetrakis(oxalato-μ-dihydroxo dichromium(III)
$Be[Cl_2(CH_3NH_2)_2]$	Dichlorobis (methylamine) berillium(II)
$[Cu(CH_3COCH{=}COCH_3)_2)$	Bis (acetylacetonato) copper(II)