Chelation - Introduction, Stability and Application in various field of Sciences

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Abstract : Chelates are usually organic compounds, but this is not a necessity, as in the case of zinc and its use as maintenance therapy to prevent the absorption of copper in people with wilson's disease. Most of the chelating group form complexes with almost all of the transition and many non-transition metal.

There are various factors which contribute to the stability of metal chelates. The number of rings formed by one molecule of chelating agent with the metal ion, the size of the rings and the nature of the donor-atoms are of prime importance.

Chelation is useful in applications such as providing nutritional supplements, in chelation therapy, to remove toxic metals from the body, as contrast agents in MRI scanning, food preservation, for solvent extraction, in manufacturing using homogenous catalysts in chemical water treatment to assist in the removal of metals.

Keywords : Chelates, Application, Stability, toxic metals, body.

I. Introduction

The term chelate was first introduced by Morgan and Drew to describe such cyclic structures which arise due to the combination of metallic atom with organic or inorganic molecules or ions. The rings of such compounds are termed as chelate rings and the phenomenon as the chelation.

In other words, chelation is a type of bonding of ions and molecules to metal ions. It involves the formation or presence of two or more separate co-ordinate bond between a polydentate ligand and a single central atom. These ligands are called chelants or chelators. Organic acid such as acetic acid, citric acid, ascorbic acid, lactic acid act as natural chelating agents.

Chelates do not exhibit any of the properties of the salts. It is because that central metal atom has valency more than one. The chelate ring may be closed by the formation of covalent linkage or co-ordinate linkage or by a combination of both.

(a) Covalent linkage -

Covalent linkage is produced by the replacement of a proton in an organic group. Functional groupof this type are some time called acidic group because of the fact that hydrogen may be replaced from them. The most common examples of these are -

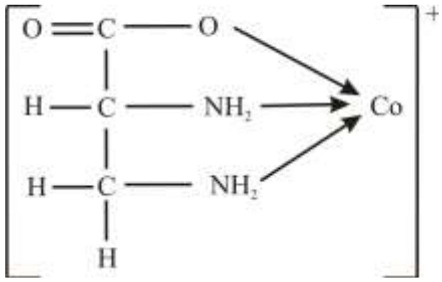
(i) -COOH (Carboxylic group)
(ii) -SO3H (Sulphonic group)
(iii) -OH (enolic hydroxyl group)
(iv) = NOH (oxime)

(b) Co-ordinate linkage - Co-ordinate linkage, without the replacement of hydrogen are formed by the donation of an electron pair. The most common functional groups which contain donor atoms are

(i) - $NH_2 \rightarrow NH \rightarrow N$ (Primary, secondary and tertiary amine)
(ii) = NOH (oxime)
(iii) - OH (alcoholic hydroxyl)
(iv) >C=O (carbonyl)
(v) -s- (Thioether)

Covalent and co-ordinate linkage can be described in following fig. (1)

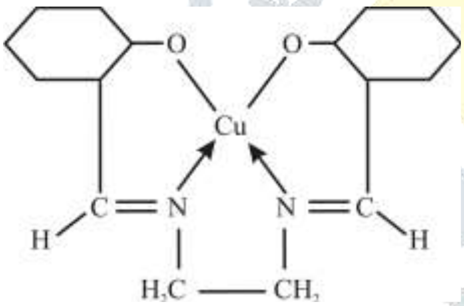
When cobalt ion interacts with diaminopropionic acid to give a tridentate compound in which each molecule of acid is attached to the cobalt atom by the two co-ordinating linkage and one covalent linkage.



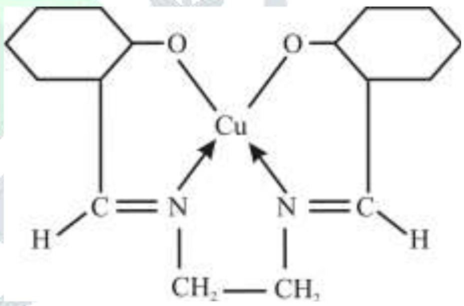
II. FACTOR INFLUENCING - THE STABILITY OF METAL CHELATES

(i) Size of the chelate ring - In general , it has been reported by many workers that saturated compounds tend to form five membered structure, while those ligands which contain double bonds tend to form six membered rings. Ley from conductometric studies of amino acid chelates concluded that chelates with five and six membered rings are more stable. According to Schewarzenbach maximum chelate stabilisation is attained when a strainless rigid ring of size, that can just accomodate the metal ion is formed.

(ii) Number of rings within the chelate - It has been known for long that increase in the number of rings within the chelate result in greater stability. Quantitative studies have confirmed this. It is also found that the formation of fused ring around the metal tends to provide greater stability than the formation of single ring. For the example the chelate(I) having three interlocked ring system (fused rings) is much more stable than the chelate (II) involving comparable two ring system.



(I)



(II)

(iii) Basic strength and chelate stability - The more available the electron pair of the donor group, the stronger is the covalent bond which it may form with a metal.

(iv) Steric effect - This effect modifies the stability of the metal chelates to a great extent. Morgan found that acetyl-acetone did not give the usual coloured chelates with cupric or ferric ion when the 3-position was substituted by an isopropyl or secondary butyl group but gave typical chelates when straight chain alkyl group were present. Strange behaviour is due to steric effect of isopropyl or secondary butyl group.

(v) Effect of substitution on the ligand - The substitution of a group on the chelating agent may influence the tendency for chelation is one of the two ways.

a) It may influence the acidity of the donor groups or may interfere with or enhance the resonance of the chelate ring.

b) The addition of groups on the ligand due to purely steric effects may prevent the ligand ions or molecule from acquiring the orientation about the central metal ion.

(vi) Effect of metal ion - Transition metal usually form covalent bond with electron donors. On the other hand, in the chelate compounds of alkaline earths and alkali metals ions must form ionic bonds.

However, the stability of transition metal chelates decreases with increasing basicity of the metal. Those transition metal which form the strongest covalent bonds with the ligand molecules produce stablest chelates.

III. Applications -

(i) Water softening - Citric acid is used to soften water in soaps and laundry detergents. A common synthetic chelator is EDTA, Phosphonates are also well known chelating agents. Chelators are used in water treatment system. Although the treatment is often repaired to as softening. Chelation has little effect on the water's mineral content. Other than to make it soluble and lower the water's P_H level.

(ii) Fertilizers - Metal chelate compounds are common components of fertilizer to provide micro nutrients. These micronutrients (Mn, Fe, Zn, Cu) are required the health of the plants. Most fertilizers contain phosphate salts that is the absence of chelating agents, typically these metal ions into insoluble solids that are of no nutritional value of the plants. EDTA is the typical chelating agent that keeps these metal ions in a soluble form.

(iii) Food Preservation - Fruits, Fruit Juices and food stuffs are preserved with the help of chelating compounds. The addition of one hundredth of one percent of request earning agent such as EDTA improves the qualities of the food on standing by catching the traces of metals (which are responsible for spoiling the food) by chelate formation.

(iv) For solvent extraction - Chelates which form soluble metal chelates with precipitates are used solvent extraction.

For example, the separation of Zr and Hf was difficult analytical task until it was found that the chelates of these two metals with theonyl trifluoroacetone possess different solubilities in benzene. The distribution coefficient of these two metal chelates differ by a factor of 20 i.e. the zirconium has a greater tendency to be extracted. Therefore, it is now possible to effect a good separationof these two metals at present.

(v) Qualitative analysis - Nickel, magnesium and aluminium in qualitatively analysis are identified by the formation of stable highy coloured chelates.

Thus, dimethyl glyoxime, 8-hydroxy quinoline, o-phenanthroline, Fehling's solution - are used for the detection of many metal ions. For example dimethyl glyoxime reacts with Ni(II) to form an insoluble scarlet red precipitate 8-hydroxyquinoline is used for the determination and detection of over 30 elements. Such as Mg, Al, Zn etc.

The precipitates form by this reagent with all these metals involve highly stable and characteristically coloured chelates.

(vi) Heavy metal detoxification - Chelation therapy is an antidote for poisoning by mercury, arsenic and lead. Chelating agent convert these metal ions into chemically and biochemically inert form that can be

excreted. Chelation using calcium disodium EDTA has been approved by U.S. Food and Drug Administration (FDA) for serious cases of lead poisoning. It is not approved for treating heavy metal toxicity.

Although beneficial in cases of serious lead poisoning. Use of disodium EDTA (edetate disodium) instead of Calcium disodium EDTA has resulted in fatalities due to hypocalcemia. Disodium EDTA is not approved by FDA for any use and all FDA approved chelation therapy products require a prescription.

III. Conclusion

Metals on the one hand serve an essential components of the normal health physiology yet on the other hand can cause serious toxic manifestations. Chelation therapy has been the mainstay treatment against metal toxicity.

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