METALS & NON-METALS

1. INTRODUCTION

All the materials found in the earth are composed of elements. All elements are classified into three categories.

(i) Metals

(ii) Nonmetal

(iii) Metalloids

- **Metals :** Metals are the elements (except hydrogen) which form cations by losing electrons.
  Ex. Gold, Silver
- **Nonmetals :** The elements which tend to form anions by gaining electrons are termed nonmetals. There are 22 nonmetals.
- **Metalloids :** The elements which behave like metals as well as nonmetals are called metalloids.
  Ex. Boron, Silicon, and Arsenic.

2. Metals

Amongst all the elements, metals are the most useful, some of the metals which find common use in our daily life are : iron, copper, aluminium, gold, silver, mercury etc.

Metals have been placed on the left side and the centre of the periodic table. The elements belonging to groups 1 and 2 of the periodic table are metallic in nature. Group 1 comprises of alkali metals such as Li, Na, K, Rb and Cs. Group 2 consists of Be, Mg, Ca, Sr and Ba. These are alkaline earth metals.

Cu, Fe, Ni and Ag are typical metals. They are very good conductors of heat and electricity. These typical metals form the central block in the periodic table and called transition metals

❑ Uses of metals

- Cu and Al are used to make wires to carry electriccurrent.
- Iron is used as a catalyst in the preparation of NH_3 gas in Haber process.
- Zn is used for galvanizing iron to protect it from rusting.
- The liquid metal 'Mercury' is used in making thermometers.

❑ Physical properties of metals

- Physical state : All metals are solid at room temperature except Mercury (Hg), Gallium (Ga) and Caesium (Cs) which are liquid at ordinary temperature.
- Lustre : Metals possess a characteristic shining appearance called metallic lusture,and they can be polished. Exceptions ; Graphite and Iodine are lustrous but they are non metals.
- Ductility : Metals are **ductile** which means that metals can be drawn into thin wires. Gold and silver are the best ductile metals. Copper and Aluminium are also highly ductile.
- Hardness : Metals are generally **hard** except sodium and potassium which are **soft metals.** Hard metals are copper, silver, gold, aluminium, iron, zinc, platinum, tin and lead.
- Malleability : Metals are **malleable** , which means that metals can be beaten into thin sheets without breaking them. Gold and silver are some of the best malleable metals. Aluminium foils are also used for packing food items, chocolates or biscuits. Aluminium foil wrappers are used for covering medicines too.

- Density : Metals generally have **high densities.** Osmium has highest density of 22 g/cm^3. It is the heaviest metal. Lithium has least density of 0.5g/cm^3. It is the lightest metal.
- Sonorous : Metals are **sonorous**. This means that metals are capable of producing sound when hit with solid objects. Bell is a good example suggesting the sonorous nature of metals
- Thermal and Electrical conductivity : All metals are good conducts of heat and electricity , Silver is the best conductor of heat and electricity , While lead is the poorest conductors.

❑ **Chemical properties of metals**

- **Reaction of metals with oxygen :**

All metals combine with oxygen to form metal oxides.

(a) Sodium and potassium react with oxygen at room temperature to form basic oxides.

$4Na_{(s)} + O_{2\,(g)} \longrightarrow 2Na_2O_{(s)}$

$4K_{(s)} + O_{2\,(g)} \longrightarrow 2K_2O_{(s)}$

(b) Magnesium does not combine with oxygen at room temperature. But when heated, it burns in oxygen with a dazzling white light and produces magnesium oxide.

$2Mg_{(s)} + O_{2\,(g)} \longrightarrow 2MgO_{(s)}$

Since magnesium reacts with oxygen less readily than sodium, **magnesium is less reactive than sodium.**

(c) Zinc reacts with oxygen only when strongly heated to form zinc oxide.

$2Zn_{(s)} + O_{2\,(g)} \longrightarrow 2ZnO_{(s)}$

Since zinc reacts with oxygen less readily that magnesium, **zinc is less reactive than magnesium.**

(d) Copper does not react oxygen even on strong heating. It however, reacts very slowly on prolonged heating, forming cupric oxide.

$2Cu_{(s)} + O_{2\,(g)} \longrightarrow 2CuO_{(s)}$

Since copper reacts with oxygen much less readily than zinc, **copper is less reactive than zinc.**

The order of reactivity of these metals with oxygen can be summed up as:

sodium > magnesium > zinc > copper

- **Reaction of metals with acids** :

Metals usually react with acids to displace hydrogen from acids. The less reactive metals, however, do not displace hydrogen from acids.

(a) Sodium reacts with dilute hydrochloric acid vigorously to form sodium choride and hydrogen gas.

$2Na\,(s) + 2HCl\,(aq) \longrightarrow 2NaCl\,(aq) + H_2\,(g)$

This is because **sodium metal is highly reactive.**

(b) Magnesium reacts with dilute hydrochloric acid quite rapidly , but much less vigorously than does sodium , to form magnesium chloride and hydrogen.

$Mg\,(s) + 2HCl\,(aq) \longrightarrow MgCl_2\,(aq) + H_2\,(g)$

This shows that **magnesium is less reactive than sodium**.

- Zinc reacts with dilute hydrochloric acid to produce zinc chloride and hydrogen , but the rate of this reaction is slower than that with magnesium. Hence, **zinc is less reactive than magnesium.**

$Zn\,(s) + 2HCl\,(aq) \longrightarrow ZnCl_2\,(aq) + H_2\,(g)$

➤ Copper does not react with dilute hydrochloric acid. This shows that **copper is less reactive than zinc.**

$Cu + 2HCl \longrightarrow$ No reaction

➤ **Reaction of metals with water :**

(a) Metals like Na and K react with cold water vigorously.

$2Na\ (s) + 2H_2O\ (l) \longrightarrow 2NaOH\ (aq) + H_2\ (g)$

(b) Metals like Mg , Fe , and Zn , react with steam.

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

$Mg\ (s) + H_2O\ (g) \longrightarrow MgO\ (s) + 4H_2\ (g)$

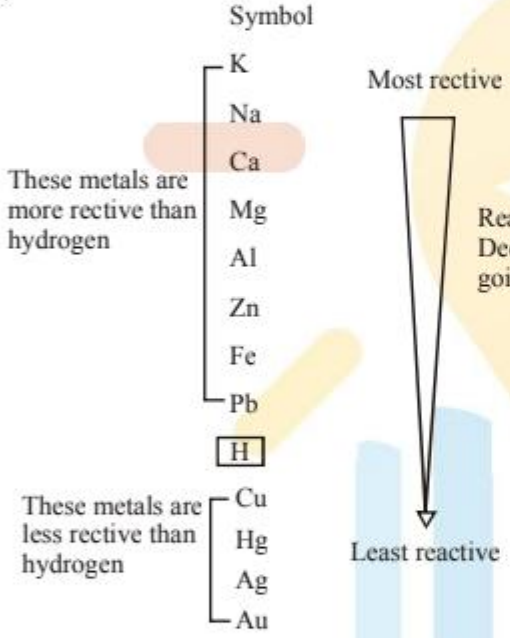
(c) Metals such as Ag, Au , Pt are not affected by water. Cu , Pb and Sn also do not react with water.

The order of reactivity of some metals with water is:

$Na > Mg > Zn > Fe > Cu$

❑ **Reactivity series of metals**

Metals can be arranged in the decreasing order of their reactivity in a series. This series is called the **reactivity** or **activity series of metals.**



➤ **Significance of Activity Series**

(a) The metals above hydrogen in the series have greater tendency than hydrogen to give up electrons in their solutions. Such metals are called electropositive metals.

The electropositive character of metals becomes less pronounced as we go down the series.

For example, potassium (K), the first metal in the series is the most electropositive, while gold (Au), the last metal of the series is the least electropositive.

(b) The metals above hydrogen in the series can liberate hydrogen when treated with an acid solution.

$Mg + H_2SO_4 \longrightarrow MgSO_4 + H_2$

$Zn + H_2SO_4 \longrightarrow ZnSO_4 + H_2$

In these reactions, electrons released by metals are accepted by H^+ or H_3O^+ ions present in the acid solution.

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

$2H^+ + 2e \longrightarrow H_2$

or, $2H_3O^+ + 2e \longrightarrow 2H_2O^+ + H_2$

Thus H^+ (or H_3O^+) ions act as oxidizing agents, while the metal acts as reducing agent.

(c) A more electropositive metal can replace a less electropositive metal from the solution of a salt of the less electropositive metal. For example , when an iron rod is dipped into a solution of copper sulphate , reddish coloured copper is deposited on the iron rod.

$Fe + CuSO_4 \longrightarrow FeSO_4 + Cu$

This is because iron is more electropositive than copper.

➤ **Metal Displacement Reactions** :

A more reactive metal is able to displace a less reactive metal from its salt solution.

(a) When a strip of Zn metal is dipped into a solution of copper sulphate , the blue colour of copper sulphate gradually disappers and metallic copper is deposited on the strip of zinc.

$Zn + CuSO_{4\,(aq)} \longrightarrow ZnSO_{4\,(aq)} + Cu_{\,(s)}$

or, $Zn + Cu^{2+}_{\,(aq)} \longrightarrow Zn^{2+} + Cu$

Thus, zinc atoms are oxidized to zinc ions, and copper ions are reduced to copper atoms. As a result, curpic ions (Cu^{2+}) that impart the blue colour to the solution are gradually replaced by zinc ions (Zn^{2+}). Hence, the blue colour of the solution gradually fades away.

(b) When a piece of iron is dipped into copper sulphate solution , the blue colour of the solution fades slowly, while red precipitate of copper is deposited on the iron piece.

$Fe_{\,(s)} + CuSO_{4\,(aq)} \longrightarrow FeSO_{4\,(aq)} + Cu_{\,(s)}$

or , $Fe + Cu^{2+}_{\,(aq)} \longrightarrow Fe^{2+} + Cu$

In this reaction, iron which is more reactive is oxidized to ferrous ion (Fe^{2+}), while copper, being less reactive, is displaced as a red precipitate. Due to the formation of Fe^{2+} ions (or $FeSO_4$), the solution becomes greenish.

(c) When a strip of copper is kept dipped in a solution of silver nitrate, the colourless solution gradually turns blue. This is because copper, being more electropositive (or more reactive), goes into the solution as cupric ions, while silver ions present in the solutions are reduced to silver atoms which are deposited on the strip of copper.

$Cu_{\,(s)} + 2AgNO_{3\,(aq)} \longrightarrow Cu(NO_3)_{\,(aq)} + 2Ag_{\,(s)}$

or, $Cu + 2Ag^+ \longrightarrow Cu^{2+} + 2Ag$

➤ **Displacement of metals from oxides** :

A more electropositive metal can displace a less electropositive metal from its oxide. For example, when cupric oxide (CuO) is heated with magnesium powder, magnesium oxide is formed and copper is set free.

$CuO + Mg_{\,(s)} \longrightarrow MgO_{\,(s)} + Cu_{\,(s)}$

This is because **magnesium is more electropositive(or more reactive) than copper.**

The more electropositive metals are good reducing agents because they easily give up electrons required for reduction.

➤ **Reaction with hydrogen :**

Not all metals combine with hydrogen. Some reactive metals such as lithium, sodium , potassium and calcium combine with hydrogen to form the hydrides of metals.

$2Li_{\,(s)} + H_{2\,(g)} \longrightarrow 2LiH_{\,(s)}$

$2Na_{\,(s)} + H_{2\,(g)} \longrightarrow 2NaH_{\,(s)}$

$Ca_{(s)} + H_{2\,(g)} \longrightarrow CaH_{2\,(s)}$

These hydrides are ionic compounds in which hydrogen is present as hydride ion (H).

➤ **Reaction with chlorine:**

Metals react with chlorine to form metal chlorides.

(a) Sodium metal reacts with chlorine gas readily.

$2Na_{(s)} + Cl_{2\,(g)} \longrightarrow NaCl_{(s)}$

(b) Magnesium , zinc and iron reacts with chlorine on heating.

$Mg_{(s)} + Cl_{2\,(g)} \xrightarrow{Heat} MgCl_{2\,(s)}$

$2Fe_{(s)} + 3Cl_{2\,(g)} \xrightarrow{Heat} 2FeCl_{3\,(g)}$

4. Occurrence of metals

Metals occur in nature in the free as well as in the combined states. The less reactive metals like silver, gold and platinum are generally found in the free state. Most of the metals, however, are found in the combined form as minerals.

➤ **Minerals :** The natural substances in which metals occur in the earth are called minerals.

➤ **Ores :** The minerals from which metal can be extracted easily is define as ores. Different types of ores.

(a) Oxide : Cu_2O (Cuprite) , Fe_2O_3 (Haematite)
MnO_2 (Pyrolusite - Maganese oxide), $Al_2O_3.2H_2O$ (Bauxite)

(b) Sulphides : PbS (Galena) , Cu_2S (Copper glance), HgS (Cinnabar), ZnS (zinc blende - zinc sulphide)

(c) Chlorides : NaCl (Sodium Chloride), $MgCl_2$ (Magnesium Chloride), $CaCl_2$ (Calcium Chlorides)

➤ **Gangue :** The ore mined from the earth's crust contain a large number of impurities. (sand ,lime stone, silicates) These impurities are known as Gangue.

5. Metallurgy

The process of extracting a metal in pure form its ores is known as metallurgy. The various steps used in metallurgy are.

(1) Concentration of the ore
(2) Conversion of ore into metal oxide
(3) Reduction to free metal
(4) Refining

❑ Concentration (Dressing) of the ore

Since the ores are obatained from the earth curst, these are generally associated with a large number of impurities like sand , limestone , quartz , silicates, etc. These impurities are known as **gangue or matrix**. The removal of these impurities from the powdered ore is known as **dressing.** Concentration of the ore can be carried out in the following ways.

➤ Magnetic separation method

This method is based on difference in the magnetic properties of ore and the gangue. The magnetic separation method is used only when either of the two, ore or gangue, is magnetic. **Ex.**
Pyrolusite (MnO_2)
Chromite Fe $(CrO_3)_2$

Magnetite (Fe_3O_4) are concentrated by this method.

➤ **Froth floatation process.**

This process is especially suitable for sulphide ores. The process is based on the different wetting characteristics of the ore and gangue particles with water and oil. The sulphide ore particles are preferentially wetted by pine oil ; whereas the gangue particles are wetted by water.

➤ **Chemical method or leaching process**

Leaching is a process in which soluble components of the ore are washed or extracted from insoluble materials by treating it with chemicals. This method depends upon the difference in chemical properties of the ore particles and impurities , therefore this method is also called **chemical separation**.

Bauxite is purified by leaching process using NaOH solution as a leachant.

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

Alumina (bauxite) — Sodium aluminate

Impurities $+ NaOH \longrightarrow$ No reaction

$NaAlO_2 + HCl + H_2O \longrightarrow Al(OH)_3 + NaCl$

white ppt.

$2Al(OH)_3 \xrightarrow[\Delta]{1500°C} Al_2O_3 + 3H_2O$

(Pure alumina)

❑ **Conversion of ore into metal oxide**

The concentrated ore is converted into the oxide of metal. This is done by the process of calcination and roasting.

➤ **Calcination :** Calcination is a process in which ore is heated, generally in the absence of air, to expel water from a hydrated oxide or carbon dioxide from a cabonate at temperature below their melting points. For example,

$Al_2O_3.2H_2O \longrightarrow Al_2O_3 + 2H_2O$

$2Fe_2O_3.3H_2O \longrightarrow 2Fe_2O_3 + 3H_2O$

$CaCO_3 \longrightarrow CaO + CO_2$

➤ **During calcination**

(i) mass becomes porous

(ii) volatile impurities are removed

(iii) carbonate ores decompose to oxides

➤ **Roasting :** It is a wider term used to denote the process in which ore (usually **sulphide**) alone or mixed with other materials is heated, usually in the presence of air, at temperatures below their melting points.

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

$HgS + O_2 \longrightarrow Hg + SO_2$

$CuS + 2O_2 \longrightarrow CuSO_4$

$Ag_2S + 2NaCl \longrightarrow 2AgCl + Na_2S$

$AgCl + 2Hg \longrightarrow Ag - Hg + HgCl$

➤ **During roasting :**

(i) Sulphide ores are partially converted to oxides

(ii) Volatile impurities are removed

(iii) Free S, As and Sb are removed as SO_2, As_2O_3 and Sb_3O_3 respectively

Difference between calcination and roasting

Calcination	Roasting
1. During calcination, the ore is heated in the absence of air	1. During roasting, the ore is heated in the presence of air.
2. Calcination is generally used to convert carbonate ores into oxides ores.	2. Roasting is generally used to convert sulphide ores into oxide ores.

❑ **Reduction to free metal**

The calcined or roasted ore is then reduced to the metallic state in either of the following ways.

➤ **Self Reduction method :**

The oxides and sulphides of the less active metals like Hg, Cu and Pb are unstable to heat and hence no reducing agent is required during their reduction. **Ex.**

Mercury $HgS + O_2 \xrightarrow{heat} Hg + SO_2 \uparrow$
(Cinnabar)

Copper $2Cu_2S + 3O_2 \longrightarrow 2Cu_2O + 2SO_2$

$Cu_2S + 2Cu_2O \longrightarrow 6Cu + SO_2$

Lead $2PbS + 3O_2 \longrightarrow 2PbO + 2SO_2$
(Galena)

$PbS + 2PbO \longrightarrow 2Pb + 2SO_2$

➤ **Reduction by carbon (smelting).**

The oxides of less electropositive metals like Pb, Zn , Fe. Sn , Cu etc. are reduced by strongly heating them with coal or coke. Reduction of oxide with carbon at high temperature is known as **smelting.**

$Fe_2O_3 + 3C \xrightarrow{\Delta} 2Fe + 3CO_2$

$Fe_2O_3 + 3CO \xrightarrow{\Delta} 2Fe + 3CO_2$

$PbO + C \xrightarrow{\Delta} Pb + CO$

$PbO + CO \xrightarrow{\Delta} Pb + CO_2$

➤ **Reduction by Aluminium (Aluminothemic reduction).**

Certain oxides like Fe_2O_3, Cr_2O_3, Mn_3O_4, etc. are not satisfactorily reduced by carbon. In such cases aluminium is used as a reducing agent. A mixture of metallic oxide and Aluminium powder is known as thermite. This process is used for those metals which have very high m.p and are to be extracted from their oxides.

$\underbrace{Cr_2O_3 + 2Al}_{\text{Thermite}} \longrightarrow Al_2O_3 + 2Cr + Heat$

$3Mn_3O_4 + 8Al \longrightarrow 4Al_2O_3 + 9Mn + Heat$

$Fe_2O_3 + 2Al \longrightarrow Al_2O_3 + 2Fe$

➤ **Electrolytic Reduction :**

Highly electropositive (active) metals like Na, K, Ca, Mg, A1, etc. are extracted by the electrolysis of their oxides, hydroxides or chlorides in fused state. The metal is liberated at the cathode. Sodium is obtained by the electrolysis of fused sodium chloride.

On fusion : $NaCl_{(s)} \rightleftharpoons Na^+ + Cl^-$

On electrolysis :

At cathod. $Na^+ + e^- \longrightarrow Na$

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

$Cl + Cl \longrightarrow Cl_{2(g)}$

➤ Aluminium metal can be extracted by the electrolysis of molten aluminium oxide, Al_2O_3.

$Al^{3+} + 3e \longrightarrow Al$

➤ Magnesium metal can also be obtained by the electrolysis of molten magnesium chloride, i.e.

$MgCl_2 \xrightarrow{\text{fused}} Mg^{2+} + 2Cl^-$

(at anode) $2Cl^- \longrightarrow Cl_2 + 2e^-$

(at cathode) $Mg^{2+} + 2e^- \longrightarrow Mg$

The net over all reaction may be written as,

$MgCl_2 \xrightarrow{\text{electrolysis}} Mg + Cl_2 \uparrow$

➤ **Some specific method :**

Silver and gold are obtained by treat the ore with a solution of sodium cyanide-which produces **sodium argentocyanide** (in case of silver) and **sodium aurocyanide** (in case of gold). On adding zinc dust to the solution, silver or gold get precipitated out i.e.

$2Na[Ag(CN)_2] + Zn \longrightarrow Na_2[Zn(CN)_4]\ Ag \downarrow$

$2Na[Au(CN)_2] + Zn \longrightarrow Na_2[Zn(CN)_4]Au \downarrow$

➤ **Electrolytic Reduction of Alumina (Hall's process)**

Aliminium is obtained from alumina (purified bauxite) by electrolytic reduction method.

Alumina does not conduct electricity in the solid state. It melts at very high (2348 K) temperature. Therefore, alumina is dissolved in molten cryolite (Na_3AlF_6) containing a small quantity of fluorspar (CaF_2).

Cryolite (Na_3AlF_6) is added to alumina to

* Lower the melting point of alumina

* Make the electrolyte a good conductor of electricity.

The following reactions take place during the electrolysis of alumina

(at cathode) $2\ Al^{3+} + 6e^- \xrightarrow{\text{reduction}} 2\ Al(\ell)$

(at anode) $3O^{2-} \xrightarrow{\text{oxidation}} \frac{3}{2}\ O_2(g) + 6e^-$

❑ **Refining or purification**

The metal obtained from the ore is not pure. It contains various impurities (silicon, phosphorous, metal oxides) The process of removing these impurities is called Refining. Different methods of Refining :-

➤ **Liquation :** This process is used when the metal is readily fusible(having low melting point) but not the impurities. Example Pb, Sn

➤ **Cupellation :** This method is used to purify noble metals like silver and gold, containing lead as an impurity. On heating in a current of air, the metal (silver or gold) melts, most of the lead volatilizes off as lead monoxide (**litharge**) and noble is left behind.

$2Pb + O_2 \longrightarrow 2PbO$

- **Distillation :** The most volatile metals such as mercury and zinc are purified by distillation method.
- **Electrolytic refining :**

Highly electropositive metals like Al, Cu, Ag, Au, Zn, Sn, Pb, Cr and Ni are refined by this method. The impure metal is made the anode of an electrolytic cell, while the cathode is a thin plate of the pure metal. A solution of a soluble salt of the metal is used as the electrolyte.

On passing the electric current, pure metal from the anode dissolves and is deposited on the cathode. The soluble impurities go into solution while the insoluble impurities settle down below the anode as **anode mud.**

6. Corrosion & Rusting Iron

❑ Corrosion

The surface of many metals is easily attacked by air and water. They react with air or water present in the environment and form undesirable compound on their surfaces. These undersirable compounds are generally oxides. This process is called corrosion.

- When iron is exposed to moisture for a long time, its surface acquires a brown flaky substance called rust.
- Copper reacts with moist carbon dioxide in the air and slavly loses its shiny brown surface and acquires a green coating of basic copper carbonate in moist air.

The corrosion causes damage to buildings, bridges, ships and many other articles especially made of iron.

The necessary conditions for the corrosion are

1. Presence of oxygen / air
2. Presence of moisture or water vapour

- **Prevention of corrosion :** By surface coating.

(a) It can be prevented by coating oil, grease or varnish on the surface

(b) By coating a thin layer of any other metal which does not corrode. Ex. Iron surface can be protected by depositing a thin layer of zinc, nickel or chromium on it.

❑ Rusting of Iron

Rusting is a process in which iron like bucket, almirah, window panes, etc., kept exposed to moist air get covered with a brown layer of a mixture of ferric oxide and ferric hydroxide known as rust.

$$4Fe + 3O_2 + 3H_2O \longrightarrow \underbrace{Fe_2O_3 + 2Fe(OH)_3}_{\text{Rust}}$$

Iron Air water

Thus, the slow conversion of iron into a mixture of Fe_2O_3 and $Fe(OH)_3$ by atmospheric oxygen in the presence of moisture is known as **rusting.** the following conditions are necessary for rusting:

- Presence of oxygen or air
- Presence of water or moisture
- Presence of acids or dissolved salts catalyzers

❑ Prevention of Rusting

- Rusting of iron can be prevented by covering its surface with paint, grease, enamel and lacquers, that does not allow air and moisture to come in contact with it and no rusting occurs.

This is known as **barrier protection.**

- Rusting of iron can be prevented by galvanization. The process of depositing a thin layer of zinc metal on iron articles is called **galvanization.**

- Rusting can be prevented by coating the surface of iron object with chromium, tin, nickel or aluminium. These metals resists corrosion.
- Rusting can also be prevented by converting it into an alloy with chromium and nickel. This alloy is called **stainless steel.**

7. Non-Metals

There are only 22 nonmetallic elements, of which 11 are gases, one is a liquid and the rest 10 are solids. Nonmetals are placed on the right-hand side of the perodic table.

❑ Uses of non-metals

- Liquid hydrogen is used as a rocket fuel.
- Due to its inertness, nitrogen is used to prepare food materials.
- Sulphur is used in the vulcanisation of rubber.

8. Physical & Chemical properties of Non-metals

❑ Physical properties

- Nonmetals are usually brittle and cannot be used to make sheets or wires.
- Nonmetals usually do not have lustre and cannot be polished. Only graphite and iodine are lustrous.
- They are generally bad conductors of heat and electricity. The only exception is graphite, which is a good conductor of electricity.
- Nonmetals can be easily broken, i.e., the tensile strength of nonmetals is low.
- Nonmetals have low melting and boiling points. The only exception is graphite, whose melting point is very high.
- Nonmetals are generally light and have low densities.
- All nonmetals, except hydrogen, are electronegative. They have the tendency to accept electrons and become negatively charged ions.
- Nonmetals shows allotropy- The property of an element to exist in more than one structural form is called allotropy. Ex. allotropic forms of carbon- diamond, graphite, coal, coke, lamp black etc.

❑ Chemical properties

- **Reaction with oxygen**

Nonmetals combine with oxygen to form covalent oxides.

$C_{(s)} + O_{2\,(g)} \longrightarrow CO_{2\,(g)}$

$CO_{2\,(g)} + H_2O_{(l)} \longrightarrow H_2CO_{3\,(aq)}$

$S_{(s)} + O_{2\,(g)} \longrightarrow SO_{2\,(g)}$

$SO_{2\,(g)} + H_2O_{(l)} \longrightarrow H_2SO_{3\,(aq)}$

- **Reaction with water or steam**

All non-metals do not react with water or steam to evolve hydrogen, because, non-metals cannot give electrons to reduce hydrogen ions of water into hydrogen gas.

Non-metals + $H_2O \longrightarrow$ No reaction

- **Reaction with acids**

Non-metals do not displace hydrogen from dilute acids, e.g.

$S + H_2SO_4$ (dil.) $\longrightarrow$ No reaction.

C + HCl (dil.) $\longrightarrow$ No reaction.

Since, non-metals have a tendency to **accept electrons,** they cannot give electrons to hydrogen

ions of the acid to reduce them to hydrogen gas. However, non-metals may be affected by concentrated acids.

➤ **Reaction with chlorine**

Nonmetals react with chlorine to form covalent chlorides.

$P_{4\ (s)} + 6Cl_{2\ (g)} \longrightarrow 4PCl_{3\ (g)}$

$H_{2\ (g)} + Cl_{2\ (g)} \longrightarrow 2HCl_{\ (g)}$

➤ **Reaction with hydrogen**

Nonmetals combine with hydrogen to form covalent hydrides.

$H_{2\ (g)} + S_{\ (s)} \longrightarrow H_2S_{\ (g)}$

$N_{2\ (g)} + 3H_{2\ (g)} \longrightarrow 2NH_{3\ (g)}$

9. Distinctions between metals and Nonmetals

❑ **Based on physical properties**

	Metals	Nonmetals
1	Metals have lustre called metallic lustre.	Nonmetals do not possess any metallic lustre. *Exceptions* Iodine and graphite
2	Metals are generally electropositive.	Nonmetals are generally electronegative. Exception Hydrogen
3	Metals are generally good conductors of heat and electricity.	Nonmetals are generally bad conductors of heat and electricity. ***Exception*** Graphite
4	Metals are usually solids at ordinary temperature. ***Exception*** Mercury	Nonmetals are gases or solids at ordianary ***Exception*** Bromine (liquid)
5	Metals are malleable and ductile, have high density, and reflect light. ***Exceptions*** Sodium and potassium are metals but their densities are less than that of water	Nonmetals are not malleable and ductile, have low density, and do not reflect light. ***Exception*** Plastic sulphur is ductile.

❑ Distinctions based on chemical prorerties

	Metals	Nonmetals
1	Metals form positive ions. Ex. Na^{+}, K^{+}, Ca^{2+}, Mg^{2+}, Fe^{2+}, etc	Nonmetals form negative ions. Ex. Cl^{-}, S^{2-}, N^{3-}, etc
2	Oxides of metals are basic in nature	Oxides of nonmentals are acidic in nature.
3	Metals dissolve in dilute acids to produce hydrogen gas. $Zn + H_2SO_4 \longrightarrow ZnSO_4 + H_2$	Nonmetals generally do not dissolve in dilute acids
4	Metals in general do not combine with hydrogen	Nonmetals combine with hydrogen to form stable compounds
5	Metals are reducing agents	Normals are oxidizing agents, except carbon which is a reducing agents

EXERCISE - 1

A. VERY SHORT ANSWER TYPE QUESTIONS

Q.1 Name two metals and two nonmetals.

Q.2 Name the metal which is the best conductor of electricity.

Q.3 Which metal is used to coat iron objects in galvanizing ?

Q.4 Name two metals that can be easily cut with a knife.

Q.5 Name the metal which exists in the liquid state.

Q.6 Name the lightest metal.

Q.7 Name two important magnetic ores.

Q.8 Name two important reducing agent used in metallurgy.

Q.9 Name the method of concentration of sulphide ores.

Q.10 Name the substance which reacts with gangue to form fusible material.

Q.11 Name the process which converts hydrated alumina to anhydrous alumina.

Q.12 Which metal is added to gold to make it hard.

Q.13 Write the chemical composition of magnetite.

B. SHORT ANSWER TYPE QUESTIONS

Q.14 Define metallurgy.

Q.15 Why Al_2O_3 cannot be reduced to Al by using carbon?

Q.16 Differentiate between calcination and roasting.

Q.17 Give two important methods to prevent rusting of iron.

C. LONG ANSWER TYPE QUESTIONS

Q.18 Differentiate between physical and chemical properties of metals and non-metals.

Q.19 What is corrosion of metals ? Name one metal which does not corrode and the ore which corrodes on being kept in the atmosphere.

Q.20 What is meant by rusting of iron ? What are necessary conditions for rusting of iron ? How can rusting be prevented ?

Q.21 What is the activity series of metals ? Rearrange the following metals in an increasing order of reactivity: Aluminium, Zinc, Mercury.

D. FILL IN THE BLANKS

Q.22 Copper and iron show variable.....

Q.23 Calcination of aluminium hydroxide produces pure.....

Q.24 Calcination is the process of heating the ore strongly in the ..... of air.

Q.25 The undesired impurities present in the ores are called .....

Q.26 ..... ore is concentrated by froth floatation method.

E. TRUE OR FALSE

Q.27 Magnesium is more reactive than calcium.

Q.28 Copper combines with dilute hydrochloric acid.

Q.29 Aluminium is the more metallic than sodium.

Q.30 Aluminium is the most abundant metal in the earth's crust.

Q.31 Argentite is an oxide ore of silver.

F. SINGLE CHOICE QUESTIONS

Q.32 The best electrical conductor is-

(A) gold (B) copper
(C) silver (D) aluminium

Q.33 In the process of heating, an ore in the presence of excess of air, below its melting point is called-

(A) roasting (B) calcination
(C) smelting (D) sublimation

Q.34 Impurities present in the ore are known as-

(A) gangue (B) slag
(C) ore (D) flux

Q.35 The process of heating an ore in the absence of air and below its melting point is called.

(A) Liquation (B) calcination
(C) smelting (D) roasting

Q.36 Iron is galvanized by coating it with-

(A) nickel (B) chromium
(C) zinc (D) copper

Q.37 Electricity is conducted by the non-metal-

(A) graphite (B) iodine
(C) sulphur (D) silicon

Q.38 Which of the following metals does not exist in free state ?

(A) Iron (B) Copper
(C) Gold (D) Aluminium

Q.39 The process of protecting iron by coating it with zinc is known as-

(A) smelting (B) galvanization
(C) rusting (D) corrosion

Q.40 Leaching is a process of-

(A) reduction (B) concentration

(C) refining (D) oxidation

Q.41 The commnest method of extraction of metals from oxide ores involves-

(A) Reduction with carbon

(B) Reduction with aluminium

(C) Reduction with hydrogen

(D) Electrolytic method

Q.42 Smelting is the reduction of oxide to metal by:

(A) C

(B) AI

(C) H

(D) electric current

Q.43 The process of converting hydrated alumina into anhydrous alumina is called:

(A) roasting (B) smelting

(C) dressing (D) calcination.

G. MULTIPLE CHOICE QUESTIONS

Q.44 Which of the following are methods of concentration of metals ?

(A) Gravity separation

(B) Froth flotation method

(C) Electromagnetic separation

(D) Smelting

Q.45 Roasting is carried out to-

(A) convert sulphide to oxide and sulphate

(B) remove water of hydration

(C) melt the ore

(D) remove arsenic and sulphur impurities

Q.46 Impurities present in ore are called-

(A) flux (B) slag

(C) matrix (D) gangue

Q.47 Which of the following processes make the ore porous ?

(A) roasting (B) calcination

(C) reduction (D) distillation

Q.48 Metals which can be extracted by smelting process are:

(A) Pb (B) Fe

(C) Zn (D) Al

Q.49 Metals which occur in native state in nature-

(A) are very reactive (B) are not reactive

(C) are noble (D) have low density

H. MATCH THE COLUMN TYPE QUESTIONS

Q.50

Column - I	**Column - II**
(A) MnO_2	(P) Cinnabar
(B) HgS	(Q) Copper Glance
(C) Ag_2S	(R) Pyrolusite
(D) Cu_2S	(S) Argentite

Q.51

Column -I	**Column -II**
(A) Self reduction	(P) Fe
(B) Carbon reducton	(Q) Cr
(C) Co reduction	(R) Zn
(D) Aluminium reduction	(S) Cu

Q.52

Column -I	**Column -II**
(A) Refining	(P) Concentration of ore
(B) Roasting	(Q) Heating in the absence of air
(C) Calcination	(R) Purification of the metal
(D) Froth floatation	(S) Heating in the presence of air

I. ASSERTION AND REASONING TYPE

(A) If both (A) and (R) are correct and (R) is the correct explanation for (A)

(B) If both (A) and (R) are correct but (R) is not the correct explanation for (A)

(C) If both (A) is correct, but (R) is incorrect

(D) If both (A) and (R) are incorrect

Q.53 **Assertion** → During calcination, the ore is heated well below its melting point in the limited supply of oxygen.

Reason → The process of calcination is carried out for sulphide ores.

Q.54 **Assertion** → Extraction of iron metal from iron oxide ore is carried out with coke.
Reason → The reaction $Fe_2O_{3(s)} \longrightarrow$

$$Fe_{(s)} + \frac{3}{2}O_{2(g)}$$

is a spontaneous process.

Q.55 **Assertion** → Froth- flotation process is used to concentrate sulphide ores
Reason → There is difference in the wettability
of different minerals.

EXERCISE - 2

A. SINGLE CHOICE QUESTIONS

Q.1 Which of the following cannot be reduced by carbon

(A) PbO (B) SnO_2

(C) ZnO (D) MgO

Q.2 Impurity of lead present in silver is removed by

(A) Cupellation (B) Electrolytic Refining

(C) Distillation (D) Liquation

Q.3 Which of the following can not be reduced by Aluminium ?

(A) Fe_2O_3 (B) Cr_2O_3

(C) MnO_2 (D) MgO

Q.4 A minerals is called an ore if-

(A) Metal present in mineral is precious

(B) Metal can be extracted from it

(C) Metal can be extracted profitably from it (D) Metal cannot be extracted from it

Q.5 Metallurgy is the process of-

(A) Concentrating the ore

(B) Roasting the ore

(C) Extracting the metal from the ore

(D) Adding carbon to the ore in blast furnace.

Q.6 The reaction $2ZnS + 3O_2 \rightarrow 2ZnO + 2SO_2$ in the metallurgical process is called.

(A) Calcination (B) Cupellation

(C) Smelting (D) Roasting

Q.7 The substance added in water in the froth floatation process is-

(A) Soap powder (B) Pine oil

(C) Coconut oil (D) None of these

Q.8 The role of calcination in metallurgical operations is-

(A) To remove moisture

(B) To decompose carbonate

(C) To drive off organic matter (D) To achieve all the above

Q.9 Smelting is termed to the process in which-

(A) The ore is heated in the absence of air (B) Ore is cold

(C) The ore is heated in the presence of air (D) Ore is heated

Q.10 In alumino- thermite process, aluminium is used as-

(A) Oxidising agent (B) Ore

(C) Reducing agent (D) Solder

Q.11 Alumina-thermic process is used for the extraction of metals, whose oxides are-

(A) Fusible

(B) Not easily reduced by carbon

(C) Not easily reduced by hydrogen (D) Strongly basic

Q.12 Purpose of smelting of an ore is-

(A) To oxidise it

(B) To reduce it

(C) To remove vaporisable impurities (D) To obtain an alloy

Q.13 All ores are minerals, while all minerals are not ores because-

(A) The metal can't be extracted economically from all the minerals

(B) Minerals are complex compounds

(C) The minerals are obtained from mines (D) All of these are correct

Q.14 The molecular formula of cryolite is-

(A) Fe_3O_4 (B) Na_3AlF_6

(C) $Na_2Al_2O_3$ (D) All of these

B. MULTIPLE CHOICE QUESTIONS

Q.15 Auto reduction process is used in extraction of

(A) Cu (B) Hg

(C) AI (D) Fe

Q.16 Metals found in free state as well as combined state are-

(A) Au (B) Ag

(C) Mg (D) Zn

Q.17 Metals which are extracted by smelting process-

(A) Pb (B) Fe

(C) Zn (D) Mg

Q.18 Pick up the correct statements-

(A) All minerals are ores

(B) A mineral cannot be ore

(C) All ores are minerals

(D) The minerals from which metals are extracted profitably are called ores

C. PASSAGE BASED QUESTIONS

Passage 1

Calcination is a process in which ore is heated, generally in the absence of air, to expel water from a hydrated oxide or carbon dioxide from a carbonate at temperature below their melting points. Roasting is a wider term used to denote the process in which ore (usually sulphide) alone or mixed with other materials is heated, usually in the presence of air, at temperatures below their melting points. Calcination and roasting are carried out in various types of furnaces, most important of which is reverberatory furnace.

The calcined or roasted ore is reduced to the metallic state by reduction.

On the basis above work-up answer the following :

19. What happens when melachite, $Cu(OH)_2 . CuCO_3$ is heated in a furnace ?

(i) Curpic oxide is formed

(ii) Cuprous oxide is formed

(iii) Carbon dioxide is formed

(iv) it is dehydrated without decomposition

(A) (i) and (iii)

(B) (ii) and (iii)

(C) (i) and (ii)

(D) All the four are correct

20. What happens when zinc blende (ZnS) is heated in a furnace ?

(A) Volatile impurities are removed

(B) Zinc oxide is formed

(C) Zinc sulphate is formed

(D) All the three.

21. Which of the following is not an example of roasting?

(A) $Ag_2S + 2NaCl \longrightarrow 2NaCl + Na_2S$

(B) $AgCl + 2Hg \longrightarrow Ag - Hg + HgCl$

(C) $CuS + 2O_2 \longrightarrow CuSO_4$

(D) $PbO + CO \longrightarrow Pb + CO_2$

Passage 2

The calcined or roasted ore is reduced to metallic state in the following ways.

Oxide of less electropositive metals are reduced either by heating with coke (smelting) or with oxygen, while oxide of active metals are reduced by electrolysis.

On the basis of above work-up answer the following:

22. Which of the following is an example of roasting as well as reduction ?

(A) $HgS + O_2 \longrightarrow Hg + SO_2$

(B) $2Cu_2S + 3O_2 \longrightarrow 2Cu_2O + 2SO_2$

(C) $Cu_2S + 2Cu_2O \longrightarrow 6Cu + SO_2$

(D) All the three

23. Which of the following oxide can't be reduced by carbon ?

(A) Fe_2O_3 (B) PbO

(C) SnO_2 (D) Al_2O_3

24. Which of the following is an example of smelting ?

(A) $ZnO + C \xrightarrow{heat} Zn + CO_2$

(B) $ZnS + 2O_2 \xrightarrow{heat} ZnSO_4$

(C) $HgS + O_2 \xrightarrow{heat} Hg + SO_2$

(D) $Cu_2S + 2Cu_2O \xrightarrow{heat} 6Cu + SO_2$

ANSWER KEY

EXERCISE-1

A. Very short type answer

1. Metals- Na, K
Non-metals- C, N

2. Silver

3. Zinc

4. Sodium and potassium

5. Mercury

6. Lithium

7. MnO_2 (pyrolusite) and Fe_3O_4 (magnetic)

8. Carbon and Carbon monoxide

9. Froth floatation

10. Flux

11. Calcination

12. Copper

13. Fe_3O_4

D. Fill in the blanks

22. Valency

23. Al_2O_3

24. Absence

25. Matrix

26. Sulphide

E. True or False

27. False **28.** False **29.** False

30. True **31.** False

F. Single Choice Question

32. (C) **33.** (C) **34.** (A) **35.** (B) **36.** (C) **37.** (A)

38. (D) **39.** (B) **40.** (B) **41.** (A) **42.** (A) **43.** (D)

G. Multiple choice Question

44. A, B, C **45.** A, C, D **46.** C, D

47. A, B **48.** A, B, C **49.** B, C

H. Match the column type question

50. A → R B → PC → S D → Q

51. A → S B → R C → P D → Q

52. A → R B → SC → Q D → P

I. Assertion & Reasoning Type

53. C **54.** D **55.** A

EXERCISE-2

Q.No	1	2	3	4	5	6	7	8	9	10	11	12
Ans.	D	C	D	C	C	D	B	D	D	C	B	B
Q.No	13	14	15	16	17	18	19	20	21	22	23	24
Ans.	A	B	A,B	A,B	A,B,C	C,D	A	D	D	A	D	A