Student 2: High Merit

NZQA Intended for teacher use only

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, $[Au(CN)_2]^-$, 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. They affect an enzyme which means that cells within the body cannot use oxygen and so suffer cellular asphyxiation. As a result death occurs. Because of this the cyanide slurry that is left after the gold has been refined must be dealt with or else it can enter waterways where it is poisonous as described above. There are a number of ways of dealing with the cyanide tailings (slurry after it has been used and is ready to be destroyed or reused). The diagram below shows how the processes that occur when the tailings are poured into a decant pond.

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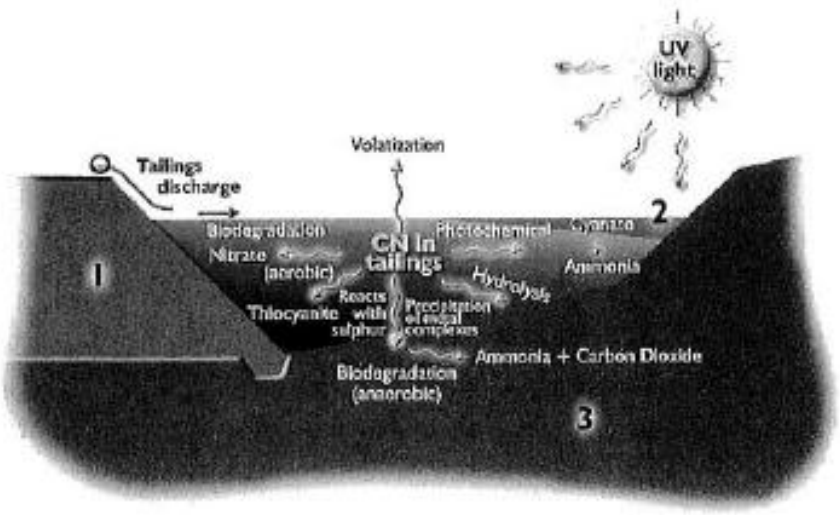

The natural processes occurring in the diagram include:

1. The cyanide ion reacts with sulphur forming thiocynate ion.
2. Bacteria breakdown the cyanide and in doing so form nitrate ions.
3. Cyanide is oxidised to form cyanate ions (OCN^-) and ammonia.
4. The cyanide forms metal complexes with iron for example. These complexes are stable and do not affect the enzyme which allows cells to use oxygen in the bloodstream.
5. Anaerobic bacteria convert the cyanide to form ammonia and carbon dioxide.
6. UV light causes iron cyano complexes to break down.
7. Hydrolysis occurs forming HCN.

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8. Volitisation occurs. If the pond is not basic the cyanide ions are converted to HCN in the equilibrium explained below. HCN is very volatile meaning that it becomes gaseous and escapes the pond. To enhance this process shallow ponds with a large surface area are used.

It has been shown by testing in the tailings under drainage that the levels of cyanide are acceptable and within acceptable safety levels.

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:

$4Au + 8CN^- + O_2 + 2H_2O \rightleftharpoons 4[Au(CN)_2]^- + 4OH^-$

1 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:

$CN^- + H_2O \rightleftharpoons HCN_{(aq)} + OH^-_{(aq)}$

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:

$2[Au(CN)_2]^-_{(aq)} + Zn_{(s)} \rightarrow [Zn(CN)_4]^{2-}_{(aq)} + 2Au_{(s)}$

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.