

SAMUEL ADEGBOYEGA UNIVERSITY, OGWA,
COLLEGE OF BASIC AND APPLIED SCIENCES
DEPARTMENT OF CHEMICAL SCIENCES
CHM 212: COORDINATION CHEMISTRY

Lecturer name: Akintelu M.T (Mrs)

Objective:

At the end of this course, the students will be able to:

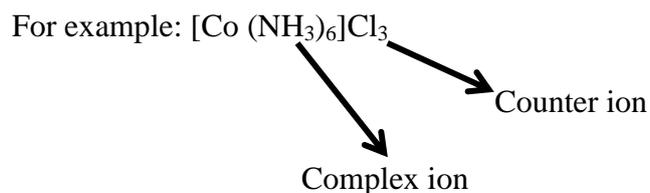
1. Understand the term coordination chemistry
2. Discuss the coordination compound, Ligands, donor atom and coordination number
3. Identify the various types Ligands
4. Expose to naming of compounds
5. Explain the types of structure and Isomerism in coordination compound
6. Know the existing bonding in coordination compound

Course content:

1. Introduction to coordination chemistry, compound, Ligands, donor atom and coordination number
2. Types of Ligands
3. Nomenclature of coordination compounds
4. Types of structure and Isomerism in coordination compound
5. Bonding in coordination compound

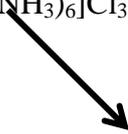
INTRODUCTION

This is the chemistry of coordination compound. Coordination compound is the interaction between the transition metals and ligands. It can also consist of complex ion and counter ion.



Ligands are the molecules or ions that surround the metal in a complex ion. They are also group of atoms, ions, radicals possessing free pairs of electrons which could be readily donated in metal atoms. The bond formed is a coordinate/dative bond. Example of ligands are NH_3 , H_2O , Cl etc.

Donor atom is the atom in a ligand that is bound directly to the metal atom. Example:



Nitrogen is the donor atom

Coordination number is the number of donor atom surrounding central metal atom in a complex ion. Example of coordination number of Ag^+ in $[\text{Ag}(\text{NH}_3)_2]^+$ is 2, Fe^{2+} in $[\text{Fe}(\text{CN}_4)]^{2+}$ is 4.

TYPES OF LIGANDS

Ligands are categorised according to the number of lone pair, when they have a **lone pair**, they are referred to as monodentate ligands. Example: H_2O , NH_3

The ligands with **two lone pairs** are called bi-dentate ligand. Example: Ethylenediamine, Oxalate ion.

The ligands that have **more than two lone pair** are called polydentate. Example: Ethylenediaminetetraacetate (EDTA). Polydentate and bidentate ligands are called chelating agents because they have the ability to hold metals atoms like a claw.

NOMENCLATURE OF COORDINATION COMPOUND

Rules of nomenclature

1. Cationic species are named before the anionic species. The rules hold regardless whether the complex ion, bears a net positive or negative charge e. g $\text{K}_3[\text{Fe}(\text{CN})_6]$ and $[\text{Co}(\text{NH}_3)_4\text{Cl}_2]\text{Cl}$
2. Within a complex ion, the ligands are named first in alphabetical order followed by the metal atom. E.g $[\text{Co}(\text{NH}_3)_4\text{Cl}_2]\text{Cl}$ (Tetraamminedichlorocobalt(I)chloride)
3. The names of anionic ligands end with letter O here as a neutral ligand is usually called by the name of the molecule but in the exception of water.

E.g Bromide___ Bromo, Chloride___ Chloro, Cyanide___ Cyano, Oxide___Oxo, Carbonate___ Carbonato, Nitrite___Nitro, Oxalate___Oxalato.

Example of neutral ligands that is called by the name of their molecule with the exception of water are Ammonia___Ammine, Carbonmonoxide___Carbonyl, Water___Aqua, Aquo

4. When there are more than one of a particular ligands, the number is specified as di for 2, tri for 3, tetra for 4 etc. If the ligands itself contain a greek prefix we use the prefixes bis for 2, tris for 3, tetrakis for 4 etc. The ligand ethylenediammine already contained di, therefore if two of such ligands are present, the name changes to bis ethylenediammine.
5. Negative complex ion always end in the suffix "ate" e.g $[\text{CrCl}_6]$ hexachlorochromate(III)ion,
Iron (Fe) changes to Ferrate,
Lead (Pb) to Plumbate,
Zink (Zn) to Zincate,
Copper (Cu) to Cupperate,
Gold (Au) to Aurate,
Silver (Ag) to Agrate.
6. In neural/positive charge complex, the name of the metal as above remains the same.
E.g $\text{Na}_3 [\text{Cr}(\text{NO}_2)_6]$ Sodiumhexanitrochromate(II)ion
7. The oxidation number of the metal is written in roman numeral following the name of the metal.

STRUCTURE IN COORDINATION CHEMISTRY

There are different types of structure in coordination chemistry.

1. Linear structure
2. Tetrahedral structure
3. Square planar structure
4. Octahedral structure

ISOMERISM OF COORDINATION COMPOUND

Isomerism is a phenomenon where compounds have the same empirical formula but different structural formula.

TYPES OF ISOMERISM

1. Optical isomerism: they are mirror images of each other and are non-superimposable.
2. Geometrical isomerism: they give rise to cis and trans images of isomer
3. Ionization isomerism: they involve the interchange of a ligand anion with an associated anion outside the complex. The complexes have the same molecular formula but differ in the ions connected to the central metal atom.
4. Linkage isomerism: it result when ligands have more than one attachment to the central metal atom
5. Coordination isomerism: In compound where both cations and anions are complex the distribution of ligands can vary given rise to isomer.

BONDING IN CORDINATION CHEMISTRY/COMPOUND

As we have discussed earlier that there are two types of theory in coordination compound which are:

- 1) Valence bond theory
- 2) Crystal field theory

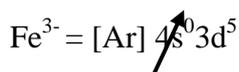
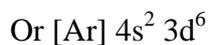
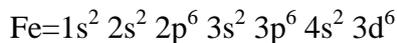
Valence bond theory: This is the type of bond formed by the overlapping of the orbitals and the sharing of electrons between the two atoms in the region of the overlap e.g $H_2 = H-----H$ Hydrogen atom share its electrons between one another. The diagram below shows an example of two hydrogen atoms sharing their electron.



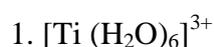
Crystal field theory: This differs from valence bond theory it builds the complex as held together by purely electrostatic attraction. It is most concern with the effort that the ligands has on the energy degeneracy orbital. This degeneracy breaks down in the presence of the ligands therefore, not all the 3d orbitals have the same energy. In the free undisturbed state of the metal, the orbitals have the same energy but the presence of the ligands split the lower orbital into two groups. The groups with the lower energy level is called E_g orbital having d_{xy} , d_{y^2} and d_{x^2} orbitals. The group with the higher energy level is called T_{2g} orbital having $d_{x^2-y^2}$ and d_{z^2} orbitals. The differences between the E_g and T_{2g} orbitals is called the crystal field splitting energy. The free electrons of the ligand can then enter orbitals of different

energy. If the crystal field stabilization energy is weak both orbitals will be singly occupied before pairing, but if the stabilization is high electrons will pair up in the T_{2g} first.

E.g. $[\text{Fe}(\text{F})_6]^{3-}$ The electron configuration of iron (Fe)

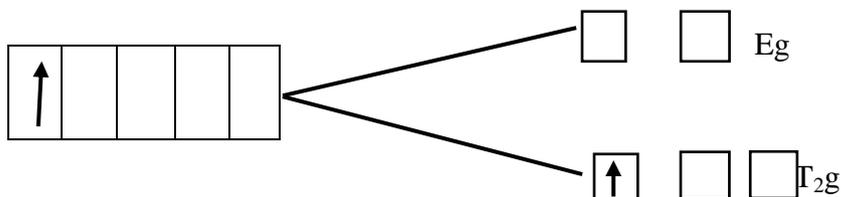
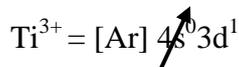
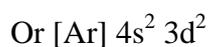
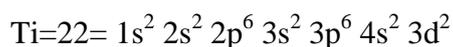


Examples: Determine the crystal field energy of the following indicating if it is paramagnetic or diamagnetic.



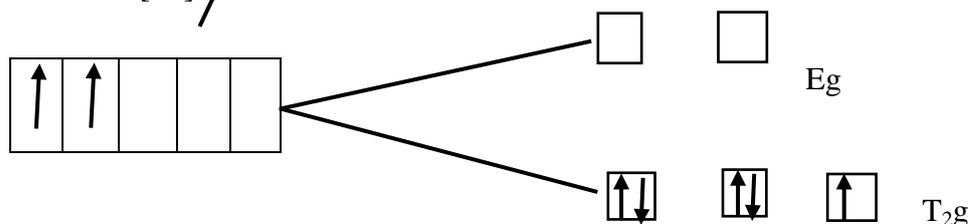
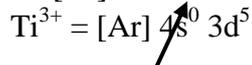
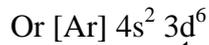
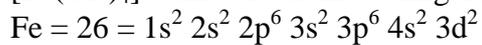
SOLUTION

1. $[\text{Ti}(\text{H}_2\text{O})_6]^{3+}$ The electron configuration of titanium (Ti)



It is paramagnetic

2. $[\text{Fe}(\text{CN})_4]^{3+}$ The electronic configuration of ion (Fe)



It is diamagnetic

Assessment:

1. Give an example of the following.
(i) Donor atom (ii) Ligand (iii) Co-ordination number (iv) Co-ordination compound (v) Mono-dentate ligand

2. Determine the crystal field theory of the following
(i) $[\text{Ti}(\text{H}_2\text{O})_6]^{3+}$
(ii) $[\text{Ti}(\text{CN})_4]^{2+}$

Reference material: Raymond Chang chemistry textbook 7th edition.