
ANNEXE 7

GENERAL DESCRIPTION OF CYANIDE CHEMISTRY IN GOLD PLANTS

1. GENERAL GOLD PROCESS DESCRIPTION

Gold bearing ore is crushed and milled into a slurry consisting of fine ground ore and water. This slurry reports to agitated tanks where cyanide solution is added to leach gold from the ore into an aqueous (dissolved) form. Dissolved gold is removed from solution by adsorption onto activated carbon. This carbon is then recovered from the slurry by screening. Using a process known as elution, gold is stripped from the carbon into an aqueous solution called "eluate". Gold is then recovered from the eluate by electrowinning and the electrowon gold is smelted into bars.

Slurry leaving the leach circuit undergoes a process called Cyanide Detoxification, which greatly reduces the toxicity of the slurry by destroying most of remaining cyanide in solution, prior to storage of the tailings in the tailings storage facility.

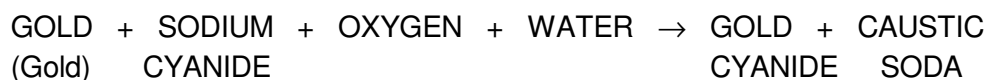
2. CYANIDATION (LEACHING) OF GOLD BEARING ORE

CHEMISTRY

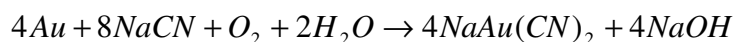
An important discovery concerning the treatment of gold ores was made in 1846 by L. Elsner, a German chemist, when he demonstrated the solubility of gold in dilute solutions of potassium cyanide. J. S. McArthur, a metallurgical chemist in Scotland, realised that Elsner's discovery of the solubility of gold in weak potassium cyanide solution might be of value. The practical use of cyanide for the recovery of gold was thus developed. In 1887 the first cyanidation patent was registered in Great Britain.

Gold is a "noble" metal, which prefers to exist in its natural state as gold metal. Very few metals are noble metals and noble metals are by nature unreactive. Cyanide is one of the few chemicals that will react with gold. Leaching is the process through which cyanide reacts with the gold in the ore to produce a gold-cyanide complex.

The reaction of gold dissolving in cyanide solution can be written as:



In chemical terms, Elsner's equation can be written as:



Gold is leached by conversion from solid phase (free gold or in ore) to gold in solution (in the form of sodium aurocyanide). It can be seen that both oxygen and cyanide are necessary for this reaction to proceed.

The Role of Oxygen

Oxygen is required for the dissolution of gold and the rate of reaction is proportional to the available dissolved oxygen. Other ore constituents (e.g. some sulphide minerals) in the treated pulp are consumers of oxygen. The supply of oxygen must therefore be maintained by good aeration if extraction is to proceed with reasonable speed. Some plants incorporate the use of liquid oxygen or peroxide as sources of oxygen when necessary.

The oxidation of sulphide minerals is accompanied by the formation of acid. If ignored, this would destroy sodium cyanide by formation of hydrocyanic acid gas. An excess of alkali is maintained in the pulp during aeration to prevent the .

The Effect of pH

pH refers to the alkalinity or acidity of the solution. In a pH range from 0 to 14, the 0 to 7 range indicates acidity and the 7 to 14 range indicates alkalinity, with a pH of 7 ± 0.5 indicating neutrality. For optimum leaching conditions, a pH value of somewhere between 9.5 and 11.0 should be maintained, depending on the requirements of the ore being treated at the time. Generally the pH is maintained at 10.5 by the addition of lime or sodium hydroxide to the slurry. This is essential to prevent the loss of sodium cyanide in solution to gaseous hydrogen cyanide (this would obviously have safety implications) which would result in high cyanide consumption.

3. CYANIDE DETOXIFICATION

GENERAL

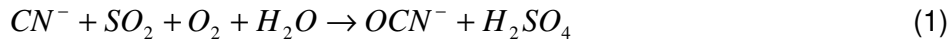
The SO₂/AIR Cyanide Detoxification Process oxidises both free cyanide (CN⁻) and cyanide weakly complexed with metals such as copper, zinc and nickel to cyanate (OCN⁻). Cyanate is two orders of magnitude less toxic than cyanide, (for example, if 1 gram of cyanide has a toxicity of 100, then 1 gram of cyanate will only have a toxicity of 1). The cyanide strongly complexed with iron can be removed as an insoluble ferrocyanide salt by the process.

The oxidising agent is a combination of sulphur dioxide (SO₂) plus oxygen in the presence of a soluble copper catalyst. Temperature is ambient and the pH range is between 8.0 and 9.5. If soluble copper is not present in the tailings solution in sufficient quantities as a product of the cyanidation process, then it must be added as copper sulphate. Sodium hydroxide (NaOH) or lime is added to neutralise sulphuric acid generated in the process and to maintain the desired pH level. In addition a small amount of thiocyanate (SCN⁻) present is oxidised.

The solution or slurry to be treated is contacted with the reagents in a simple mixing tank. Sodium metabisulphite is used to supply the SO₂. The oxygen requirement for the process is normally supplied by adding large volumes of air. The copper catalyst is provided by copper sulphate addition if it is not already present in the feed solution. Retention times vary depending on the solution composition being treated, but generally range from 1 to 3 hours.

CHEMISTRY

Sodium cyanide and other alkaline cyanides are extensively used to extract gold and silver from their ores. Dissolution of these precious metals in alkaline cyanide solution to form stable complex cyanide anions depends on excess cyanide in solution. This excess cyanide is referred to as dissociated or free cyanide. The oxidation of free cyanide to cyanate in the Cyanide Destruction Process can be represented by the equation:



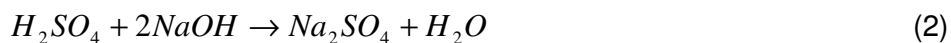
Reaction (1) requires dissolved copper to act as a catalyst. The cyanidation leaching process frequently provides sufficient soluble copper in the tailings solution as a copper cyanide complex to eliminate the need to add it as copper sulphate. The theoretical SO₂ requirement, according to reaction (1) above, is 2.46 parts by weight to one part of cyanide. However, the SO₂ dosage is greater due to its consumption by other chemical reactions.

The best pH range for cyanide destruction is 8.0 to 9.5 , and is normally controlled by lime or sodium hydroxide addition.

Temperature has little effect on the cyanide oxidation reaction, but the type of effluent, solution or slurry, can have a large effect on the reaction (usually determined in laboratory test work).

The oxygen for reaction (1) is obtained from air sparging. Owing to the low solubility of oxygen in water, and its low transfer rate between gas phase and water, only a small fraction of the oxygen added at the bottom of the reactor is actually transferred to the solution. Once in solution, oxygen readily reacts with the SO₂ and cyanide. Insufficient oxygen transfer will limit the destruction performance.

Sulphuric acid generated during cyanide oxidation and other oxidation reactions is neutralised with sodium hydroxide in the reactor as follows:

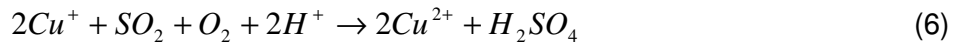


In addition to gold and silver, variable amounts of other metals such as copper, zinc, nickel and iron are leached during the cyanidation process. Reactive sulphides such as pyrrhotite can also react with cyanide to form thiocyanate, or produce partially oxidised species such as thiosulphate. Generally, metals dissolve only slightly, or their dissolution can be minimised by additional treatment.

Weakly complexed cyanides of copper, zinc and nickel are dissociated as follows:



Cuprous copper in solution is oxidised in the Cyanide Destruction Process to the cupric ion, as follows:



The liberated metal ions precipitate as metal hydroxides (below) and the liberated cyanide is oxidised to cyanate, according to equation (1):



The cyanate ion (OCN⁻) is unstable, and hydrolyses to ammonium and carbonate ions, as follows:



This reaction is accelerated at low pH. The carbonate ion precipitates as calcium carbonate. The ammonium (NH₄⁺) ion is in equilibrium with ammonia (NH₃) with some escaping the slurry as NH₃ gas and some reporting to the solid phases present.