

Introduction of Coordination Chemistry

What are Coordination Compounds?

Coordination compounds are chemical compounds that consist of an array of anions or neutral molecules that are bound to a central atom via coordinate covalent bonds. Coordination compounds are also referred to as **coordination complexes**. These molecules or ions that are bound to the central atom are referred to as ligands (also known as complexing agents).

In coordination compounds, the central atoms or ions are typically [Lewis Acids](#) and can, therefore, act as electron-pair acceptors.

Ligands

The atoms, molecules, or ions that are bound to the coordination centre or the central atom/ion are referred to as **ligands**.

These ligands can either be a simple ion or molecule (such as Cl^- or NH_3) or in the form of relatively large molecules, such as ethane-1,2-diamine ($\text{NH}_2\text{-CH}_2\text{-CH}_2\text{-NH}_2$).

Coordination Number

The **coordination number** of the central atom in the coordination compound refers to the total number of sigma bonds through which the ligands are bound to the coordination centre.

For example, in the coordination complex given by $[\text{Ni}(\text{NH}_3)_4]^{2+}$, the coordination number of nickel is 4.

Coordination Sphere

The non-ionizable part of a complex compound which consists of central transition metal ion surrounded by neighbouring atoms or groups enclosed in square bracket.

The coordination centre, the ligands attached to the coordination centre, and the net charge of the chemical compound as a whole, form the **coordination sphere** when written together.

This coordination sphere is usually accompanied by a counter ion (the ionizable groups that attach to charged coordination complexes).

Example: $[\text{Co}(\text{NH}_3)_6]\text{Cl}_3$ – coordination sphere

Coordination Polyhedron

The geometric shape formed by the attachment of the ligands to the coordination centre is called the **coordination polyhedron**.

Examples of such spatial arrangements in coordination compounds include tetrahedral and square planar.

Oxidation Number

The oxidation number of the central atom can be calculated by finding the charge associated with it when all the electron pairs that are donated by the ligands are removed from it.

For example, the oxidation number of the [platinum atom](#) in the complex $[\text{PtCl}_6]^{2-}$ is +4.

Homoleptic and Heteroleptic Complex

- When the coordination centre is bound to only one type of electron pair donating ligand group, the coordination complex is called a **homoleptic complex**, for example: $[\text{Cu}(\text{CN})_4]^{3-}$.
- When the central atom is bound to many different types of ligands, the coordination compound in question is called a **heteroleptic complex**, an example for which is $[\text{Co}(\text{NH}_3)_4\text{Cl}_2]^+$.

Properties of Coordination Compounds

The general properties of coordination compounds are discussed in this subsection.

- The coordination compounds formed by the transition elements are coloured due to the presence of unpaired electrons that absorb light in their electronic transitions. For example, the complexes containing Iron(II) can exhibit green and pale green colours, but the coordination compounds containing iron(III) have a brown or yellowish-brown colour.
- When the coordination centre is a metal, the corresponding coordination complexes have a magnetic nature due to the presence of unpaired electrons.
- Coordination compounds exhibit a variety of chemical reactivity. They can be a part of inner-sphere electron transfer reactions as well as outer-sphere electron transfers.
- Complex compounds with certain ligands have the ability to aid in the transformation of molecules in a catalytic or a stoichiometric manner.

Double Salts and Coordination Complex

Double Salts

Double salts are completely ionizable in aqueous solutions and each ion in the solution gives the corresponding confirmatory test.

Example: Potash Alum is double sulphate. It is $\text{K}_2\text{SO}_4 \cdot \text{Al}_2(\text{SO}_4)_3 \cdot 24\text{H}_2\text{O}$ on Ionization it gives:

K^+ , SO_4^{-4} and Al^{+3} ions which response to the corresponding tests.

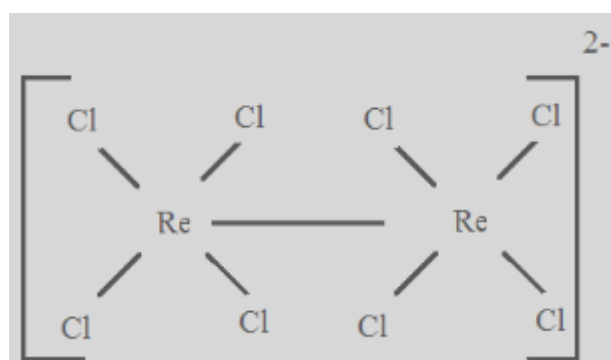
Coordination Complex

Co-ordinate complex are incompletely ionizable in the aqueous solutions. These give a complex ion which does not show complete ionization.

Example: Potassium Ferrocyanide. $[K_4Fe(CN)_6]$ It ionizes to give K^+ and $[Fe(CN)_6]^{4-}$ [ferrocyanide ions]

Types of Coordination Complexes

- **Cationic complexes:** In this co-ordination sphere is a cation. Example: $[Co(NH_3)_6]Cl_3$
- **Anionic complexes:** In this co-ordination sphere is Anion. Example: $K_4[Fe(CN)_6]$
- **Neutral Complexes:** In this co-ordination sphere is neither cation or anion. Example: $[Ni(CO)_4]$
- **Homoleptic complex:** The complex consist of a similar type of ligands. Example: $K_4[Fe(CN)_6]$
- **Heteroleptic complexes:** These consists of different types of ligands. Example: $[Co(NH_3)_5Cl]SO_4$
- **Mononuclear complexes:** In this co-ordination sphere has single transition metal ion. Example: $K_4[Fe(CN)_6]$
- **Polynuclear complexes:** More than one transition metal ion is present. Example:



Polynuclear complexes

Types of Ligands

Based on the nature of the bond between the ligand and the central atom, ligands are classified as follows:

- Anionic ligands: CN^- , Br^- , Cl^-

- Cationic ligands: NO^+
- Neutral ligands: CO , H_2O , NH_3

Ligands can be further classified as:

Monodentate Ligands

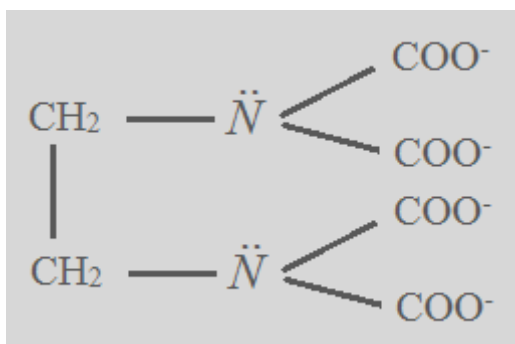
The ligands which only have one atom that can bind to the coordination centre are called unidentate ligands. Ammonia (NH_3) is a great example of a unidentate ligand. Some common unidentate are Cl^- , H_2O etc.

Bidentate Ligands

Ligands which have the ability to bind to the central atom via two separate donor atoms, such as ethane-1,2-diamine, are referred to as bidentate ligands.

Oxalate ion is a bidentate as it can bond through two atoms to the central atom in a coordination compound and Ethane-1, 2-diamine:

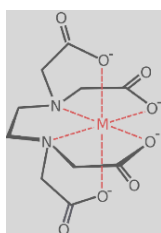
acetylacetonato, $(\text{CH}_3\text{COCHCOCH}_3)^-$, oxalato, $\text{C}_2\text{O}_4^{2-}$



Polydentate Ligands

Some ligands have many donor atoms that can bind to the coordination centre. These ligands are often referred to as polydentate ligands.

A great example of a polydentate ligand is the EDTA^{4-} ion (ethylene diamine tetraacetate ion), which can bind to the coordination centre via its four oxygen atoms and two nitrogen atoms.



Ex: diethylenetriamine, $\text{NH}(\text{CH}_2\text{CH}_2\text{NH}_2)_2$

Chelate Ligand

When a polydentate ligand attaches itself to the same central metal atom through two or more donor atoms, it is known as a chelate ligand. The atoms that ligate to the metal ion are termed as the denticity of such ligands.

Ambidentate Ligand

Some ligands have the ability to bind to the central atom via the atoms of two different elements.

For example, the SCN^- ion can bind to a ligand via the nitrogen atom or via the sulfur atom. Such ligands are known as ambidentate ligands.

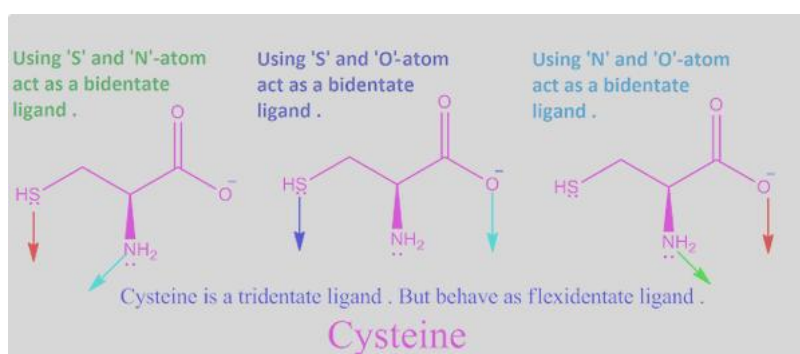
Ex: $\text{NO}_2^-/\text{ONO}^-$ (O and N), and $\text{SO}_3^{2-}/\text{OSO}_2^-$ (O and S)

Flexidentate ligand

There are **few ligands** in **co-ordination chemistry** which have two or more donor atoms. But, they do not use their entire donor atom at once in the formation of co-ordination compound that is in **co-ordination with central metal ion**. They use their different donor atom with different metal ion to form co-ordinate bond. Such types of ligands are **called flexi dentate ligands**.

For example, **Cysteine**, a tri dentate ligand with three different donor atoms (S, N, O) act as a di dentate ligand in three different way [when it uses S,N, N,O and S,O atom separately]

So, Cysteine is a flexi dentate ligand .



Similarly, there are many other poly dentate ligands those are behaved as a **flexi dentate ligand**.

Such as, **EDTA**, a poly dentate ligand, but in some cases it uses as a penta dentate or tetra dentate ligand. So, **EDTA is also a flexi dentate ligand**.