Materials : Metals And Non-Metals 4

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INTRODUCTION

Various known elements can be broadly classified into two categories on the basis of their general characteristics. These are metals and non-metal. Metals are hard, solid, ductile, possess lustre and are good conductors of heat and electricity. Non-metals on the other hand are non lustrous, brittle and are poor conductors of heat and electricity. There is yet another category of elements which show some characteristics of metals and of non-metals both. Such element are called metalloids. Boron (B), Silicon (Si), Arsenic (As) and Antimony (Sb) etc. are examples of metalloids.

Metals

Occurrence of Metals

In nature, many metals occur in the complex state as minerals. All rocks contain some metallic minerals. However, often the amount of metal present in the rock is so little that mine it is too expensive to mine it. There rocks and extract the metal from them. If the amount of metal is more, it is profitable to mine the rocks and extract the metal.

Such rocks are called ores.

In ores, the useful metallic mineral is mixed with other minerals which are not of so much use.

These minerals, present as impurities are called gangue.

Some metals, such as silver, platinum and gold are not very reactive. They occur in a free state in nature. Their ores contain particles of metals mixed with large quantities of impurities.

Rock salt

Gold

Bauxite

They are known as noble metals.

The ores of very reactive metals, such as sodium or calcium, contain chlorides or carbonates of the metals, for example rock salt (NaCl), dolomite ($CaCO_3.MgCO_3$).

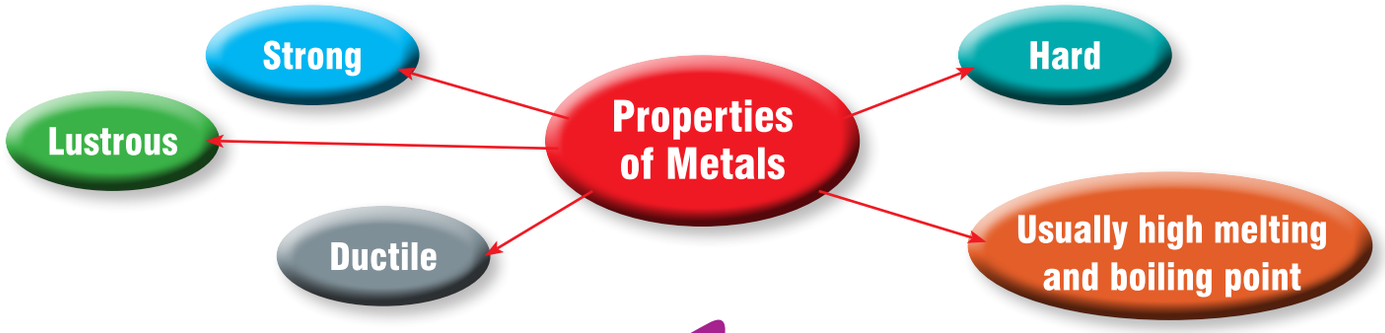
The ores of other metals such as aluminium, iron, zinc or copper, contain mostly oxides or sulphides, for example, bauxide (Al_2O_3), iron pyrites (FeS_2), haematite (Fe_2O_3), copper glance (CuS) and zinc blende (Zns)

The series of processes carried out to extract pure metals from their ores is called metallurgy. The various operations are concentration, reduction and refining of ore.

PROPERTIES OF METALS

Physical Properties

1. Metals are solid at room temperature except mercury, which is liquid at room temperature.
2. They are generally hard and strong with few exceptions such as sodium and potassium, which are soft. It can be like a butter.
3. They have characteristic metallic lustre (shine) specially when freshly cut.
4. They have high melting and boiling points with few exceptions such as sodium, potassium and mercury.
5. They are good conductors of heat and electricity. Silver and copper are the best conductors of electricity followed by gold and aluminium.
6. Metals are sonorous. They produce a ringing sound when struck.
7. Most metals have high tensile strength. They can take heavy loads without breaking.
8. They are malleable. Metals with exceptions like sodium and potassium, can be beaten into thin sheets and foils.
9. They are ductile. Metals with exceptions like sodium and potassium, can be drawn into wires.
10. They have high densities. Metals with exceptions like sodium and potassium, have high densities. Sodium and potassium, have low densities and float on water.



CHEMICAL PROPERTIES

Reaction with Oxygen (O_2)

Most metals react with oxygen to form metal oxides. When metal objects are exposed to air, a dull layer of oxide is formed on the surface and the metal loses its lusture.

Some metals do not react with oxygen easily. Sodium and potassium react with oxygen vigorously at room temperature.

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

To prevent this oxidation, sodium and potassium are stored in kerosene.

Magnesium reacts with oxygen only upon burning in it. It gives a bright dazzling flame and forms a white powder a magnesium oxide.

$$2Mg + O_2 \longrightarrow 2MgO$$

Copper and iron react with oxygen only upon heating in oxygen to a very high temperature.

$$2Cu + O_2 \longrightarrow 2CuO$$

Reacton with Water (H_2O)

Metal react with water to form oxides or hydroxides along with hydrogen. Different metal react at different temperatures. Sodium, potassium and calcium react vigorously with cold water to form hydroxides.

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

Magnesium reacts with steam or hot water to form magnesium oxide.

$$Mg + H_2O \longrightarrow MgO + H_2$$

Aluminium too forms an oxide but this oxide makes a protective covering over the metal and prevents any further reaction.

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

Zinc can react only with steam.

$$Zn + H_2O \longrightarrow ZnO + H_2$$

Iron can react with steam when heated strongly.

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

Reaction with Dilute Acids

Copper, gold, silver and platinum do not react with water or steam.

Metals react with dilute acids to form their salts and liberate hydrogen gas. The reaction with reactive metals like sodium, potassium and calcium is violent. Magnesium, aluminium and zinc do not react violently.

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

$$Mg + H_2SO_4 \longrightarrow MgSO_4 + H_2$$

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

Rusting of Iron

Iron (Fe) reacts with oxygen in the presence of water or moisture (water vapour) to form iron oxide. Iron oxide is commonly known as rust. Iron objects lying in open places accumulate rust on the surface. Iron oxide is a metal oxide.

Iron + Oxygen + Water $\longrightarrow$ Iron Oxide

Corrosion

Some metals react with oxygen, moisture and pollutants in the atmosphere and form compounds on their surface. This is known as corrosion. Rusting of iron is a form of corrosion. Due to corrosion, the metal loses its shine. In the long run, corrosion damages the metal. Corrosion is a serious problem. It breaks up the surface of the metal and gradually makes it weak. Gold (Au) and platinum (Pt) do not corrode.

Metals React with Bases

Most metals do not react with alkalies. A base such as sodium hydroxide (NaOH) that readily dissolves in water is known as alkali. For example, iron and copper do not react with alkalis. Aluminium is an exception. It reacts with sodium hydroxide (NaOH) and potassium hydroxide (KOH) to form sodium and potassium aluminate. Hydrogen gas is released during this reaction.

Aluminium + Sodium hydroxide + water $\longrightarrow$ Sodium aluminate + Hydrogen

DISPLACEMENT REACTIONS

Chemical reactions where one element displaces another because it is more reactive, is called a displacement reaction. For knowning which element is more reactive than the other, one has to consider the reactivity of the elements. Displacement reactions take place when one metallic salt solution reacts with another metal. If the second metal is more reactive, then it replaces the first metal from its salt.

Displacement of a Metal by other Metals

A more active metal displaces a less active metal from the latter's salt solution.

For example :

$$Mg + CuSO_4 \longrightarrow MgSO_4 + Cu$$

$$Zn + CuSO_4 \longrightarrow ZnSO_4 + Cu$$

$$Fe + CuSO_4 \longrightarrow FeSO_4 + Cu$$

Reactivity Series of Metals

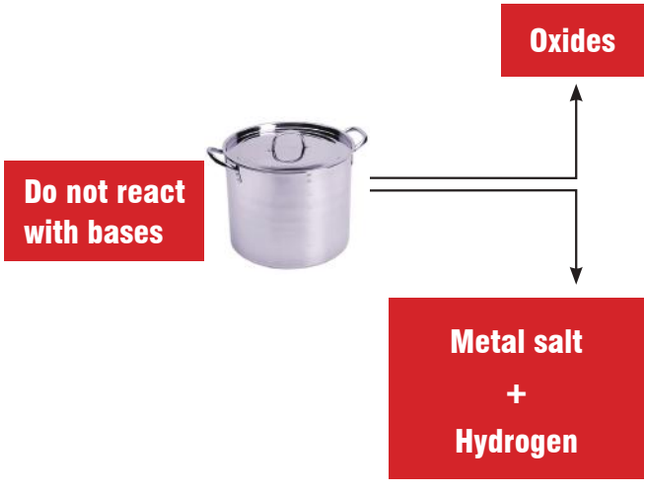
Potassium (K) and Sodium (Na) being highly reactive with oxygen and water are stored in kerosene or paraffin wax.

Sodium and potassium react with water and produce Hydrogen gas (H_2) and also generate enough heat which ignites the hydrogen.

Some Common Methods to Prevent Corrosion

Painting : Surfaces of iron can be coated with paint or with plastics. This keeps air and water away from the metal surface. However, rusting takes place quickly on an iron surface if the paint is even slightly damaged. Therefore, if paint peels off, the portion should be painted again.

Coating with oil or grease : Objects such as a bicycle chain, door hinges and car engines which cannot be painted are protected by coating with a layer of oil or grease.



Some metals are resistant to oxygen : Iron is coated with metals like chromium (Cr), tin (Sn) or nickel (Ni) which are more resistant to oxygen or corrosion.

Most metals are reactive that is why they are not found as free elements. Metals like gold (Au) and platinum (Pt) do not react with other substances easily.

They are found as pure elements. Most metals occur below the earth's surface as minerals.

A mineral is a naturally occurring compound which is a combination of a particular metal with some other elements. Minerals are found among rocks, inside the earth's crust. Such rocks are called mineral ores. Ores are mined, crushed and metals are extracted from them by various chemical processes. These processes form a separate branch of study called metallurgy. Metallurgy deals with extraction and refining of pure metals from ores.


Iron pillar, Delhi

Centuries ago, India was far ahead of the others in metallurgy. Indians excelled in extracting and using metals for various purposes. The zinc ore was mined and the metal was first put to use by metal experts in Rajasthan.

The famous Damascus swords are believed to be fabricated from extremely high quality steel in Andhra Pradesh around 400 B.C. The Iron Pillar at Delhi is known for its amazing corrosion resistance property despite exposure to rain for more than sixteen hundred years.

Some Important Metals

Iron ore

Iron (Fe) : It is a greyish white metal. Its surface may appear brown due to rust. It is a reactive metal and is not found in free state in nature. In India, iron is mostly mined from hematite ores.

Iron is used for making stainless steel, which has wide applications in homes and industries. It is also used in the construction of bridges and houses. Iron is also used for making magnets.

Copper pipes

Copper (Cu) : Chalcopyrite is a common copper ore. Copper is a reddish-brown metal. Its surface may appear dull due to the formation of an oxide layer. It does not react with water. Hence it is used for making water pipes, industrial boilers used in heating water and utensils. Copper is used for making coins and electric wires.

Aluminium utensils

Aluminium (Al) : It is a whitish metal. Aluminium is the third most abundant element on the earth after oxygen and silicon. It is not found in the free state as it is reactive metal. Aluminium is obtained from its ore known as bauxite. Bauxite is used in making cement. Due to its high tensile strength aluminium is used in ship building, aeroplanes, automobile and utensils.

Importance of Metals in Human Body

Certain metals are essential to living beings and are present in minute quantities in them. The human body requires the following metals.

- Sodium (Na) and potassium (K) help in transmitting electrical signals to and from the brain through nerves.
- Iron (Fe) is a component of haemoglobin in the red blood cells (RBCs)
- Calcium (Ca) salts are needed in the formation of bones and teeth.
- Other metals manganese (Mn), copper (Cu) magnesium (Mg) and zinc (Zn) are needed in different life processes.

NON–METALS

Some elements are non metals. For example carbon (C), sulphur (S), hydrogen (H), phosphorus (P) and bromine (Br) are non-metals.

Occurrence of Non-Metals

Hydrogen : Hydrogen is the most abundant element in the universe. It is the chief element that makes up the sun and other stars.

On the earth, hydrogen mainly occurs in combined form as a constituent of water, petroleum, natural gas, coal, clay and all animals and plant matter.

Nitrogen : Nitrogen mainly occurs in the free state in the atmosphere. About 78% by mass of air is nitrogen. In the combined state, it is a constituent of minerals such as chile salt petre ($NaNo_3$) and nitre (No_3).

Oxygen : Oxygen is the most abundant element on the earth. It occurs in the free state in the atmosphere forming about 23% by mass. It is also present in the combined state in the earth's crust as oxides, carbonates and silicates of metals.

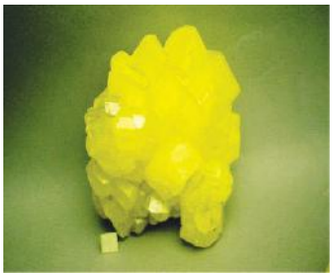
Carbon : In the free state carbon occurs as graphite diamond and coal. Diamond and graphite are pure forms of carbon. Coal contains 60-90% of carbon. In the combined state, it occurs in the atmosphere as carbon dioxide. In the earth's crust, it occurs as carbonates of metals and as fossil fuels. Carbon is the central element of all living matter.

Silicon : Silicon is the second most abundant element in the earth's crust. It does not occur in the free state. In the combined state, it occurs as silica (SiO_2) and silicates. The most common form of silica is sand.

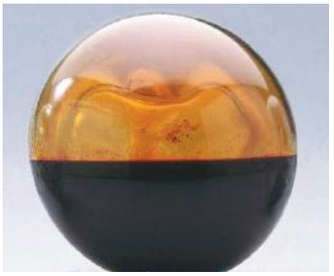
Sulphur : Sulphur occurs in the free state in the earth's crust. In the combined state, it occurs in rocks as metal sulphates and sulphides. It is also present as hydrogen sulphide (H_2S) which is present in petroleum and natural gas.

Some non-metals occur in a free state in nature. Noble gases, such as helium, neon, argon, krypton,xenon and radon occur in elemental form in air. Extraction of non-metals from their sources is equally important. Non-metals so obtained help in the production of many useful chemicals.

Physical Properties



Sulphar, a non-metal (solid)



Bromine, a non-metal (liquid)

Non-metals can be in the form of solids, liquids or gases at room temperature. Some non-metals like carbon, sulphur and phosphorus are solid at room temperature. Bromine is a liquid at room temperature. Most of the non-metals like Hydrogen (H), Nitrogen (N), Oxygen (O) and Chlorine (Cl) are gaseous at room temperature. Helium (He), Neon (Ne), Argon (Ar), Krypton (Kr), Xenon (Xe) and Radon (Ra) are called noble gases because they are mostly non reactive.

Solid non-metals are soft materials. Diamond, a form of carbon is an exception. It is the hardest substance found in nature.

Brittleness

Solid non-metals cannot be hammered or beaten into thin sheets. They break into pieces when hammered. Brittleness is a characteristic property of non-metals.

Bad Conductors of Heat and Electricity

Other than graphite, which is a form of carbon, none of the other non-metals are good conductors of heat and electricity.

Non-Lustrous

Non-metals are generally in the form of powder or are gaseous. They cannot be polished. They do not have luster. Most of the powders are dull in colour. Diamond a form of carbon is an exception.

Density

Non-metals have low densities as compared to metals which have high densities.

Non-Sonorous

Non-metals do not make any characteristic sound when hit with an object.

Do You Know ?

Some elements do not fit in the category of metals or non-metals and are called metalloids, e.g., silicon, germanium, etc.

Low Melting and Boiling Points

All non-metals have low melting and boiling points. Graphite and diamond are exceptions. They have high melting points.

Chemical Properties of Non-Metals

Non-metals react with oxygen, but do not react with water or dilute acids.

REACTION WITH OXYGEN

Non-metals react with oxygen to form non-metallic oxides.

Non-metals + Oxygen $\longrightarrow$ Non-metallic oxides

Carbon reacts with oxygen to form carbon dioxide (CO_2).

Carbon + Oxygen $\longrightarrow$ Carbon dioxide

Sulphur reacts with oxygen and burns with a blue flame. It forms sulphur dioxide which is a colourless gas with pungent odour.

Sulphur + Oxygen $\longrightarrow$ Sulphur dioxide

Non- metals occur in the earth's crust mostly combine with metal elements. Oxides are most commonly found compounds, hence, oxygen is the most abundant of all non-metals within the earth's crust. The second most abundant non-metal element found on the earth and within its crust is silicon. Phosphorus and sulphur are also found in large quantities below the earth's surface.

Some Important Non-Metals

Silicon (Si)

Silicon is not found as a free element in nature. It is found mostly as sand or combined with some metal. Silicon is a grey, hard shiny solid. It is used for making electronic components like transistors, integrated circuits, microprocessors and chips used in computers.

Silicon when combined with carbon forms silicon carbide. It is the second most hard substance. It is used in the manufacture of cutting and grinding tools for industries. Quartz crystals oscillate at an extremely stable ratio. That is why quartz crystals are used in watches. Silicon dioxide is used for making glass, china dish and cement. It is also used for making waterproof cloth, insulation material and silicon alloys.

Phosphorus (P)

Phosphorus (P) is a non-metal and exists in many forms. Red phosphorus and yellow phosphorus are the two common forms of it.

It is not found as a free element in nature.

Phosphorus is used in the making of fertilizers. Red phosphorus is used to make matchstick heads. It is also used in fire works. Since phosphorus is poisonous it is used for preparing chemicals that kill domestic pests like rats.

Sulphur (S)

Sulphur (S) is a non-metal and exists in the earth's crust either as pure sulphur or as a metal-sulphide. Sulphur is a yellow crystalline solid. It is found as hydrogen sulphide gas, in petroleum gas and coal gas. Hydrogen sulphide has the pungent odour of onions. It is present in hair, eggs many proteins and wool. Sulphur is used to make sulphuric acid,

Matchstick heads, made from phosphorus

Pencil lead, made from graphite

Sulphur, a non-metal (solid)

which is used in the manufacture of many compounds such as detergents plastics and explosives. It is also used in the rubber industry to improve elasticity and strength or to harden rubber. This process is known as vulcanization. It was discovered by Charles good year in 1839. Sulphur is used in the manufacture of fire works, agriculture as pesticides and in artificial hair colours.

Non-Metals in the Human Body

Non-metals like carbon and phosphorus are important elements for living beings. Phosphorus is indispensable to all living organisms. It is present in bones. Compounds of phosphorus convert energy stored in food into energy required by the oils for performing various tasks. Phosphorus also forms an important part in the cells.

Alloys

An alloy is obtained by mixing two or more metals or a metal and a non-metal. For example, brass is an alloy. It is generally produced by heating 80% copper metal and 20% zinc metal. Some other common alloys are steel, bronze and duralium. In its simplest form, bronze is an alloy of copper and tin. Steel is made by mixing small amounts of carbon (C) with iron (Fe).

Mixing two or more metals can improve the physical properties of metals. An alloy has properties of a typical metal but differs from the properties of the metals it is made from. For example steel which is an alloy of iron is very different from iron metal. Alloys are generally harder and stronger and have lower melting points. Stainless steel is a highly malleable and strong substance which is rust proof. It is produced by mixing certain amount of nickel metal, chromium metal and carbon with iron.

Alloy	Constituent Elements	Properties	Uses
Duralium	Aluminium, copper, Traces of magnesium and manganese	Very strong, Corrosion-resistant, light weight	Aircraft engines, car engines, pressure cookers, and ships
Magnalium	Aluminium and Magnesium	Very hard and light weight	Instruments Automobile parts and screws
Steel	Iron and carbon	Hard	Railway lines, Bridges and buildings
Stainless Steel	Iron, carbon, Nickel and chromium	Shiny, strong and Corrosion resistant	Nuts and bolts, Tubes Decorative items such as vases.

Know the Keywords :

Ores : Minerals from which metals can be extracted on commercial scale.
Minerals : Naturally occurring compounds of metals in the earth.
Malleability : The ability of a metal to be beaten into sheets.
Ductility : The property by which metals can be drawn into wires.
Brittle : Materials which can be easily broken.

Point to Remember

- The series processes carried out to extract pure metals from their ores is called metallurgy.
- Most metals react with oxygen to form metal oxides.
- Some metals react with oxygen, moisture and pollutants in the atmosphere and form compounds on their surface. This is known as corrosion.
- A base such as sodium hydroxide (NaOH) that readily dissolves in water is known as alkali.

EXERCISE TIME

A. Answer the following questions :

1. List out at least four physical properties of metals.
2. How do metals occur in nature ?
3. What is coating ? Why it is used ?
4. How is rust formed ?
5. What is a displacement reaction ? Explain with an example.
6. Mention any two ways of preventing iron from rusting.

B. Complete the given equations :

1. Iron + Moisture + Oxygen ⟶ ☐
2. Copper + Copper oxide ⟶ ☐
3. Sodium + Oxygen ⟶ ☐
4. Non Metal + Oxygen ⟶ ☐
5. Metal + Oxygen ⟶ ☐

C. Write 'T' for true and 'F' for false statement :

1. Rusting is a form of corrosion. ◯
2. Metals are generally bad conductors of heat and electricity. ◯
3. Sodium can be stored under water. ◯
4. Sulphur is a metal. ◯
5. Iron is more reactive than sodium. ◯
6. Non-metals react with oxygen to form metallic oxides. ◯

D. Tick (✓) the correct option :

1. The ability of a metal to be drawn into a wire is a measure of its :
   (i) ductility ◯ (ii) malleability ◯ (iii) brittleness ◯
2. Brass is an alloy of copper and :
   (i) zinc ◯ (ii) aluminium ◯ (iii) iron ◯
3. At room temperature the metal mercury is a :
   (i) liquid ◯ (ii) solid ◯ (iii) gas ◯
4. Rust is formed when iron combines with :
   (i) hydrogen ◯ (ii) oxygen ◯ (iii) none of these ◯
5. If zinc replaces a metal from its salt, the metal could be :
   (i) lead ◯ (ii) sodium ◯ (iii) none of these ◯

Creative Work

- **Collect objects made up of metals and non metals. Write their names and components. Hence, make a table of the same in your exercise book.**