Metals and Non-metals

Physical Properties of Metals and Non-Metals

Do you know how many elements are there in our periodic table?

There are 118 elements in the modern periodic table. These elements can be broadly classified as metals and non-metals depending on their properties.

Elements that lose electrons to form compounds are called **metals** whereas elements that gain electrons to form compounds are called **non-metals**. Elements such as Si, Ge, As, Sb and Te show the characteristic properties of both metals and non-metals. They are called **semi-metals** or **metalloids**. Here, we will discuss metals and non-metals along with their physical properties in detail.

Metals

These elements are electropositive and contain less than or equal to three electrons in their valence shell. Metals such as aluminium, copper, and iron are widely used around us. Metals are used for the construction of bridges, automobiles, airplanes, ships, trains, etc. We will now discuss the physical properties of metals.

Physical properties of metals:

1. Metallic Lustre: The surface of most metals is shiny. The lustre associated with metals is known as **metallic lustre**. For example, iron, copper, gold, and silver are very shiny. Metals such as gold and silver are very lustrous. Therefore, they are used for making jewellery.

> Silver is used for making mirrors because of its excellent shine and reflective nature.

Do you know that metals like gold, silver, platinum, paladium and rhodium are known as **noble metals.** They occur in the elemental state in nature.

Some metals do not look very lustrous. This is because they either lose their lustre or their lustre gets reduced when exposed to air for a long time. This happens due to the formation of a layer of oxide, carbonate, and sulphide on their surface.

If a metal surface is rubbed with sand paper, then this layer gets removed and the shiny surface of the metal can be seen. The layer formed in some cases is stable and sticks on the surface of the metal, but in other cases, it is unstable and falls off (as in the case of rusting of iron).

2. Hardness: Metals are generally hard in nature. However, this hardness varies from metal to metal. Most metals such as iron, aluminium, etc. are very hard and cannot be cut with a knife whereas some metals such as sodium and potassium are very soft and can be cut using a knife.

3. Malleability: Metals are malleable. Most metals such as iron, copper, silver, and gold can be hammered without breaking to form thin sheets. Aluminium, and silver are highly malleable metals and are often used for making foils, which are extensively used in the decoration of sweets, packing of food items, etc.

4. Ductility: Most metals are ductile, which means that they can be drawn into thin wires without breaking. For example, iron, copper, silver, and gold can be drawn into thin wires without breaking. For this reason, copper and aluminium are extensively used for making electrical wires.

Gold and silver are the most malleable and ductile metals. Hence, they are extensively used in jewellery.

5. Conduction of heat: Metals are generally good conductors of heat. This means that if one end of a metal rod is heated for some time, then the entire rod becomes hot. For example, aluminium, copper, and silver are good conductors of heat. Hence, copper and aluminium are generally used for making vessels. The following activity can be performed to explain that metals can conduct heat.

6. Conduction of electricity: Metals are good conductors of electricity i.e., they allow an electric current to pass through them easily. Silver, copper, and aluminium are the best conductors of electricity. For this reason, most electric wires are made of copper and aluminium.

However, using silver for making electric wires is not cost effective. The following activity can be performed to explain that metals can conduct electricity.

Activity:

Take two electric wires and attach two clips to each wire (as shown in the given figure). Then, take a bulb fitted in a holder and connect it to a battery with the help of electric wires. Now, take pieces of iron, copper, and aluminium and place them one by one between the clips.

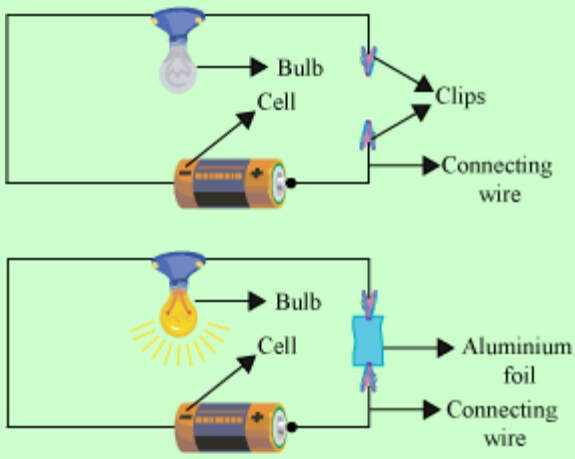


Figure 2: Conduction of electricity in metals

It will be observed that the bulb glows every time when the metal pieces are used to connect the two clips. This shows that metals are good conductors of electricity.

7. Melting and boiling points: Melting and boiling points of metals are usually high.

8. Physical state: All metals exist as solids at room temperature except mercury, which exists as a liquid.

9. Sonority: Metals such as iron and copper produce a sound on being struck. Hence, metals are said to be sonorous.

Non-metals

Many elements in the periodic table do not behave like metals. These elements are known as **non-metals**. These elements gain electrons to form compounds. These are electronegative and contain more than three electrons in their valence shell. Carbon, sulphur, iodine, oxygen, etc. are some examples of non-metals. Non-metals exist in all three physical states i.e., as solids, liquids, and gases. Bromine is the only non-metal, which exists as a liquid.

Physical properties of non-metals:

1. Lustre: Non-metals do not have a shiny surface. However, iodine is an exception, which has a very shiny surface.

2. Hardness: Non-metals generally exist as solids, liquids, or gases. Non-metals that exist in a solid state are very soft. For example, sulphur, which exists in solid state, is quite soft. Similarly, carbon, in the form of graphite, is quite soft. However, diamond,

another allotrope of carbon, is very hard. It is in fact the hardest known natural substance.

3. Malleability and ductility: Non-metals that exist in solid states are not very strong. They are brittle and break when pressure is applied on them. Therefore, non-metals are neither malleable nor ductile.

4. Conduction of heat and electricity: Non-metals are poor conductors of heat and electricity. Examples include sulphur and phosphorus. However, there is an exception. Graphite, an allotrope of carbon, is a good conductor of electricity.

5. Physical state: Non-metals exist in all three physical states at room temperature. Non-metals such as carbon, sulphur, and phosphorus exist in solid states while oxygen, chlorine, and nitrogen exist in gaseous states. Bromine is the only non-metal that exists in a liquid state.

6. Melting and boiling points: Melting and boiling points of non-metals are quite low. For example, the melting point of phosphorus is 44.2°C. However, diamond, an allotrope of carbon, is the only non-metallic substance that has a very high melting and boiling point. The melting point of diamond is more than 3500°C.

7. Sonority: Non-metals are not sonorous.

The given table summarizes the properties of metals and non-metals.

Metals	Non-metals
Metals are very hard and strong.	Solid non-metals are soft and can be easily broken.
Metals have a shiny lustre.	Non-metals are not shiny and have a dull appearance.
Metals are sonorous.	Non-metals are not sonorous.
Metals are malleable and ductile.	Non-metals are neither malleable nor ductile.
Metals are good conductors of heat and electricity.	Non-metals are poor conductors of heat and electricity.

Corrosion: Causes and Prevention

You must have observed that when metals such as iron, silver, and copper are exposed to air for some time, they lose their shine. For example, iron, when exposed to moist air for a long period of time, acquires a coating of a brown-flaky substance.

This is because metals react with moisture and the different gases present in the air. **The reaction of metals with moisture and gases present in the air is known as corrosion.** Rusting of iron is the most common example of corrosion.

DO YOU KNOW?

Rust is a general term given to iron oxides, which are formed when iron reacts with oxygen in the presence of moisture. Rust primarily consists of hydrated iron (III) oxides, $Fe_2O_3 .nH_2O$. The number of water molecules in rust is variable. Hence, they are represented by *n.*

Other examples of corrosion:

1. You must have observed that ornaments made of silver lose their shine after some time. This is because silver reacts with sulphur present in the air to form silver sulphide, which forms a layer over its surface.

2. Copper reacts with carbon dioxide to form copper carbonate, which is greenish in appearance. This is the reason why a copper article loses its shiny brown surface when exposed to air.

DO YOU KNOW?

Corrosion of aluminium metal is extremely slow. This is because of aluminium oxide, which is formed when aluminium reacts with oxygen, is very stable and forms a protective coating or layer on the surface of the metal. This prevents the oxidation of the remaining metal.

Corrosion can drastically reduce the quality and strength of metals. The higher a metal lies in the reactivity series, more readily it is corroded. Here, we will study about the rusting of iron and the conditions necessary for the same. Let us find out about the conditions necessary for rusting of iron to take place with the help of the following activity.

Therefore, we can say that both air and water are required for rusting to take place.

Effect of Corrosion on Other Metals based on the Reactivity Series:

1. Reactive alkali metals react with oxygen, water and carbon dioxide present in air to form oxide, hydroxide and carbonate, respectively. Hence, they are kept immersed in kerosene oil to prevent the corrosion.
2. Aluminium and magnesium when exposed to air form a white layer of the oxide on their surface.
3. Iron forms hydrated ferric oxide (rust) on exposure to moisture in the air.
4. Lead forms a white deposit of lead hydroxide and lead carbonate called basic lead carbonate on coming in contact with moist air.
5. Copper forms a green deposit of copper hydroxide and copper carbonate called basic copper carbonate on exposure to moist air.
6. Siver forms a black coating of silver sulphide on its surface on coming in contact with hydrogen sulphide present in the air. This phenomenon is known as tarnishing of silver.

Factors Affecting Corrosion

Besides oxygen and moisture in the air, there are other factors that enhance the corrosion of metals. These are:

- Reactive nature of metal: Highly reactive metals corrode easily.
- Presence of dissolved salts: They act as electrolyte and increase the rate of corrosion.
- Presence of pollutants: They increase the rate of corrosion.
- Presence of less reactive metal: If a less reactive metal is present, it will make the more reactive metal susceptible to corrosion.

Every year our world suffers a huge monetary loss owing to the process of rusting, which causes harm to articles made of iron. Attempts were made to prevent rusting. Here are some ways that can prevent rusting or corrosion.

We now know that both air and water are required for rusting to take place. Thus, rusting can be prevented by cutting off the contact of iron articles with air or water or both. There are different methods by which rusting can be checked:

- Rusting can be prevented by electroplating, painting, oiling, and greasing of iron articles. In fact, paints and grease should be applied regularly to prevent rusting.
- Rusting can also be prevented by applying a layer of a metal such as chromium or zinc on the surface of iron articles. **The process of depositing zinc on iron is called galvanization.**
- Rusting can also be prevented by connecting the iron object with a more reactive metal like zinc with the help of a wire. **The process of connecting iron with a more reactive metal through a wire is called cathode protection**.
- Alloying can also be used to prevent rusting or corrosion.

Do you know what alloys are?

An alloy is a homogeneous mixture of two or more elements, at least one of which is a metal. An alloy of a metal is made by first melting the metal and then, adding and dissolving the element with which it is to be alloyed. This is done in a molten state so that an even distribution of elements can take place. Usually, the resulting substance has properties different from those of its components.

Alloy	Components	Properties	Uses
Stainless steel	Iron, nickel and chromium	Does not get affected by the action of air, water and alkali.	In preparation of utensils, blades and surgical instruments.
Brass	Copper and zinc	Malleable, strong, corrosion resistant and can be easily shaped.	In preparation of cooking utensils, parts of machines and instruments.
Bronze	Copper and tin	Stronger and more corrosion resistant.	In preparation of statues, coins and medals.

Do you know?

Pure gold is known as 24 carat gold. In India, the gold that is generally used to make ornaments is 22 parts of pure gold alloyed with 2 parts of either silver or copper.

Do you know that alloying is a good method for improving the properties of metals?

Properties of metals can be improved by combining them with other elements i.e., by alloying. Alloying can also be used to prevent rusting. Pure iron is not very hard and stretches when heated. However, when it is mixed with a small amount of carbon, it becomes very hard. This is known as steel.

Even though steel is hard, it does rust. Stainless steel is obtained when nickel and chromium are added to iron. **Stainless steel contains iron as the primary constituent, but it does not rust at all.** Thus, by adding different elements, the properties of iron can be changed.

The iron pillar near the Qutub Minar in New Delhi was made around 400 B.C. It is 8 m tall and weighs around 6 tonnes (6000 kg). The workers who made it knew that pure iron would rust after some time and devised a method to prevent the pillar from rusting.

They painted the surface of the pillar using a mixture of salts, followed by heating and quenching (rapid cooling). This finishing treatment resulted in the formation of a thin layer of magnetic oxide (Fe_3O_4) on the surface of the pillar and prevented the iron present in the pillar from rusting.

Even though corrosion and rusting causes much damage, but sometimes this phenomenon has an **advantage**. Let us understand with the help of an example. Aluminium and zinc articles when exposed to air form a white deposit of their respective oxides on their surface. These oxides stick to the surface of the metal and are impervious in nature. So in a way, this oxide prevents the next layer of metal from getting corroded. This is the reason why objects made from aluminium and zinc do not corrode easily.

Uses of Metals and Non-Metals

We are familiar with a number of substances, which are very hard and shiny in nature such as iron, aluminium, gold, silver, and copper. You must have observed that these materials produce a sound on being struck. Such substances are called **metals**.

Substances which are dull in appearance and not very hard are called **non-metals** such as carbon, sulphur, iodine, etc.

There are 92 naturally occurring elements, which are classified into metals and non-metals. Among them, most elements are metals with less than 20 elements as non-metals. Here, we will discuss the properties and uses of metals and non-metals.

Metals are hard and shiny in appearance. They are malleable, ductile, and good conductors of heat and electricity. As a result of all these properties, metals have many uses.

1. Metals such as gold and silver are very shiny in appearance. These metals are quite ductile and malleable in nature. Also, these metals are expensive and do not corrode easily (though silver becomes black after some time due to corrosion). Hence, these metals are used in making jewellery.

2. Metals such as copper and aluminium are used to make wires as they are very good conductors of electricity. Also, they are very ductile. Copper and aluminium wires are widely used in electrical fittings in houses.

3. Metals such as iron, copper, and aluminium are good conductors of heat. Hence, they are used for making cooking utensils and water boilers.

4. Metals are malleable. Hence, they can be hammered into very thin sheets. For example, silver and aluminium foils are made by hammering these metals. Silver foils are used for decorating food items, whereas aluminium foils are used for wrapping food items such as chocolates and many such materials.

5. Metals are hard and rigid. Hence, they can be used in making machinery, automobiles, aeroplanes, trains, satellites etc. Aluminium is used for making parts of aeroplanes as it is very light in comparison to other metals.

Do You Know:

Silver is shiny and is a good reflector. It reflects about 90 percent of light falling on it. Hence, it is used for making high reflecting mirrors.

Like metals, non-metals also have various uses. We will now discuss the uses of non-metals.

1. Oxygen, which is a non-metal, is essential for life. It is used by plants and animals for the process of respiration. Oxygen is also used in factories, homes etc. as it supports combustion.

2. Nitrogen, a non-metal, is used in fertilizers to enhance the growth of plants.

3. Chlorine has the ability to kill germs. Hence, it is used in water purification as a disinfectant.

4. Tincture iodine is a solution of iodine in alcohol, which is used as an antiseptic.

5. Non-metals are also used in manufacturing crackers.

Some Common Uses of Metals

Uses of aluminium

- Aluminium is cheap and resistant to corrosion, so it is used for making cooking vessels, picture frames and household fittings.
- It is used in high-voltage electric transmission wires.
- Aluminium foils are used for packing purposes.
- It is used for making alloys like duralumin and magnalium.
- It is also used in paints.
- It is used in making mirrors of telescopes as it is an excellent reflector of light.
- It is used in thermite welding.
- Thermit (a mixture of 3 parts of Fe_2O_3 and 1 part of Al powder) is covered with an ignition mixture (Potassium chlorate and magnesium powder) in a crucible.
- The ignition mixture is ignited using a fuse of burning magnesium.

- In the reaction, Fe_2O_3 is reduced to Fe with the evolution of a large amount of heat.
- The molten Fe falls between the broken pieces and solidifies, joining the pieces in turn.
- $Fe_2O_3 + 2\ Al \rightarrow Al_2O_3 + 2\ Fe + Heat$

Curiosity Corner

Aluminium-air batteries, also called **Al-air** batteries, are batteries in which the reaction of oxygen present in the air with aluminium is used to produce electricity.

Uses of magnesium

Magnesium is a silvery white metal.

- A mixture of powdered magnesium and potassium chlorate is used in fireworks.
- It is used as a fuse wire in thermite welding.
- It is used as a reducing agent in the extraction of metals.
- It is also used for the preparation of alloys like magnalium.

Uses of mercury

- It is used as a thermometric liquid in labs.
- It is used in thermometers.
- It is also used as an amalgam in dentistry for filling tooth cavities.

DO YOU KNOW?

As a liquid mirror, mercury is used as an alternative to big telescopes.

Uses of zinc

- It is used for galvanising iron.
- It is used for making containers of the dry cell.
- It is used in the preparation of alloys.
- It is also used in the extraction of gold and silver.

DO YOU KNOW?

The most exploited zinc ore is sphalerite or zinc sulfide; the largest exploitable deposits are found in Germany, Canada and the United States

Uses of iron

- Wrought Iron (carbon content 0.1 - 0.25%) is used for making tin roofing, buckets, trunks and electromagnets.
- Cast iron (carbon content 2.5 - 5%) is used for making drain pipes, manhole covers and machinery.
- It is also used for manufacturing steel.

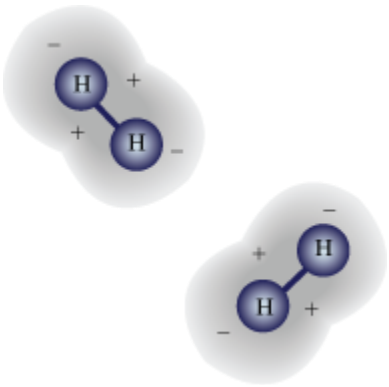
Uses of copper

- It is used for making electric transmission wires.
- It is used in the coils of electric motors and electric generators.
- It is used for making alloys such as brass and bronze.
- It is used in the radiators of automobiles.
- It is also used for making coins and printed circuits.

Some Common Uses of Non-metals

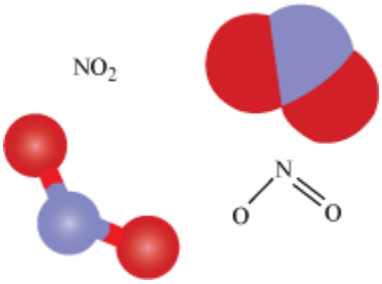
Hydrogen - It is the lightest element. It is found in the gaseous state.

- It is used as a non-polluting fuel. It is present in coal gas and water gas.
- Oxy-hydrogen flame is used for cutting and welding metals.
- It is also used for filling weather observation balloons.



Nitrogen

- It dilutes the activity of oxygen, so it is used for controlling the rate of combustion.
- It helps plants manufacture proteins.
- It is used in the manufacture of ammonia gas.
- It is also used for preserving packaged food.



Oxygen

- It is essential for the respiration of living beings. It is also needed for artificial respiration.
- It is required for the combustion of fuels and is also used in rocket fuels.
- As dissolved oxygen, it keeps water fresh and is used for respiration by marine organisms.
- It is also used for cutting and welding purposes.

Do you know?

The diamagnetic form of molecular oxygen (O_2) is commonly known as molecular oxygen.

Chlorine

- It is used in bleaching powders.
- It is used for sterilising drinking water.
- It is also used in pesticides and acids.

Do you know?

Insecticides and pesticides are used for killing insects. They include fungicides, larvicides and rodenticides.

Iodine

- In the form of sodium iodide or potassium iodide, it is required for the proper functioning of the body.
- In the form of silver iodide, it helps in making photographic films.
- It is also used for dressing wounds.
- In the form of iodoform, it is used in medicines.

Do you know?

Iodoform is a compound of iodine with the chemical formula CHI_3. It is a pale-yellow solid which was quite commonly used in antiseptics and disinfectants.

Carbon

- It is used in the electrodes of electrolytic cells.
- In the form of graphite, it is used as a dry lubricant, and as pencil lead.
- Graphite is also used as electrode material in electrolytic cells because it is a good conductor of electricity.
- It is used for making heat-resistant crucibles.
- It is employed in nuclear reactors.
- It is used in carbon arc lamps.
- Coal is used as a fuel in homes, industries, pharmaceutical and textile sectors.
- Diamond is the most crystalline form of carbon and is used as a precious gem. The impure gem is used for grinding hard substances and drilling heads.

Do you know?

Coke is the dry solid material left after heating coal to a very high temperature.

Sulphur

- It is used in the chemical industry for manufacturing sulphuric acid, sodium thiosulphate, carbon disulphide, etc.
- It is used in insecticides and fungicides
- It is used in medicines.
- It is also used for vulcanising rubber.

Do you know?

Natural rubber is sticky, easily deforms when warm and is brittle when cold**. Vulcanisation** refers to a specific process which involves heating rubber to high temperatures and adding sulphur or other equivalent curatives.

Some Common Uses of Metalloids

Silicon

- It is used for making solar cells, microchips and transistors.
- It is used for manufacturing polymers, also called silicones.
- It is used for manufacturing ferro-silicon, a special form of steel and silicon carbide. It is one of the hardest substances known.
- It is a very important component of cement and glass.

Do you know?

A **solar cell** or **photovoltaic cell** is a device that converts light into electric energy.

Germanium

- Germanium is commonly used as a semiconductor.
- It is used as a transistor in many electronic applications when mixed with arsenic, gallium, etc.

- It is used to form alloys and as a phosphor in fluorescent lamps.

Noble gases

- Noble gases are very non-reactive gases and are therefore used to provide the inert environment.
- **Helium:** for filling weather observation balloons
- **Argon:** For filling electric bulbs

The metals that are not acted upon by mild acids and alkalis, and occur in nature in the free state are called **noble metals**. Thus, they are resistant to corrosion and oxidation. These metals are very precious.

They include −

- Silver
- Gold
- Platinum
- They also include ruthenium, rhodium, palladium, osmium and iridium.

Do you know?

In India, pure gold is denoted as 24 carats. The gold that is generally used for making ornaments is 22 parts of pure gold alloyed with 2 parts of either silver or copper. This mixture is known as 22 carat gold.

Let us study the uses of noble metals.

Uses of silver

Silver is a shiny, heavy metal, and the best conductor of electricity.

- It is used for making silver ornaments and expensive utensils such as glasses, mugs, etc.
- It is used for making coins.
- Salts of silver like silver chloride are used for making photographic films.
- Silver foils are used for decorating sweets.
- Silver is also used for making mirrors using a process called sputtering.

Uses of gold

Gold is bright yellow and a highly malleable and ductile metal.

- Gold is used as the index of wealth. The countries which have more gold reserve are considered to be wealthy.
- It is used for making ornaments.N
- It is used for making high-value coins and medals.
- It is used for covering the mainframe of artificial satellites.

Uses of platinum

Platinum is silvery white, a highly malleable and ductile metal**.**

- It is used for making ornaments and watches.
- It is used as a catalyst in the manufacture of sulphuric acid and nitric acid.
- It is used in platinum catalytic converters.
- It is also used in chemical laboratories.

Do you know?

The word ‘platinum’ has been derived from the Spanish term *platina del Pinto*.