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"The Role Of Chelating Agent In Medical Inorganic Chemistry"

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Abstract:

Chelating agents are ligands possessing multiple donor atoms that form stable, ring like coordination complexes with metal ions. In medical inorganic chemistry, these compounds are essential for applications in detoxification, metal redistribution, imaging, targeted therapy, and novel bio medical strategies.

Keywords: Chelating agent, chelate, Ethylenediammine tetra acetic acid (EDTA), Ligands, Donor atoms etc.

Introduction:

The ligand that bond to metal cation or atom through electron pairs present on more than one donor atoms are called multidentate or Polydentate ligands. Polydentate ligands are called chelating ligand because interaction of two or more electron pairs to the metal ion resulting the formation of one or more rings. The Polydentate ligands in general forms five or six member rings including metal ion, which are called **chelate rings** and the complexes containing chelate rings are called **Chelates** [4]. Many enzymes required metal ions as cofactors to function like Iron (Fe) vital for oxygen transport in Hemoglobin and redox reactions, Metal based drug such as Platinum (Pt) is used in the form of **cisplatin** and **carboplatin** for chemotherapy for cancer. Inorganic compound helps remove toxic metals. Silver (Ag) ions are used in wound dressings, catheters, & cream for antibacterial properties[2].

Chelation therapy involves the administration of **Chelating agent**- Molecule bind tightly to metal ions to remove toxic metal or control excess metal in body. In 1930s the concept of chelating agent was introduced in Coordination Chemistry by researchers like Gillberts N.Lewis and Others. In 1941 **British Anti-Lewisite** (BAL,dimercaprol) was developed by British scientists as an antidote to arsenic based chemicals weapons during World War II. In 1950s **EDTA** was introduced to treat **Lead poising**, especially in workers exposed to industrial pollutants. EDTA found more safer and more effective than BAL for treating heavy metal toxicity like Lead(Pb), Cadmium (Cd), Mercury (Hg).Now a day's Chelation therapy is standard treatment for Lead, Mercury, Arsenic poisoning and Iron ,copper overload. Ongoing research into :
1) New targeted chelators for neurodegenerative diseases like Alzheimer's, Parkinson's.

2) Radiometal chelators in nuclear medicine.
3) Cancer therapies using metal - Chelator complexes.

TYPES OF CHELATING AGENTS:

There are different types of Chelating agent as follows:

1. **Based on Origin** :- a. Natural Chelators found in biological systems.
e.g. Citrate, Phytochelatins, Firettin, transferrin etc.
b. Synthetic Chelators are chemically designed to bind specific metals.
e.g. EDTA, DTPA, Deferoxamine, DMSA etc.

2. **Based on Ligand structure**:- a. Bidentate ligands binds metal ions at two sites
e.g. BAL, DMSA
b. Polydentate ligands binds metal at multiple sites.
e.g. EDTA , DTPA, Deferoxamine

c. Macrocyclic Chelators are ring shaped highly stable
chelators. e.g. DOTA , NOTA (used for radiopharmaceuticals).

3. **Based on Medical Application** :- a. Cancer Therapy - Chelators with Platinum, Gallium or Ruthenium complexes are used for Anticancer activity.
b. Copper overload- Chelating agents like Penicillamine, Trientine are used for treatment of Wilson's disease.

4. **Based on Industrial or Environmental Chelators**: EDTA is used for water softening, Nitrilotriacetic acid (NTA) is used for water treatment, Citric acid is used for preservation of food (Eco- friendly chelation).

CHELATE EFFECT:

Chelate effect ,which enhance stability that metal complex gains when bound by a multidentate ligand verses similar number of monodentate ligand. Chelating ligand forms ring structure with the metal "**Clawing**" onto it, which leads to much stronger complexes.

COORDINATION NUMBER (CN):

Coordination number is the number of donor atoms directly attached to the metal ion through coordinate bond. It determine the geometry of the complexes like if CN 2,the geometry will be linear. If CN is four the geometry will be tetrahedral or square planer (depends on the nature ligand, i.e. strong or weak). If the CN is six the geometry will be Octahedral.

Denticity explains how many donor atoms bind, increase CN and usually stability.

THERAPEUTICAL APPLICATION:

Chelating agents are pivotal in treating poisoning by heavy metals by forming water - soluble complexes that the body can excrete efficiently. Some common examples are as follows-

1. Preventing Essential Metal Overload- Chelators like deferoxamine & deferiprone maintain the Iron level in transfusion patients and reducing the long time organ damage.
2. EDTA ($CaNa_2$ - EDTA) - $CaNa_2$EDTA that provoked a10-fold increase in urinary excretion of zinc, and doubled that of copper and Iron.
3. Wilson's Disease and Copper Toxicity - Chelating agents like Penicillamine, Trientine and BAL are used for treatment of Wilson's disease.
4. Diagnostic Imaging and Cancer Treatment - DOTA based chelates are used in targeting radiometals e.g. Y= 90 to tumor tissue for diagnosis and radiotherapy. some Platinum based drug like cisplatin is useful for treatment of cancer.
5. Application in Neurodegenerative Diseases - Abnormal accumulation of metals like iron, copper, or aluminum may contribute to diseases like: Alzheimer’s disease, Parkinson’s disease, Huntington’s disease

Future Direction & Research Trends in Chelation Therapy:

a. Create chelators that specifically bind to toxic metals without disturbing essential metals.
b. Ligand engineering to improve selectivity, affinity, and biocompatibility.
Example: Chelators that distinguish between Fe^{3+} (toxic excess) and Fe^{2+} (essential).
c. Development of oral chelators that are stable in the gastrointestinal (GI) tract and have good bioavailability.Examples: Improved forms of DMSA, deferasirox.
d. Use of nanoparticles or nanocarriers to deliver chelators specifically to affected

tissues. Benefits: Improved targeting, reduced side effects, controlled release.

e. Research is exploring plant-based or biological chelators (e.g., phytochelatins, flavonoids) for safer detoxification.Lower toxicity, enhance compatibility with human metabolism.

CONCLUSION:

Chelating agents play a vital role in medical inorganic chemistry by binding to metal ions, forming stable complexes that can prevent unwanted chemical reactions. This property makes them useful in various medical applications.

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