METALS AND NONMETALS

CONTENTS

METALS AND NONMETALS

Lavoiser classified all elements into metals, nonmetals and metalloids on the basis of their properties. Some commonly used metals, nonmetals and metalloids are given below.

- **Metals :** Iron, Copper, Gold, Silver, Aluminium, Zinc Lead are some commonly used meats.
- **Nonmetals :** Hydrogen, Oxygen, Nitrogen, Carbon, Sulphur, Phosphorus, Chlorine, Bromine, Iodine are commonly used nonmetals.
- **Metalloids :** Boron, Silicon, Arsenic and Germanium are some metalloids.

CHARACTERISTIC OF METALS

Some important characteristics of metals are :

- Metals are good conductors of heat and electricity.
- All metals except mercury are solid at room temperature. Mercury is the only metal which is liquid at room temperature.
- Metals are malleable and ductile – that is metals can be beaten into thin leaves and drawn into thin wires.
- Metals have lustre and can be polished.
- Metals have tensile strength.
- Metals are electropositive elements. That is, metals have a tendency to lose electrons and form positively charged ions, (called cations).

Occurrence of Metals

Metals occur in nature in the free as well as in the combined states.

Metal in nature

- **In free (or native) form** — Silver, Gold, Platinum, Mercury
- **In the combined state** — (Sodium, Potassium, Calcium, Magnesium, Iron, Aluminium, Copper etc.)

- All metals which are not affected by water and by the gases present in the air occur in free state in nature.
- The naturally-occurring compounds of metals mixed with earthly materials are called minerals.
- A mineral from which a metal can be extracted on the commercial scale, economically and easily, is called an ore.

Physical Properties of Metals

All metals show similar physical properties. There are however a few exceptions.

- **Physical State :** Under normal pressure, all metals except mercury are solids at room temperature. Mercury is liquid at room temperature.
- **Colour :** Most metals except gold and copper are silver-grey in colour. Copper is reddish-brown and gold is golden yellow.

- **Appearance :** All metals are shiny. The characteristic shine of metals is called metallic lustre. Thus all metals have metallic lustre. Metals can be easily polished.
- **Hardness :** Most metals are hard except sodium and potassium. Sodium and potassium metals can be easily cut with a knife. Osmium is hard enough to scratch glass.
- **Tensile strength :** Metals have high tensile strength. Metals are very strong. For example, iron can bear a lot of stress. That is why it is widely used in construction of buildings, bridges, railway lines etc.
- **Malleability :** Metals are malleable. This means that metals can be hammered into very thin sheets. Silver can be beaten to very thin leaves. You must have seen silver varak on burfee. Aluminium foil is used in the packaging of food materials.
- **Ductility :** Metals are ductile. This means that metals can be drawn into thin wires. Silver and gold can be drawn into very thin wires.
- **Conductivity :** Metals are good conductor of heat and electricity. Silver is the best conductor of electricity. Copper is the next best conductor of electricity.
- **Density :** Metals, except sodium and potassium have high densities. Sodium and potassium have much lower densities.
- **Sound :** Metals are sonorous. Metals when hit by a hammer produce a ringing sound. That is why metal are used for making bells and wires for musical instruments.

CHEMICAL PROPERTIES OF METALS

All metals give similar chemical reactions. However, the reactivity of a metal depends upon its nature and reaction conditions.

Some typical reactions of metals are described below :

- **Reaction with oxygen :** All metals combine with oxygen to form metal oxides. Different metals react with oxygen under different conditions.

Sodium (Na)	:	Sodium	+	Oxygen/air	$\xrightarrow{\text{room temp.}}$	Sodium oxide
Magnesium (Mg)	:	Magnesium	+	Oxygen	$\xrightarrow[\text{(burns with a dazzling white light)}]{\text{Heat}}$	Magnesium oxide
Zinc (Zn)	:	Zinc	+	Oxygen	$\xrightarrow[\text{(burns with a blue flame)}]{\text{strong heating}}$	Zinc oxide
Iron (Fe)	:	Iron	+	Oxygen	$\xrightarrow[\text{(no burning)}]{\text{strong heating}}$	Ferroso-ferric oxide
Copper (Cu)	:	Copper	+	Oxygen	$\xrightarrow[\text{(no burning)}]{\text{prolonged strong heating}}$	Copper oxide

From the reaction conditions of the reactions given above, the order of reactivity of metals with oxygen is,

Sodium (Na) > Magnesium (Mg) > Zinc (Zn) > Iron (Fe) > Copper (Cu)

- **Reaction with Water :** Different metals react with water under different conditions.

Reactions of some common metals with water are given below :

Sodium (Na)	:	Sodium	+	Water (cold)	$\longrightarrow$	Sodium hydroxide	+	Hydrogen
Magnesium (Mg)	:	Magnesium	+	Water (boiling)	$\longrightarrow$	Magnesium oxide	+	Hydrogen
Iron (Fe)	:	Iron (red hot)	+	Steam	$\longrightarrow$	Ferroso-ferric oxide	+	Hydrogen

Copper (Cu) : Copper + Water ⟶ No reaction even at high temperature

gas. Reaction of some common metals with dilute hydrochloric acid are given below :

◆ **Reactions with Acids :** Most metals react with dilute acids produce salt and hydrogen

Sodium (Na)	: Sodium	+ Hydrochloric acid (dil)	⟶	Sodium chloride	+ Hydrogen	**Vigorous**
Magnesium (Mg)	: Magnesium	+ Hydrochloric acid (dil)	⟶	Magnesium chloride	+ Hydrogen	**Rapid**
Zinc (Zn)	: Zinc	+ Hydrochloric acid (dil)	room temp. ⟶	Zinc chloride	+ Hydrogen	**Moderate**
Iron (Fe)	: Iron	+ Hydrochloric acid (dil)	heating ⟶	Iron chloride	+ Hydrogen	**Moderate**
Copper (Cu)	: Copper	+ Hydrochloric acid (dil)	⟶	No reaction even on heating		

From the reaction conditions of the reaction given above, the order of reactivity of these metals with dilute acid is

Sodium (Na) > Magnesium (Mg) > Zinc (Zn) > Iron (Fe) > Copper (Cu)

➢ USES OF SOME COMMON METALS

Main uses of some common metals are listed below :

Metal	Main Uses
Iron	For making bridges, engine parts, iron sheets and bars used in construction, steels etc.
Copper	For making electrical wires and cables, utensils, kettles, coins etc; for making alloys
Silver	For making jewellery, in electroplating, in photography, silvering of mirrors
Gold	For making jewellery, for decorative purposes, in photography for toning
Mercury	Used in thermometers and barometers
Aluminium	For making electrical wires and cables, domestic utensils, alloys, metallic paints, aluminium foil for packaging
Lead	For making automobile batteries, lead pipes, alloys such as solder, protective screen for X-ray machines, for manufacturing many chemical compounds and paints.

➢ CHARACTERISTICS OF NON-METAL

Some important characteristics of metals are :

- ◆ Nonmetals are soft solids, liquids or gases.
- ◆ Nonmetals (except graphite) are nonconductors of heat and electricity.
- ◆ Solid nonmetals are brittle.
- ◆ Nonmetals (except graphite and diamond) are low melting and low boiling.
- ◆ Nonmetals are electronegative elements. That is, nonmetals have a tendency to gain electrons and form negatively charged ions (called anions).

◈ Occurrence of Nonmetals

Many nonmetals occur free in nature, whereas metal many more occur only in the form on their compounds as minerals.

The modes of occurrence of some typical nonmetal are described below :

Nonmetal	Free native form	Combined form
Nitrogen	Air contains about 78% (by volume) of nitrogen	In all living organisms as proteins, in the soil as nitrogen compounds
Oxygen	Air contains about 21% (by volume) of oxygen	As water, oxides in the soil/rocks
Nobal gases	Air contains these gases in smaller	—

	amounts	
Hydrogen	Free hydrogen is present in stars	As water
Sulphur	Native sulphur occurs inside the earth.	As sulphide, sulphate ores, as H_2S in certain spring water
Phosphorus	—	As phosphate rocks, in bones of our body as calcium phosphate
Silicon	—	As oxide (SiO_2, Silica, Sand), As silicate rocks
Carbon	As diamonds, graphite	As carbonate rocks, minerals As hydrocarbons – petroleum, natural gas etc. As carbon dioxide in the air.

Most nonmetals are either mined directly from their mines or obtained as by-products in some industrial processes.

- Nitrogen and Oxygen are obtained from the air by fractional distillation of liquid air.
- Chlorine is obtained from common salt by electrolytic method.
- Sulphur is mined in its elemental form
- Nonmetals such as phosphorus and silica are obtained from their ores by chemical methods.

◈ Physical Properties of Nonmetals

Some common general physical properties of nonmetals are given below :

- **Physical state :** Nonmetals may occur as solids, liquids or gases at room temperature. For example, under normal conditions, sulphur, phosphorus are solids, bromine is a liquid, whereas hydrogen, oxygen and nitrogen are gases.
- **Colour :** Nonmetals come in many colours. For example, sulphur is yellow, phosphorus is white, or red, chlorine is greenish-yellow, bromine is redish-brown. Hydrogen, oxygen and nitrogen are colourless.
- **Appearance :** Nonmetals have dull appearance i.e., they do not shine. However, graphite and iodine are the only nonmetals which have metallic lustre.
- **Malleability and ductility :** Nonmetals are neither ductile nor malleable. Nonmetals cannot be drawn into wires, and beaten into leaves/sheets.
- **Conductivity :** Nonmetals do not conduct heat and electricity, i.e., nonmetals are insulators. Graphite however, is a good conductor of heat and electricity.
- **Density :** Nonmetals usually have low densities and are soft. Diamond however is an exception. Diamond is the hardest natural substance known.
- **Tensile strength :** Nonmetals have low tensile strength, i.e., Nonmetals can be easily broken.
- **Melting and boiling points :** Nonmetals except graphite have low melting and boiling points.
- **Sound :** Nonmetals do not produce sound when hit with an object, i.e., nonmetals are non-sonorous.

➢ CHEMICAL PROPERTIES OF NONMETALS

Some general chemical properties of nonmetals are described below :

◈ Electronegative Character

Nonmetals are electronegative elements. Nonmetals have a tendency to accept electrons and form negatively charged ions (anions).

For examples.

$$\text{Chlorine} + e^- \longrightarrow \text{Chloride ion (an anion)}$$

$$\text{Oxygen} + 2e^- \longrightarrow \text{Oxide ion (an anion)}$$

Thus, nonmetals are able to gain electrons from electropositive elements and act as oxidising agents.

Hydrogen is the only nonmetal which can lose as well as gain an electron.

$$\text{Hydrogen} + \underset{\text{from a highly electropositive element}}{e^-} \longrightarrow \text{Hydride ion (an anion)}$$

Hydrogen – e^- (from a highly electronegative element) $\longrightarrow$ Hydrogen ion (a cation)

Thus, hydrogen can act both as an oxidising as well as reducing agent.

◈ Reaction with Oxygen

Nonmetals react with oxygen to give covalent oxides. Such oxides are either neutral or acidic in nature. Acids oxides of nonmetals dissolve in water to form corresponding acids. Reaction of some common nonmetals with oxygen are described below:

◆ **Nitrogen :** Nitrogen reacts with oxygen under different conditions to form five different oxides. Some of these are neutral, while others are acidic in nature.

For example,

Nitrogen	+	Oxygen	$\longrightarrow$	Nitrous oxide	(neutral)
Nitrogen	+	Oxygen	$\longrightarrow$	Nitric oxide	(neutral)
Nitrogen	+	Oxygen	$\longrightarrow$	Dinitrogen trioxide	(acidic)
Nitrogen	+	Oxygen	$\longrightarrow$	Nitrogen dioxide	(acidic)
Nitrogen	+	Oxygen	$\longrightarrow$	Dinitrogen pentoxide	(acidic)

Dinitrogen pentoxide reacts with water to give nitric acid.

Dinitrogen pentoxide + Water $\longrightarrow$ Nitric acid.

◆ **Carbon :** Carbon reacts with oxygen to form two oxides – carbon monoxide (CO) and carbon dioxide (CO_2). Carbon monoxide is neutral, whereas carbon dioxide (CO_2) is acidic in nature. Carbon dioxide dissolves in water to give carbonic acid.

Carbon	+	Oxygen (limited supply)	$\longrightarrow$	Carbon monoxide (neutral)
Carbon	+	Oxygen (excess)	$\longrightarrow$	Carbon dioxide (acidic)
Carbon dioxide	+	Water	$\longrightarrow$	Carbonic acid

◆ **Phosphorus :** Phosphorus reacts with oxygen to give two oxides – phosphorus trioxide (P_2O_3) and phosphorus pentoxide (P_2O_5). Both are acidic oxides.

Phosphorus	+	Oxygen (limited)	$\longrightarrow$	Phosphorus trioxide (acidic)
Phosphorus	+	Oxygen (excess)	$\longrightarrow$	Phosphorus pentoxide (acidic)

◆ **Sulphur :** Sulphur on burning in air forms two oxides – sulphur dioxide (SO_2) and sulphur trioxide (SO_3). Both these oxides are acidic.

Sulphur	+	Oxygen	$\longrightarrow$	Sulphur dioxide (acidic)
Sulphur	+	Oxygen	$\longrightarrow$	Sulphur trioxide (acidic)
Sulphur trioxide	+	Water	$\longrightarrow$	Sulphuric acid

◆ **Hydrogen :** Hydrogen reacts with oxygen to form an oxide H_2O. H_2O is called water. Water (H_2O) is a neutral oxide

Hydrogen + water ⟶ Water (neutral)

◈ Reaction with Halogens

Nonmetals react with halogen to give covalent halides. In pure state, the halides of nonmetals do not conduct electricity.

For example with chlorine,

Phosphorus + Chlorine $\xrightarrow{\text{Heat}}$ Phosphorus trichloride

Phosphorus + Chlorine $\xrightarrow{\text{Heat}}$ Phosphorus pentoxide

Hydrogen + Chlorine $\xrightarrow{\text{sunlight}}$ Hydrogen chloride

Sulphur reacts with fluorine at higher temperature to give sulphur hexafluoride.

Sulphur + Fluorine $\xrightarrow{\text{high temp.}}$ Sulphur hexafluoride

◈ Reaction with Hydrogen

Nonmetals react with hydrogen to form covalent hydrides. Thus in the hydrides of nonmetals, hydrogen is bonded to the nonmetal atom by covalent bonds. The hydrides of nonmetals atom by covalent bonds. The hydrides of nonmetals do not conduct electricity. The hydrides of nonmetals may be acidic, basic or neutral depending upon the nature of the nonmetal.

For example,

◆ Sulphur with hydrogen gives hydrogen sulphide (H_2S). H_2S is weakly acidic in nature.

Hydrogen + Sulphure ⟶ Hydrogen sulphide (weakly acidic)

◆ Nitrogen reacts with hydrogen to give ammonia (NH_3). Ammonia is basic in nature.

Hydrogen + Nitrogen ⟶ Ammonia (basic)

◆ Oxygen reacts with hydrogen to given water (H_2O). Water is neutral in nature.

Hydrogen + Oxygen $\xrightarrow{\text{electric spark}}$ Water

◈ Reaction with Acids

Nonmetals do not displace hydrogen from dilute acids. This is because nonmetals are not able to give electron(s) for the reduction of H^+. Some nonmetals however react with concentrated oxidising acids to form the corresponding oxyacids.

For example, sulphur reacts with conc. nitric acid to give sulphuric acid.

Sulphur + $\longrightarrow$ Nitric acid (conc.) Sulphuric acid + Nitrogen dioxide + Water

◈ Displacement Reactions

Certain more reactive nonmetals displace less reactive nonmetals from their salt solutions.

For example, Chlorine displaces bromine from bromides and iodine from iodies.

Potassium bromide + Chlorine $\longrightarrow$ Potassium chloride + Bromine

Potassium iodide + Chlorine $\longrightarrow$ Potassium chloride + Iodine

➢ USES OF SOME COMMON NONMETALS

Main uses of some common nonmetals are listed below :

Nonmetal	Main Uses
Carbon	In the form of diamond, it is used for making jewellery, cutting and grinding equipments. In the form of graphite it is used for making black lead pecils, and high temperature crucibles
Sulphur	For the manufacture of gun powder, Sulphuric acid and in the vulcanization of rubber
Phosphorus	For the manufacture of matchsticks, rat poison, phosphoric acid and fertilizers.
Oxygen	Supporter of combustion, for respiration by living organisms.
Nitrogen	For manufacturing ammonia, nitric acid etc.
Chlorine	For bleaching, sterilizing water, manufacturing chlorine compounds
Hydrogen	As a fuel, in oxygen-hydrogen flame used in welding For manufacturing ammonia, hydrogen chloride, vegetable ghee by hydrogenation of oils, and as a reducing agent.
Iodine	For preparing iodised common salt , tincture iodine is used as an antiseptic.

➢ OXIDES OF METALS AND NONMETALS

Both metals and nonmetals react with oxygen (present in the air) to form oxides. The oxides of metals and nonmetals differ in their properties.

◈ Oxides of Metals

The oxides of metals are basic in nature. When dissolved in water, metal oxides give alkaline (or basic) solution which turn red litmus blue.

For example, magnesium (Mg) burns in air to give magnesium oxide (MgO), which is basic in nature.

Magnesium	+	Oxygen (from air)	⟶	Magnesium oxide (basic oxide)
Magnesium oxide	+	Water	⟶	Magnesium hydroxide (basic in nature) turns red litmus blue

◈ Oxides of Nonmetals

The oxides of nonmetals are acidic in nature. When dissolved in water nonmetal oxides give acidic give solutions which turn blue litmus red.

For example, sulphur on burning in air, gives sulphur dioxide (SO_2) which is acidic in nature.

Sulphur	+	Oxygen (from air)	⟶	Sulphur dioxide (acidic oxide)
Sulphur dioxide	+	Water	⟶	Sulphurous acid (acidic in nature) turns blue litums red