

Extraction of gold using cyanide

Gold is found in very low concentrations in the ore from which it is mined. To collect the gold from the ore it needs to be separated from the other minerals in the ore. To do this the gold needs to be made into a soluble form so that it can be separated from the other minerals as gold is insoluble. To make gold soluble sodium cyanide (NaCN) is added and the cyanide ion forms a complex ion with the gold. This complex ion, $[\text{Au}(\text{CN})_2]^-$, is readily soluble.

Issues of gold extraction using cyanide:

Cyanide is toxic to humans and may cause death if exposed to high enough doses. Liquid or gaseous hydrogen cyanide, as well as salts of cyanide can enter the body through inhalation, ingestion or absorption through the eyes and skin.

The Absorption causes asphyxiation. This is because cyanide binds to cytochrome oxidase. This is an enzyme in the mitochondria of the cell that is involved in respiration. In other words it is involved in the conversion of oxygen to water and eventually energy. When cyanide binds to this enzyme the cell can no longer use the oxygen present in the bloodstream and asphyxiation occurs.

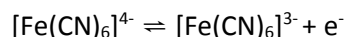
Even at low concentrations convulsions, shallow breathing, irregular heartbeat, and a weaker/erratic pulse can occur.

In the environment cyanide is rapidly degrading or forming stable complexes and salts. This occurs via a number of ways.

1. Complexation: Ionic complexes between cyanide and many metals form. Most of these are much less toxic than free cyanide as in a complexed form the cyanide can no longer bind to cytochrome c. Iron cyanide complexes are especially stable and are important due to large amounts of iron in the soil. Ferro cyanide is formed in the following reactions:



This can be converted to ferricyanide in the following reaction:



Less stable complexes with copper and zinc are unstable and can release free cyanide.

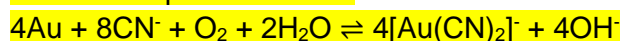
- Volatilisation: in the form of HCN which is very volatile and forms naturally into a gas
- Oxidation: Cyanide can be oxidised to the cyanate ion (OCN^-) which is less toxic. This can occur via an oxidising agent or by micro-organisms that can promote oxidation.
- Biodegradation: microbes can convert cyanide to ammonia.
- Precipitation: Insoluble metal cyanide complexes can form which will not enter the waterways.
- Absorption: Cyanide can strongly bind to organic matter in soil.

Even though some of the above processes occur rapidly and no examples of bio magnification have been found, the problem remains that cyanide is toxic to many living things at very low concentrations.

The process:

The ore is ground and crushed and any free gold is extracted by use of gravity as it may be too large to react readily with the cyanide. If the gold ore contains other metals and/or sulphide minerals it may require additional treatments prior to the leaching process.

The treated gold then has sodium cyanide added to it and the following reaction known as **Elsener's equation occurs:**



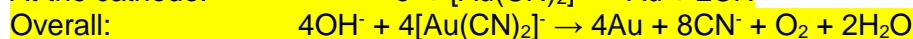
The oxygen is added in the form of dissolved oxygen. This oxygen is also added as it oxidises some of the possible cyanide consuming species in the slurry. By lessening the effect of these species the leach rate of gold is sped up.

The sodium cyanide has lime added to it so that the pH is about 10-11 so that the equilibrium favours the reactants side. This is due to the cyanide ion/hydrogen cyanide equilibrium shown below:



Now the slurry is now treated with either activated carbon or zinc to extract the gold.

For the activated carbon process the slurry is mixed with carbon which is porous and can absorb the gold onto its surface. The activated carbon is then removed from the slurry by adding NaCN and NaOH to the mixture and heating it to 110°C. This removes the gold back into solution which goes through an electrolytic process (known as 'electrowinning') to extract the gold.



For the Zinc process the slurry has Zn powder added to it and a displacement reaction occurs:



The zinc is leached out with acids and the less reactive gold remains.

The remaining slurry after extraction of the gold has occurred is then sent for recovery or destruction. There are several different methods that can be used. Some of these are listed below:

1. Natural degradation:

- If the pH drop below 9 most of the free cyanide is in the HCN form. HCN is volatile and readily evaporates into the air.
- Oxidation occurs to form ammonia and bicarbonate when cyanide reacts with water and air.
- Several species of bacteria degrade cyanide (biodegradation).
- Photodecomposition can break down cyanide when sunlight is present.

2. Chemical degradation which involves oxidation of weaker cyanide complexes and precipitate the more stable complexes.

- Oxidation using hydrogen peroxide.
- Oxidation using a combination of sulphur dioxide and air.

Case study – Golden cross mine using the Cyanisorb process near Waihi.

The Golden Cross mine is close to important river fisheries on the Coromandel Peninsula. The Cyanisorb process was introduced in 1991. It recovers cyanide directly from the slurry (tailings) and uses this recovered cyanide again in the leaching process. This reduces cost and reduces the amount of cyanide entering groundwater and therefore the risk to wildlife which may access the tailings dam (storage pools for natural degradation).

The pH of the tailings is adjusted to 7.5 using sulphuric acid. This causes most of the free cyanide to be converted to HCN. This HCN is then mixed with turbulent air in a packed tower. This causes the HCN to volatilise into a gaseous form. This is then redissolved in an absorber by recirculating a strong sodium hydroxide solution.