

Basic Principles of Metallurgy

Ore and Metallurgical Processing:-

What is Metallurgy:-

Metallurgy is a domain of materials science and engineering that studies the physical and chemical behavior of metallic elements, their inter-metallic compounds, and their mixtures, known as alloys.

Metal technology -

Metallurgy is also the technology of metals: the way in which science is applied to the production and industrialization of metals, and the engineering of metal components for use in products for consumers and manufacturers.

Chemical metallurgy-

The scientific approach to metallurgy involves chemical and physical metallurgy. Chemical metallurgy deals with the domain of the reduction and oxidation of metals. It is the science of obtaining metals from their ores, and of the consideration of the reactions of metals derived through a chemical approach. It involves the reactivity of metals, which includes the science of electrochemical (electrochemistry deals with the interaction between electrical energy and chemical change), and corrosive behaviors within metals.

Physical metallurgy-

Physical metallurgy involves the mechanical, magnetic, electrical, and thermal properties of metals evaluated through the discipline of solid state physics (the study of rigid matter, or solids, by methods such as quantum mechanics, crystallography, electromagnetism, and metallurgy.) Physical metallurgy is a systematic way of evaluating the physical properties of metals and alloys, and is basically the fundamental applications of the theory of phase transformation within metallic and alloyed substances.

Extractive metallurgy:-

Extractive metallurgy is a branch of metallurgical engineering where the processes and methods of the extraction of metals from their natural mineral deposits are studied. The field of ferrous and non-ferrous extractive metallurgy have specialties that are generically grouped into the categories, which are based on the process adopted to extract the metal:

- Mineral processing
- Hydrometallurgy
- Pyrometallurgy
- Electrometallurgy

Several processes can be used for the extraction of a given metal, depending on where that metal occurs naturally, and its chemical requirements.

Mineral processing-

This begins with beneficiation*, consisting of initially breaking down the ore to required sizes depending on the concentration process to be followed, by crushing, grinding, sieving etc. Thereafter, the ore is physically separated from any unwanted impurity, depending on the form of occurrence and/or further process involved. Separation processes take advantage of physical properties of the materials. These physical properties can include density, particle size and shape, electrical and magnetic properties, and surface properties.

Beneficiation is any process that improves or benefits the economic value of the ore by removing the gangue (or commercially worthless material) that surrounds the mineral, thus resulting in a higher grade product (concentrate) and a waste stream (tailings). Examples of beneficiation processes include froth flotation and gravity separation.

Major physical and chemical methods include magnetic separation, froth flotation, leaching etc., whereby the impurities and unwanted materials are removed from the ore and the base ore of the metal is concentrated, meaning the percentage of metal in the ore is increased. This concentrate is then either processed to remove moisture or else used as is for extraction of the metal or made into shapes and forms that can undergo further processing, with ease of handling. Ore bodies often contain more than one valuable metal. Tailings of a previous process may be used as a feed in another process to extract a secondary product from the original ore. Additionally, a concentrate may contain more than one valuable metal. That concentrate would then be processed to separate the valuable metals into individual constituents.

Hydrometallurgy -

This is concerned with extraction processes involving aqueous solutions used to extract the desired metal or metals from the raw ore. Leaching process The first step in the hydrometallurgical process is leaching, which involves dissolution of the valuable metals into the aqueous solution and/or a suitable solvent. Purification and concentrating processes After the solution is separated from the ore solids, the extract is often subjected to various processes of purification and concentration before the valuable metal is recovered either in its metallic state or as a chemical compound. This may include precipitation, distillation, adsorption, and solvent extraction. Final recovery processes The final recovery step may involve precipitation, cementation, or electrometallurgical processing.

Pretreatment -

Sometimes, hydrometallurgical processes may be applied directly to the ore material without the need for pretreatment steps. However, often the ore must be pretreated by various mineral processing steps, and sometimes by pyrometallurgical processes.

Pyrometallurgy:-

This involves high temperature processes where chemical reactions take place among gases, solids, and molten materials. Solids containing valuable metals are treated to form intermediate compounds for further processing or converted into their elemental or metallic state.

Pyrometallurgical processes that involve gases and solids are typified by calcining and roasting operations. Processes that produce molten products are collectively referred to as smelting operations.

Heat sources used in Pyrometallurgy:-

Heat via the exothermic chemical reactions The energy needed to sustain the high temperatures used in pyrometallurgical processes may be derived from the exothermic nature of the chemical reactions taking place. Typically, these reactions are oxidation, e.g. of sulfide to sulfur dioxide . Heat via electrical arcing or combustion Often, energy must be added to the pyrometallurgical process using the combustion of fuel or, in the case of some smelting processes, by the direct application of electrical energy (such as plasma arcing).

Electrometallurgy:-

This involves metallurgical processes that take place in some form of electrolytic cell. The most common types of electrometallurgical processes are: Electrowinning - is an electrolysis process used to recover metals in aqueous solution, usually as the result of an ore having undergone one or more hydrometallurgical processes. The metal of interest is plated onto the cathode, while the anode is an inert electrical conductor. Electro-refining - is used to dissolve an impure metallic anode (typically from a smelting process) and produce a high purity cathode. Fused salt electrolysis process - is a process where the valuable metal has been dissolved into a molten salt (which acts as the electrolyte, with the valuable metal collecting on the cathode of the cell.) The fused salt electrolysis process is conducted at temperatures sufficient to keep both the electrolyte (molten salt) and the metal from being produced in the molten state.

Overlapping of electrometallurgy with other processes:-

The scope of electrometallurgy significantly overlaps the areas of Hydrometallurgy and (in the case of fused salt electrolysis) Pyrometallurgy. Additionally, electrochemical phenomena has a considerable role in many mineral processing and hydrometallurgical processes