Student 3: Low Merit
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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.

1 Cyanide can also be found in the form of HCN (hydrogen cyanide). An equilibrium exists between the two as shown below:

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

At a high pH the equilibrium is to the left and cyanide ion predominates. As the pH lowers the equilibrium is forced to the right and hydrogen cyanide is in higher concentrations.

Issues of gold extraction using cyanide:

2 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.

It is toxic as it prevents cells using oxygen in the bloodstream.

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 In this form the gold is now soluble. This process is known as leaching. One form of this is heap leaching. In this method dilute sodium cyanide is dripped into ore stacked on an impermeable pad or membrane. Because the gold is now in a soluble form it can move through the membrane whereas the rest of the ore cannot move through the membrane. 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 ensures that the cyanide ion is not converted to hydrogen cyanide ion/hydrogen cyanide equilibrium. If heap leaching is not used then this process occurs in leaching tanks.

Now the slurry is now treated with either activated carbon or zinc to extract the gold. Cementation involves using a zinc electrode in carbon paste which is immersed directly into the gold cyanide solution. The following reactions occur:

Cathode:	$e^- + [Au(CN)_2]^- \rightarrow Au + 2CN^-$	Gold is reduced as it is gaining electrons or decreasing in oxidation number
Anode:	$Zn + 2OH^- \rightarrow Zn(OH)_2 + 2e^-$	Zinc is oxidised as it is losing electrons or increasing in oxidation number

And: $Zn(OH)_2 + 4CN^- \rightarrow Zn(CN)_4^{2-} + 2OH^-$

Note that at the anode there is an intermediate step which forms $Zn(OH)_2$.

The gold is then further purified and refined for use.

3 The remaining cyanide in the tailings (slurry after gold leaching) now needs to be destroyed or recycled in some way. As mentioned above cyanide is toxic and cannot be allowed into the local environment. Until the last 20 years the main process used has been natural degradation. These are natural processes that include volitisation, biodegradation, oxidation,

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and absorption onto the surfaces of solids. Absorption means attachment to solid soils, etc. Volitisation occurs when cyanide ions are converted to hydrogen cyanide via the cyanide/ hydrogen cyanide equilibrium. This hydrogen cyanide the changes to a gaseous form as it is volatile. A low pH is used to promote this transformation.

More recently chemical processes that involve recycling have also been used.

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