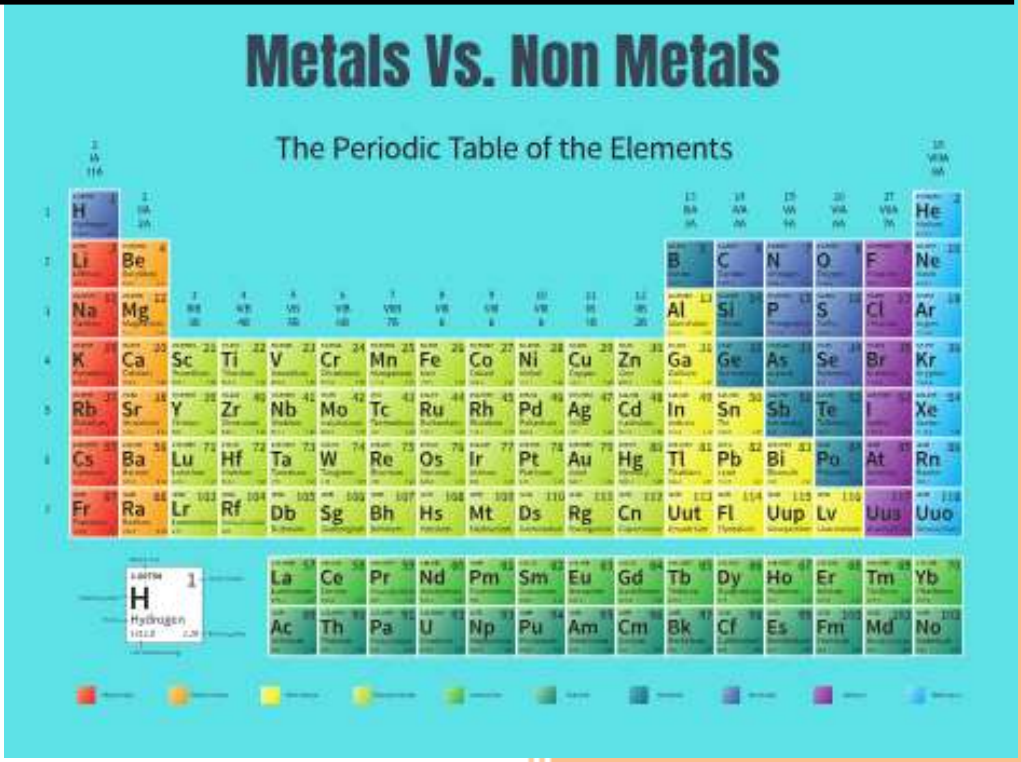
EKADEMY Class-10

Chapter 3

Metals and Non-metals



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Chapter 3: Metals and Non-Metals

Introduction

- Elements are classified as metals and non-metals based on different properties.
- Metals are electron doners and non-metals are electron acceptors.
- Mercury is the only metal which is liquid at room temperature.
- Graphite is the only non-metal that conducts electricity at normal temperature and pressure.

Physical properties

- Metals and Non-metals can easily be grouped by comparing their physical properties.
- The physical properties of metals and non-metals are given in the form of the table below-

Property	Metals	Non-metals
Metallic Lustre	Metals are lustrous, that is, they have a property to shine.	They are not lustrous, that is, they do not have a shining surface (except graphite and iodine).
Physical State	All metals generally exist as solid (except mercury which is liquid) at room temperature.	They are generally found in solid or gaseous state at room temp. Bromine is the only non-metal found in liquid state at room temp.
Ductility	They can be drawn into wires; this is known as **Ductility**.	They are non-ductile.
Malleability	Metals can be hammered and converted into sheets; this property of metal is known as **Malleability** (except mercury).	They are non-malleable.
Conductivity	They are good conductors of electricity and heat (except Lead and mercury).	They are poor conductors of electricity and heat. (Exception- graphite is a good conductor of electricity)

Density	They generally have high density.	They generally have low density.
Melting Points and Boiling Points	Metals (except mercury and Gallium) generally have high belting and boiling points	They generally have low melting and boiling point (except graphite, diamond and boron).
Hardness	They are generally hard (Except lithium, sodium and potassium).	They are generally soft, except diamond and boron.
Sonorosity	They are sonorous, ie, they produce a special metallic sound when hit with a hard object.	They are non-sonorous.

Chemical Properties of Metals

- Physical properties alone cannot distinguish between metals and non-metals as there are several exceptions.
- Hence, elements can be more clearly classified as metals and non-metals using chemical properties.
- A comparison of chemical properties of metals and non-metals are given in the table below:

Property	Metals	Non-metals
Nature of ions	Metals are electropositive elements and hence lose one or more electrons to form positive ions (cations).	Non-metals are electronegative elements and hence, gain one or more electron to form negative ions (anions).
Nature of Oxides	Metals mostly form basic oxides. Some metals such as Zn and Al form amphoteric oxides.	Non-metals form either acidic or neutral oxides.
Reaction with water	Most of the metals displace hydrogen from water or steam.	Non-metals (except fluorine) generally do not react with water.
Reaction with dilute acids	Metals which lie above hydrogen in the reactivity series displace hydrogen from dilute acids.	Non-metals do not react with dilute acids and hence do not displace hydrogen from dilute acid.
Oxidizing and reducing behaviour	Metals have strong tendency to lose electrons and hence they behave as reducing agents.	Non-metals have a strong tendency to accept electrons and hence they behave as oxidizing agents.

Reaction with Oxygen

What happens when metals are burnt in the air?

- Different metals react with oxygen at different rates.
  - Metals like K and Na react vigorously and catch fire if kept open in air, hence they are kept immersed inside kerosene oil.
  - Surface of metals like Mg, Al, Zn, Pb, etc. are covered with thin layer of metal oxide. This oxide layer provides protection against further oxidation of these metals.
  - Iron does not burn on heating as its ignition temp is very high, however iron fillings burn vigorously when sprinkled over flame.
  - Copper does not burn, but hot copper is coated with a black coloured layer of CuO.
  - Ag and Au do not react with oxygen even at high temperature.
- Almost all metals react with air or oxygen to form metal oxides.

$$\boldsymbol{Metal + O_2 \rightarrow Metal\ oxide}$$

  - **For example**, Copper reacts with oxygen to form copper oxide.

$$\boldsymbol{2Cu + O_2 \rightarrow 2CuO}$$

$$\boldsymbol{4Al + 3O_2 \rightarrow 2Al_2O_3}$$

- Some oxides of metals can react with both acids and bases to produce salt and water. Such oxides are known as **Amphoteric Oxides**.

$$\boldsymbol{Al_2O_3 + 6HCl \rightarrow 2AlCl_3 + H2O}$$

$$\boldsymbol{Al_2O_3 + 2NaOH \longrightarrow 2NaAlO_2 + H_2O}$$

- Most metallic oxides are insoluble in water, but some metallic oxides dissolve in water to form alkalis.
  - For example, sodium oxide dissolves in water to form sodium hydroxide (alkali).

$$Na_2O + H_2O \longrightarrow 2NaOH$$

  - Potassium oxide dissolves in water to form potassium hydroxide.

$$K_2O + H_2O \longrightarrow 2KOH$$

Reaction of metals with water

- Metals react with water to produce metal oxide and hydrogen gas.

$$\boldsymbol{Metal + H_2O \longrightarrow Metal\ oxide + H_2}$$

- Some metal oxides which are soluble in water (like oxides of sodium or potassium) dissolve further in water to form metal hydroxides.
- Na and K reacts violently with cold water. Reaction is so exothermic that evolved hydrogen gas catches fire immediately.

$$K + H_2O \longrightarrow KOH + H_2 + heat$$
$$Na + H_2O \longrightarrow NaOH + H_2O + heat$$

- Reaction of Ca with cold water is less violent. The heat evolved is not sufficient for the hydrogen to catch fire.
- Mg do not react with cold water. It reacts with hot water to form magnesium hydroxide and hydrogen gas.
    - Calcium and magnesium start floating in water because bubbles of hydrogen gas formed sticks to the surface of the metal.
- Al, Fe and Zn do not react with cold or hot water. They react with steam to form metal oxides and hydrogen gas.

$$2Al + 3H_2O \longrightarrow Al_2O_3 + 3H_2$$
$$3Fe + 4H_2O \longrightarrow Fe_3O_4 + 4H_2$$

- Pb, Cu, Ag and Au do not react with water at all.

Reaction of Metals with Acids

- Metals also react with dilute acids to form salt and hydrogen.
- **For example**, magnesium reacts with dilute hydrochloric acid to form magnesium chloride and hydrogen.

Metal + Acid → Metal Salt + Hydrogen

$$Mg + 2HCl \rightarrow MgCl_2 + H_2$$

Chemical Properties of Nonmetals

- Non-metals react with oxygen to form non-metal oxide.

Non-metal + Oxygen → Non-metal oxide

$$C + O_2 \rightarrow CO_2$$

- Non-metals do not react with water and acids to evolve hydrogen gas.
- Non-metals can react with salt solution; the more reactive element will displace the less reactive non-metal.

$$2NaBr\,(aq) + Cl_2(aq) \rightarrow 2NaCl\,(aq) + Br_2\,(aq)$$

- Non-metals can also react with hydrogen to form hydrides.

$$H_2(g) + S(l) \rightarrow H_2S(g)$$

Reactivity Series

- The series in which metals are arranged in the decreasing order of reactivity is known as the Reactivity **Series**.

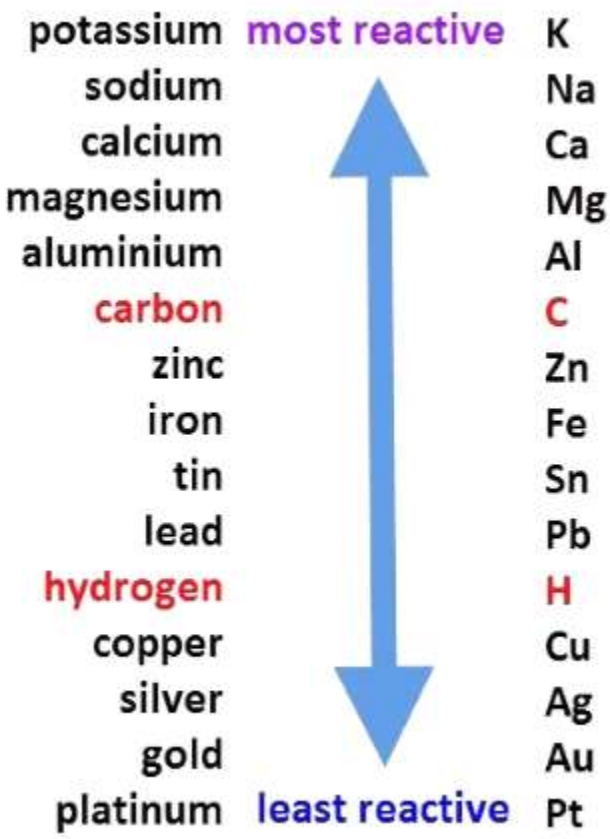
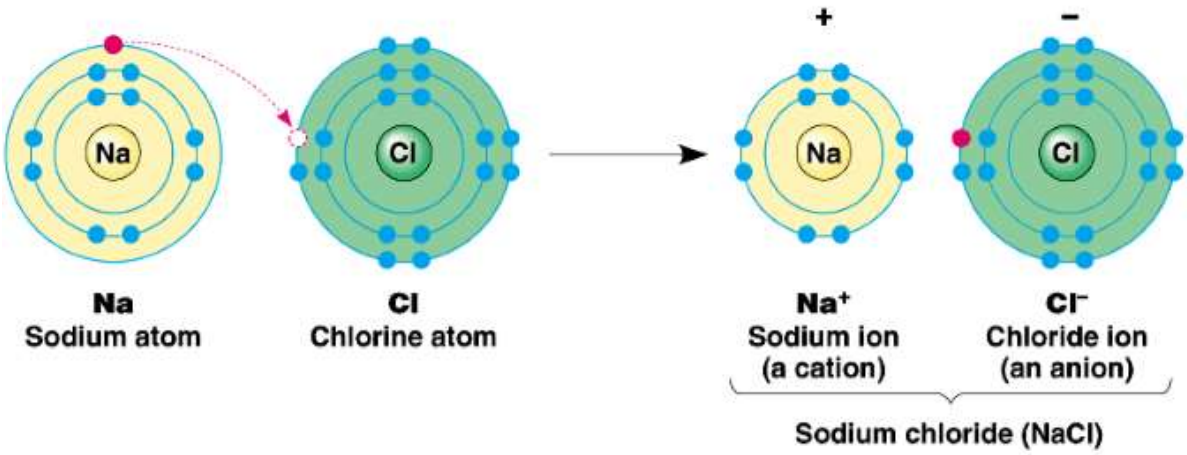


Fig.1. Reactivity Series

Ionic Compounds

- Compounds formed due to the transfer of electrons from a metal to a non-metal are known as **Ionic Compounds**.



Covalent Bond

- A bond is formed by the sharing of electrons between the two atoms. They share their valence electrons to gain stability.
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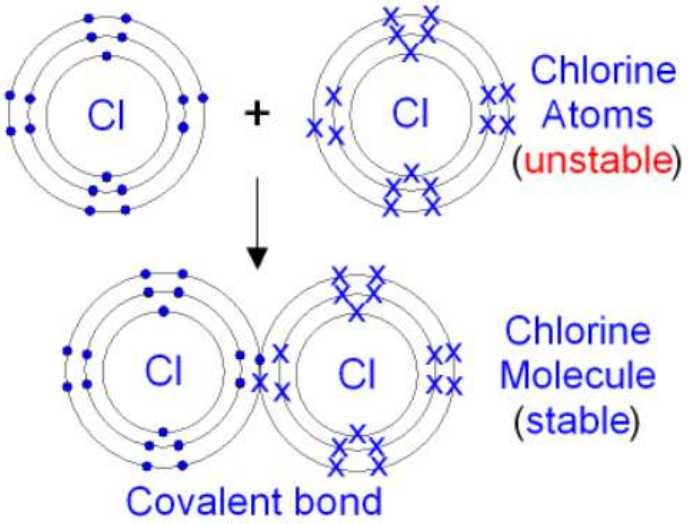
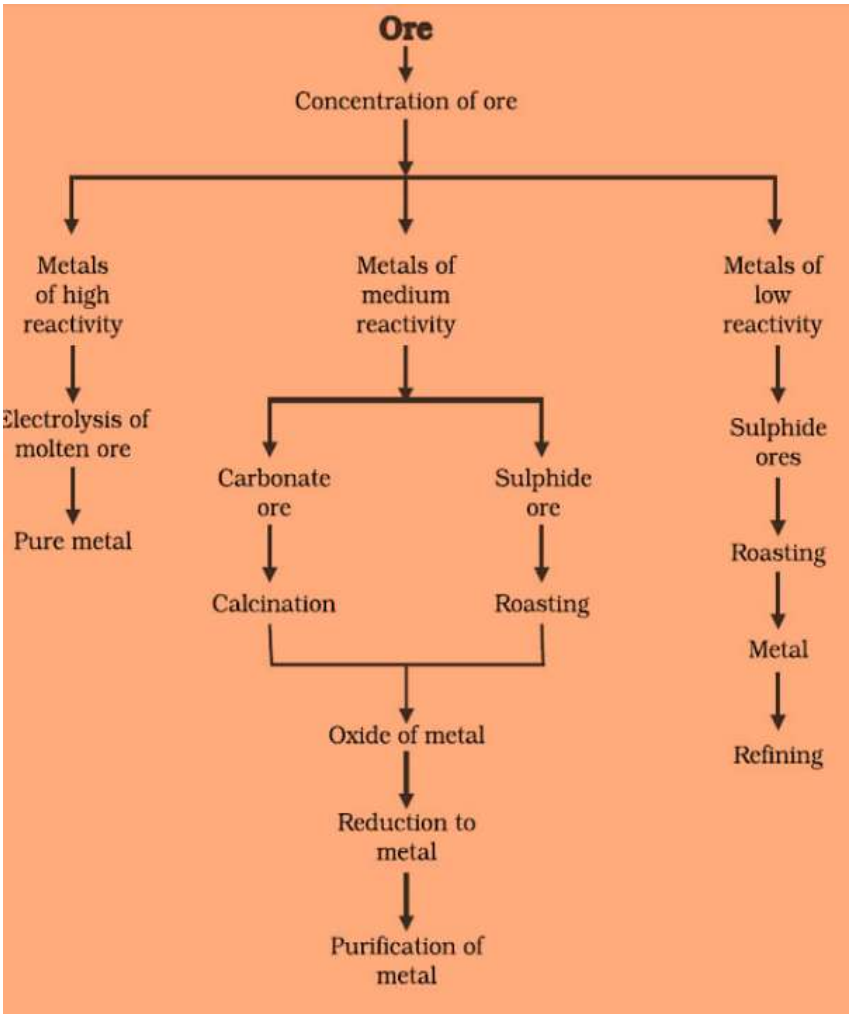


Properties of Ionic Compounds

- They are generally hard and solid.
- They have a high melting and boiling point.
- They are soluble in water but insoluble in inorganic solvents such as ether etc.
- They are conductors of electricity in molten and solution states.

Occurrence of Metals

- Elements or compounds which occur naturally in earth crust are known as **Minerals**.
- Minerals from which pure metals can be extracted are known as **Mineral Ores**.



Extraction of pure metals from its ores/steps for extraction of metals from its ore

- The first step is the enrichment of the ore
- The second step includes extraction of metals
- Third steps involve refining of metal
- **Gangue** - Ores contain different impurities in it such as sand, soil etc. These impurities are known as **Gangue**.

Extracting Metals which are low in activity series

- Metals which are low in the activity series are unreactive.
- The oxides of such metals can be reduced to metals by heating alone.
- **For Example**, Cinnabar (HgS)
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$$2HgS(s) + 3O_2(g) \xrightarrow{Heat} 2HgO(s) + 2SO_2(g)$$

$$2HgO(s) \xrightarrow{Heat} 2Hg(l) + O_2(g)$$

Extracting Metals in the middle of the Activity Series

- These metals are moderately reactive.
- They exist as sulphides or carbonates in nature.
- Before reduction, metal sulphides and carbonates must be converted into metal oxides. Sulphide ores are converted into oxides by heating strongly in the presence of excess air, this is known as **Roasting**. Carbonate ores are converted into oxides by heating in limited air. This is known as **Calcination**.

Roasting

$$2ZnS(s) + 3O_2(g) \xrightarrow{Heat} 2ZnO(s) + 2SO_2(g)$$

Calcination

$$ZnCO_3(s) \xrightarrow{Heat} ZnO(s) + CO_2(g)$$

Reduction: metal oxides can be reduced to metals using a reducing agent such as **Carbon**.

Extracting metals towards the top of the activity series

- The metals are highly reactive.
- They cannot be obtained by heating.
- **For Example**, Sodium, magnesium and calcium are obtained by the electrolysis of their molten chlorides.

$$\textbf{At cathode: } Na^+ + e^- \rightarrow Na$$

$$\textbf{At anode: } 2Cl^- \rightarrow Cl_2 + 2e^-$$

Refining of Metals

- Refining of impure metal is done using electrolytic refining.
- Impure copper is used as anode and a strip of pure copper is used as **Cathode**.
- Acidified copper sulphate is used as an electrolyte.
- When an electric current is passed through this, impure metal from the anode gets dissolved in the electrolyte solution, whereas pure metal from the electrolyte is deposited at the cathode.
- Insoluble residue formed from the dissolution of the anode during electrolysis, gets deposited under anode as heap and is called **anode mud**.

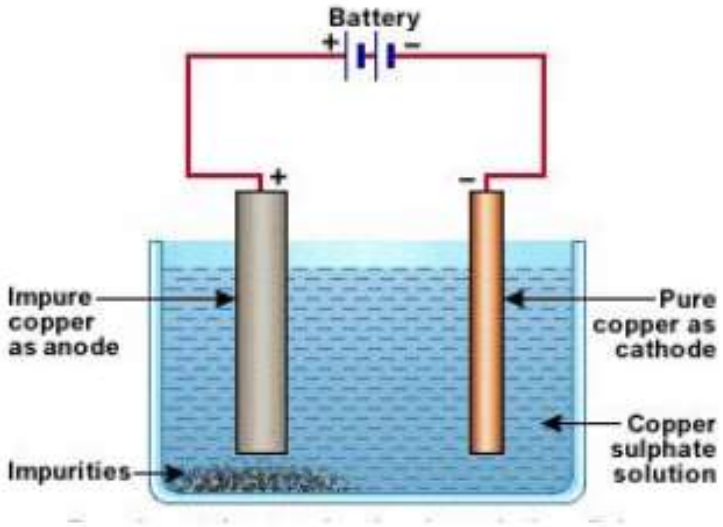

Fig.2. Electrolytic refining

Corrosion

- When exposed to moist air for a long period of time, metals become corroded. This is known as **Corrosion**.
- **For Example**, Silver reacts with moist air and becomes black in colour due to silver sulphide coating.
- Similarly, iron reacts with oxygen and moisture to form rust (iron oxide)

Iron + oxygen → Iron (III) oxide

$$Fe + O_2 \rightarrow Fe_2O_3.xH_2O$$

Prevention of Corrosion

- Rusting of iron can be prevented by oiling, galvanising, painting, greasing etc.
- To protect steel and iron from rusting, a thin layer of zinc is coated on them, this is known as **Galvanization**.

Alloy

- The mixture of two or more metals or metal and non-metal is known as **Alloy**.
- **For Example**,
  - Brass is an alloy of copper and zinc.
  - Bronze is an alloy made of copper and tin.
  - Solder is an alloy of lead and tin.