



## Extractive Metallurgy and Mineral Processing: An Overview

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### Perspective

Extractive metallurgy is a subfield of metallurgical engineering that studies the processes and methods of extracting metals from their natural mineral sources. The field is a materials science that covers all aspects of ore types, washing, concentration, separation, chemical processes, and extraction of pure metal and their alloying to suit various applications, sometimes as a finished product, but more often in a form that requires further work to achieve the given properties to suit the applications.

Mineral processing starts with beneficiation, which entails first breaking down the ore to the needed sizes depending on the concentration procedure to be used, followed by crushing, grinding, sieving, and so on. Following that, depending on the nature of occurrence and/or further process required, the ore is physically separated from any undesired impurities. The physical qualities of the materials are used in separation operations. Density, particle size and shape, electrical and magnetic properties, and surface properties are examples of physical properties. Magnetic separation, froth flotation, leaching, and other major physical and chemical processes are used. Ore bodies frequently contain multiple precious metals. Tailings from a previous operation can be fed into another process to obtain a secondary product from the original ore. A concentration may also contain more than one precious metal. This concentrate would next be treated in order to separate the valuable metals into their respective constituents. Mineral processing and metal extraction are both energy-intensive operations that generate enormous amounts of solid residues and wastewater, both of which require energy to clean and dispose of.

Furthermore, as metal demand grows, the metallurgical sector must rely on materials with lower metal concentrations derived from primary (e.g., mineral ores) and/or secondary (e.g., slags, tailings, municipal waste) raw materials. As a result, mining activities and waste recycling must improve in order to create more selective, efficient, and ecologically friendly mineral and metal processing pathways. Mineral

processing operations are required first and foremost to concentrate the mineral phases of interest and eliminate undesired material that is physically or chemically related with a specific raw material. However, the process requires approximately 30 GJ/tonne of metal, which accounts for approximately 29 percent of total energy used on mining in the United States. Meanwhile, pyrometallurgy is a major source of greenhouse gas emissions and hazardous flue dust. Hydrometallurgy necessitates the use of huge amounts of lixiviants with low selectivity, such as H<sub>2</sub>SO<sub>4</sub>, HCl, KCN, and NaCN. Ionometallurgy employs non-aqueous ionic solvents such as ionic liquids (ILs) and deep eutectic solvents (DESs), allowing the construction of closed-loop flow sheets to effectively recover metals by merging, for example, the metallurgical unit operations of leaching and electrowinning.

DESs are fluids made up of two or three inexpensive and safe components that can self-associate, often through hydrogen bond interactions, to form eutectic mixes with melting points lower than those of the individual components. DESs are normally liquid at temperatures below 100 °C, and they have similar physicochemical qualities as standard ILs while being significantly cheaper and less harmful to the environment. The majority of them are choline chloride mixtures with a hydrogen-bond donor (e.g., urea, ethylene glycol, malonic acid) or choline chloride mixtures with a hydrated metal salt. During Ethaline extraction of copper from copper sulphide minerals, chalcocite (Cu<sub>2</sub>S) and covellite (CuS) generate a yellow solution, indicating the formation of [CuCl<sub>4</sub>]<sup>2-</sup> complexes. Meanwhile, due to the formation of reducing Fe<sup>2+</sup> species at the cathode, Cu<sup>2+</sup> and Cu<sup>+</sup> species coexist in the solution generated from chalcopyrite. The best selective recovery of copper (>97%) from chalcopyrite may be obtained with a mixed DES of 20% ChCl-oxalic acid and 80% Ethaline. Most ionic liquids' stability under practical electrochemical conditions is unknown at the moment, and the fundamental choice of ionic fluid is still empirical due to a lack of data on metal ion thermodynamics to input into solubility and speciation models. There are also no Pourbaix diagrams, standard redox potentials, no knowledge of speciation or pH-values.

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