16.6A: Microbial Ore Leaching

Microbial ore leaching is the process in which microorganisms are used to extract metals from ores.

Learning Objectives

• Assess the advantages of microbial ore leaching

Key Points

• Bioleaching is cheaper than chemical extraction, safer for the environment, and more efficient in extracting metals with low concentration in ores.
• It is performed by iron and sulfide oxidizing bacteria or acid producing fungus.
• Bacteria recycle the major leaching reagent, like ferric iron, and perform further oxidation steps while gaining energy from the electron transfer.

Key Terms

• ore leaching: The process of recovering metals from ores by using a number of different techniques.

Microbial ore leaching (bioleaching) is the process of extracting metals from ores with the use of microorganisms. This method is used to recover many different precious metals like copper, lead, zinc, gold, silver, and nickel. Microorganisms are used because they can:

• lower the production costs.
• cause less environmental pollution in comparison to the traditional leaching methods.
• very efficiently extract metals when their concentration in the ore is low.

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**The Leaching Process**

Bacteria perform the key reaction of regenerating the major ore oxidizer which in most cases is ferric iron as well as further ore oxidation. The reaction is performed at the bacterial cell membrane. In the process, free electrons are generated and used for the reduction of oxygen to water which produces energy in the bacterial cell.

Ores, like pyrite (FeS$_2$), are first oxidized by ferric iron (Fe$^{3+}$) to thiosulfate (S$_2$O$_3^{2-}$) in the absence of bacteria.

In the first step, disulfide is spontaneously oxidized to thiosulfate by ferric iron (Fe$^{3+}$), which in turn is reduced to give ferrous iron (Fe$^{2+}$):

1. FeS$_2$+6Fe$^{3+}$+3H$_2$O?7Fe$^{2+}$+S$_2$O$_2^{-3}$+6H$^+$
2. FeS$_2$+6Fe$^{3+}$+3H$_2$O?7Fe$^{2+}$+S$_2$O$_3^{2-}$+6H$^+$

Bacteria are added in the second step and recover Fe$^{3+}$ from ferrous iron (Fe$^{2+}$) which is then reused in the first step of leaching:

(2) 4Fe$^{2+}$+O$_2$+4H$^+$?4Fe$^{3+}$+2H$_2$O (iron oxidizers)

Thiosulfate is also oxidized by bacteria to give sulfate:

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Figure: **Sulfide mineral bacterial leaching**: Bacterial cells oxidizing the ferrous iron back to ferric iron while using slightly different contact mechanisms with the metal.
(3) \( \text{S}_2\text{O}_2^-3+2\text{O}_2+\text{H}_2\text{O} \rightarrow 2\text{SO}_3^{2-}+2\text{H}^+ \) (sulfur oxidizers) \( \text{S}_2\text{O}_3^{2-}+2\text{O}_2+\text{H}_2\text{O} \rightarrow 2\text{SO}_4^{2-}+2\text{H}^+ \) (sulfur oxidizers)

The ferric iron produced in reaction (2) oxidized more sulfide as in reaction (1), closing the cycle and given the net reaction:

(4) \( 2\text{FeS}_2+7\text{O}_2+2\text{H}_2\text{O} \rightarrow 2\text{Fe}^{2+}+4\text{SO}_4^{2-}+4\text{H}^+ \)

The net products of the reaction are soluble ferrous sulfate and sulfuric acid.

The microbial oxidation 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 while reducing oxygen to water. The critical reaction is the oxidation of sulfide by ferric iron. The main role of the bacterial step is the regeneration of this reactant.

Copper leaching has a very similar mechanism.

**Microorganisms Capable of Ore Leaching**

Bioleaching reactions industrially are performed by many bacterial species that can oxidize ferrous iron and sulfur. An example of such species is *Acidithiobacillus ferroxidans*. Some fungi species (*Aspergillus niger* and *Penicillium simplicissimum*) have also been shown to have the ability to dissolve heavy metals. When fungi are used, the leaching mechanism is different. The fungi use the acids that they produce in their metabolic reactions to dissolve the metal.

In general, bioleaching is cleaner and safer for the environment than chemical processing. However environmental pollution with toxic products, like sulfuric acid from the pyrite leaching, and heavy metals is still possible. Another drawback of microbial leaching is the slow rate at which microbes work.