Metallurgy

Metals

- **Physical properties**
- Shining surface (in pure state) [called metallic lustre]
- Generally hard [varies from metal to metal]
- Malleable [i.e. can be made thin sheets by beating]
- Ductile [i.e. can be drawn into thin wires]
    - [Gold → Highly ductile]
- Good conductors of heat
- High melting point
- Conduct electricity
- Produce sound [some metals; these are called sonorous]

Non-metals

- Non-metals are found in all the three states i.e. solid, liquid and gas, at room temperature.
- Iodine (non-metal) has lustre
- Carbon has allotropes (exists in different forms)
    - Diamond is hard
    - Graphite (Conducts electricity)

Metals	Non-metals
1. Generally, these are hard and lustrous.	These are soft and have no lustre.
2. These are malleable and ductile (Malleable: can be beaten into sheets; Ductile: can be drawn into wires).	These are non-malleable and non-ductile.
3. These are sonorous (produce ringing sound when struck).	These are not sonorous.
4. These are good conductors of	These are poor conductors of heat

heat and electricity.	and electricity.

- **Reactivity Mg > Al > Zn > Fe > Cu**
- **Reaction with solutions of other metal salts**
- Displacement reactions
- Metal A + Salt solution of B → Salt solution of A + Metal B
- Reactivity series
- **Main Features of Reactivity Series**
    - Metals are arranged in the decreasing order of their electropositive character.
    - Metals at the top have greater reducing power. This power decreases on moving down the series.
    - Metals at the top show greater tendency to get oxidised.
    - Metals above hydrogen in the reactivity series liberate hydrogen gas from mineral acids.
    - Metals at the top displace metals lower in the series from the aqueous solution of their salts.
    - Metal oxides above Al, cannot be reduced by common reducing agents, the reverse is true for metal oxides below Al.
- **K > Na > Ca > Mg > Al > Zn > Fe > Pb > H > Cu > Hg > Ag > Au**

Corrosion:

The process of breaking down of metals because of their reactions with moisture and gases present in the air is known as corrosion. Rusting of iron is the most common example of corrosion.

Factors Affecting Corrosion

- Reactive nature of metal: Highly reactive metals corrode easily.
- Presence of dissolved salts: They act as electrolyte and increase the rate of corrosion.
- Presence of pollutants: They increase the rate of corrosion.
- Presence of less reactive metal: If a less reactive metal is present, it will make the more reactive metal susceptible to corrosion.

Methods to prevent corrosion:

- Rusting can be prevented by painting, oiling, and greasing of iron articles. In fact, paints and grease should be applied regularly to prevent rusting.
- Rusting can also be prevented by applying a layer of a metal such as chromium or zinc on the surface of iron articles. **The process of depositing zinc on iron is called galvanization.**
- Rusting can also be prevented by connecting the iron object with a more reactive metal like zinc with the help of a wire. **The process of connecting iron with a more reactive metal through a wire is called cathode protection.**
- Alloying can also be used to prevent rusting or corrosion.

Alloys
An alloy is a homogeneous mixture of two or more elements, at least one of which is a metal. Some common alloys are stainless steel (iron+nickel+chromium), brass (copper+zinc) and bronze (copper+tin).

Occurrence of metals:

Metal	Ores	Composition
Aluminium	Bauxite	$AlO_x(OH)_{3-2x}$ [where $0 < x < 1$]
	Kaolinite (a form of clay)	$[Al_2(OH)_4 Si_2O_5]$
Iron	Haematite	Fe_2O_3
	Magnetite	Fe_3O_4
	Siderite	$FeCO_3$
	Iron pyrites	FeS_2
Copper	Copper pyrites	$CuFeS_2$
	Malachite	$CuCO_3.Cu(OH)_2$
	Cuprite	Cu_2O
	Copper glance	Cu_2S
Zinc	Zinc blende or Sphalerite	ZnS
	Calamine	$ZnCO_3$
	Zincite	ZnO

- **Metallurgy**: Process of extracting pure metal from their ore

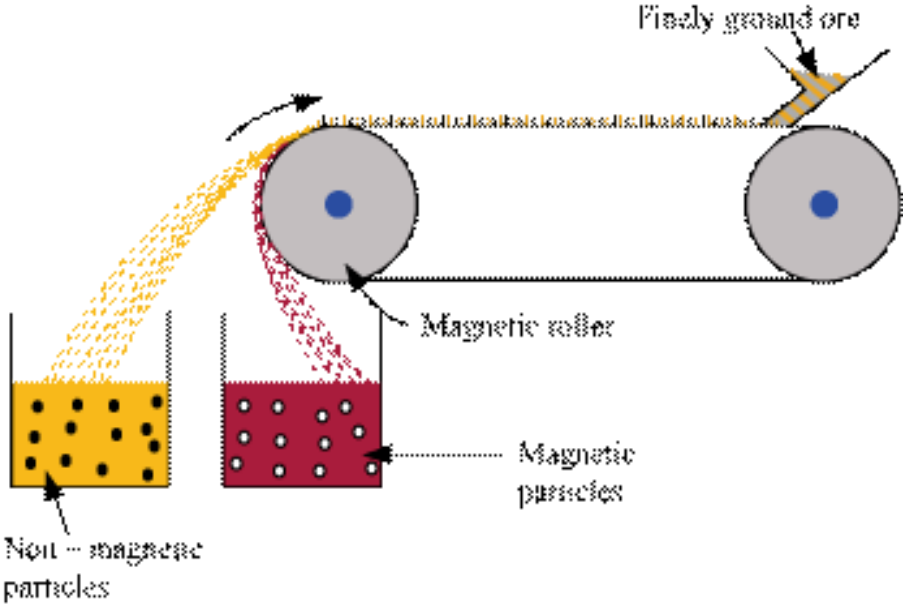
- **Minerals**: Mixture of metal compounds, soil, sand, limestone and rock
- **Gangue**: Impurities present in ore like mud, silica etc.
- **Ores**: Minerals from which metals can be extracted economically at low cost and with minimum cost
- **Flux**: Substance added in furnace to remove gangue
- **Slag**: The fusible mass formed when flux combined with gangue
- **Smelting**: Process of extracting metal from their oxide ores by reducing the roasted oxides

The major steps involved in the extraction and isolation of metals from ores are:

1. Crushing and grinding ore
2. Concentration of the ore
3. Roasting and Calcination of the ore
4. Reduction of the metal oxide
5. Refining of the pure metal

Concentration of ores:

- Hydraulic washing: It is the washing away of lighter gangue particles from the heavier ore. It is based on the gravity difference between the ore and the gangue particles.
- Magnetic separation: This separation is carried out if either the ore or the gangue is attracted by a magnetic field.



- Froth floatation method: This method is used for removing gangue from sulphide ores. ‘Depressants’ are used for separating two sulphide ores. E.g., for separating ZnS and PbS, NaCN is used as the depressant.

- Leaching: If the ore is soluble in some suitable solvent, then this process is used. For example, ores of aluminium (bauxite), silver and gold
    1. **Leaching of alumina**

$$Al_2O_{3(s)} + 2NaOH_{(aq)} + 3H_2O_{(l)} \text{ ® } 2Na[Al(OH)_4]_{(aq)}$$

$$2Na[Al(OH)_4]_{(aq)} + CO_{2(g)} \text{ ® } Al_2O_3.xH_2O_{(s)} + 2NaHCO_{3(aq)}$$

$$Al_2O_3.xH_2O_{(s)} \xrightarrow{\text{HEAT}} Al_2O_{3(s)} + xH_2O_{(}$$

Elements on earth are found in different parts of earth and are found in different forms. Different parts of earth include lithosphere, hydrosphere and atmosphere.

- Elements or compounds, which occur naturally in the Earth’s crust, are known as minerals.

- **Extraction of metals**

K Na Ca Mg Al	Zn Fe Pb Cu	Ag An
Highly reactive metals	Medium reactive metals	Foundin native form
–	–	
Electrolysis	Carbon reduction	

- **Low active metals**

$$\left.\begin{aligned} &2HgS+3O_2 \rightarrow 2HgO+2SO_2 \\ &2HgO(s) \rightarrow 2Hg(I)+O_2(g) \\ &2Cu_2S+3O_2 \rightarrow 2Cu_2O(s)+2SO_2(g) \\ &2Cu_2O+Cu_2S \rightarrow 6Cu(s)+SO_2(g) \end{aligned}\right\} \text{Heated in air}$$

- **Middle active metals**

- **Roasting** – Heating of sulphide ore in **excess air**

$$2ZnS+3O_2 \rightarrow 2ZnO+2SO_2$$

- **Calcination –** Heating of carbonate ores in **limited air**

$$ZnCO_3 \rightarrow ZnO+CO_2$$

- **Thermite reaction**

$$Fe_2O_3 + 2AI \rightarrow 2Fe+AI_2O_3 + Heat$$

- **Electrolytic Reduction**

Reaction at cathode (negative electrode): $Na^+ + e^- \rightarrow Na$

Reaction at anode (positive electrode): $2Cl^- \rightarrow Cl_2 + 2e^-$

$$\text{Net reaction: } 2NaCl(l) \xrightarrow{\text{Electrolytic reduction}} 2Na(s) + Cl_2(g)$$

Sodium chloride (Molten) — Sodium — chlorine

- **Electrolytic refining of metals**
  - Impure metal is made the anode and thin strip of pure metal is made cathode.
  - A solution of metal salt is used as an electrolyte

Refining (Purification):

- **Distillation** –
  The impure forms of low-boiling metals like zinc and mercury are evaporated to obtain pure metals as distillate.

- **Liquation** –
  Low-melting metals (like tin) are separated from higher-melting liquids by allowing them to flow on a sloping surface.

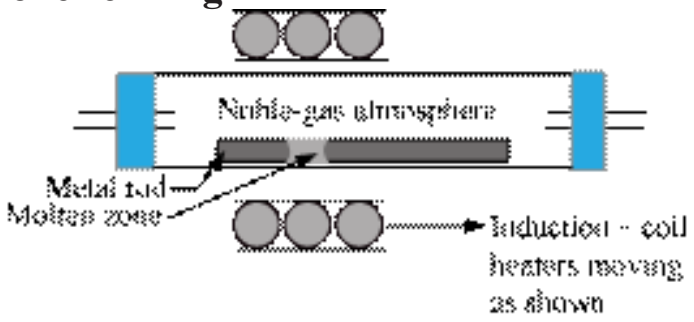
- **Electrolytic refining** –

  Anode: $M \rightarrow M^{n+} + ne^-$

  Cathode: $M^{n+} + ne^- \rightarrow M$

a. Impure metal is taken as anode and a strip of pure metal is taken as cathode.
b. Copper and zinc are refined by this process.
c. Anode mud obtained during electrolytic refining of copper contains antimony, selenium, tellurium, silver, gold and platinum.

- **Zone refining –**



a. Principle – The impurities are more soluble in the molten state than in the solid state of a metal.
b. Germanium, silicon, boron, gallium, indium are refined by this process.

- **Vapour-phase refining –**

a. **Requirements –**
b. The metal should form a volatile compound with an available reagent.
c. The volatile compound should be easily decomposed so that it can be recovered easily.

a. Mond process for refining nickel:

$$Ni + 4CO \xrightarrow{330\text{–}350\ K} Ni(CO)_4$$

$$Ni(CO)_4 \xrightarrow{450\text{–}470\ K} Ni + 4CO$$

a. van Arkel method for refining ziroconium (Zr) or titanium (Ti):

Used for removing oxygen and nitrogen present as impurities

$$Zr + 2I_2 \rightarrow ZrI_4$$

$$ZrI_4 \rightarrow Zr + 2I_2$$

- Chromatographic methods:

a. Principle – Different components of a mixture are differently adsorbed on an adsorbent.
b. Chromatography involves a mobile phase and a stationary phase.
c. There are several chromatographic techniques –
d. Paper chromatography
e. Column chromatography
f. Gas chromatography

Extraction of Aluminium from Alumina

- Aluminium is generally extracted from the bauxite ore. The bauxite ore can be concentrated by the process of leaching by digesting it with concentrated sodium hydroxide solution at 473-523 K and 35-36 bar pressure.
- In Electrolytic Reduction of Alumina, Na_3AlF_6 or CaF_2 is added to pure alumina to lower the melting point and to increase the conductivity of the electrolyte.
- This electrolytic process is known as the Hall-Heroult process. The oxygen liberated at the anode reacts with the carbon of the anode to produce CO and CO_2. Therefore, the carbon anode has to be replaced periodically as the oxygen released oxidises it.
- The obtained aluminium metal is purified by Hoope's process.

Properties of Aluminium

- It is a silvery white light metal.
- It is malleable, ductile and a good conductor of electricity.
- It reacts with oxygen and nitrogen present in the air to form a protective layer over its surface.
- It reacts with acids as well as bases.
- It is affected by steam and a layer of oxide is formed on exposure to steam.
- It reacts with non-metals.
- It has reducing property and is used in aluminothermy.

Uses of Aluminium

- As wrappers for foods in the form of foils
- In paints and lacquers
- In the extraction of chromium and manganese from their oxides
- In conduction of electricity in the form of wire

Alloys of Aluminium

- **Duralumin** (95 % Al, 4 % Cu, 0.5 % Mg, 0.5 % Mn) which is used in the manufacture of aeroplanes as it is very light, strong, ductile, and resistant to corrosion

- **Magnelium** (90 % Al, 10 % Mg) which is used in the manufacture of light tools and machine parts as it is very light, strong, and resistant to corrosion

- **Uses of metals:**
    - In making machinery, automobiles, jewellery, trains, aeroplanes, cooking utensils, etc.
    - Gold is used for making jewellery, wires, and coins and in dentistry.
    - Silver is used for making coins, ornaments, very thin wires, table cutlery and in photographic films.
    - Copper is used for making wires, utensils, statues, alloys and coins.
    - Iron is used for construction of ships, buildings, automobiles and railway bridges etc.
    - Tin is used for tinning food cans, and making alloys.
    - Lead is used for making batteries, and alloys.
    - Zinc is used in prevention of rusting, making brass and bronze and in dry cells.
    - Aluminium is used in making wires, foils, and alloys.
    - Mercury is used for making amalgams and in thermometers.
    - Magnesium is used for making fire works, and alloys.
- **Uses of non-metals:**

- They are used in fertilizers, in water purification process, crackers, etc. Oxygen, a non-metal, is essential for our life as all living beings inhale it during breathing.
- Nitrogen dilutes the activity of oxygen in air. It is used by plants to manufacture proteins.
- Oxygen is essential for respiration and combustion of fuels.
- Chlorine is used for bleaching fabrics, sterilization of drinking water, and in manufacturing insecticides and pesticides.
- Iodine is essential for proper functioning of human body, and in photographic films.
- Graphite is used as pencil lead, dry lubricant, in electrolytic cells and nuclear reactors.
- Helium is a noble gas which is used in weather observation balloons.
- Argon is a noble gas which is used for filling electric bulbs.

Alloys

- Alloys are homogeneous mixtures of two or more metals (or metal and non-metal). Alloying is done to enhance the properties of metals.
- Alloys are made to alter the properties of metals for achieving a specific objective.
- Alloys of aluminium are also useful as they are both light and strong. Some of its alloys are duralumin, magnelium, etc.
- Some alloys of iron are steel, stainless steel, etc. Steel is an alloy of iron and carbon.
- Some alloys of zinc are brass, bronze, and German silver.
- On the basis of composition, alloys are of two types: Substitutional alloys in which atoms of one element randomly replace the atoms of another metal. And interstitial alloys in which small atoms like hydrogen, boron, carbon and nitrogen occupy the holes in the crystal structure of the metal.
- On the basis of constituent elements, alloys are of two types: Ferrous alloys which contain iron as base metal. For example: steel, alnico etc. And non ferrous alloys which do not contain iron as base metal. For example: brass, bronze, duralumin etc.