ENGINEERING CHEMISTRY

Semester: 1ST/2ND

STUDY MATERIAL

Inorganic Chemistry

Mr Soumya Ranjan Dash

Lecturer

Department of Mining Engineering

IIPM School of Engineering & Technology Kansbahal, Rourkela, Odisha

IORGANIC CHEMISTRY

METALLURGY

MINERALS:

Minerals are naturally occurring substances that are formed in the Earth's crust through geological processes. They are solid, inorganic, and have a crystalline structure. Minerals can be classified based on their chemical composition and physical properties, such as hardness, color, and luster. They are important resources for human civilization, as they are used in various industries such as construction, electronics, and energy production.
Examples of minerals: quartz, feldspar, calcite, and mica.

ORES:

Ores are naturally occurring rocks or minerals that contain a high enough concentration of a desirable substance, such as a metal, to make it economically feasible to extract and process the substance. The extraction of metals from ores typically involves a process of mining, crushing, and smelting,
The desirable substance in an ore is typically a metal like iron, copper, aluminum, or gold.

GANGUE:

Gangue is the unwanted material or minerals that accompany the valuable ore or mineral deposit in a geological deposit. It is the commercially worthless material that must be separated from the ore during the extraction process.
Gangue materials are typically composed of non-valuable minerals or rocks, such as quartz, calcite, or feldspar.

DISTINCTION BETWEEN ORES & MINERALS:

Minerals	Ores
Minerals are naturally occurring substances with a defined chemical composition and crystal structure	while ores are rocks or minerals that contain a high concentration of a valuable substance, such as a metal
Minerals may or may not have economic value	while ores are commercially valuable and are extracted and processed to obtain the valuable substance.
Minerals may or may not be extracted through mining	while ores are extracted through mining or other extraction processes.
Minerals are typically present in larger quantities than ores as they are more abundant in nature	Ores are found less quantity than minerals deposit in nature.
Minerals have a defined chemical composition and physical properties	while ores may contain a variety of minerals and can have a range of physical properties depending on their composition

GENERAL METHODS OF EXTRACTION OF METALS:

Metals can be extracted from their ores using various methods depending on their chemical properties and the concentration of the ore. Some of the general methods of extraction of metals are:

Pyrometallurgy: This involves heating the ore at high temperatures in the presence of oxygen or air to form metal oxides, which can be further reduced to obtain the metal. This method is commonly used for the extraction of iron, copper, and zinc.
Hydrometallurgy: This involves the use of aqueous solutions to dissolve the metal from the ore, followed by precipitation or electrolysis to obtain the metal in pure form. This method is commonly used for the extraction of gold, silver, and platinum.
Electrometallurgy: This involves the use of electricity to extract metals from their ores. For example, aluminum is extracted from bauxite ore by electrolysis.

Biohydrometallurgy: This involves the use of microorganisms to extract metals from ores. This method is used for the extraction of copper, gold, and uranium from low-grade ores.
Solvent extraction: This involves the use of organic solvents to extract metals from their ores. This method is commonly used for the extraction of copper and uranium.
Carbon Reduction: In this method, metals which are highly reactive, like sodium and potassium, are obtained by reducing their oxides with the help of highly reactive carbon.

ORE DRESSING/ CONCENTRATION OF ORES:

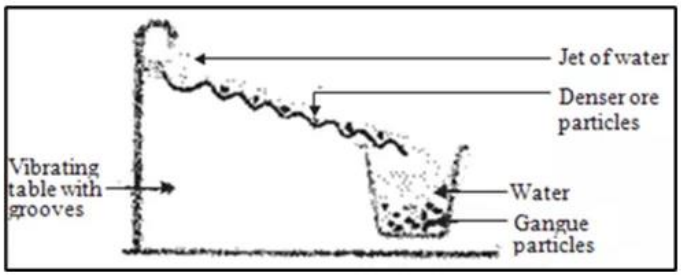
Ore dressing or concentration of ores is the process of separating the valuable minerals from the gangue (unwanted material) in an ore. The aim of ore dressing is to increase the concentration of the ore and remove impurities, so that the valuable minerals can be economically extracted.
The various methods of ore dressing include:

1. ***Gravity Separation:***

Gravity separation is a method of separating two or more components from a mixture based on their differences in weight or density. This method is commonly used in the mining industry to separate minerals from their ores. It is based on the principle that denser components settle to the bottom of a container or medium, while less dense components float to the top.

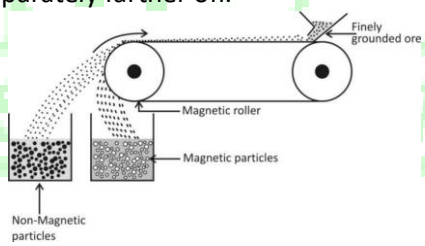
In the gravity separation process, the mixture is fed onto a inclined vibrating table or a drum, which is set in motion. The denser components settle to the bottom due to the force of gravity, while the less dense components are carried to the top. The separated components can be collected from different points of the table or drum.

It is particularly useful for separating heavy minerals such as gold, tin, and tungsten from their ores. The method is simple, economical, and environmentally friendly, as it does not involve the use of any chemicals or reagents. However, it has some limitations, such as low efficiency for fine particles and low selectivity for some mineral combinations.



2. ***Magnetic separation:***

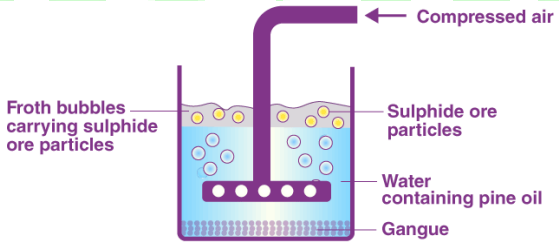
Magnetic separation process:
-The magnetic separation process is based on the differences in magnetic properties of the ore components.
-If either ore or the gangue is attracted by a magnet, then the ore can be separated from the impurities with the help of magnetic separation method.
-It requires an electromagnetic separator which consists of a brass or leather belt moving over two rollers, one of which is magnetic in nature as shown in the figure.
-Powdered ore is dropped over the moving belt at one end.
-At the other end, the magnetic portion of the ore is attracted by the magnetic roller and falls nearer to the roller, while the non-magnetic impurities fall separately farther off.



3. *Froth Floatation:*

The process of froth floatation starts with the Comminution process, in which the surface area of the ore is increased. First of all, the ores are crushed into very fine powder-sized particles and mixed with water. The mixture obtained is called Slurry. A collector, which acts as a surfactant chemical, is added to the slurry. This is done to enhance the hydrophobic nature of the mineral.

The slurry has now been converted into pulp. This pulp is added to the container filled with water, and then air jets are forced into it to create bubbles. The required mineral is repelled by water and thus gets attached to the air bubbles. As these air bubbles rise up to the surface with mineral particles sticking to them, they are called froth. This froth is separated and further taken for the next process of refining and extraction.



4. *Leaching:*

An example of the leaching process would be the leaching of Al2O3.2H2O (or bauxite) with a heated and concentrated solution of sodium hydroxide. In this example, the concentrated NaOH dissolves the aluminium present in the bauxite whereas the impurities such as Fe2O3 , TiO2 , and SiO2, are not dissolved by the reagent. The chemical reaction for this example can be written as:

$$Al_2O_3.2H_2O + 2NaOH \rightarrow 2NaAlO_2 + 3H_2O$$

Another example of this process would be the leaching of noble metals such as gold and silver with the help of dilute aqueous solutions of sodium cyanide or potassium cyanide, with air present. The chemical reaction for the leaching of silver can be given by:

$$Ag_2S + 4NaCN \rightarrow 2Na[Ag(CN)_2] + Na_2S$$

OXIDATION OF MINERALS:

It involves two methods:

a) **Calcination:** Calcination refers to thermal treatment of a solid chemical compound whereby the compound is raised to high temperature without melting under restricted supply of ambient oxygen, generally for the purpose of removing impurities or volatile substances.

Ex: $Fe_2O_3.3H_2O \rightarrow Fe_2O_3 + 3H_2O$

$CuCO_3 \rightarrow CuO + CO_2$

b) Roasting: Roasting is a process where concentrated ore is converted into its oxide form by heating it below its melting point in the presence of excess air.

It is a method that is used for converting sulfide ores.

Ex: $PbS + O_2 \rightarrow PbO + 2SO_2$

$2CuFeS_2 + O_2 \rightarrow Cu_2S + 2FeS + SO_2$

REDUCTION OF MINERALS:

The metal oxide formed in the process of calcination or roasting is reduced to the metal form by the following method. This is called reduction of the metal oxide.

Smelting: This is the process by which a metal is obtained, either as the element or as a simple compound, from its roasted ore by heating beyond the melting point, ordinarily in the presence of oxidizing agents, such as air, or reducing agents, such as coke.

For the extraction of less electropositive metals such as Pb, Zn, Fe etc., powerful reducing agents such as C, H_2, CO Na, K, Mg, Al may be used.

$$PbO + C \rightarrow Pb + CO$$
$$WO + 3H_2 \rightarrow W + 3H_2O$$
$$CuO + CO \rightarrow Cu + CO_2$$
$$Cr_2O_3 + 2Al \rightarrow Al_2O_3 + 2Cr$$

During the smelting process, an additional substance is added to the ore which reacts with the impurities still present in the ore to form a fusible product. The additional substance is called *flux* and the fusible product formed is called *slag.*

Flux: it is defined as a substance which when mixed with furnace charge and heated, combine with gangue to form an easily fusible material which is not soluble in the molten metal.

Slag: Slag is a chemical substance which is formed after the combination of impurities in the ore and flux and is lighter in weight than molten metal. It may be basic or acidic. It is a neutral compound in nature.

Acidic flux such as silica, borax are used when the ore has basic impurities:

$$\underset{\text{Gangue (Basic)}}{CaO} + \underset{\text{Flux (Acidic)}}{SiO_2} \rightarrow \underset{\text{Slag}}{CaSiO_3}$$

Basic flux such as $CaCO_3$, $MgCO_3$ are used when the ore has acidic impurities:

$$\underset{\text{Gangue (Acidic)}}{SiO_2} + \underset{\text{Flux (Basic)}}{CaCO_3} \rightarrow \underset{\text{Slag}}{CaSiO_3} + CO_2$$

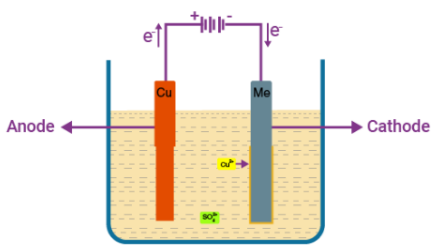
REFINING OF THE METAL:

Refining is a method of removing impurities in order to obtain metals of high purity. The impurities are removed from crude metal by various methods based on the properties of the metal and the properties of impurities. Some methods involved in the purification of crude metal are:

Distillation: Distillation is the process of separating the components of a liquid mixture through selective evaporation and condensation. The basis of separation is the difference in the vapor pressures (volatilities) of the respective components. Some volatile metals like Mercury, Zinc, Lead etc.

Electro-refining: Electrolytic refining is a process of refining a metal (mainly copper) by the process of electrolysis. As far as the mechanism of the process is concerned, during electrolysis, a large chunk or slab of impure metal is used as the anode, with a thin strip of pure metal as the cathode. In this setup, an electrolyte (metal salt aqueous solution), depending on the metal, is often used.

The clean or pure metal is formed at the cathode when the electrical current of a sufficient voltage is applied by dissolving impure metal at the anode. Electrolytic refining is also sometimes referred to as electrorefining.



ALLOYS

Alloy:

An alloy is a homogeneous solid mixture of two or more elements obtained by melting together, where at least one element is a metal.

Types of alloys are as follows:

1. Ferro alloys 2. Non-ferro alloys 3. Amalgams

1. Ferro alloys: Ferroalloy refers to various alloys of iron with a high proportion of one or more other elements such as manganese (Mn), aluminium (Al), or silicon (Si). They are used in the production of steels and alloys.
   Ex: Steel, Stainless steel, Duralumin, Alnico
2. Non-ferro alloys: Non-ferro alloys are non-iron based metals or alloys used for a wide range of applications.
   Ex: Brass, Bronze, Gun metal, German silver
3. Amalgams: When one of the constituent metal of an alloy is mercury then, the alloy is known as Amalgam. It may be a liquid, a soft paste or a solid, depending upon the proportion of mercury.
   Ex: Sodium Amalgam (good reducing agent; decreases the reactivity of Na)
   Copper Amalgam (used for filling dental cavities)
   Tin Amalgam (used for silvering cheap mirrors)

COMPOSITION & USES OF

Brass: Cu = 80% , Zn = 20%

Harder than pure Cu & Zn, used for making utensils, cartridges etc.

Bronze: Cu = 90% , Sn = 10%

For making statues, medals, coins, ships, machine etc

Alnico: Fe = 60%, Al = 12%, Ni = 20%, Co = 8%

High magnetic, permanent magnets

Duralumin: Al = 95%, Cu = 4%, Mg = 0.5%, Mn = 0.5%

Aircraft, kitchenware, automobile parts etc.