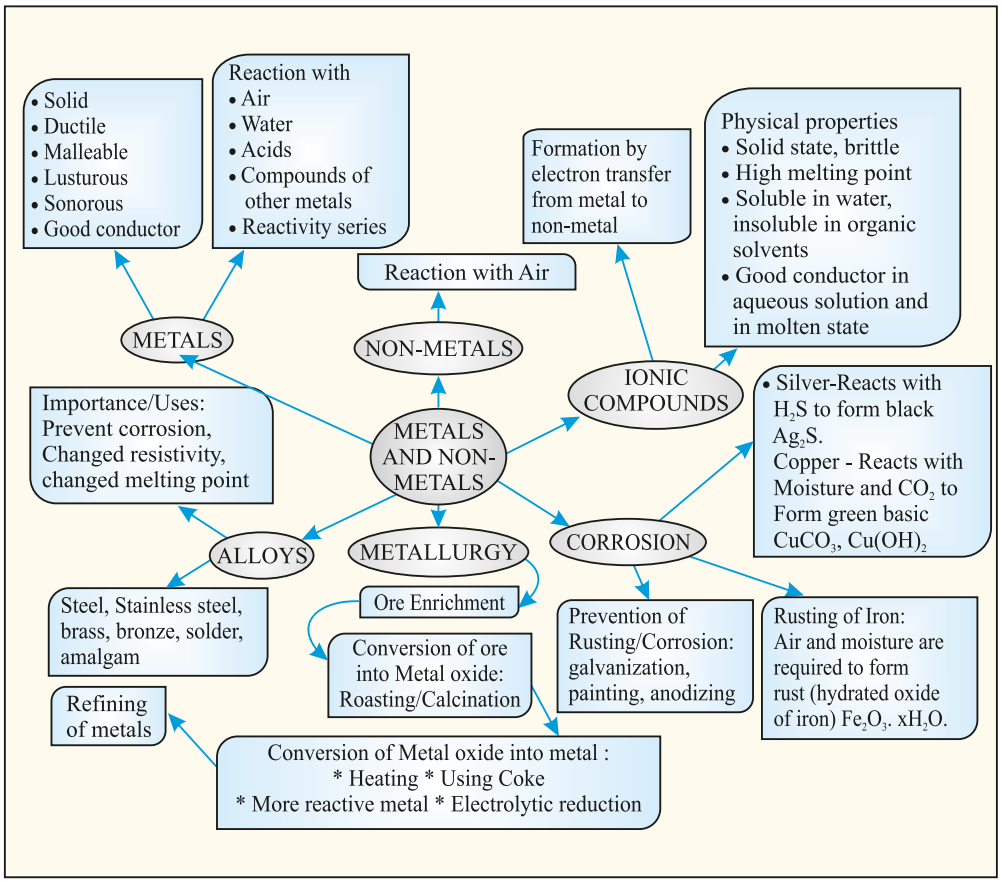
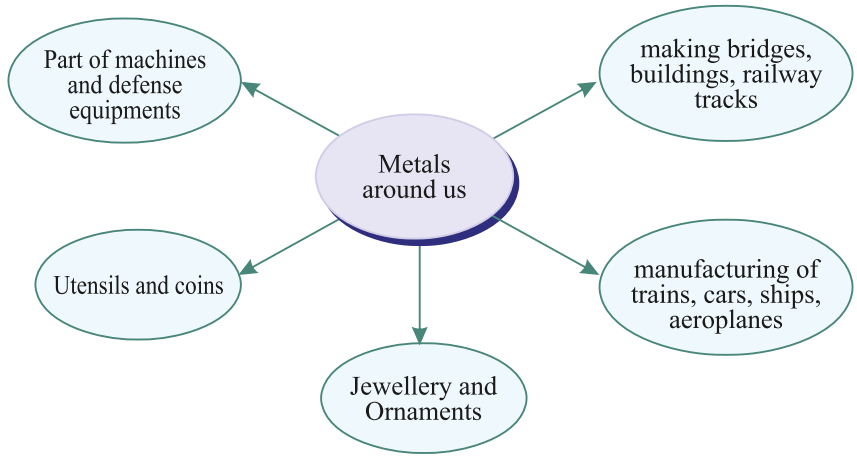
Chapter - 3

Metals And Non-Metals

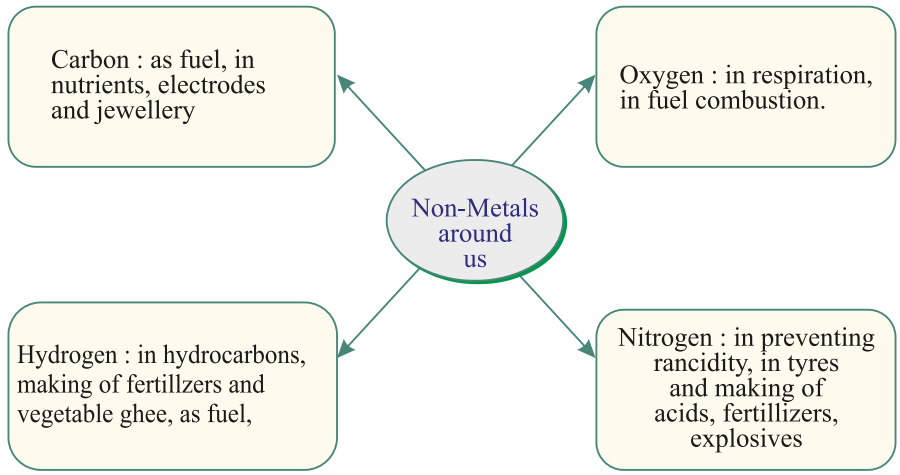


Metals and Non Metals

- About 118 elements are known till date. There are more than 90 metals, 22 non metals and few metalloids.
- Sodium (Na), Potassium (K), Calcium (Ca), Magnesium (Mg), Iron (Fe), Aluminium (AI) are some metals.



- Oxygen(O), Nitrogen(N), Hydrogen(H), Sulphur(S), Phosphorus(P), Fluorine(F), Bromine(Br) are a few non metals.



- Differences between metals and non-metals

Metals	Non-Metals
• Solid at room temperature except mercury	• Exist in all the three states, chlorine-gas, Bromine-Liquid, iodine-solid
• Ductile and malleable	• Non-ductile and non-malleable
• Sonorous and lustruous	• Non-sonorous and non-lustruous (iodine and graphite are shiny)
• Generally have high melting point, cesium and gallium have low melting point.	• Have low melting point, except diamond.
• Generally good conductors of heat and electricity, except lead and mercury.	• Poor conductors, except graphite.
• Have high density, but sodium and potassium have low density.	• Have low density.
• Metal oxides can be basic or amphoteric in nature.	• Oxides of non-metals are generally acidic in nature, while a few are neutral oxides.
• Many metals displace hydrogen from dilute acids and release hydrogen gas.	• Non metals cannot displace hydrogen from dilute acids.
• Metal oxides are ionic in nature.	• Non metal oxides are covalent in nature.

Chemical Properties of Metals

1. Reaction with air

Metals can either burn, react or don't react with air

Metal + Oxygen ⟶ Metal oxide

Some metals like Na and K are kept immersed in kerosene as they react vigorously with air. Metals like Mg, Aℓ,Zn and Pb react slowly with air and form a protective layer. Mg can burn in air but combine with oxygen to form oxide. Fe and Cu do not burn in air but combine with oxygen to form their oxides. Iron filings burn when sprinkled in the flame of burner. Silver, platinum and gold show no reaction with air.

$$2Na + O_2 \longrightarrow Na_2O$$

$$3Fe + 2O_2 \longrightarrow Fe_3O_4$$

- **Amphoteric oxides:** These are metal oxides which react with both acids as well bases to produce salt and water. e.g. ZnO, Al_2O_3

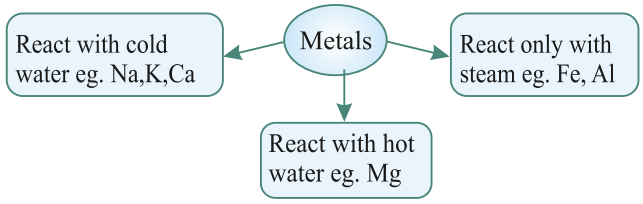
$$Al_2O_3 + 6HCl \longrightarrow 2AlCl_3 + 3H_2O$$

$$Al_2O_3 + 2NaOH \longrightarrow 2NaAlO_2 + H_2O$$

(Sodium aluminate)

- **Anodizing of metals:** In anodizing, aluminium is made anode and graphite as cathode, oxygen gas is released by the electrolysis of sulphuric acid, which reacts with aluminium to form a thick protective oxide layer on the surface of metal.

2. **Reaction with water:** Metals react with water differently. Not all metals react with water



$$2K + 2H_2O \longrightarrow 2KOH + H_2\uparrow$$

$$Ca + 2H_2O \longrightarrow Ca(OH)_2 + H_2\uparrow$$

$$Mg + 2H_2O \longrightarrow Mg(OH)_2 + H_2\uparrow$$

- In case, of Ca and Mg, the metal starts floating due to bubbles of hydrogen gas sticking to its surface.

$$2Al + 3H_2O(g) \longrightarrow Al_2O_3 + 3H_2\uparrow$$

$$3Fe + 4H_2O(g) \longrightarrow Fe_3O_4 + 4H_2\uparrow$$

3. **Reaction with dilute acids:**

(i) Most metals react with dilute HCl and dilute H_2SO_4 to form salt and hydrogen gas.

$$\text{Metal} + \text{dilute acid} \longrightarrow \text{salt} + \text{hydrogen gas}$$

$$Mg + 2HCl \longrightarrow MgCl_2 + H_2\uparrow$$

$$Al + 6HCl \longrightarrow 2AlCl_3 + 3H_2\uparrow$$

$$Zn + H_2SO_4 \longrightarrow ZnSO_4 + H_2\uparrow$$

- Copper, mercury and silver don't react with dilute acids.

(ii) With dilute nitric acid: As metals react with dilute nitric acid, hydrogen gas produced is oxidised to water. Mg and Mn are exceptions.

$$Mg + 2HNO_3 \longrightarrow Mg(NO_3)_2 + H_2 \uparrow$$

Aqua Regia: It is a mixture of concentrated HCl and concentrated HNO_3 in a 3:1 ratio. It dissolves gold and platinum.

4. **Reaction with other metal compounds:**

$$\text{Metal A} + \underset{\text{of metal B}}{\text{Salt solution}} \longrightarrow \underset{\text{Metal A}}{\text{Salt solution of}} + \text{Metal B}$$

More reactive metals can displace less reactive metals from their compounds in solution. This forms the basis of reactivity series of metals.

- **Reactivity series of metals:** It is an arrangement of metals in decreasing order of their reactivity.

$$K > Na > Ca > Mg > Al > Zn > Fe > Pb > H > Cu > Hg > Ag > Au$$

Decreasing reactivity

$$Cu + 2AgNO_3 \longrightarrow Cu(NO_3)_2 + 2Ag$$

Copper being more reactive displace silver.

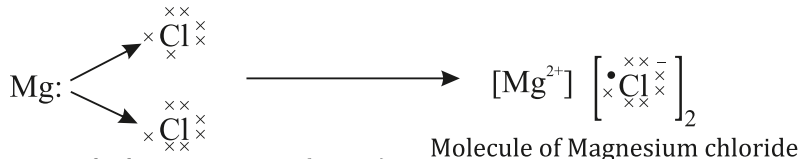
5. **Reaction between metals and non-metals:**

- Reactivity of elements can be understood as a tendency to attain a completely filled valence shell arrangement.
- Atom of metals lose valence electron(s) to form cations (+ve ions)
- Atoms of non-metals can gain electron(s) in valence shell to form anions (–ve ions)
- Oppositely charged ions attract each other forming an ionic compound.

Formation of $MgCl_2$

$$\underset{(2,8,2)}{Mg} \longrightarrow \underset{(2,8)}{Mg^{2+}} + 2e^-$$

$$\underset{(2,8,7)}{2Cl} + 2e^- \longrightarrow \underset{(2,8,8)}{2Cl^-}$$



(Electron transfer from Mg atom to Cl atoms)

Molecule of Magnesium chloride

- Properties of Ionic compounds: Are solid and mostly brittle.
- Have high melting and boiling points. More energy is required to overcome the strong inter-ionic force of attraction.
- Generally soluble in water, but insoluble in inorganic solvents like kerosene, petrol,etc.
- Conduct electricity in aqueous solutions and in molten state. In both cases, free ions are formed and conduct electricity.

Occurance of Metals

- **Minerals:** Compounds of metals present in earth's crust can be termed as minerals.
- **Ores:** Mineral from which metal can be economically obtained is called an ore e.g. sulphide ores, carbonate ores, oxide ores. Not all the minerals are ores.
- Metals at the bottom of reactivity series like gold, platinum, silver, copper occur in free state. But copper and silver also occur in sulphide and oxide ores.
- Metals of moderate reactivity (Zn, Fe,Pb) occur mainly as oxide, sulphide or carbonate ores. Metals of high reactivity (K,Na,Ca,Mg,Aℓ) are found in combined states.

  Gangue: Ores are found mixed with earthly impurities like soil, sand,etc. known as gangue. The gangue is removed from the ore.

  Metallurgy: It is the step-wise process of obtaining metal from its ore. These steps are

  1. Enrichment of ore.
  2. Obtaining metal from enriched ore.
  3. Refining of impure metal to obtain pure metal.

  Obtaining Metals low in the reactivity series: These metals can be obtained by heating the ore in air at high temperature.

* Mercury from cinnabar:

Sulphide $\xrightarrow{\Delta}$ oxide $\xrightarrow{\Delta}$ metal $\xrightarrow{\Delta}$ refining

HgS $\xrightarrow{\Delta}$ HgO $\xrightarrow{\Delta}$ Hg $\xrightarrow{\Delta}$ Hg(pure)

* Copper from copper sulphide

$$2Cu_2S + 3O_2 \xrightarrow{heat} 2Cu_2O + 2SO_2 \uparrow$$

$$2Cu_2O + Cu_2S \xrightarrow{heat} 6Cu + SO_2 \uparrow$$

EXTRACTING METALS IN THE MIDDLE OF ACTIVITY SERIES:

Metals are easier to obtain from oxide ores, thus, sulphide and carbonate ores are converted into oxides.

Metal ore heated strongly in excess of air (Roasting)

$$2ZnS + 3O_2 \xrightarrow{heat} 2ZnO + 2SO_2\uparrow$$

Metal ore heated strongly in limited supply of air (Calcination)

$$ZnCO_3 \xrightarrow{heat} ZnO + CO_2\uparrow$$

Reduction of metal oxide:

1. **Using coke:** Coke as reducing agent.

$$ZnO + C \xrightarrow{heat} Zn + CO\uparrow$$

2. **Using Displacement Reaction:** highly reactive metal like Na, Ca and Al are used to displace metals of lower reactivity from their compounds.

$$MnO_2 + 4Al \xrightarrow{heat} 3Mn + 2Al_2O_3 + heat$$

$$Fe_2O_3 + 2Al \xrightarrow{heat} 2Fe + Al_2O_3 + heat$$

In the above reaction mclten iron is formed and is used to join railway tracks. This is called thermit reaction.

EXTRACTING METALS AT THE TOP OF ACTIVITY SERIES:

These metals

* Have more affinity for oxygen than carbon

* Are obtained by electrolytic reduction. Sodium is obtained by electrolysis of its molten chloride

$$NaCl \longrightarrow Na^{+} + Cl^{-}$$

As electricity is passed through the solution metal gets deposited at cathode and non-metal at anode.

At cathode:

$$Na^{+} + e^{-} \longrightarrow Na$$

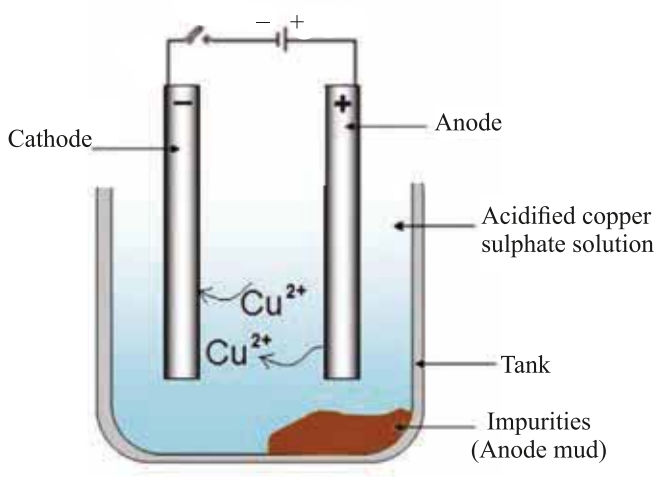
At anode:

$$2Cl^{-} \longrightarrow Cl_2 + 2e^{-}$$

REFINING OF METALS:

Impurities present in the obtained metal can be removed by electrolytic refining. Copper is obtained using this method. Following are present inside the electrolytic tank.

- Anode- slab of impure copper
- Cathode- slab of pure copper
- Solution-aqueous solution of copper sulphate with some amount of dilute sulphuric acid.
- From anode copper ions are released in the solution and equivalent amount of copper from solution is deposited at cathode.
- Insoluble impurities containing silver and gold gets deposited at the bottom of anode as anode mud.



CORROSION:

- Metals are attacked by substances in surroundings like moisture, acids, and moist air.

  Silver- it reacts with H_2S in air to form silver sulphide and articles become black.

- Copper- reacts with moist carbon dioxide in air and gains a green coat of basic copper carbonate.
- Iron- acquires a coating of a brown flaky substance called rust. Both air and moisture are necessary for rusting of iron.

Prevention of Corrosion:

- Rusting of iron is prevented by painting, oiling, greasing, galvanizing, chrome plating, anodising and making alloys.
- In galvanization iron or steel is coated with a layer of zinc because zinc is preferably oxidized than iron.
- **Alloys:** these are mixture of metals with metals or non-metals. Adding small amount of carbon makes iron hard and strong.
- Stainless steel is obtained by mixing iron with nickel and chromium. It is hard and doesn't rust. Mercury is added to other metals to make amalgam. Brass: alloy of copper and zinc (Cu+Zn). Bronze: alloy of copper and tin (Cu+Sn).
- In brass and bronze, melting point and electrical conductivity is lower than that of pure metal.
- Solder: alloy of lead and tin (Pb+Sn) has low melting point and is used for welding electrical wires.