Extractive metallurgy deals with extraction of metals from its naturally existing ore/minerals and refining them.

Minerals: Inorganic compounds with more than one metal in association with non-metals like S,O,N etc. Naturally existing minerals are sulphides, oxides, halides like: Hematite (Fe_2O_3), Magnetite (Fe_3O_4), Chalcopyrite ($CuFeS_2$), Dolomite ($CaCO_3.MgCO_3$) etc.

• MINERAL: It is a naturally occurring inorganic compound of one or more metals in association with nonmetals such as oxygen, Sulphur and the halogens. A mineral has fixed composition and well defined physical and chemical properties.

• ORE: It is the naturally occurring aggregate or combination of minerals from which one or more metals or minerals may be extracted economically (profitably).

Types of ores

• Oxide ores: Examples: Fe_2O_3, Fe_3O_4 Apart from Fe, other heavy metals which are produced from oxide ores are: Manganese, Chromium, Titanium, Tungsten, uranium and Tin.

• Sulphide ores: Copper ore ($CuFeS_2$, Chalcopyrite), sphalerite (Zn,Fe)S, Galena PbS, Pyrite FeS_2. Others: Nickel, Zinc, Mercury and Molybdenum

• Halide ores: Rock salts of Sodium, Magnesium chloride in sea water

UNIT OPERATIONS AND UNIT PROCESSES

• UNIT OPERATIONS: The physical processes like crushing, grinding, classification, concentration etc. are called unit operations.

• UNIT PROCESSES: The chemical processes like calcination, smelting, roasting, leaching etc. are called unit processes.

Classification based upon methods of metal extraction

Physical seperation/Mineral processing

The objective is to concentrate the metallic content in the ore, achieved by a series of communation (crushing and grinding), screening and seperation process.

Pyrometallurgy : It involves the smelting, converting and refining of metal concentrate.

Hydrometallurgy: It involves the precipitation of metal in an aqueous solution.

Electrometallurgy: Electrolysis process to extract metal. Electro-winning: Extraction of the metal from electrolyte; Electro-refining: Refining of impure metals in the form of an anode.

PYROMETALLURGY:

Pyrometallurgy deals with the methods of extraction of metals from their ores and their refining and is based on physical and chemical changes occurring at high temperatures.

WHAT ARE THE ADVANTAGES OF HIGH TEMPERATURE?

As at high temperature, the reaction rate is accelerated which leads to more metal production.

Also at high temperature the inexpensive reducing agent can be used and cheaper raw material can be used.

As we know that the reaction rate doubles in each 10ºC rise of temperature which requires small activation energy. It helps in fast reaction.

• Shift of reaction is possible. UNIT PROCESS PYROMETALLURGY HYDROMETALLURGY ELECTROMETALLURGY

• Brings about a reduction which cannot takes place in presence of water.

• Only pyrometallurgy and fused salt electrolysis can extract reactive metals namely the alkaline earth metals zirconium and titanium.

• Ability to treat a large tonnage of ore in a compact space, which leads to a saving in capital cost. There are 4 processes that are included in pyrometallurgical treatment. i.e.

1. Calcination 2. Roasting 3. Smelting 4. Refining

CALCINATION:

• **Calcination** is the thermal treatment of an ore that brings about its decomposition and elimination of volatile products i.e. carbon dioxide and water.

• Temperature required for this process can be calculated from free energy temperature relationship for the reaction under consideration.

• As the most decomposition reaction is endothermic, so the temperature of calcination is generally depends on the transfer of heat into the particle. This result in even high temperature of the furnace (kiln) at the expanse of some fuel.

• For example, CaCO3 (c) = CaO (c) + CO2. This reaction is endothermic and requires high temperature to decompose it in the kiln.

ROASTING

Roasting of an ore or a concentrate is a chemical process in which chemical conversion of ore is taken place by employing oxygen or other element.

This process was used to remove Sulphur or other elements such as arsenic and tellurium in the form of a volatile oxide from an ore.

Ore is crushed and heated to a high temp using a strong blast of hot air. The process converts the ores to their oxides which can then be reduced.

Consider the natural occurring ores of zinc (ZnSZnS (sphalerite) and ZnCO3ZnCO3 (smithsonite).

When roasted, smithsonite decomposes to ZnO(s)ZnO(s) and CO2(g)CO2(g) and the hot air involved in roasting sphalerite oxidizes it to produces ZnO(s)ZnO(s) and SO2(g)SO2(g).

$$ZnCO_{3(s)} \longrightarrow ZnO_{(s)} + CO_{2(g)}$$

$$2ZnS_{(s)} + 3O_{2(g)} \longrightarrow 2ZnO_{(s)} + 2SO_{2(g)}$$

Different types of roasting

1. OXIDIZING ROASTING
2. VOLATIZING ROASTING
3. CHLORIDIZING ROASTING

FACTORS AFFECTING ROASTING:

❖ Time (duration)

❖ Availability of oxygen or air

❖ Temperature

❖ Physical condition of the ore

❖ Nature of the mechanical device used

Smelting

Smelting is a Heating process of production of metal or matte.

• Reducing agent- C/S/sulphide

• Furnace used- reverberatory furnace, blast furnace, electric arc furnace

• As gangue is less fusible than metal so flux must be added to form slag which is easily fusible.

Mineral + gangue+ reducing agent+ flux = metal/matte + slag + gas Blast furnace- reduction smelting Reverberatory furnace- matte smelting Electric arc furnace- reduction smelting and matte smelting In matte smelting no reducing agent is used because sulphide itself acts as reducing agent.

REASON OF USING FLUXES:

1. Used to lower the liquidus temperature.

2. lowers the viscosity of slag (increase the fluidity).

SMELTING FURNACES

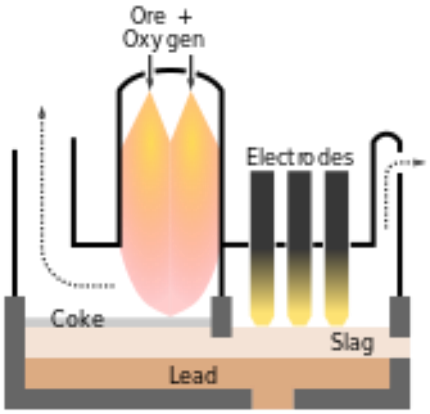
1. DIRECT ARC ELECTRIC FURNACE
2. BLAST FURNACE
3. REVERBERATORY FURNACE

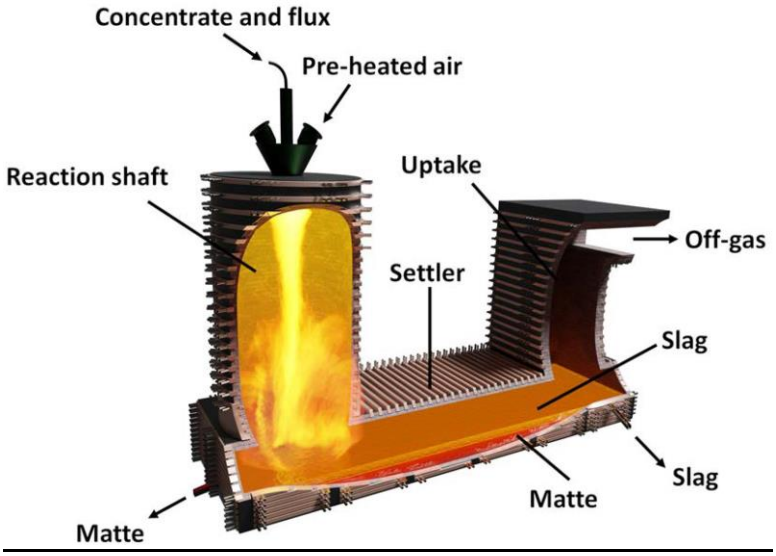
FLASH SMELTING

Flash smelting is done for the concentrates of nickel sulphide and copper sulphide.

This process combines the process of **flash roasting and smelting**.

In this smelting process, enriched preheated air or pure oxygen is usually used instead of air to increase the combustion rate and to maintain autogenous smelting.





MATTE SMELTING

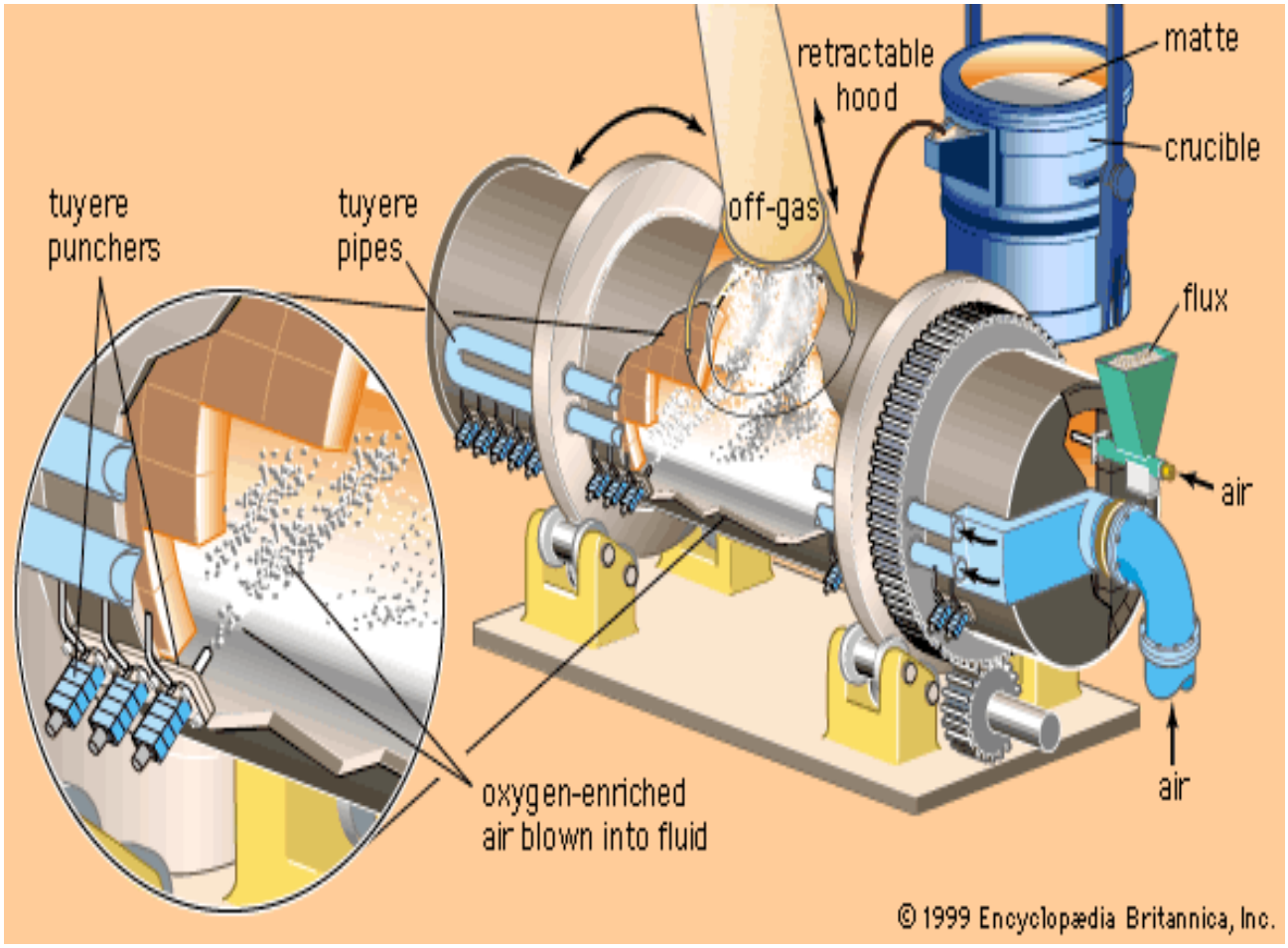
In matte smelting, the sulphide ore is fused with a flux to produce a molten mixture of sulphides known as a matte.

The gangue materials pass off into the slag, which is immiscible with the matte, i.e., it forms a separate layer.

A matte is a metallic sulphide solution that contains minor amounts of oxygen and, sometimes, some metals too.

Matte smelting, which is usually carried out in a reverberatory furnace, follows a roasting operation.

Matte smelting is adopted in the extraction of copper, nickel, and, sometimes, antimony.



CONVERTING

The purpose of converting is to remove iron ore, Sulphur and other impurities from matte.

For the process, the molten matte produced as a result of smelting, is fed into the side blown converter which is a cylindrical vessel with a capacity of **100-200 tons of matte.**

Inside the converter the atmosphere is highly oxidizing.

Air or oxygen enriched air is injected into the molten bath through tuyeres. The products of converting process are slag and metal.

REFINING

DISTILLATION : It is a process of separation of one component from a liquid mixture according to their difference in boiling point.

Important refining methods :

1) Zone Refining
2) Fire Refining

HYDROMETALLURGY

Hydrometallurgy refers to production of metal or pure compounds with the help of reaction in aqueous and organic solution. It is a process of beneficiation as well as extraction.

STEPS OF HYDROMETALLURGY PROCESS

1) Preparation of ore for leaching
2) LEACHING
3) SEPARATION OF LEACH LIQUOR
4) RECOVERY OF METALLIC VALUES FROM LEACH LIQUOR

LEACHING :

In leaching, a mineral decompose in an aqueous environment, the mineral may simply dissolves completely, leaving behind the gangue as a solid residue. Sometime, only some constituent of the mineral may dissolve.

TYPES OF LEACHING OPERATION:-

1- In Situ leaching :

It is an operation in which either the leaching of the shattered rock residues left behind in a mine after the major mining operation have been carried out or the direct leaching of the ore deposited .

2- Dump Leaching:

It is the application of the leach solutions to dumps consisting of off-grade ore rejected during the normal mining operation. It is similar to heap leaching, however in the case of dump leaching ore is taken directly from the mine and stacked on the leach pad without crushing**.**

3- Heap Leaching :

It is a technique where run-of-mine crushed(generally>5mm) and agglomerated ores are stacked over an engineered impermeable pad, wetted with lixiviant(solvent)chemicals under atmospheric condition and leachate(metal loaded solution)are collected for metal recovery processes.

4- Percolation Leaching :

It is a selective removal of the metal values from a mineral by causing a suitable solvent or leaching agent to seep into and through a mass or pile of material containing the desired material. In this process, the

leach solution is percolated upward or downward through an ore which has already been crushed and bedded into tanks.

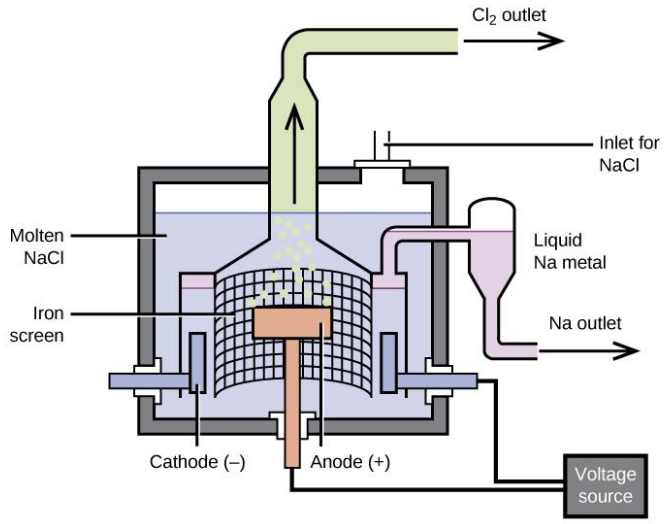
ELECTROMETALLURGY

Principle:

- **Electrometallurgy** is a method in metallurgy that uses electrical energy to produce metals by electrolysis. It is usually the last stage in metal production and is therefore preceded by pyrometallurgical or hydrometallurgical operations..
- Such media include aqueous solutions molten salts and silicates, and organic liquids.

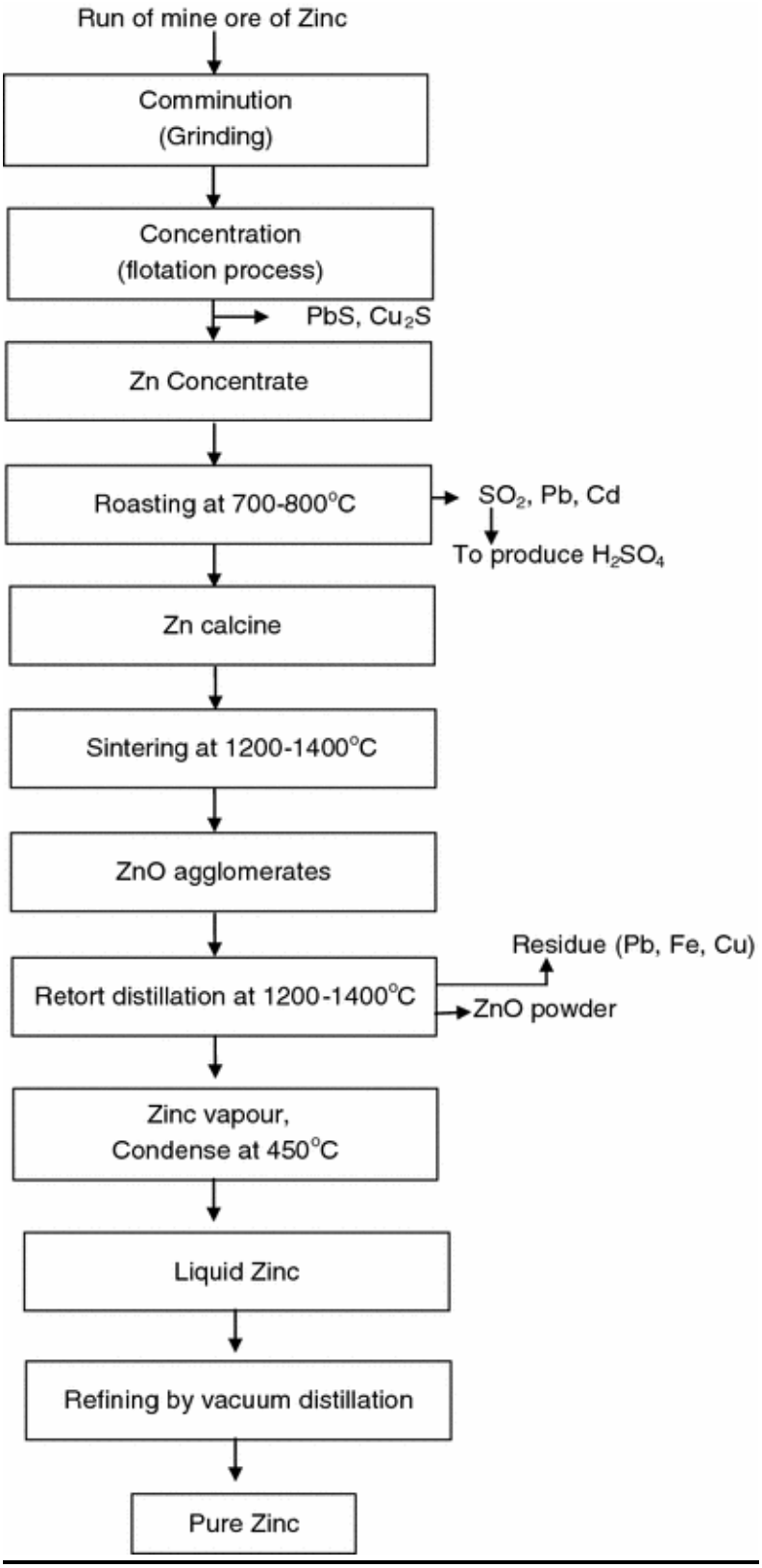
METHODS OF ELECTROMETALLURGY

- **Electrowinning** refers to a process that produces a metal by the electrolysis of an aqueous solution or a fused salt.
- **Electrorefining** is a refining process based on electrolytic phenomena.
- **Electrode position** refers to the technique of depositing one metal on another at the cathode

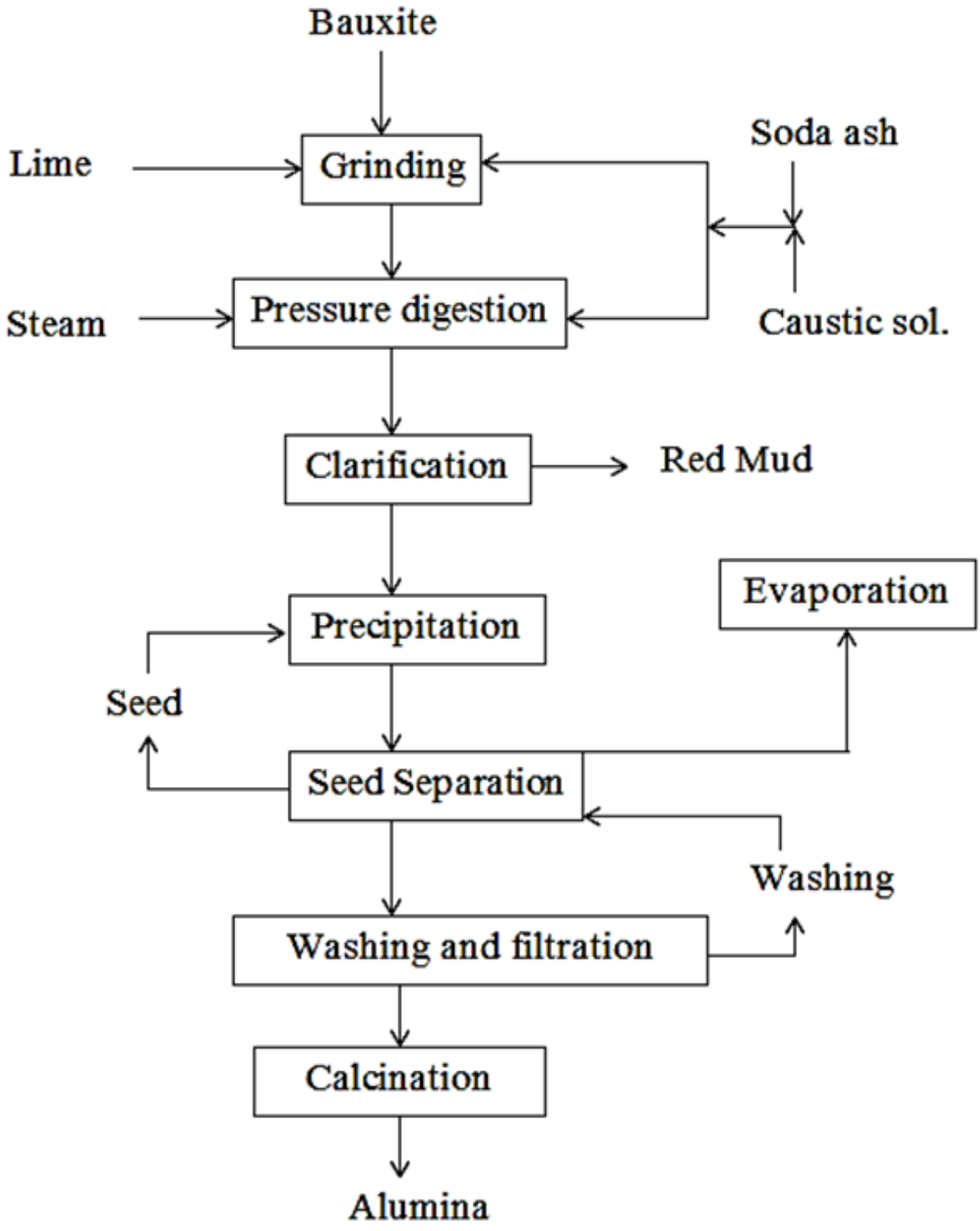


FLOWCHARTS OF EXTRACTION

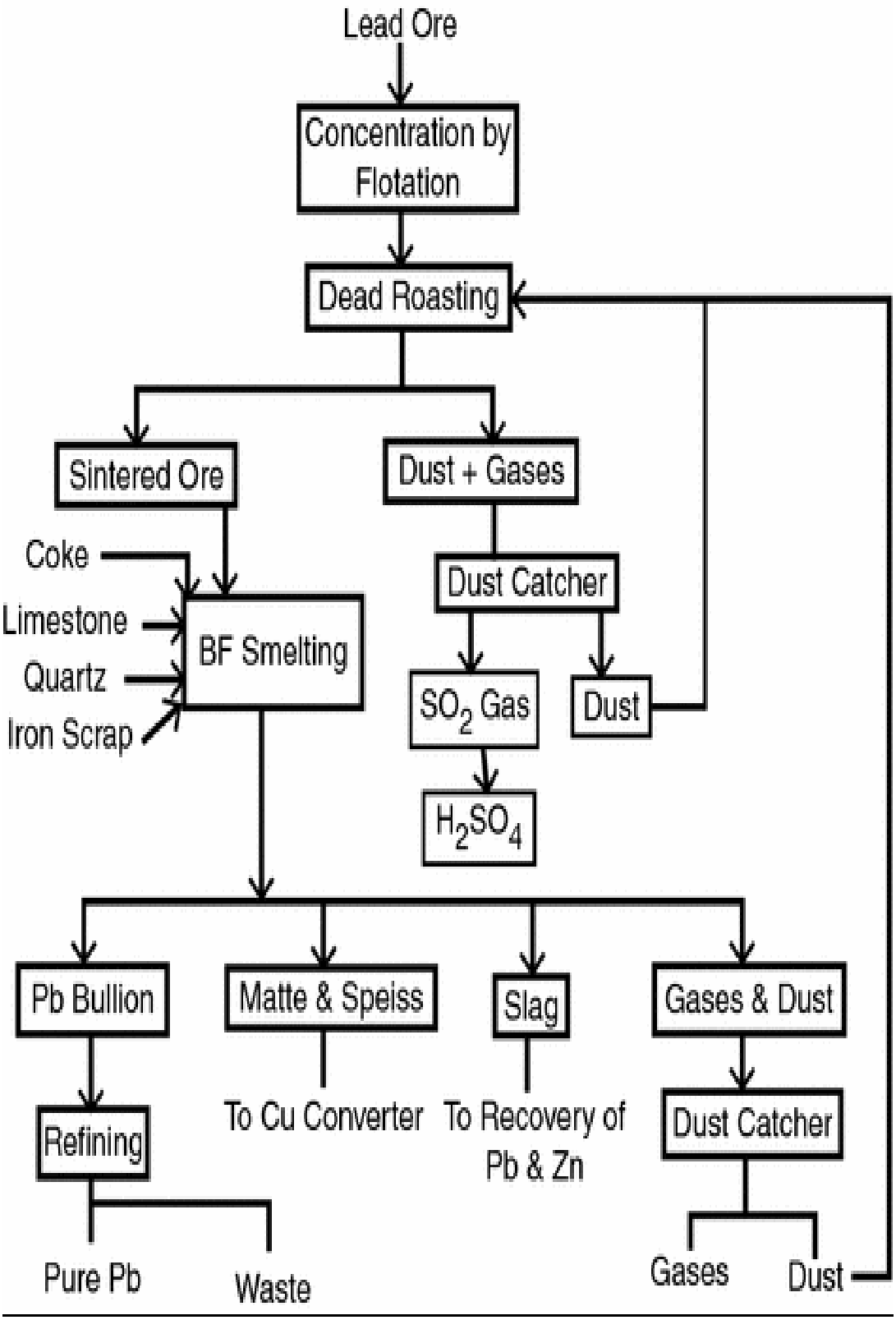
Extraction of ZINC



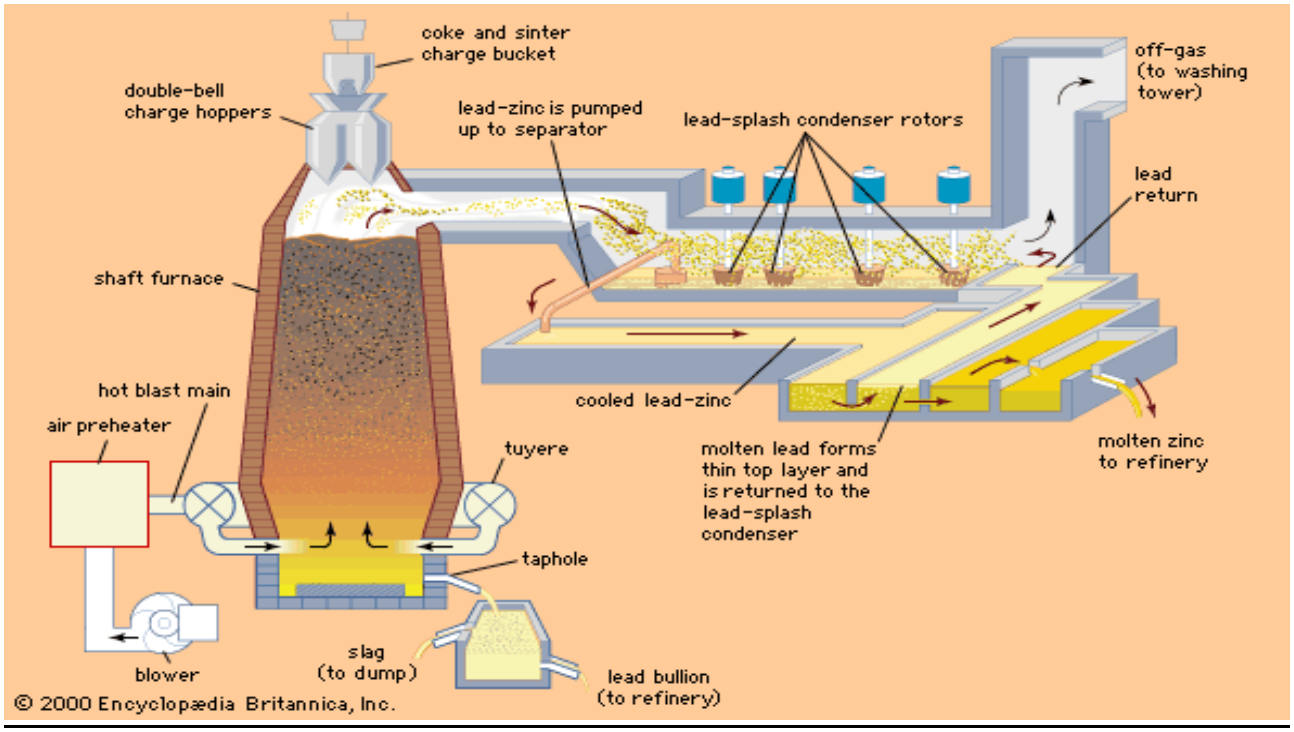
Extraction of ALUMINIUM



Extraction of LEAD



PROCESS ROUTE OF EXTRACTION OF LEAD



Extraction of GOLD