

ADHIKAANSH ACADEMY (IITJEE NEET IX X XI XII)

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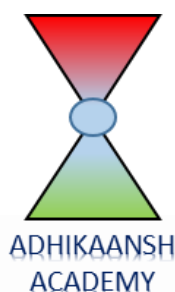
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CHEMISTRY NOTES (CLASS 12TH)



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CBSE Class-12 Chemistry Quick Revision Notes
Chapter-09: Co-ordination Compounds

- **Co-ordination compounds:**
 - a) A coordination compound contains a central metal atom or ion surrounded by number of oppositely charged ions or neutral molecules. These ions or molecules are bonded to the metal atom or ion by a coordinate bond.
 - b) Example: $K_4[Fe(CN)_6]$
 - c) They do not dissociate into simple ions when dissolved in water.
- **Double salt**
 - a) When two salts in stoichiometric ratio are crystallised together from their saturated solution they are called double salts
 - b) Example: $FeSO_4 \cdot (NH_4)_2SO_4 \cdot 6H_2O$ (Mohr's salt)
 - c) They dissociate into simple ions when dissolved in water.
- **Coordination entity:**
 - a) A coordination entity constitutes a central metal atom or ion bonded to a fixed number of ions or molecules.
 - b) Example: In $K_4[Fe(CN)_6]$, $[Fe(CN)_6]^{4-}$ represents coordination entity.
- **Central atom or ion:**
 - a) In a coordination entity, the atom/ion to which a fixed number of ions/groups are bound in a definite geometrical arrangement around it, is called the central atom or ion.
 - b) Example: In $K_4[Fe(CN)_6]$, Fe^{2+} is the central metal ion.
- **Ligands:**
 - a) A molecule, ion or group that is bonded to the metal atom or ion in a complex or coordination compound by a coordinate bond is called ligand.
 - b) It may be neutral, positively or negatively charged.
 - c) Examples: H_2O , CN^- , NO^+ etc.
- **Donor atom:**
 - a) An atom of the ligand attached directly to the metal is called the donor atom.
 - b) Example: In the complex $K_4[Fe(CN)_6]$, CN is a donor atom.
- **Coordination number:**
 - a) The coordination number (CN) of a metal ion in a complex can be defined as the number of ligand donor atoms to which the metal is directly bonded.
 - b) Example: In the complex $K_4[Fe(CN)_6]$, the coordination number of Fe is 6.
- **Coordination sphere:**
 - a) The central atom/ion and the ligands attached to it are enclosed in square bracket and are collectively termed as the coordination sphere.
 - b) Example: In the complex $K_4[Fe(CN)_6]$, $[Fe(CN)_6]^{4-}$ is the coordination sphere.
- **Counter ions:**
 - a) The ions present outside the coordination sphere are called counter ions.
 - b) Example: In the complex $K_4[Fe(CN)_6]$, K^+ is the counter ion.
- **Coordination polyhedron:**
 - a) The spatial arrangement of the ligand atoms which are directly attached to the central atom/ ion defines a coordination polyhedron about the central atom.

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- b) The most common coordination polyhedra are octahedral, square planar and tetrahedral.
- c) Examples: $[\text{PtCl}_4]^{2-}$ is square planar, $\text{Ni}(\text{CO})_4$ is tetrahedral while $[\text{Cu}(\text{NH}_3)_6]^{3+}$ is octahedral.
- **Charge on the complex ion:**
The charge on the complex ion is equal to the algebraic sum of the charges on all the ligands coordinated to the central metal ion.
 - **Denticity:**
The number of ligating (linking) atoms present in ligand is called denticity.
 - **Unidentate ligands:**
 - a) The ligands whose only one donor atom is bonded to metal atom are called unidentate ligands.
 - b) Examples: H_2O , NH_3 , CO , CN^-
 - **Didentate ligands:**
 - a) The ligands which contain two donor atoms or ions through which they are bonded to the metal ion.
 - b) Examples: Ethylene diamine ($\text{H}_2\text{NCH}_2\text{CH}_2\text{NH}_2$) has two nitrogen atoms, oxalate ion

$$\begin{pmatrix} \text{COO}^- \\ | \\ \text{COO}^- \end{pmatrix}$$
 has two oxygen atoms which can bind with the metal atom.
 - **Polydentate ligand:**
 - a) When several donor atoms are present in a single ligand, the ligand is called polydentate ligand.
 - b) Examples: In $\text{N}(\text{CH}_2\text{CH}_2\text{NH}_2)_3$, the ligand is said to be polydentate and Ethylenediaminetetraacetate ion (EDTA^{4-}) is an important hexadentate ligand. It can bind through two nitrogen and four oxygen atoms to a central metal ion.
 - **Chelate:**
 - a) An inorganic metal complex in which there is a close ring of atoms caused by attachment of a ligand to a metal atom at two points.
 - b) An example is the complex ion formed between ethylene diamine and cupric ion, $[\text{Cu}(\text{NH}_2\text{CH}_2\text{NH}_2)_2]^{2+}$.
 - **Ambidentate ligand:**
 - a) Ligands which can ligate (link) through two different atoms present in it are called ambidentate ligand.
 - b) Example: NO_2^- and SCN^- . Here, NO_2^- can link through N as well as O while SCN^- can link through S as well as N atom.
 - **Werner's coordination theory:**
 - a) Werner was able to explain the nature of bonding in complexes.
 - b) The postulates of Werner's theory are:
 - i) Metal shows two different kinds of valencies: primary valence and secondary valence.
 - ii) The ions/ groups bound by secondary linkages to the metal have characteristic spatial arrangements corresponding to different coordination numbers.
 - iii) The most common geometrical shapes in coordination compounds are octahedral, square planar and tetrahedral.
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- **Primary valence**
 - a) This valence is normally ionisable.
 - b) It is equal to positive charge on central metal atom.
 - c) These valencies are satisfied by negatively charged ions.
 - d) Example: In CrCl_3 , the primary valency is three. It is equal to oxidation state of central metal ion.
 - **Secondary valence**
 - a) This valence is non – ionisable.
 - b) The secondary valency equals the number of ligand atoms coordinated to the metal. It is also called coordination number of the metal.
 - c) It is commonly satisfied by neutral and negatively charged, sometimes by positively charged ligands.
 - **Oxidation number of central atom:**

The oxidation number of the central atom in a complex is defined as the charge it would carry if all the ligands are removed along with the electron pairs that are shared with the central atom.
 - **Homoleptic complexes:**

Those complexes in which metal or ion is coordinate bonded to only one kind of donor atoms. For example: $[\text{Co}(\text{NH}_3)_6]^{3+}$
 - **Heteroleptic complexes:**

Those complexes in which metal or ion is coordinate bonded to more than one kind of donor atoms. For example: $[\text{CoCl}_2(\text{NH}_3)_4]^+$, $[\text{Co}(\text{NH}_3)_5\text{Br}]^{2+}$
 - **Isomers:**

Two or more compounds which have same chemical formula but different arrangement of atoms are called isomers.
 - **Types of isomerism:**
 - a) Structural isomerism
 - i. Linkage isomerism
 - ii. Solvate isomerism or hydrate isomerism
 - iii. Ionisation isomerism
 - iv. Coordination isomerism
 - b) Stereoisomerism
 - i. Geometrical isomerism
 - ii. Optical isomerism
 - **Structural isomerism:**
 - a) It arises due to the difference in structures of coordination compounds.
 - b) Structural isomerism, or constitutional isomerism, is a form of isomerism in which molecules with the same molecular formula have atoms bonded together in different orders.
 - **Ionisation isomerism:**
 - a) It arises when the counter ion in a complex salt is itself a potential ligand and can displace a ligand which can then become the counter ion.
 - b) Example: $[\text{Co}(\text{NH}_3)_5\text{Br}] \text{SO}_4$ and $[\text{Co}(\text{NH}_3)_5 \text{SO}_4] \text{Br}$
 - **Solvate isomerism:**
 - a) It is isomerism in which solvent is involved as ligand.
 - b) If solvent is water it is called hydrate isomerism, e.g., $[\text{Cr}(\text{H}_2\text{O})_6]\text{Cl}_3$ and $[\text{CrCl}_2(\text{H}_2\text{O})_4] \text{Cl}_2 \cdot 2\text{H}_2\text{O}$.
-

- **Linkage isomerism:**
 - a) It arises in a coordination compound containing ambidentate ligand.
 - b) In the isomerism, a ligand can form linkage with metal through different atoms.
 - c) Example: $[\text{Co}(\text{NH}_3)_5\text{ONO}]\text{Cl}_2$ and $[\text{Co}(\text{NH}_3)_5\text{NO}_2]\text{Cl}_2$.
- **Coordination isomerism:**
 - a) This type of isomerism arises from the interchange of ligands between cationic and anionic entities of different metal ions present in a complex.
 - b) Example: $[\text{Co}(\text{NH}_3)_6][\text{Cr}(\text{C}_2\text{O}_4)_3]$ and $[\text{Cr}(\text{NH}_3)_6][\text{Co}(\text{C}_2\text{O}_4)_3]$.
- **Stereoisomerism:**
This type of isomerism arises because of different spatial arrangement.
- **Geometrical isomerism:**
It arises in heteroleptic complexes due to different possible geometrical arrangements of ligands.
- **Optical isomerism:**
Optical isomers are those isomers which are non-superimposable mirror images.
- **Valence bond theory:**
 - a) According to this theory, the metal atom or ion under the influence of ligands can use its $(n-1)d$, ns , np or ns , np , nd orbitals for hybridisation to yield a set of equivalent orbitals of definite geometry such as octahedral, tetrahedral, and square planar.
 - b) These hybridised orbitals are allowed to overlap with ligand orbitals that can donate electron pairs for bonding.

Coordination number	Type of hybridisation	
	sp^3	Tetrahedral
	dsp^2	Square planar
	sp^3d	Trigonal bipyramidal
	sp^3d^2 (nd orbitals are involved – outer orbital complex or high spin or spin free complex)	Octahedral
	d^2sp^3 ($(n-1)d$ orbitals are involved – inner orbital or low spin or spin paired complex)	Octahedral

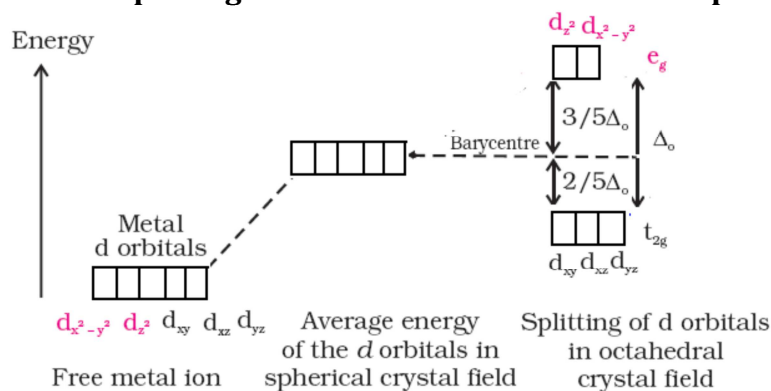
- **Magnetic properties of coordination compounds:**
A coordination compound is paramagnetic in nature if it has unpaired electrons and diamagnetic if all the electrons in the coordination compound are paired.

Magnetic moment $\mu = \sqrt{n(n+2)}$ where n is number of unpaired electrons.

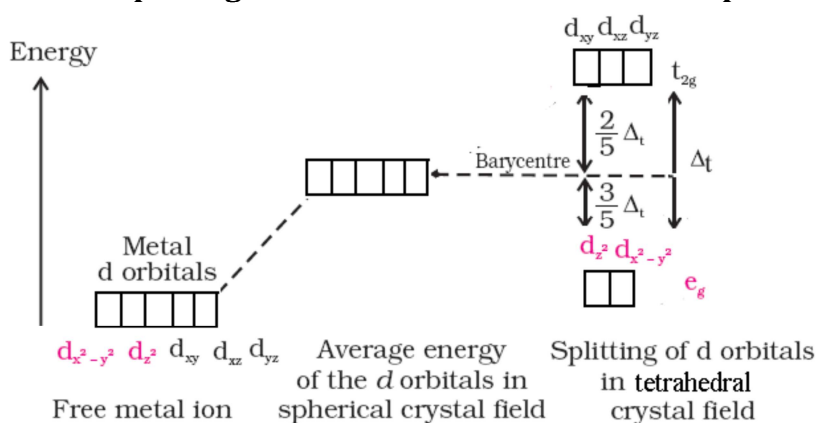
- **Crystal Field Theory:**

- a) It assumes the ligands to be point charges and there is electrostatic force of attraction between ligands and metal atom or ion.
- b) It is theoretical assumption.

- **Crystal field splitting in octahedral coordination complexes:**



- **Crystal field splitting in tetrahedral coordination complexes:**



- For the same metal, the same ligands and metal-ligand distances, the difference in

energy between e_g and t_{2g} level is

$$\Delta_t = -\frac{4}{9} \Delta_o$$

- **Metal carbonyls:**

- a) Metal carbonyls are homoleptic complexes in which carbon monoxide (CO) acts as the ligand.
- b) Example: $Ni(CO)_4$
- c) The metal-carbon bond in metal carbonyls possess both s and p character.
- d) The M-C σ bond is formed by the donation of lone pair of electrons from the carbonyl carbon into a vacant orbital of the metal.
- e) The M-C π bond is formed by the donation of a pair of electrons from a filled d orbital of metal into the vacant antibonding π^* orbital of carbon monoxide.
- f) The metal to ligand bonding creates a synergic effect which strengthens the bond between CO and the metal.

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