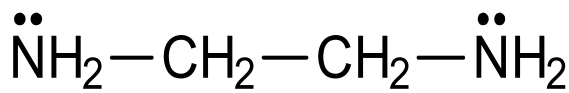
# Learn About ...

## CHELATES & CHLOROPHYLL

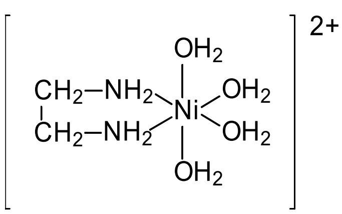
Many essential biological chemicals are chelates. Chelates play important roles in oxygen transport and in photosynthesis. Furthermore, many biological catalysts (enzymes) are chelates. In addition to their significance in living organisms, chelates are also economically important, both as products in themselves and as agents in the production of other chemicals.

A chelate is a chemical compound composed of a metal ion and a chelating agent. A chelating agent is a substance whose molecules can form several bonds to a single metal ion. In other words, a chelating agent is a multidentate ligand. An example of a simple chelating agent is ethylenediamine.

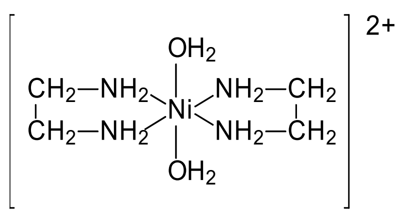


**ethylenediamine**

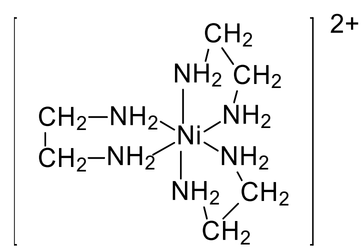
A single molecule of ethylenediamine can form two bonds to a transition-metal ion such as nickel(II), $Ni^{2+}$. The bonds form between the metal ion and the nitrogen atoms of ethylenediamine. The nickel(II) ion can form six such bonds, so a maximum of three ethylenediamine molecules can be attached to one $Ni^{2+}$ ion.



**chelate with one ethylenediamine ligand**



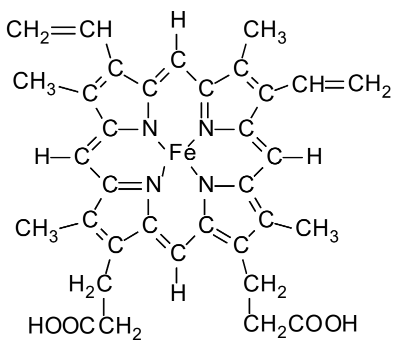
**chelate with two ethylenediamine ligands**



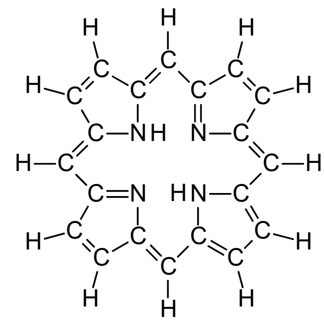
**chelate with three ethylenediamine ligands**

In the two structures on the left, the bonding capacity of the $Ni^{2+}$ ion is completed by water molecules. Each water molecule forms only one bond to $Ni^{2+}$, so water is not a chelating agent. Because the chelating agent is attached to the metal ion by several bonds, chelates tend to be more stable than complexes formed with monodentate ligands such as water.

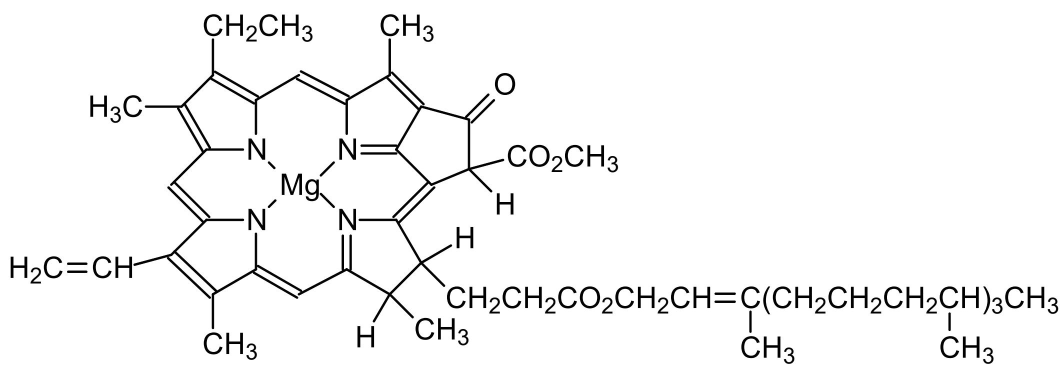
Porphine is a chelating agent similar to ethylenediamine in that it forms bonds to a metal ion through nitrogen atoms. Each of the four nitrogen atoms in the center of the molecule can form a bond to a metal ion. Porphine is the simplest of a group of chelating agents called porphyrins. Porphyrins have a structure derived from porphine by replacing some of the hydrogen atoms around the outside with other groups of atoms. One important porphyrin chelate is heme, the central component of hemoglobin, which carries oxygen through the blood from the lungs to the tissues. Heme contains a porphyrin chelating agent bonded to an iron(II) ion. Iron, like nickel, can form six bonds. Four of these bonds tie it to the porphyrin. One of iron's two remaining bonds holds an oxygen molecule as it is transported through the blood. In the red blood cells of vertebrates, heme is bound to proteins forming hemoglobin. Hemoglobin combines with oxygen in the lungs, gills, or other respiratory surfaces and releases it in the tissues. In muscle cells, myoglobin, the name given to hemoglobin in muscles, stores oxygen as an electron source for energy-releasing oxidation-reduction reactions.



**heme**



**porphine**



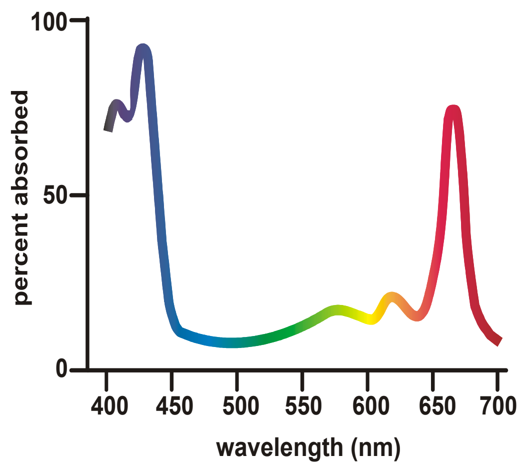
Chlorophyll, the green pigment of plants, is another biologically important porphyrin chelate. In chlorophyll the central ion is magnesium. There are several forms of chlorophyll. The structure of one form, chlorophyll *a*, is shown.

Chlorophyll is one of the most important chelates in nature. It is capable of channeling the energy of sunlight into chemical energy through the process of photosynthesis. In photosynthesis, the energy absorbed by chlorophyll transforms carbon dioxide and water into carbohydrates and oxygen.

$$CO_2 + H_2O \longrightarrow (CH_2O) + O_2$$

(In this equation, $(CH_2O)$ is the empirical formula of carbohydrates.) The chemical energy stored by photosynthesis in carbohydrates drives biochemical reactions in virtually all living organisms.

In the photosynthetic reaction, carbon dioxide is reduced by water; in other words, electrons are transferred from water to carbon dioxide. Chlorophyll assists this transfer. When chlorophyll absorbs light energy, an electron in chlorophyll is excited from a lower energy state to a higher energy state. In this higher energy state, this electron is more readily transferred to another molecule. This starts a chain of electron-transfer steps, which ends with an electron transferred to carbon dioxide. Meanwhile, the chlorophyll which gave up an electron can accept an electron from another molecule. This is the end of a process which starts with the removal of an electron from water. Thus, chlorophyll is at the center of the photosynthetic oxidation-reduction reaction between carbon dioxide and water. The intense color of chlorophyll suggests that it may be useful as a commercial pigment. In fact, chlorophyll *a* is a green dye (Natural Green 3) used in soaps and cosmetics. The absorption spectrum of chlorophyll shows that it absorbs strongly in the red and violet regions of the visible spectrum. Because it absorbs red and violet light, the light it reflects and transmits appears green. Commercial pigments with structures similar to chlorophyll have been produced in a range of colors. Some of these have slightly modified porphyrins, such as having hydrogen atoms replaced with chlorine atoms. Others have different metal ions. For example, one bright blue pigment has a copper(I) ion at the center of the porphyrin and is used primarily in coloring.




Absorption spectrum of chlorophyll *a*.