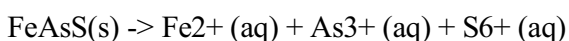


CHEMISTRY OPEN BOOK

Bacterial leaching is used to extract certain metals from its ores via bacteria. The old fashion way of doing this was by smelting and roasting which is quite expensive, and requires an adequate amount of concentration in its ore. The low concentration doesn't prove to be a problem for bacteria as the micro-organisms gains energy from breaking down minerals into there constituent elements.

Process of extracting gold and copper using bacterial leaching : iron and sulphur oxidising – acidophilic bacteria are able to oxidise certain sulphidic ores containing encapsulated particles of gold, making it easily accessible. The process is shown below.

The process of extracting of gold happens in a two stage process. The bacteria catalyse the break down of the mineral arsenopyrite FeAsS by oxidising the sulphur and metal arsenic to higher oxidation states, which simply means that the sulphur and arsenic (lose electrons thus making them positive ions), whilst reducing oxygen (this is the gain of electrons by an atom) by H_2 and Fe^{3+} . This allows soluble products to dissolve.



This Process occurs at the cell membrane of the bacteria. The electrons pass into the cells and are used in biochemical processes to produce energy for the bacteria in order to reduce the oxygen in water.

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Stage 2

the bacteria then oxidise the Fe^{2+} to Fe^{3+}
 $\text{Fe}^{2+} \rightarrow \text{Fe}^{3+}$

The bacteria then oxidises the metal to a higher oxidation state. With the electrons they gain from that they reduce Fe^{3+} to Fe^{2+} to continue the cycle. The gold is now separated from the ore and its solution.

The process for copper is very similar. The mineral chalcopyrite CuFeS_2 (pictured) follows the two stages of being dissolved and then further oxidised, with Cu^{2+} ions being left.

Copper can be extracted from low-grade ore by means of bacterial leaching. The low-grade ore and tailings are put onto an area of impermeable ground. This is then covered in an acidic leaching solution that contains the bacteria, *T. ferro-oxidans* and *T. thio-oxidans*. These bacteria are best suited to an acidic environment. All the bacteria need are Fe^{2+} ions or S^{2-} ions, oxygen, carbon dioxide and bacterial nutrients containing phosphorus and nitrogen. The final result is that the bacteria convert the insoluble chalcopyrite into a solution containing Cu^{2+} , Fe^{2+} , Fe^{3+} and SO_4^{2-} ions. The solution carrying the copper ions can be straightforwardly drained off as it is on an impermeable base layer. *T. ferro-oxidans* catalase the oxidation of Fe^{2+} and Fe^{3+} ions.

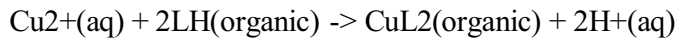
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Extraction from the Mixture using bacterial leaching

Copper (Cu^{2+}) ions are removed from the solution by ligand exchange solvent extraction which leaves other ions in the solution.

Ligand - is an atom, ion or functional group that is bonded to one or more central atoms or ions, usually metals generally through co-ordinate covalent bond. A lot of such ligands around a centre are termed a complex.

The copper is removed by bonding to a ligand, which is a large molecule consisting of a number of smaller groups each possessing a lone pair. The ligand is dissolved in an organic solvent such as kerosene and shaken with the solution producing this reaction:

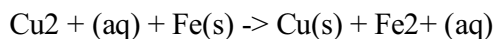


The ligand donates electrons to the copper, producing a complex - a central metal atom (copper) bonded to 2 molecules of the ligand. Because this complex has no charge, it is no longer attracted to polar water molecules and dissolves in the kerosene, which is then easily separated from the solution. Because the initial reaction is reversible, and therefore not a displacement reaction, it is determined by pH. Adding concentrated acid reverses the equation, and the copper ions go back into an aqueous solution.

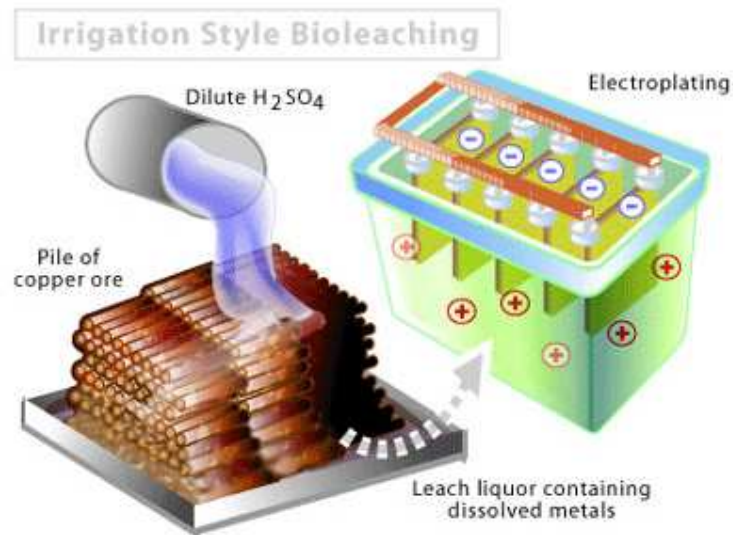
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Then the copper is passed through an electro-winning process to increase its purity: an electric current is passed through the resulting solution of copper ions. Because copper ions have a 2+ charge, they are attracted to the negative cathodes and collect there.

The copper can also be concentrated and separated by displacing the copper with Fe from scrap iron:



the electrons lost by the iron are taken up by the copper. Copper is the oxidising agent, and iron is the reducing agent



(Reference: <http://www.scq.ubc.ca/the-little-workers-of-the-mining-industry/>, 23rd February 2008)



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The crushed ore of gold is treated with H_2SO_4 . The slurry of crushed ore and liquid ore is moved from tank to tank to ensure adequate time for arsenopyrite oxidation, Bacteria oxidise the iron or arsenic or sulphur in mineral; and release gold that is encapsulated. Also the Bacterial leaching solution contains *Sulpholobus acidocaldarius*. It is then extracted by treating with sodium cyanide (cyanidation) gold forms a soluble complex with cyanide ion.

'Bacteria can expose 85-100% of the latter to extraction by cyanide'

(Reference: Salters, 'Advanced chemistry', 'activities booklet', chapter M2.5, page 83)

advantages and disadvantages of bacterial leaching compared to traditional methods

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Bacterial leaching is cheaper and quieter and less polluting than smelting process.

(Reference: Salters' Advanced Chemistry: Chemical Storylines, page 49, chapter M2, published 1994, by George Burton)

Environmental advantages also include that the bacteria used can be recycled for reuse, decreasing expenditure.

Some environmental disadvantages are associated with bacterial leaching including that heavy ions such as iron, zinc and arsenic, can leak out of the mine during draining, forming an ionic precipitate when diluted by fresh water.

Bacterial leaching requires little labour so it's profitable compared to the Traditional methods.

Sulphur dioxide is not released in bacterial leaching and doesn't need high temperatures to run

Development stages of new mining process

Bacterial leaching is used a secondary for copper as it is extracted too slow and the companies can't profit at all-because the metal recovery may take decades. Bacterial leaching is used as primary extraction for gold: the arsenic produces is non toxic and greater % of gold is extracted by bacterial leaching.

A lot of research has gone into to find to find best bacterial culture and conditions. A lot of funding has gone into developing the pilot stages.

'Research at BacTech quickly progressed from 450 dm³ laboratory plant then to a 32m³ transportable pilot plant.'

(Reference: Chemistry Salters, 1st march 1999, Open book, article 3, golden opportunity, golden opportunism)

Bibliography

(Reference: <http://www.scq.ubc.ca/the-little-workers-of-the-mining-industry/>, 23rd February 2008)

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(Reference: Salters, 'Advanced chemistry', 'activities booklet', chapter M2.5, page 83)

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