CHAPTER 3

METALS AND NON-METALS

Metals: Elements that are electropositive in nature are called metals. It means metals lose electrons to form positive ions, e.g. copper.

Physical Properties of Metals:

- **Hardness:** Most of the metals are hard, except alkali metals, such as sodium, potassium; lithium, etc. are very soft metals. These can be cut by using a knife.
- **Strength:** Most of the metals are strong and have high tensile strength. Because of this, big structures are made using metals, such as copper (Cu) and iron (Fe). (Except Sodium (Na) and potassium (K) which are soft metals).
- **State:** Metals are solid at room temperature except for mercury (Hg).
- **Sound:** Metals produce ringing sound, so, metals are called Sonorous. Sound of metals is also known as Metallic sound. This is the cause that metal wires are used in making musical instruments.
- **Conduction:** Metals are a good conductor of heat and electricity. This is the cause that electric wires are made of metals like copper and aluminium.
- **Malleability:** Metals are malleable. This means metals can be beaten into a thin sheet. Because of this property, iron is used in making big ships.
- **Ductility:** Metals are ductile. This means metals can be drawn into thin wire. Because of this property, a wire is made of metals.
- **Melting and Boiling Point:** Metals have generally high melting and boiling points. (Except sodium and potassium metals which have low melting and boiling point.)
- **Density:** Most of the metals have a high density.
- **Colour:** Most of the metals are grey in colour. But gold and copper are exceptions.

Chemical Properties of Metals

1. Reaction with oxygen: Most of the metals form respective metal oxides when reacting with oxygen.

Metal + Oxygen → Metal Oxide

Examples:

Reaction of Potassium with Oxygen: Potassium metal forms potassium oxide when reacts with oxygen.

$$4K + O_2 \longrightarrow 2K_2O$$

Reaction of Sodium with Oxygen: Sodium metal forms sodium oxide when reacts with oxygen.

$$4Na + O_2 \longrightarrow 2Na_2O$$

Lithium, potassium, sodium, etc. are known as Alkali-metals. Alkali metals react vigorously with oxygen.

Reaction of Copper metal with Oxygen: Copper does not react with oxygen at room temperature but when burnt in air, it gives oxide.

$2Cu + O_2 \longrightarrow 2CuO$

Silver, gold and platinum do not combine with the oxygen of air even at high temperature. They are the least reactive.

2. Reaction of metals with water: Metals form respective hydroxide and hydrogen gas when reacting with water.

Metal + Water → Metal hydroxide + Hydrogen

Most of the metals do not react with water. However, alkali metals react vigorously with water.

Reaction of Sodium metal with Water: Sodium metal forms sodium hydroxide and liberates hydrogen gas along with lot of heat when reacting with water.

$Na + 2H_2O \longrightarrow NaOH + 2H_2$

Reaction of Calcium metal with Water: Calcium forms calcium hydroxide along with hydrogen gas and heat when react with water.

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

Reaction of Magnesium metal with Water: Magnesium metal reacts with water slowly and forms magnesium hydroxide and hydrogen gas.

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

When steam is passed over magnesium metal, magnesium oxide and hydrogen gas are formed.

$Mg + H_2O \longrightarrow MgO + H_2$

Reaction of Aluminium metal with Water: Reaction of aluminium metal with cold water is too slow to come into notice. But when steam is passed over aluminium metal, aluminium oxide and hydrogen gas are produced.

$2Al + 3H_2O \rightarrow Al_2O_3 + 2H_2$

Reaction of Zinc metal with Water: Zinc metal produces zinc oxide and hydrogen gas when steam is passed over it. Zinc does not react with cold water.

$Zn + H_2O \longrightarrow ZnO + H_2$

Reaction of Iron with Water: Reaction of iron with cold water is very slow and comes into notice after a long time. Iron forms rust (iron oxide) when reacts with moisture present in the atmosphere. Iron oxide and hydrogen gas are formed by passing of steam over iron metal.

$$2Fe + 3H_2O \longrightarrow Fe_2O_3 + 3H_2$$

Both calcium (Ca) and magnesium (Mg) are heavier than water but still float over it: Both calcium and magnesium float over water surface because hydrogen gas is evolved when these metals react with water. It is in the form of bubbles which stick on the metal surface. Therefore, they float over it.

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

Other metals usually do not react with water or react very slowly. Lead, copper, silver and gold do not react with steam. Thus, the order of reactivity of different metals towards water may be written as:
K > Na > Ca > Mg > Al > Zn > Fe > Pb > Cu > Ag > Au

3. Reaction of metals with dilute acid: Metals form respective salts when reacting with dilute acid.
Metal + dil. acid → Metal salt + Hydrogen

Reaction of Sodium metal with dilute hydrochloric acid: Sodium metal gives sodium chloride and hydrogen gas when react with dilute hydrochloric acid.

$$2Na + 2HCl \longrightarrow 2NaCl + H_2$$

Reaction of Magnesium metal with dilute hydrochloric acid: Magnesium chloride and hydrogen gas are formed when magnesium reacts with dilute hydrochloric acid.

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

Reaction of Zinc with dilute Sulphuric acid: Zinc sulphate and hydrogen gas are formed when zinc reacts with dilute Sulphuric acid. This method is used in the laboratory to produce hydrogen gas.

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

Hydrogen (H_2) gas is not evolved when metal is treated with nitric acid (HNO_3):
Nitric acid is strong oxidising agent and it oxidizes the hydrogen gas (H_2) liberated into water (H_2O) and itself get reduced to some oxide of nitrogen like nitrous oxide $(N_2O)_3$ nitric oxide (NO) and nitrogen dioxide (NO_2).

Copper, gold, silver are known as noble metals. These do not react with water or dilute acids.
The order of reactivity of metal towards dilute hydrochloric acid or Sulphuric acid is in the order;
K > Na > Ca > Mg > Al > Zn > Fe > Cu > Hg > Ag

Metal Oxides
Chemical Properties: Metal oxides are basic in nature. The aqueous solution of metal oxides turns red litmus blue.
Reaction of Metal oxides with Water: Most of the metal oxides are insoluble in water. Alkali metal oxides are soluble in water. Alkali metal oxides give strong base when dissolved in water.

Reaction of Sodium oxide with Water: Sodium oxide gives sodium hydroxide when reacts with water.

$Na_2O + H_2O \longrightarrow 2NaOH$

Reaction of Potassium oxide with Water: Potassium oxide gives potassium hydroxide when reacts with water.

$K_2O + H_2O \longrightarrow 2KOH$

Reaction of Zinc oxide and Aluminium oxide: Aluminium oxide and zinc oxide are insoluble in water. Aluminium oxide and zinc oxide are amphoteric in nature. An amphoteric substance shows both acidic and basic characters. It reacts with base like acid and reacts with an acid like a base.
When zinc oxide reacts with sodium hydroxide, it behaves like an acid. In this reaction, sodium zincate and water are formed.

$ZnO + 2NaOH \longrightarrow Na_2ZnO_2 + H_2O$

Zinc oxide behaves like a base when reacts with acid. Zinc oxide gives zinc chloride and water on reaction with hydrochloric acid.

$ZnO + 2HCl \longrightarrow ZnCl_2 + H_2O$

In a similar way, aluminium oxide behaves like a base when reacts with acid and behaves like acid when reacts with a base.
Aluminium oxide gives sodium aluminate along with water when reacts with sodium hydroxide.

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

Aluminium oxide gives aluminium chloride along with water when it reacts with hydrochloric acid.

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

Reactivity Series of Metals: The order of intensity or reactivity of metal is known as Reactivity Series. Reactivity of elements decreases on moving from top to bottom in the given reactivity series.
In the reactivity series, copper, gold, and silver are at the bottom and hence, least reactive. These metals are known as Noble metals. Potassium is at the top of the series and hence, most reactive.
Reactivity of some metals is given in descending order:
K > Na > Ca > Mg > Al > Zn > Fe > Pb > Cu > Hg > Ag > Au
4. Reaction of metals with solution of other metal salts: Reaction of metals with the solution of other metal salt is displacement reaction. In this reaction, more reactive metal displaces the less reactive metal from its salt.
Metal A + Salt of metal B → Salt of metal A + Metal B
Examples:
Iron displaces copper from copper sulphate solution.

$Fe + CuSO_4 \longrightarrow FeSO_4 + Cu$

Similarly, aluminium and zinc displace copper from the solution of copper sulphate.

$2Al + 3CuSO_4 \longrightarrow Al_2(SO_4)_3 + 3Cu$

$Zn + CuSO_4 \longrightarrow ZnSO_4 + Cu$

In all the above examples, iron, aluminium and zinc are more reactive than copper. This is why they displace copper from its salt solution.
When copper is dipped in the solution of silver nitrate, it displaces silver and forms copper nitrate.

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

In the reaction, copper is more reactive than silver and hence, displaces silver from silver nitrate solution.
Silver metal does not react with copper sulphate solution because silver is less reactive than copper and not able to displace copper from its salt solution.

$Ag + CuSO_4 \longrightarrow$ No reaction

Similarly, when gold is dipped in the solution of copper nitrate, no reaction takes place because copper is more reactive than gold.

$Au + Cu(NO_3)_2 \longrightarrow$ No reaction

In similar way, no reaction takes place when copper is dipped in the solution of aluminium nitrate because copper is less reactive than aluminium.

$Al(NO_3)_3 + Cu \longrightarrow$ No reaction

Non-Metals: Elements that are electronegative in nature are called non-metals. It means non-metals gain electrons to form negative ions, e.g. iodine

Physical properties of non-metals

- **Hardness:** Non-metals are not hard rather they are generally soft. But the diamond is an exception; it is the hardest naturally occurring substance.
- **State:** Non-metals may be solid, liquid or gas.
- **Luster:** Non-metals have a dull appearance. Diamond and iodine are exceptions.
- **Sonority:** Non-metals are not sonorous, i.e., they do not produce a typical sound on being hit.
- **Conduction:** Non-metals are a bad conductor of heat and electricity. Graphite which is allotrope of carbon is a good conductor of electricity and is an exception.
- **Malleability and ductility:** Non-metals are brittle.
- **Melting and boiling point:** Non-metals have generally low melting and boiling points.
- **Density:** Most of the non-metals have low density.
- **Colour:** Non-metals are in many colours.

Carbon in the form of graphite is non-metal which conduct electricity.

Carbon in the form of diamond is a non-metal which is extremely hard. Diamond is a non-metal which has a very high melting point and boiling point.

Iodine is non-metal which is lustrous having a shining surface.

Chemical properties of Non-metals:
1. Reaction of Non-metals with Oxygen: Non-metals form respective oxide when reacting with oxygen.
Non-metal + Oxygen → Non-metallic oxide
when carbon reacts with oxygen, carbon dioxide is formed along with the production of heat.

$C + O_2 \longrightarrow CO_2 +$ heat

When carbon is burnt in an insufficient supply of air, it forms carbon monoxide. Carbon monoxide is a toxic substance. Inhaling of carbon monoxide may prove fatal.

$2C + O_2 \longrightarrow 2CO + heat$

Sulphur gives sulphur dioxide when reacting with oxygen. Sulphur catches fire when exposed to air.

$S + O_2 \longrightarrow SO_2$

When hydrogen reacts with oxygen it gives water.

$2H_2 + O_2 \longrightarrow 2H_2O$

Non-metallic Oxide: Non-metallic oxides are acidic in nature. The solution of non-metal oxides turns blue litmus red.
Carbon dioxide gives carbonic acid when dissolved in water.

$CO_2 + H_2O \longrightarrow H_2CO_3$

Sulphur dioxide gives sulphurous acid when dissolved in water.

$SO_2 + H_2O \longrightarrow H_2SO_3$

Sulphur dioxide gives Sulphuric acid when reacts with oxygen.

$SO_2 + 2O_2 \longrightarrow 2SO_3$

$SO_3 + H_2O \longrightarrow H_2SO_4$

2. Reaction of Non-metal with Chlorine: Non-metal gives respective chloride when they react with chlorine gas.
Non-metal + Chlorine → Non-metal chloride
Hydrogen gives hydrogen chloride and phosphorous gives phosphorous trichloride when reacting with chlorine.

$H_2 + Cl_2 \longrightarrow 2HCl$

$P_4 + 6Cl_2 \longrightarrow 4PCl_3$

3. Reaction of Non-metals with Hydrogen: Non-metals reactive with hydrogen to form covalent hydrides.

Non-metal + Hydrogen → Covalent Hydride
Sulphur combines with hydrogen to form a covalent hydride is called Hydrogen sulphide.

$H_2 + S \longrightarrow H_2S$

Nitrogen combines with hydrogen in presence of an iron catalyst to form covalent hydride ammonia.

$N_2 + 3H_2 \longrightarrow 2NH_3$

Non-metals do not react with water (or steam) to evolve Hydrogen gas.

Non-metals do not react with dilute acids.

4. Reaction of Metal and Non-metal: Many metals form ionic bonds when they react with non-metals. Compounds so formed are known as Ionic Compounds.

Ions: Positive or negative charged atoms are known as ions. Ions are formed because of loss or gain of electrons. Atoms form ions obtain by the electronic configuration of the nearest noble gas.
Positive ion: A positive ion is formed because of the loss of electrons by an atom.

Following are some examples of positive ions:
Sodium forms sodium ion because of the loss of one electron. Because of the loss of one electron, one positive charge comes over sodium.

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

Magnesium forms positive ion because of the loss of two electrons. Two positive charges come over magnesium because of loss of two electrons.

$Mg \longrightarrow Mg^{2+} + 2e^-$

Negative ion: A negative ion is formed because of the gain of an electron.
Some examples are given below:
Chlorine gains one electron in order to achieve a stable configuration. After the gain of one electron, chlorine gets one negative charge over it forming chloride ion.

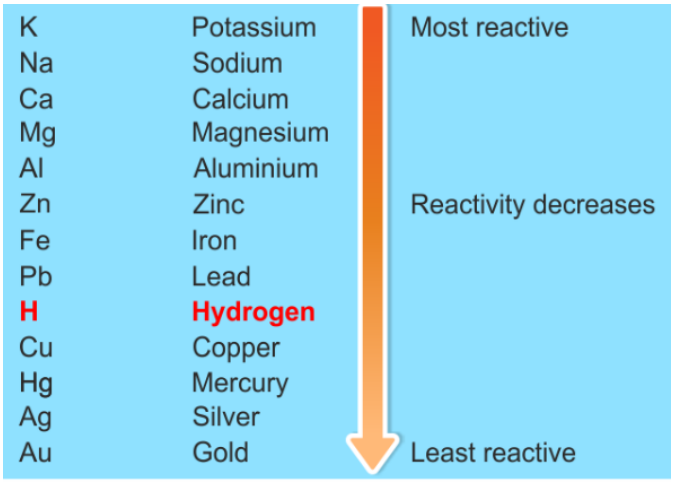
$Cl + e^- \longrightarrow Cl^-$

Difference between Metals and Non-metals:

Metals	Non-metals
1. Metals generally occur as hard solid substances.	1. Non-metals generally occur in all the three forms of matter- solid, liquid and gases.
2. Metals are malleable and ductile.	2. Non-metals are not malleable and ductile.
3. Metals produce ringing sound on striking which is called their sonorous property.	3. Non-metals do not show this sonorous property.
4. Metals are good conductors of heat and electricity.	4. Non-metals are poor conductors of heat and electricity with the exception of graphite which is a good conductor of heat and electricity.

Reactivity series: The arrangement of metals in a vertical column in the order of decreasing reactivity is called reactivity series of metals. The most reactive metals are placed at the top and least reactive metals are placed at the bottom of the reactivity series.

The reactivity series is:



Ionic Compounds: The compounds formed by transfer of electrons from a metal to a non-metal are known as Ionic Compounds. Sodium Chloride (NaCl), Magnesium chloride ($MgCl_2$)

Ionic Bonds: Ionic bonds are formed because of transfer of electrons from metal to non-metal. In this course, metals get positive charge because of transfer of electrons and non-metal gets negative charge because of acceptance of electrons. In other words, bond formed between positive and negative ion is called Ionic Bond.

Some examples are given below:
Formation of Sodium Chloride (NaCl): In sodium chloride, sodium is a metal (alkali metal) and chlorine is a non-metal.
Atomic number of sodium = 11

Electronic configuration of sodium: 2, 8, 1
Number of electrons in outermost orbit = 1

Atomic number of chlorine = 17
Electronic configuration of chlorine: 2, 8, 7
Electrons in outermost orbit = 7

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

2, 8, 1 2, 8

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

(2, 8, 7) (2, 8, 8)

$Na^{x} :\overset{\cdot}{Cl} \longrightarrow Na^{+}\ Cl^{-} \longrightarrow NaCl$

Sodium has one valence electron and chlorine has seven valence electrons. Sodium requires losing one electron to obtain stable configuration and chlorine requires gaining one electron in order to obtain stable electronic configuration. Since, sodium chloride is formed because of ionic bond, thus, it is called Ionic compound. In similar way, Magnesium chloride ($MgCl_2$) is formed.

$Mg \longrightarrow Mg^{2+} + 2e^{-}$

2, 8, 2 2, 8

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

(2, 8, 7) (2, 8, 8)

Properties of Ionic Compounds:
Properties of ionic compounds are as follows.

(i)Physical nature: Ionic compounds are solids and hard due to the strong attracting force between the positive and negative ions. These compounds are generally brittle and break into pieces on pressure.

(ii) Melting and boiling point: Ionic compounds have high melting and boiling points because amount of energy can break the strong inter-ionic attraction.

(iii) Solubility: Ionic compounds are soluble in water but insoluble in solvents like kerosene, petrol, etc.

(iv) Conduction of Electricity: Conduction of electricity through a solution is possible when there is movement of charged particles. Ionic compounds in the solid state do not conduct electricity because movement of ions in the solid is not possible due to their rigid structure.

A solution of an ionic compound in water contains ions, which move to the opposite electrodes when electricity is passed through the solution. Ionic compounds conduct electricity in the molten state as in the molten state the electrostatic forces of attraction between the oppositely charged ions overcome due to the heat. Thus, the ions move freely and conduct electricity.

Corrosion and its prevention:

Corrosion is an electrochemical process in which redox reactions occur between the metal and water, oxygen and sulphur dioxide, etc. It is a ***spontaneous and irreversible*** process in which the metal changes into chemical compounds such as oxide, sulphide and hydroxides, etc.

For example, due to corrosion or rusting, the iron changes into red iron oxide (rust) in the presence of moisture and oxygen present in the air. The rusting of iron when it comes in contact with water and oxygen which leads to the formation of a brown coat over its surface is a type of corrosion. The chemical reaction involved in rusting is shown below;

$$\mathbf{4Fe + 3O_2 \rightarrow 2Fe_2O_3}$$

$$\mathbf{2Fe_2O_3 + xH_2O \rightarrow Fe_2O_3.xH_2O\ (rust)}$$

Methods to prevent corrosion, some of them are described below;

(i) Electroplating:

- In this method, an electric current is used to create a thin layer of metal over another metal. It is done to make cheaper metals more appealing as well as to protect them from corrosion.
- This method requires two different metals, an electrolytic solution, and two electrodes in a tank and a battery or source of current that will pass the required current into the solution to carry out the electrolysis.
- When current is passed one electrode gets a positive charge and another gets the negative charge. The ions of the positively charged metal shift to the surface of the negatively charged metal to create a thin layer. For example, when we take brass and copper for electroplating, the copper metal slowly gets deposited or covers the brass and thus a thin coating of copper covers the surface of the brass. Here, the electrolytic solution must contain copper sulphide.

(ii) Galvanization: In this method, iron is coated with a layer of zinc. The iron is dipped in the molten zinc. The layer of zinc protects the iron from corrosion. This method has been in use for more than 200 years.

(iii) Painting and Greasing: In this method, a layer is created over the metal surface by painting or greasing. This layer of paint or grease protects the metal from corrosion. Carbon fibre coating can be used for this purpose.

(iv) Selection of Material: Select the materials that are not affected by corrosion. For example, stainless steel and aluminium are resistant to corrosion.

(v) Dry and clean: Keep the metal surface dry and clean.

Assignments:

Q1.Write one example of each of
(i) a metal which is so soft that, it can be cut with knife and a non-metal which is the hardest substance.
(ii) A metal and a non-metal which exist as liquid at room temperature.
Answer.
(i) Sodium, carbon (diamond).
(ii) Mercury is liquid metal, bromine is liquid non-metal.

Q2. Mention the names of the metals for the following:
(i) Two metals which are alloyed with iron to make stainless steel.
(ii) Two metals which are used to make jewellery.
Answer.
(i) Nickel and chromium.
(ii) Gold and platinum.

Q3. Write the electron dot structures for
(a) Potassium and chlorine.
(b) Calcium and sulphur.
(c) Calcium and chlorine.
Answer. (a) KCl (b) CaS (c) $CaCl_2$

Q4. You are given samples of three metals. Sodium, magnesium and copper. Suggest any two activities to arrange them in order of decreasing activity.
Answer. Activity 1: Sodium reacts with cold water vigorously to form sodium hydroxide and hydrogen gas

$$Na\ (s) + H_2O\ (cold) \longrightarrow NaOH\ (aq) + H_2\ (g)$$

Magnesium does not react with cold water but with hot water to form magnesium hydroxide and hydrogen gas.

$$Mg\ (s) + H_2O\ (Hot) \longrightarrow Mg\ (OH)_2\ (aq) + H_2\ (g)$$

Hence sodium is more reactive than magnesium.
Activity 2: $Mg\ (s) + CuSO_4\ (aq) \longrightarrow Mg\ SO_4\ (aq) + Cu\ (s)$

$$Cu\ (s) + MgSO_4\ (aq) \longrightarrow \text{No reaction}$$

Q5. Give reason for the following:
(a) School bells are made up of metals.
(b) Electric wires are made up of copper.
Answer.
(a) It is because metals are sonorous, i.e. they produce sound when struck with a hard substance.
(b) It-is because copper is good conductor of electricity.

Q6. (a) Define activity series of metals. Arrange the metals gold, copper, iron and magnesium in order of their increase in reactivity.
(b) What will you observe when:
(i) Some zinc pieces are put in copper sulphate solution.
(ii) Some silver pieces are put into green coloured ferrous sulphate solution.
Answer.
(a) The series of metals in which metals are arranged in decreasing order of their reactivity.
Au < Cu < Fe < Mg is increasing order of reactivity.
(b) (i) The blue solution will become colourless and reddish brown copper metal will be deposited.
$Zn\ (s) + CuSO_4\ (aq) \longrightarrow Zn\ SO_4\ (aq) + Cu\ (s)$
$Ag\ (s) + FeSO_4\ (aq) \longrightarrow$ No reaction
Reaction will not take place because Ag is less reactive than iron.

Q7. Name the following:
(a) A metal, which is preserved in kerosene.
(b) A lustrous coloured non-metal.
(c) A metal, which can melt while kept on palm.
(d) A metal, which is a poor conductor of heat.
Answer.
(a) Sodium is preserved in kerosene (b) Iodine is lustrous coloured non-metal
(c) Gallium (d) Lead

Q8**.** Give reason for the following:
(a) Aluminium oxide is considered as an amphoteric oxide.
(b) Ionic compounds conduct electricity in molten state.
Answer.
(a) It is because it reacts with acids as well as bases to produce salts and water. Al is less electropositive metal. So, it forms amphoteric oxide which can react with acid as well as base.
(b) Ionic compounds can conduct electricity in molten state because ions become free to move in molten state.
Q9. State reasons for the following:
(i) Sulphur is a non-metal (ii)Magnesium is a metal
Answer**:** (i) Sulphur is a non-metal because it is a poor conductor of heat and electricity.
(ii)Magnesium is a metal because it is a good conductor of heat and electricity.
Q10. Write two differences between calcination and roasting.
Answer

Calcination	Roasting
It is carried out by heating ore in the absence of air.	It is carried out by heating ore in the presence of air.
(ii) It converts carbonate ores into oxides.	(ii) It converts sulphide ores into oxides.