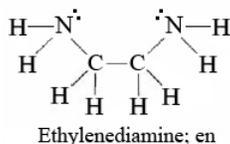


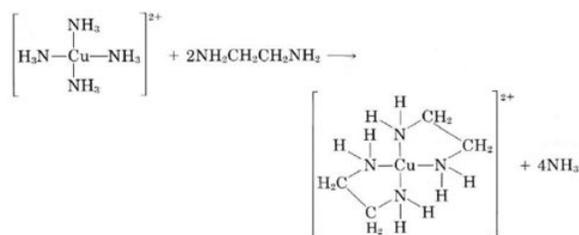
22.10: Chelating Agents

Although we have confined our discussion so far to simple ligands such as Cl^- , NH_3 , or H_2O , much larger and more complicated molecules can also donate electron pairs to metal ions. An important and interesting example of this is the **chelating agents**—ligands which are able to form two or more coordinate covalent bonds with a metal ion. One of the most common of these is 1,2-diaminoethane (usually called *ethylenediamine* and abbreviated *en*.)

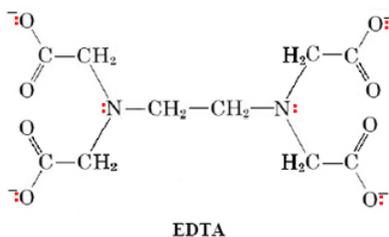


When both nitrogens coordinate to a metal ion, a stable five-member ring is formed. The word *chelating*, derived from the Greek *chele*, “claw,” describes the pincer-like way in which such a ligand can grab a metal ion.

A chelating agent which forms several bonds to a metal without unduly straining its own structure is usually able to replace a similar simpler ligand. For example, although both form coordinate covalent bonds via >N: groups, ethylenediamine can readily replace ammonia from most complexes:



For metals which display a coordination number of 6, an especially potent ligand is ethylenediaminetetraacetate ion (abbreviated EDTA):



All six electron pairs marked in color are capable of coordinating to a metal ion, in which case the EDTA ion wraps completely around the metal and is very difficult to dislodge. EDTA is used to treat lead and mercury poisoning because of its ability to chelate these metals and aid their removal from the body.

Chelate complexes are often important in living systems. The coordination of iron in proteins such as myoglobin or hemoglobin involves four nitrogens of the heme group and one from a histidine side chain. Since iron normally has a coordination number of 6, this leaves one open site, to which oxygen can bond. The presence of carbon monoxide, a stronger ligand than oxygen, causes displacement of oxygen from hemoglobin. This prevents transport of oxygen from the lungs to the brain, causing drowsiness, loss of consciousness, and even death upon long exposure to carbon monoxide. Consequently operating an automobile in a closed garage, a cookstove in a tent, or burning any fossil fuel incompletely in an enclosed space may be hazardous to one's health.

Another important application of chelates is transport of metal ions across membranes. The interior of a biological membranes contain the nonpolar, hydrophobic tails of lipid molecules. This makes it quite difficult for ionic species such as K^+ and Na^+ to travel from one side of a membrane to the other. One way in which this barrier may be circumvented is by carrier molecules, called ionophores. Ionophores are able to chelate an ion, but also have a hydrophobic exterior.

One such ionophore is the antibiotic *nonactin*, a medium-sized organic molecule with the formula

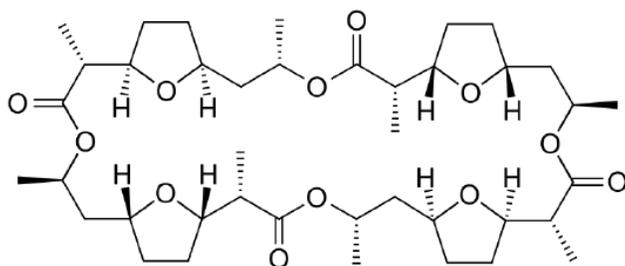


Figure 22.10.1: Chemical structure of nonactin. (CC SA-BY; JaGa).

This molecule is able to transport K^+ ions but not Na^+ ions. Apparently the Na^+ ion is too small to fit in among the eight coordinating O's, while the K^+ ion can (Figure 1). Other than these O's, most of the nonactin molecule is a hydrocarbon chain. Therefore once K^+ is chelated, the outer part of the complex is quite hydrophobic. It can easily pass through the interior of a membrane, releasing K^+ on the other side. The toxic effect of nonactin and several related antibiotics is the result of their ability to transport alkali-metal ions to regions of a cell where they should not be. This breaks down ion gradients the cell has created to perform tasks and store energy. Consequently the cell wastes energy pumping K^+ and other ions out again.

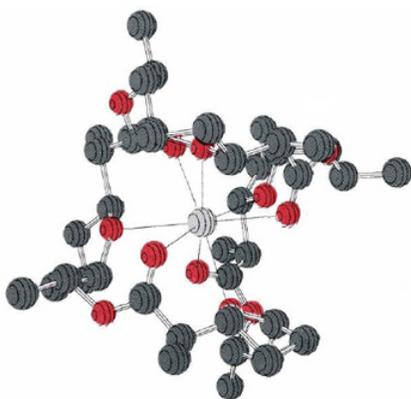


Figure 22.10.2: The K^+ complex of nonactin (K^+ is light gray). Coordinate covalent bonds are indicated as thin solid lines. Hydrogen atoms have been omitted for clarity.

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