



Zinc Extraction

Zinc ores are widely distributed throughout the world, although more than 40 percent of the world's output originates in North America and Australia. The common zinc-containing minerals are the

- Zinc sulfide known as zinc blende or sphalerite (ZnS),
- A ferrous form of zinc blende known as marmatite [$(ZnFe)S$],
- Zincite (ZnO)
- Zinc carbonate known as calamine or smithsonite ($ZnCO_3$).

Extraction Process:

Zinc smelting is the process of converting zinc concentrates (ores that contain zinc) into pure zinc. Zinc smelting has historically been more difficult than the smelting of other metals, e.g. iron, because in contrast, zinc has a low boiling point. At temperatures typically used for smelting metals, zinc is a gas that will escape from a furnace with the flue gas and be lost, unless specific measures are taken to prevent it.

The most common zinc concentrate processed is zinc sulfide which is obtained by concentrating sphalerite using the froth flotation method. Secondary (recycled) zinc material, such as zinc oxide, is also processed with the zinc sulfide. Approximately 30% of all zinc produced is from recycled sources.

There are two methods of smelting zinc: the Pyrometallurgical process and the Electrolysis or Hydrometallurgical process.

Roasting:

Roasting is a process of oxidizing zinc sulfide concentrates at high temperatures into an impure zinc oxide, called "Zinc Calcine".

Approximately 90% of zinc in concentrates is oxidized to zinc oxide. However, at the roasting temperatures around 10% of the zinc reacts with the iron impurities of the zinc sulfide concentrates to form zinc ferrite. A byproduct of roasting is sulfur dioxide, which is further processed into sulfuric acid, a commodity.

The process of roasting varies based on the type of roaster used. There are three types of roasters: multiple-hearth, suspension, and fluidized-bed.

Multiple-hearth roaster

In a multiple-hearth roaster, the concentrate drops through a series of 9 or more hearths stacked inside a brick-lined cylindrical column. As the feed concentrate drops through the furnace, it is first dried by the hot gases passing through the hearths and then oxidized to produce calcine. The reactions are slow and can be sustained only by the addition of fuel. Multiple hearth roasters are unpressurized and operate at about $690\text{ }^{\circ}\text{C}$ ($1,270\text{ }^{\circ}\text{F}$). Operating time depends upon the composition of concentrate and the amount of the sulfur removal required. Multiple hearth roasters have the capability of producing a high-purity calcine.



Suspension roaster

In a suspension roaster, the concentrates are blown into a combustion chamber very similar to that of a pulverized coal furnace. The roaster consists of a refractory-lined cylindrical steel shell, with a large combustion space at the top and 2 to 4 hearths in the lower portion, similar to those of a multiple hearth furnace. Additional grinding, beyond that required for a multiple hearth furnace, is normally required to ensure that heat transfer to the material is sufficiently rapid for the desulfurization and oxidation reactions to occur in the furnace chamber. Suspension roasters are unpressurized and operate at about 980 °C (1,800 °F).^[1]

Fluidized-bed roaster

In a fluidized-bed roaster, finely ground sulfide concentrates are suspended and oxidized in a feedstock bed supported on an air column. As in the suspension roaster, the reaction rates for desulfurization are more rapid than in the older multiple-hearth processes. Fluidized-bed roasters operate under a pressure slightly lower than atmospheric and at temperatures averaging 1,000 °C (1,830 °F). In the fluidized-bed process, no additional fuel is required after ignition has been achieved. The major advantages of this roaster are greater throughput capacities, greater sulfur removal capabilities, and lower maintenance.

Hydrometallurgical Process

The electrolysis process consists of 4 steps:

- a) Leaching,
- b) Purification,
- c) Electrolysis, and
- d) Melting and casting.

Leaching

The basic leaching chemical formula that drives this process is:

This is achieved in practice through a process called double leaching. The calcine is first leached in a neutral or slightly acidic solution (of sulfuric acid) in order to leach the zinc out of the zinc oxide. The remaining calcine is then leached in strong sulfuric acid to leach the rest of the zinc out of the zinc oxide and zinc ferrite. The result of this process is a solid and a liquid; the liquid contains the zinc and is often called leach product; the solid is called leach residue and contains precious metals (usually lead and silver) which are sold as a by-product.

Purification

The purification process utilizes the cementation process to further purify the zinc. It uses zinc dust and steam to remove copper, cadmium, cobalt, and nickel, which would interfere with the electrolysis process. Purification is usually conducted in large agitated tanks. The process takes place at temperatures ranging from 40 to 85 °C (104 to 185 °F), and pressures ranging from atmospheric to 2.4 atm (240 kPa) (absolute scale). The by-products are sold for further refining.



The zinc sulfate solution must be very pure for electrowinning to be at all efficient. Impurities can change the decomposition voltage enough to where the electrolysis cell produces largely hydrogen gas rather than zinc metal.

Electrolysis

Zinc is extracted from the purified zinc sulfate solution by electrowinning, which is a specialized form of electrolysis. The process works by passing an electric current through the solution in a series of cells. This causes the zinc to deposit on the cathodes (aluminium sheets) and oxygen to form at the anodes. Sulfuric acid is also formed in the process and reused in the leaching process. Every 24 to 48 hours, each cell is shut down, the zinc-coated cathodes are removed and rinsed, and the zinc is mechanically stripped from the aluminium plates.

Electrolytic zinc smelters contain as many as several hundred cells. A portion of the electrical energy is converted into heat, which increases the temperature of the electrolyte. Electrolytic cells operate at temperature ranges from 30 to 35 °C (86 to 95 °F) and at atmospheric pressure. A portion of the electrolyte is continuously circulated through the cooling towers both to cool and concentrate the electrolyte through evaporation of water. The cooled and concentrated electrolyte is then recycled to the cells. This process accounts for approximately one-third of all the energy usage when smelting zinc.

There are two common processes for electrowinning the metal: the *low current density process*, and the *Tainton high current density process*. The former uses a 10% sulfuric acid solution as the electrolyte, with current density of 270–325 amperes per square meter. The latter uses 22–28% sulfuric acid solution as the electrolyte with a current density of about 1,000 amperes per square metre. The latter gives better purity and has higher production capacity per volume of electrolyte, but has the disadvantage of running hotter and being more corrosive to the vessel in which it is done. In either of the electrolytic processes, each metric ton of zinc production expends about 3,900 kWh (14 GJ) of electric power.

Melting and casting

The final step is to melt the cathodes in an induction furnace. It is then either cast into pure zinc (99.995% pure) ingots or alloyed and cast into ingots.

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