Gold Cyanide Solution
(Leaching Gold With Cyanide)

Since the 1890's, cyanide has been used to recover gold from gold bearing ores. And today, over 115 years later, most of the worlds gold is recovered with cyanide playing a large part in the beneficiation of the yellow precious metal. Chemically, it is a rather simple reaction:
$4\ Au + 8(NaCN) + O2 + 2\ H2O = 4\ NaAu(CN)2 + 4\ NaOH$

That presumes that the only elements are the gold, Sodium Cyanide and water. However, as any geologist will tell you, no two ores are the same, and their chemical composition will vary greatly throughout the ore body. These "extra" elements in the mineral compounds will often play havoc with a chemical reaction, as illustrated above.

Copper is definitely worth mentioning, since copper minerals will dissolve in cyanide solutions, and cause a increased use of cyanide, the copper-cyanide complexes formed by the dissolution will tend to inhibit the dissolution of gold in the cyanide solution. Zinc, the element used to precipitate gold from solution, if present in the ore, will bond with the cyanide to form a zinc cyanide compound. Another element that plays with the cyanide chemistry is nickel. Nickel, however does not interfere with the gold going into solution, but rather the precipitation of the gold from the cyanide solution.

Arsenic and antimony do present a larger problem, by reacting with the cyanide and using up all of the excess oxygen, leaving little or no oxygen to effect the dissolution of gold. Carbonaceous gold ores can have the carbon adsorb the gold onto its surface, and as a result will not be recovered from the pregnant solution.

Leaching gold from sulfide ores is difficult, at best. Generally, the recovery for cyanide leaching of sulfide or refractory ores is no better than 30%, which is not a worthwhile venture.

The use of alkalies such as calcium oxide, will prevent the decomposition of cyanide in solution to form hydrogen cyanide gas. It reduces the volume of cyanide required to leach the gold or silver. In addition, hydrogen cyanide is highly toxic to people. So, the few dollars spent on adding a cheap calcium oxide to the ore or solution, prior to leaching is worth the money spent. Most cyanide leaching is carried out at a alkaline pH of between 10 and 11, depending upon lab testing of individual ores and the optimum leaching/chemical use rates.

The cyanide solution strength is also important in leaching gold, with the typical range of solution being in the 0.02% -0.05% NaCN. The gold particle size has a tremendous effect on the time required for dissolution in a cyanide solution. Generally, the finer the gold, the quicker it will dissolve. A 45 micron particle of gold would dissolve in 10-13 hours, while a 150 micron particle might take from 20 to 44 hours to dissolve in the same solution.

Oxygen plays an important role in the leaching of gold in a cyanide solution, also. It has been proven that the rate of dissolution of gold in cyanide solution is directly proportional to the amount of oxygen present. Normal water will have 8-9 ppm dissolved oxygen present in it. If this oxygen is used up by other reactions, it may be necessary to aerate the solution, inducing oxygen into it, to speed up the reaction. With cost being always the determining factor (except in safety), the decision to aerate and speed up the reaction will be made based upon economics and laboratory testing. It

is not used much anymore, because most leaching is heap leaching, carried out in the outdoors, where drip emitters or sprays distribute the cyanide solution to a large structure of gold ore, called a "heap". And while the pile of ore is called a heap, it is not a haphazard pile of rocks. Much thought and design goes into the making of a heap leach, to derive the best, most economical solution for recovering the gold from the ore.

Once the gold has been dissolved in the cyanide, and the ore body has been reasonably depleted of its gold, there are two main processes for recovering the gold from the pregnant cyanide solution. One is the Merrill-Crowe zinc precipitation process and the other is the adsorption of the gold onto activated carbon. The oldest method, Merrill Crowe, involves first removing the oxygen from the solution, then mixing a fine zinc powder with it (-200 mesh), and recovering the very fine gold precipitate on a precoat filter, since the gold precipitate is very fine, ranging from a few microns to 50 or so microns. The zinc reacts with the cyanide:
$2Au(CN) + Zn = 2Au + Zn(CN)4^{-2}$

Other chemicals have been used to leach gold, and they include bromine, chlorine, and thiourea. There has also been a lot of experimentation with various biological media for recovering gold from ores, but no one has come up with a more cost effective and productive method than leaching with cyanide. In some special circumstances, some of the other methods may show promise, but for a good oxide gold ore, CN leaching is usually the best of the leach methods for the yellow precious metal. Silver is also leached easily using cyanide, however much silver ore is in sulfide forms, and at higher concentrations (several ounces per ton and above), so other methods such as gravity concentration and froth flotation may be employed.

Information provided by Charles Kubach, Mining and Mineral Processing Engineer
Reference: Chemistry of Cyanidation, American Cyanamid