Metallurgy

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.

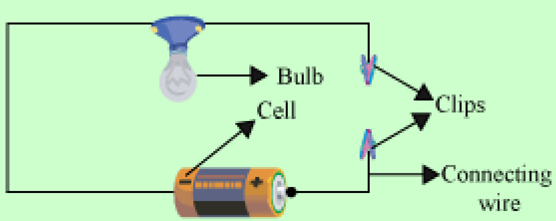
Gold and silver are the most malleable and ductile metals. Hence, they are extensively used in jewellery.

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.



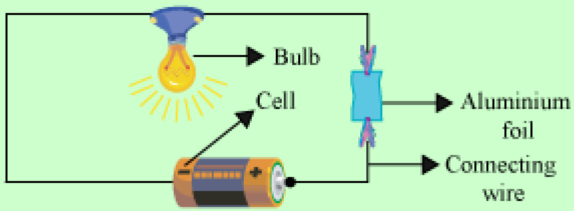


Figure 2: Conduction of electricity in metals

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.

Reaction of Metals with Solution of Salts of other Metals; And The Reactivity Series

Categorisation of Metals

Based on the positioning of metals in the periodic table, their characteristics are given below:

	Alkali Metals	**Alkaline Metals**
Elements	Li, Na, K	Mg, Ca, Sr
Position	Placed in IA group	Placed in IIA group

Occurence	Do not occur in free state	Do not occur in free state
Nature	Soft Low melting and boiling point	Hard Greyish white in colour
Bonding	Salts of alkali metals form ionic compounds (except for some lithium salts)	Salts of alkaline metals form ionic compounds (except for beryllium)
Action of air	React rapidly Reactivity increases down the group	Less reactive Reactivity increases down the group
Action of water	$2M + 2H_2O \rightarrow 2MOH + H_2$	$M + 2H_2O \rightarrow M(OH)^2 + H^2$
Action of acids	$2\ M + 2\ HCl \rightarrow 2\ MCl + H_2$	$M + 2HCl \rightarrow MCl_2 + H_2$
Ionisation energy	Low ionisation energy	Low ionisation energy (but higher than alkali metals)
Colour of the flame	Impart characteristics colour to the flame Crimson red − Lithium (Li) Golden yellow − Sodium (Na) Pale violet − Potassium (K)	Impart colour to the flame Calcium − Brick red Strontium − Crimson Barium − Apple green Mg and Be do not impart colour because the electrons are too strongly bound to be excited.
Obtained	By electrolysis of their molten salts	By electrolysis of their molten salts

Some other categories of metals:

Transition Metals:

- Elements like Fe, Zn etc. are transition metals. They are placed in the middle of the periodic table.
- Have high melting and boiling point
- Good conductors of heat and electricity
- Show variable valencies

Inner transition metals:

- Elements like La, Ce are inner transition metals. They are placed at the bottom of the periodic table.
- Heavy metals with high melting and boiling point
- Good conductor of heat and electricity
- Show variable valencies

In the reaction of metals with air, water, and acids, we observed that some metals react very vigorously, some others react rather slowly, and some do not react at all.

What can you conclude from the given information? Are all elements equally reactive?

As different metals react with the same chemicals in different ways, the reactivity of metals cannot be similar.

If the reactivity of metals is different, then how can we determine the reactivity of two metals?

Displacement reactions help us for this. Actually, some metals are more reactive than others. Metals that are more reactive can displace the less reactive metals from their salts in a solution or molten form. The general equation for such reactions is given as:

$$\text{Metal A} + \text{Salt solution of metal B} \rightarrow \text{Salt solution of metal A} + \text{Metal B}$$

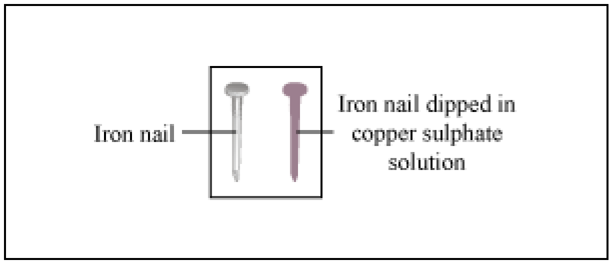
Such reactions are called **displacement reactions**. In displacement reactions, a more reactive metal replaces a less reactive metal from the latter's salt.

For example, iron can replace copper from copper sulphate solution, but copper cannot replace iron from iron (II) sulphate solution.

$$\underset{\text{Iron}}{Fe(s)} + \underset{\text{Copper sulphate}}{CuSO_4(aq)} \rightarrow \underset{\text{Iron (II) sulphate}}{FeSO_4(aq)} + \underset{\text{Copper}}{Cu(s)}$$

$$\underset{\text{Copper}}{Cu(s)} + \underset{\text{Iron (II) sulphate}}{FeSO_4(aq)} \rightarrow \text{No reaction}$$

When an iron nail is kept in a copper sulphate solution, the intensity of copper sulphate solution decreases, and the iron nail gets covered with copper.

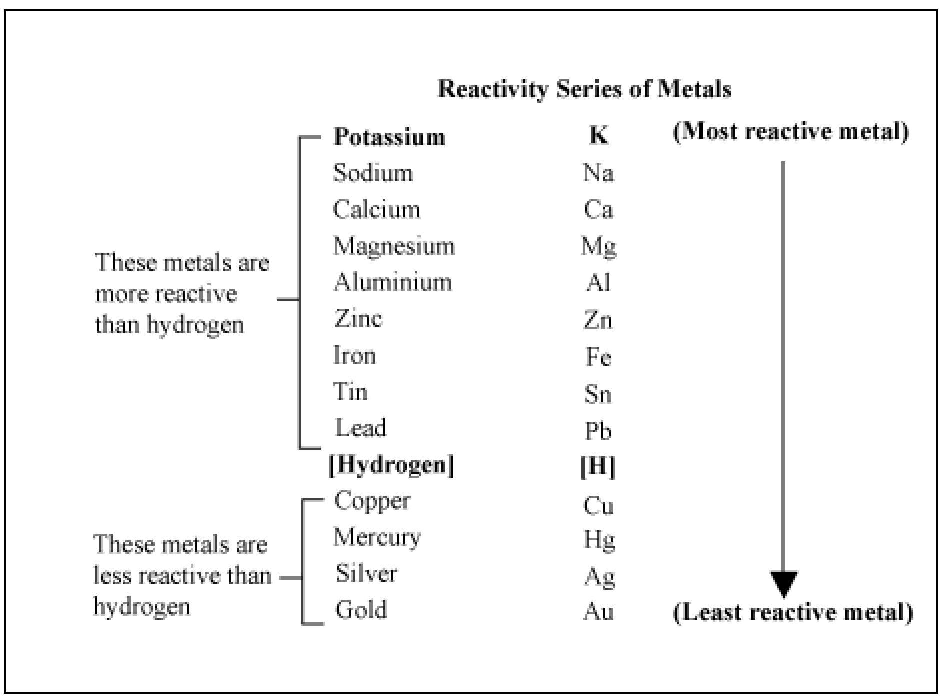


This means that iron is more reactive than copper as it can replace copper from copper sulphate solution.

The reactivity of metals can be determined by observing their reactions with salt solutions of other metals. When the reactivity of a metal is determined, it can be arranged in an increasing or decreasing order of their reactivities.

The series in which various metals are arranged in the order of their decreasing reactivity is called a Reactivity series.

This series is prepared by performing displacement reactions between various metals and their salt solutions. The reactivity series is given as follows:



Reactivity series of metals

In the reactivity series, metals present above a particular metal are more reactive than that metal, while the metals present below the particular metal are less reactive than it.

We know that all metals lose electrons to form positive ions. The tendency to lose an electron can be related to the reactivity of metals. If a metal can lose electrons easily, then it is very reactive. On the other hand, if the tendency of a metal to lose electrons is less, then it is less reactive.

In general, we say that the metals present above hydrogen are more reactive than it, and displace it from acids to liberate hydrogen gas.

However, the metals present below hydrogen are less reactive than it, and cannot displace it from acids to liberate hydrogen gas.

Metals such as sodium and potassium (that lie above hydrogen) readily react with dilute acids to evolve hydrogen gas, whereas metals such as copper, gold, and silver (that lie below hydrogen) do not react with dilute acids.

Main Features of Reactivity Series

- Metals are arranged in the decreasing order of their electropositive character.
- Metals at the top have greater reducing power. This power decreases on moving down the series.
- Metals at the top show greater tendency to get oxidised.
- Metals above hydrogen in the reactivity series liberate hydrogen gas from mineral acids.
- Metals at the top displace metals lower in the series from the aqueous solution of their salts.
- Metal oxides above Al, cannot be reduced by common reducing agents, the reverse is true for metal oxides below Al.

Let us now see the action of heat on some metallic compounds like oxides, hydroxide, carbonates and nitrates.

Oxides:

Metal	**K, Na, Ca, Mg, Al**	**Zn**	**Fe, Pb, Cu**	**Hg, Ag**
Action of Heat on metal oxide	Stable to heat Reduced by electrolysis	Reduced by coke only	Reduced by C, CO, H_2, NH_3	Decompose on heating to give metal and oxygen

Hydroxides:

Metal	**K, Na**	**Ca, Mg, Al, Zn, Fe, Pb, Cu**	**Hg, Ag**

Action of Heat on metal oxide	Stable to heat Soluble in water	Decompose on heating to give metal oxide and water vapour	Decompose on heating to give metal, oxygen and water vapour

Carbonates:

Metal	K, Na	Ca, Mg, Al, Zn, Fe, Pb, Cu	Hg, Ag
Action of Heat on metal oxide	Stable to heat Soluble in water	Decompose on heating to give metal oxide and carbon dioxide	Decompose on heating to give metal, oxygen and carbon dioxide

Nitrates:

Metal	K, Na	Ca, Mg, Al, Zn, Fe, Pb, Cu	Hg, Ag
Action of Heat on metal oxide	Decompose on heating to give metal nitrite and oxygen	Decompose on heating to give metal oxide, nitrogen dioxide and oxygen	Decompose on heating to give metal, nitrogen dioxide and oxygen

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.

Concentration of Ores

- Some important ores of some metals are given in the following table.

Metal	Occurrence
Aluminium	1. Bauxite, $Al_2O_3 . x H_2O$ 2. Cryolite, Na_3AlF_6
Iron	1. Haematite, Fe_2O_3 2. Magnetite, Fe_3O_4
Copper	1. Copper pyrites, $CuFeS_2$ 2. Copper glance, Cu_2S 3. Malachite, $CuCO_3 . Cu(OH)_2$ 4. Cuprite, Cu_2O
Zinc	1. Zinc blende or Sphalerite, ZnS 2. Calamine, $ZnCO_3$ 3. Zincite, ZnO

Some Important Terms

- **Metallurgy**: Process of extracting pure metal from their ore
- **Minerals**: Mixture of metal compounds, soil, sand, limestone and rock
- **Gangue**: Impurities present in ore like mud, silica etc.
- **Ores**: Minerals from which metals can be extracted economically at low cost and with minimum cost
- **Flux**: Substance added in furnace to remove gangue
- **Slag**: The fusible mass formed when flux combined with gangue

- **Smelting**: Process of extracting metal from their oxide ores by reducing the roasted oxides

Steps Involved in Extraction

1. Crushing and grinding ore
2. Concentration of the ore
3. Roasting and Calcination of the ore
4. Reduction of the metal oxide
5. Refining of the pure metal

Crushing and Grinding

- Crushing of the ore to fine powder with the help of big jaw crushers and ball mills
- The process is known as **pulverisation**

Concentration (or Dressing or Benefaction) of ores

- Removal of unwanted materials such as sand and clay from ores

Some Important Procedures

- **Hydraulic washing**

- Based on gravity differences between the ore and the gangue particles

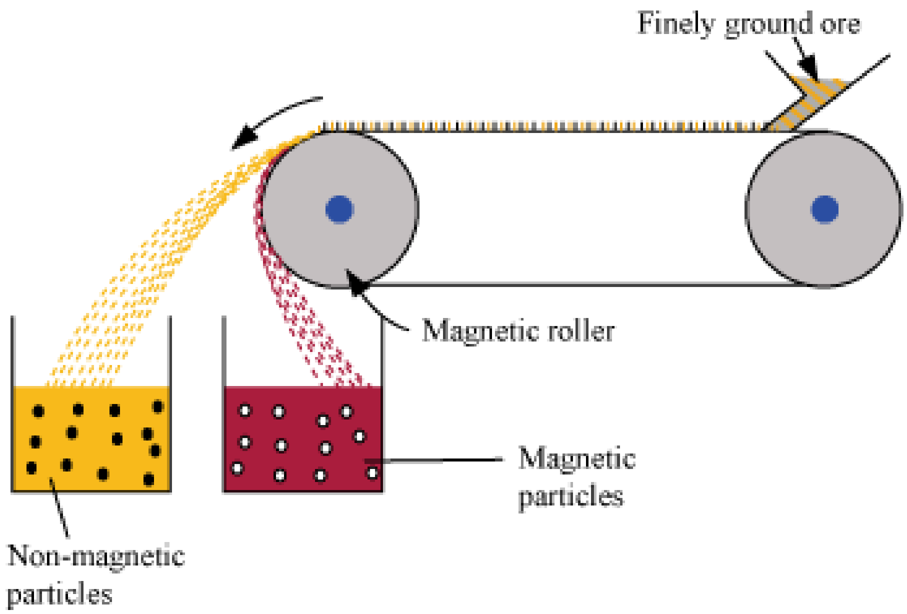
- In one such process, the lighter gangue particles are washed away by a stream of water, leaving behind the heavier ore.

- **Magnetic separation**

- Based on differences in magnetic properties between the ore and the gangue particles

- Magnetic field is applied to separate magnetically attractive particles from magnetically non-attractive particles.

- Schematic diagram of magnetic separation is as follows:



- **Froth-Floatation method**
- Applied to remove gangue from sulphide ores
- Mineral and gangue particles are separated by first wetting the mineral particles with oil, and gangue particles with water, and then the mineral particles are carried out by forming froth.
- Sometimes, depressants are used for separating two sulphide ores by selectively preventing one ore from forming froth. For example, NaCN is used as a depressant for separating two sulphide ores, ZnS and PbS.
- **Leaching**

  Used if the ore is soluble in some suitable solvent
- Leaching of alumina from bauxite:

$$Al_2O_{3(s)} + 2NaOH_{(aq)} + 3H_2O_{(l)} \xrightarrow[35-36\text{ bar}]{473-523\text{K}} 2Na\left[Al(OH)_4\right]_{(aq)}$$

$$2Na\left[Al(OH)_4\right]_{(aq)} + CO_{2(g)} \longrightarrow Al_2O_3 \cdot xH_2O_{(s)} + 2NaHCO_{3(aq)}$$

$$Al_2O_3 \cdot xH_2O_{(s)} \xrightarrow{1470\text{ K}} Al_2O_{3(s)} + xH_2O_{(g)}$$

- Leaching of some other ores:

  Ores of metals like Ag and Au are leached with a dilute solution of NaCN and KCN in the presence of air.

$$4M_{(s)} + 8CN^-_{(aq)} + 2H_2O_{(aq)} + O_{2(g)} \rightarrow 4[M(CN)_2]^-_{(aq)} + 4OH^-_{(aq)}$$

$$(M = Ag \text{ or } Au)$$

$$2[M(CN)_2]^-_{(aq)} + Zn_{(s)} \rightarrow [Zn(CN)_4]^{2-}_{(aq)} + 2M_{(s)}$$

Extraction and Refining of Metals

Elements on earth are found in different forms from the different parts of the earth:

Lithosphere: This part of earth is made up of sand, clay, stone and elements such as aluminium, copper, iron, calcium, sodium etc. which are found in the form of sulphides or oxides.

Hydrosphere: This part of the earth includes water of seas, lakes and ice of polar regions. In this part, many non-metals and metals are obtained in combined forms such as, chlorine, flourine, sodium, potassium, magnesium and calcium.

Atmosphere: The blanket of air around the earth is called atmosphere. Non-metallic gases like nitrogen, carbon dioxide and oxygen are present majorly.

We know that metals are highly reactive. Therefore, they do not occur in the free state. For example, sodium, potassium, etc. are never found in the free state and occur in nature in chemically combined forms known as **minerals.**

Elements or compounds, which occur naturally in the Earth's crust, are known as minerals. Most minerals found in the earth's crust contain metals. Some metals are also found in the oceans in the form of salts such as sodium chloride, magnesium chloride, etc.

There are some minerals which contain a large amount of a particular metal and from them, metals can be extracted profitably (using practically possible techniques).

The minerals from which metals can be extracted commercially are known as ores.

The process by which a pure metal is obtained from its ore is known as extraction.

Do you know that metals are classified into three groups on the basis of their reactivity series? The three groups are as follows:

1. Metals of low reactivity

2. Metals of medium reactivity

3. Metals of high reactivity

Reactivity series

The reactivity series is a list of metals arranged in the order of their decreasing reactivity (as shown in **Figure 1**).

The metals at the bottom of the reactivity series are less reactive and they often exist in nature in the free state. For example, gold, silver, and platinum are less reactive metals.

The metals at the top of the reactivity series are very reactive. Hence, they never occur in nature in the free state. For example, sodium, potassium, calcium, etc. are highly reactive but do not occur in nature in the free state.

The metals in the middle of the reactivity series are moderately reactive. For example, zinc, iron, and lead are moderately reactive.

Now, let us study how these metals are extracted. A number of steps are involved in the extraction of metals. They can be summarized in the form of a figure as follows.

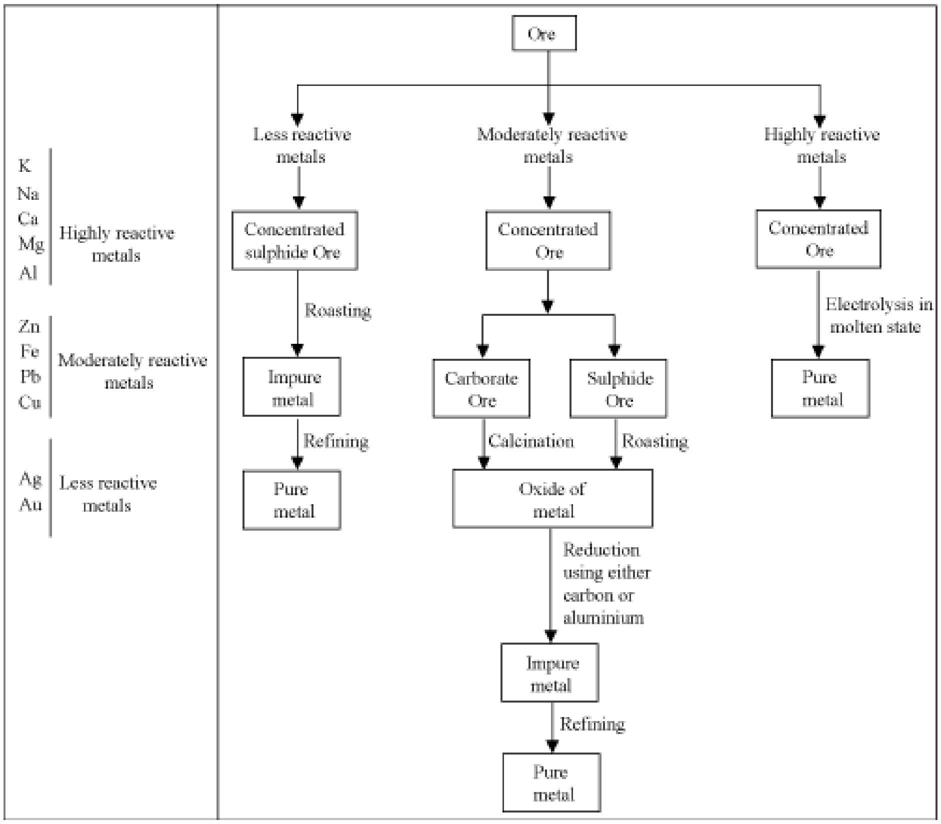


Figure 1: Reactivity series and steps involved in the extraction of metals from ores.

An ore is found in nature along with a large number of impurities such as sand, silt, soil, and gravel. The impurities are called **gangue**.

Hence, before the process of extracting a metal from its ore begins, these impurities, called gangue, have to be removed. When the gangue is removed from the ore, the **enriched or concentrated ore** is obtained.

Thus, the process of removing gangue from the ore is known as the **enrichment of ore**. The process that is employed to separate the gangue from the ore depends upon the physical and chemical properties of both the gangue and the ore.

Now, let us see how metals at the bottom of the reactivity series can be extracted. **These metals are unreactive.** The oxides of these metals can be reduced easily on heating as follows:

Step I: In the first step, cinnabar (an ore of mercury, HgS) is converted into mercury (II) oxide. Sulphur dioxide is also released in the process.

$$\underset{\text{Mercury (II) sulphide}}{2HgS(s)} + \underset{\text{Oxygen}}{3O_2(g)} \xrightarrow{\Delta} \underset{\text{Mercury (II) oxide}}{2HgO(s)} + \underset{\text{Sulphur dioxide}}{2SO_2(g)\uparrow}$$

Step II: In the second step, mercury (II) oxide obtained by heating the cinnabar is reduced to mercury metal on further heating.

$$\underset{\text{Mercury (II) oxide}}{2HgO(s)} \xrightarrow{\Delta} \underset{\text{Mercury}}{2Hg(l)} + \underset{\text{Oxygen}}{O_2(g)}$$

Concentration (or Dressing or Benefaction) of ores

- Removal of unwanted materials such as sand and clay from ores

Some Important Procedures

Hydraulic washing

- Based on gravity differences between the ore and the gangue particles
- In one such process, the lighter gangue particles are washed away by a stream of water, leaving behind the heavier ore.

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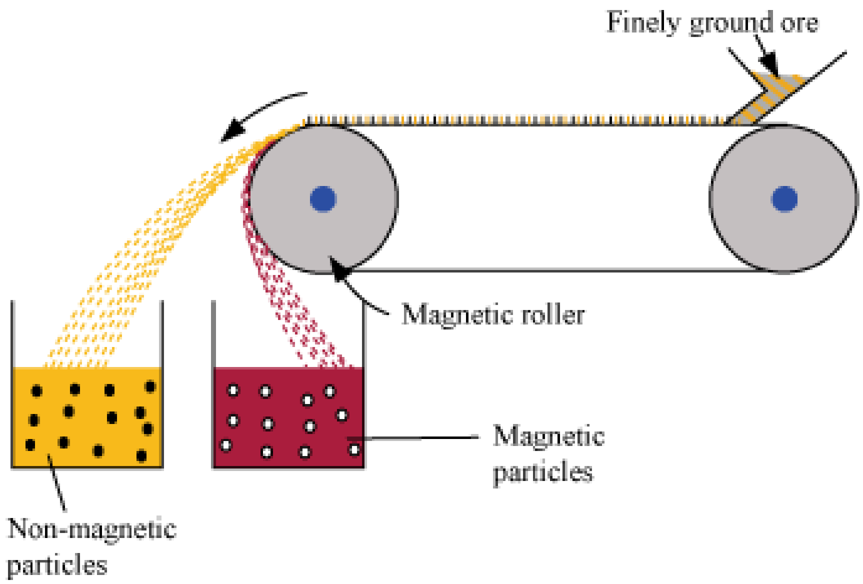
- Based on differences in magnetic properties between the ore and the gangue particles
- Magnetic field is applied to separate magnetically attractive particles from magnetically non-attractive particles.
- Schematic diagram of magnetic separation is as follows:



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Sometimes, depressants are used for separating two sulphide ores by selectively preventing one ore from forming froth. For example, NaCN is used as a depressant for separating two sulphide ores, ZnS and PbS.

Leaching

- It is applied for extracting metals like gold, silver and aluminium.
- It is based on the difference in the solubility of the ore and gangue in a particular type of solution.
- In this method, the ore is soaked in a solution in which the ore dissolves whereas the gangue particles remain insoluble.
- So, the gangue particles and the ore can be separated easily.
- For example: Aluminium is extracted from its ore, bauxite, by soaking bauxite in an aqueous solution of NaOH or Na_2CO_3.

DO YOU KNOW?

Metals such as mercury and copper, which lie quite low in the reactivity series, exist in nature as sulphides. These ores when heated react with oxygen present in the air and get converted into oxides. When these oxides are further heated, pure metals are obtained**.** The process in which a sulphide ore is heated in the presence of air is known as **roasting.**

Metals of medium reactivity i.e., metals that are present in the middle of the reactivity series such as zinc, iron, lead, and manganese are quite reactive and exist in nature as oxides, sulphides, and carbonates. These metals are extracted from their ores by first converting ores to oxides and then by the reduction of these oxides, mostly using carbon.

There are two methods by which ores are converted into their respective oxides:

1. **Roasting**
2. **Calcination**

Roasting: It is used to convert sulphide ores into oxides. Roasting involves strong heating of iron ore in the **presence** of excess air. For example, copper sulphide in copper glance ore is converted into copper (I) oxide by heating it in the presence of oxygen.

$$\underset{\text{Copper (I) sulphide}}{2Cu_2S(s)} + \underset{\text{Oxygen}}{3O_2(g)} \xrightarrow{\text{Roasting}} \underset{\text{Copper (I) oxide}}{2Cu_2O(s)} + \underset{\text{Sulphur dioxide}}{2SO_2(g)\uparrow}$$

Calcination: It is used to convert carbonate ores into oxides. Calcination involves strong heating of the ore in the **absence** of air. For example, calamine ore, which is chemically zinc carbonate, is converted into zinc oxide by heating it in the absence of air.

$$\underset{\text{Calamine ore}}{2ZnCO_3(s)} \xrightarrow{\text{Calcination}} \underset{\text{Zinc oxide}}{2ZnO(s)} + \underset{\text{Carbon dioxide}}{2CO_2(g)\uparrow}$$

After obtaining metal oxides from the ores, reduction of these metal oxides is done to obtain pure metals. Mostly, carbon in the form of coke is used for this.

However, **the oxides of metals, which are present relatively higher in the reactivity series such as manganese, cannot be reduced with coke**. To reduce these oxides of metals, more reactive metals than manganese such as sodium, calcium, and aluminium are used.

For example, iron is also a very reactive metal and cannot be reduced using carbon. Hence, it is reduced using aluminium metal. The reaction is highly exothermic. The heat evolved is so large that the metals are produced in the molten form. This reaction is known as thermite reaction and is used to join railway tracks or cracked machine parts.

$$\underset{\text{Iron (III) oxide}}{Fe_2O_3(s)} + \underset{\text{Aluminium}}{2Al(s)} \rightarrow \underset{\text{Iron}}{2Fe(l)} + \underset{\text{Aluminium oxide}}{Al_2O_3(s)} + \text{Heat}$$

Similarly, manganese cannot be reduced using carbon. Hence, it is also reduced by aluminium metal.

$$\underset{\text{Manganese dioxide}}{3MnO_2(s)} + \underset{\text{Aluminium}}{4Al(s)} \rightarrow \underset{\text{Manganese}}{3Mn(l)} + \underset{\text{Aluminium oxide}}{2Al_2O_3(s)} + \text{Heat}$$

Metals present at the top of the series such as sodium, potassium, calcium, manganese, and aluminium are very reactive**.** These metals cannot be reduced using coke as their affinity for oxygen is much more than that of carbon. Therefore, these metals are reduced by passing an electric cCrrent through their molten salts. This process is known as **electrolytic reduction.**

For example, sodium metal is extracted from sodium chloride. To extract the metal, electrolytic reduction of molten sodium chloride is carried out. When an electric current is passed, sodium ions which have positive charge move towards the cathode and get deposited over it after accepting electrons. The chloride ions have a negative charge and move towards the anode, lose their extra electrons, and escape out of the solution as chlorine gas.

Reaction at the cathode (negative electrode): $Na^+ + e^- \rightarrow Na$

Reaction at the anode (positive electrode): $2Cl^- \rightarrow Cl_2 + 2e^-$

$$\text{Net reaction: } \underset{\substack{\text{Sodium chloride} \\ \text{(Molten)}}}{2NaCl(l)} \xrightarrow{\text{Electrolytic reduction}} \underset{\text{Sodium}}{2Na(s)} + \underset{\text{chlorine}}{Cl_2(g)}$$

Do you know that the metals obtained by various reduction processes, except electrolytic reduction, contain many impurities and require purification? How are these metals purified?

The method that is most commonly used to purify metals is electrolytic refining. Many metals such as copper, zinc, gold, etc. are refined electronically.

Refining:
This method is used for the metals with low melting points i.e, which melt easily. A

furnace with a slope in it, temperature is kept slightly higher than the melting point of the metal. When the impure metal is passed through the furnace, the pure metal is melted there and collected in the vessel. However, the melting points of the impurities is higher than the the metal so that they can be found solid on the slope.

Zone Refining:
This method works on the principle of fractional distillation and trace impurities are removed from the metal using this method. The impurities remain more soluble in molten form which upon cooling the molten metal, decreases the solubility of impurities and separates in the from crystals. Semi-metals such as boron, silicon are refined by this method.

Refining

Distillation

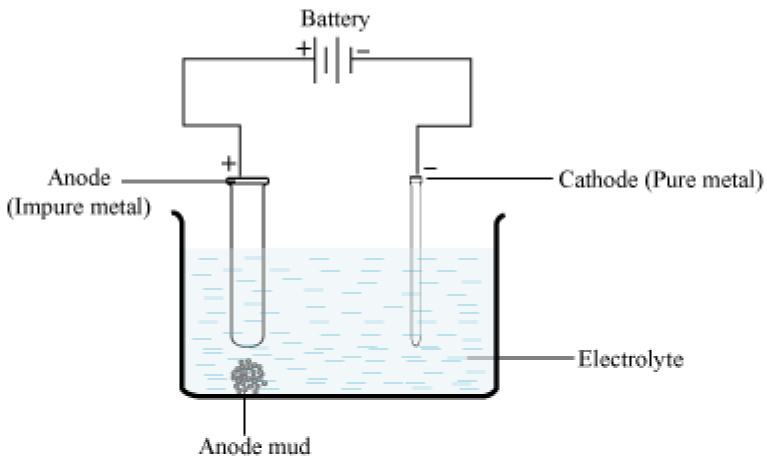
- Involves evaporation of impure metal
- Used for metals having low boiling points, such as Zn, Hg

Liquation

- Involves flowing of low melting metal like tin on a sloping surface so that higher melting impurities are left behind

Electrolytic Refining

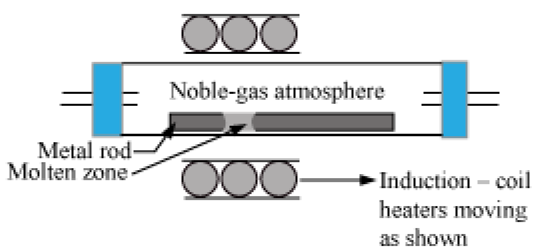
- Impure metal is refined using electricity.
- The impure metal is made the anode, and a strip of pure metal is made the cathode.
- A solution of a soluble salt of the same metal is taken as the electrolyte.
- Impurities get collected below the anode and are known as anode mud.
- At anode: $M \longrightarrow M^{n+} + ne^-$
- At cathode: $M^{n+} + ne^- \longrightarrow M$



- Anode mud of blister copper contains antimony, selenium, tellurium, silver, gold and platinum.

Zone Refining

- Principle − Impurities are more soluble in the molten state of metal (the melt) than in the solid state.
- In this process, a circular heater is fixed at one end of a rod of impure metal.



- As the heater moves, the molten zone of the rod also moves along with it.
- As a result, pure metal crystallises out of the melt, and the impurities pass to the adjacent molten zone.
- This process is repeated several times, which leads to the segregation of impurities at one end of the rod. Then, the end with the impurities is cut off.

Vapour Phase Refining

- In this process, the impure metal is converted into its volatile compound, which is decomposed to obtain the pure metal.
- To carry out this process −

- The metal should form a volatile compound with an available reagent
- The volatile compound should be easily decomposable so that the metal can be easily recovered
- Nickel, zirconium and titanium are refined using this process
- **Mond process for refining nickel**

$$\underset{}{Ni + 4CO} \xrightarrow{330-350\ K} \underset{\text{(volatile complex)}}{Ni(CO)_4} \xrightarrow[\text{(Decomposition)}]{450-470\ K} Ni + 4CO$$

- **van Arkel Method for refining zirconium or titanium**
- All the oxygen and nitrogen present as impurity are removed.
- Crude metal is heated with iodine in an evacuated vessel.

$$Zr + 2I_2 \longrightarrow ZrI_4$$

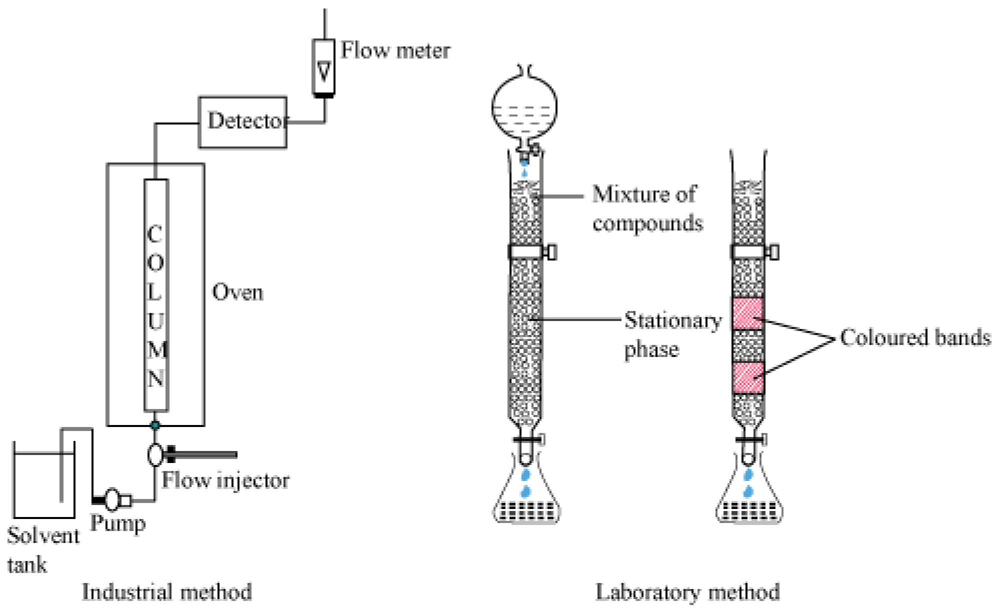
- Metal iodide is decomposed on a tungsten filament, electrically heated to about 1800 K to give the pure metal.

$$ZrI_4 \longrightarrow Zr + 2I_2$$

Chromatographic Methods

- Principle − Different components of a mixture are differently adsorbed on an adsorbent.
- Some chromatographic techniques are −
- Column chromatography
- Paper chromatography
- Gas chromatography
- There are two phases in chromatography: mobile phase and stationary phase.
- Column chromatography is useful for the purification of elements available in minute quantities. It is also used for removing the impurities that are not very different in chemical properties from the element to be purified.

- Adsorbed components are removed (eluted) using suitable solvents (eluents).
- Schematic diagrams of column chromatography in industrial and laboratory methods are as follows:



Metallurgy of Aluminium

Some Common Ores of Aluminium

1. Bauxite or hydrated aluminium oxide ($Al_2O_3.2H_2O$)
2. Cryolite or sodium aluminium fluoride (Na_3AlF_6)
3. Corundum or anhydrous aluminium oxide (Al_2O_3)

In the metallurgy of aluminium, first, the ore of aluminium is **concentrated**.

Removal of unwanted materials such as sand and clay from ores is known as **concentration** (or **dressing** or **benefaction**) of ores.

Aluminium is generally extracted from the bauxite ore. The bauxite ore can be concentrated by the process of leaching.

Leaching of alumina from bauxite (Baeyer's Process)

The powdered ore of bauxite is concentrated by digesting it with concentrated sodium hydroxide solution at 473-523 K and 35-36 bar pressure. As a result, Al_2O_3 is leached out as sodium aluminate along with SiO_2 as sodium silicate leaving behind the impurities.

$$Al_2O_{3(s)} + 2NaOH_{(aq)} + 3H_2O_{(l)} \xrightarrow[35-36\ \text{bar}]{473-523\text{K}} 2Na\left[Al(OH)_4\right]_{(aq)}$$

Then, carbon dioxide gas is passed through the aluminate solution to neutralise it and as a result, hydrated Al_2O_3 gets precipitated. Freshly prepared hydrated Al_2O_3 is added to induce the precipitation.

$$2Na\left[Al(OH)_4\right]_{(aq)} + CO_{2(g)} \longrightarrow Al_2O_3 \cdot xH_2O_{(s)} + 2NaHCO_{3(aq)}$$

The hydrated Al_2O_3 is filtered out of the solution, then dried and heated to obtain pure Al_2O_3 while sodium silicate remains in the solution.

$$Al_2O_3 \cdot xH_2O_{(s)} \xrightarrow{1470\ \text{K}} Al_2O_{3(s)} + xH_2O_{(g)}$$

Another method of extracting alumina from bauxite is the Hall's process.

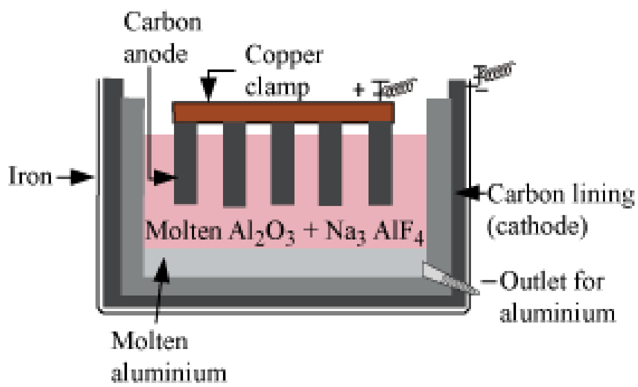
Hall's Process

In this method the ore is powdered and heated with an aqueous solution of sodium carbonate. This results in the formation of water soluble sodium aluminate. The insoluble impurities are filtered out and the filtrate is warmed and neutralised by passing carbon dioxide gas through it. This causes the precipitation of aluminum hydroxide.

$$Al_2O_3.2H_2O\ (s) + Na_2CO_3 \rightarrow 2NaAlO_2\ (aq) + CO_2 + 2H_2O\ (l)$$
$$2NaAlO_2\ (aq) + 3H_2O + CO_2\ (g) \rightarrow 2Al(OH)_3 + Na_2CO_3$$

Alumina which is obtained after Bayer's process and Hall's process is very stable and cannot be reduced using conventional reducing agents. Aluminium can be extracted from the pure alumina by the process of electrolytic reduction.

Electrolytic Reduction of Alumina



Electrolytic cell for the extraction of aluminium

The melting point of alumina is too high to be used as an electrolyte. In this process, 60% of Na_3AlF_6 with 20% of CaF_2 is added to 20 % of pure alumina to lower the melting point and to increase the conductivity of the electrolyte. The inner lining of the electrolytic cell acts as the cathode and graphite rod acts as the anode.

The temperature of the electrolyte is maintained at 950 ^oC by electrical heating using a voltage of 5 to 6 V. This low voltage avoids decomposition of molten cryolite.

The overall reaction that takes place is

$$2Al_2O_3 + 3C \longrightarrow 4Al + 3CO_2$$

This electrolytic process is known as the Hall-Heroult's process. The oxygen liberated at the anode reacts with the carbon of the anode to produce CO and CO_2. Therefore, the carbon anode has to be replaced periodically as the oxygen released oxidises it.

The cell reactions are:

At Cathode: $Al^{3+}_{(melt)} + 3e^- \longrightarrow Al_{(l)}$

At Anode:

$$2\,O^{2-} \longrightarrow 2\,O + 4\,e^-$$
$$O + O \longrightarrow O_2$$
$$C_{(s)} + O^{2-}_{(melt)} \longrightarrow CO_{(g)} + 2e^-$$
$$C_{(s)} + 2O^{2-}_{(melt)} \longrightarrow CO_{2(g)} + 4e^-$$

The anode is oxidised by the oxygen-evolving at anode so it has to be replaced from time to time.

Functions of Important Substance in Extraction of Aluminium

1. Cryolite:
1. Lowers melting point
2. Increases conductivity
2. Fluorspar and cryolite:
1. Solvent for electrolytic mixture
2. Increases conductivity

3. Powdered coke:
1. Reduces heat loss by radiation
2. Prevents burning of anode

Purification of aluminium

Aluminium obtained is about 99.9 % pure. However, it can be further purified by an electrolytic process known as Hoope’s process. In this process, a three-layered electrolytic cell is used. These layers are made up of molten substances of different specific gravity.

Bottom layer: Molten impure aluminium with Carbon lining (anode)
Middle later: Mixture of sodium fluoride, barium fluoride and aluminium fluoride
Top layer: Molten pure aluminium with carbon electrodes (cathode)

When current passes through the cell, the aluminium from middle layer moves to the top and similarly, an equivalent amount of aluminium from bottom layer moves to the middle layer. Pure aluminium is thus obtained from the top layer.

Reactions:

At anode: $Al \longrightarrow Al^{3+} + 3\,e^-$
At cathode: $Al^{3+} + 3\,e^- \longrightarrow Al$

Physical and Chemical Properties

<u>Physical Properties</u>

- Appearance: Silvery white metal
- Strength: Light but strong metal with high tensile strength
- Malleable and ductile
- Good conductor of heat and electricity
- Lustrous after polishing
- Melting and boiling point: 600 ^oC and 2050 ^oC, respectively

<u>Chemical Properties</u>

- Reaction with air:

$$4\ \mathrm{Al}\ +\ 3\,\mathrm{O_2}\ \xrightarrow{800\,^{\circ}\mathrm{C}}\ 2\ \mathrm{Al_2\,O_3}$$
$$2\ \mathrm{Al}\ +\ \mathrm{N_2}\ \longrightarrow\ 2\ \mathrm{AlN}$$

- Reaction with water:

$$2\ \mathrm{Al}\ +\ 3\,\mathrm{H_2O(steam)}\ \longrightarrow\ \mathrm{Al_2\,O_3}\ +\ 3\,\mathrm{H_2}$$

- Amphoteric nature:

$$2\ \mathrm{Al}\ +\ 2\ \mathrm{NaOH}\ +\ 2\,\mathrm{H_2O}\ \longrightarrow\ 2\ \mathrm{NaAlO_2}\ +\ 3\,\mathrm{H_2}$$
$$2\ \mathrm{Al}\ +\ 6\ \mathrm{HCl}\ \longrightarrow\ 2\ \mathrm{AlCl_3}\ +\ 3\,\mathrm{H_2}$$

- Reaction with non-metals

$$2\ \mathrm{Al}\ +\ \mathrm{N_2}\ \xrightarrow{\Delta}\ 2\ \mathrm{AlN}$$
$$2\ \mathrm{Al}\ +\ 3\ \mathrm{Cl_2}\ \xrightarrow{\Delta}\ 2\ \mathrm{AlCl_3}$$
$$2\ \mathrm{Al}\ +\ 3\,\mathrm{S}\ \xrightarrow{\Delta}\ \mathrm{Al_2\,S_3}$$
$$4\ \mathrm{Al}\ +\ 3\,\mathrm{C}\ \xrightarrow{\Delta}\ \mathrm{Al_4\,C_3}$$

- Reducing nature: Aluminothermy

$$\mathrm{Fe_2\,O_3}\ +\ \underset{\text{Strong Reducing Agent}}{2\ \mathrm{Al}}\ \longrightarrow\ 2\ \mathrm{Fe}\ +\ \mathrm{Al_2\,O_3}\ +\ \mathrm{Heat}$$

Uses of aluminium

Some important uses of aluminium are:

- As wrappers for foods in the form of foils
- In paints and lacquers
- In the extraction of chromium and manganese from their oxides
- In conduction of electricity in the form of wires

Alloy**s** of aluminium are also useful as they are light. Some alloys of aluminium are:

- **Duralumin** (95 % Al, 4 % Cu, 0.5 % Mg, 0.5 % Mn) which is used in the manufacture of aeroplanes as it is very light, strong, ductile, and resistant to corrosion
- **Magnelium** (90 % Al, 10 % Mg) which is used in the manufacture of light tools and machine parts as it is very light, strong, and resistant to corrosion

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.

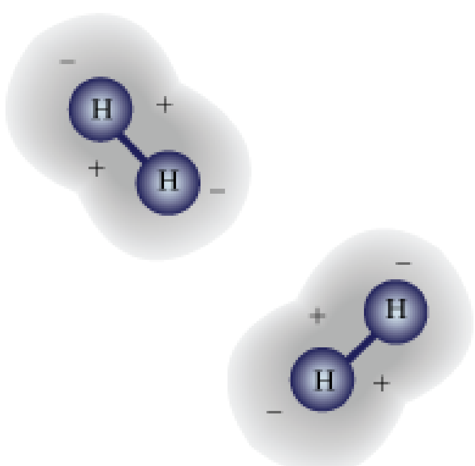
Uses of copper

- 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.

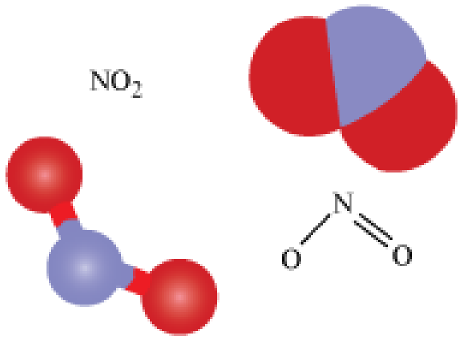
- It is used as a non-polluting fuel. It is present in coal gas and water gas.
- Oxy-hydrogen flame is used for cutting and welding metals.
- It is also used for filling weather observation balloons.



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*.

ALLOYS

Alloys are homogeneous mixtures of two or more elements (at least one of which is metal). They are made to improve the properties of metals such as their malleability, ductility, strength, and hardness.

Purpose of making alloys:
(a) To change the property of metal
(b) To achieve a specific objective

Reason to make alloys:
The process of alloying the metals alters their properties such as:
(a) Enhanced appearance
(b) Altered chemical reactivity
(c) Lowered melting point
(d) Modified casting ability
(e) Increased hardness
(f) Enhanced tensile strength
(g) Increases electrical resistant

Characteristics of an alloy:
(a) It enhances the hardness of metals.
(b) It increases the tensile strength of metals.
(c) It improves the corrosion resistance of metals.
(d) It changes or modifies the colour.
(e) It improves the castability of metals.

How do we prepare alloys?

Alloys are obtained by melting two or more elements in fixed proportions and then cooling them to room temperature.

We will now discuss some common alloys.

1. **Stainless steel**

   Stainless steel is obtained by combining carbon, chromium, and nickel in iron. The composition of various elements in steel is:

   Fe(73%) + Cr(18%)+Ni(8%) + C(1%)

   Stainless steel has many advantages over iron. The most important is that unlike iron, it does not rust. Hence, it is widely used for making utensils, cutlery, surgical instruments, and ornamental articles. It is also stronger than iron.

2. **Alloyed gold**

   Did you know that although gold is a very soft metal, it has a very high melting point of 1064ºC? Therefore, it is very difficult to work upon. Metals such as silver or copper are added to gold in small quantities to make it harder.

3. **Duralumin**

   Duralumin is obtained by combining copper, manganese, and magnesium in aluminium. The composition of various elements in duralumin is:

   Al (95%) + Cu(4%) + Mn (.5%) + Mg (.5%)

   It is very lightweight, yet very hard and strong. Therefore, it is used for making frames of aircrafts, automobiles, and speedboats.

   It is also used for making household articles.

4. **Brass**

   Brass is obtained by mixing zinc and copper. The composition of various elements in brass is:

   Zn (40-30%) + Cu (60-70%)

   It is used for making electric switches, statues, utensils, and ammunition.

5. **Bronze**

Bronze is obtained by mixing tin and copper. The composition of various elements in bronze is:

Cu(80%) + Sn(18%) + Zn(2%)

It is very resistant to corrosion. Therefore, it is used for making coins, statues, and utensils.

Alloys of iron and zinc

Alloys are homogeneous mixtures of two or more metals. Alloys are prepared to enhance the properties of metals.

Some alloys of iron are steel, stainless steel, tungsten steel, nickel, chrome steel, etc. Steel contains carbon. The constituents of stainless steel are Fe, C, Cr, and Ni. It is used in automobiles, cycles, pens, utensils, etc. Tungsten steel, which contains 20% tungsten, is used in high speed machinery.

Nickel steel, which contains 36% nickel, is used for making cables, automobiles, aeroplane parts, pendulum, measuring tapes, etc. Chrome steel is used for cutting tools and crushing machines.

The table given below discusses some more important alloys:

Primary Metal	Name of the Alloy	Composition of the Alloy	Properties of the Alloy	Uses of the Alloy
Aluminium	Magnalium	Al (90-95 %) Mg (10-5%)	(a) Corrosion resistant (b) Light and strong	(a) Making aircrafts (b) Making scientific instruments (c) Making mirrors (d) Making household appliances
Aluminium	Alnico	Al, Ni, Co, Fe	(a) Corrosion resistant (b) Light and shiny	(a) Making magnets
Iron	Manganes steel	Fe (85%) Mn (14%) C (1%)	(a) Durable (b) Hard	(a) Making safes (b) Making rock drills (c) Making armour

Iron	Tungsten steel	Fe (84%) W (5%) C (1%)	(a) Hard	(a) Making cutting tools for high-speed lathes
Iron	Nickel steel	Fe (95-98%) Ni (5-3%)	(a) Hard (b) Elastic (c) Corrosion resistant	(a) Making electric wires (b) Making automobile parts
Iron	Invar	Fe (63%) Ni (36%) C (1%)	(a) Negligible expansion	(a) Making metre scale (b) Making scientific equipment
Copper	German silver	Cu (50%) Zn (30%) Ni (20%)	(a) Silvery light alloy (b) Malleable (c) Ductile (d) Electricity resistant	(a) Making decorative items (b) Making electric heaters (c) Making rheostat (d) Making resistors
Copper	Bell metal	Cu (78%) Sn (22%)	(a) Hard (b) Brittle (c) Sonorous	(a) Making bells (b) Making gongs (c) Making statues
Copper	Gun metal	Cu (88%) Sn (8%) Zn (1%) Pb (1%)	(a) Hard (b) Brittle (c) Easily cut	(a) Making barrels of canons (b) Making bearings (c) Making gears
Lead	Solder (Fuse metal)	Pb Sn	(a) Low melting point (b) High tensile strength	(a) For welding purposes (b) For making fuse
Lead	Type metal	Pb (75%) Sb (15%) Sn (10%)	(a) Low melting point (b) Easy to cast	(a) For making printing blocks

Some people think that alloys were the first discovery of modern science. **But do you know that alloys are not at all a discovery of modern science?**

History of alloys

The first alloy created by man was bronze. It got its name from the Italian word 'bronzo' or the Persian word 'birinj'. Bronze, an alloy of copper and tin, came into use from as early as 3000

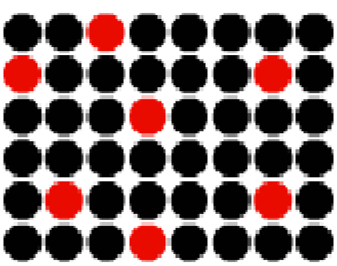
BC. In the third millennium BC, the Sumerians developed bronze to make tools and weapons for ruling their neighbours.

In Asia, some mines produced good quality alloys that were used to make better musical instruments and mirrors. In the 16th century BC, Persians developed carbon steel and started the Iron Age.

In the 20th century BC, the Romans developed their own gold substitute. Under the reign of Caesar Augustus, they developed brass, containing 75% copper and 25% zinc.
About 125 years ago, white gold was developed. This alloy was called German Silver or Mock Platinum. In the 12th century, silversmiths in Germany started using Sterling Silver alloy for coinage.

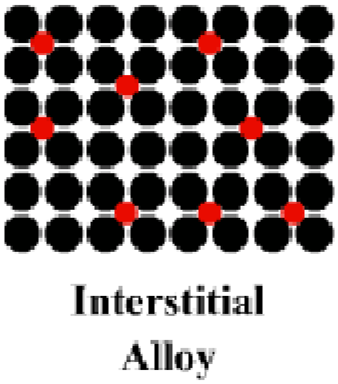
The first official coinage system of Lydia was developed by King Croesus during the period 560–546 BC, using a naturally occurring alloy of gold and silver called electrum.

On the basis of composition, alloys are of two types. They are as follows:



Substitution Alloy

(a) Substitutional alloy: In this kind of alloy, an atom of one metal randomly replaces the atom of the other.



(b) Interstitial alloy: In this kind of alloy, small atoms of elements like hydrogen, boron, carbon and nitrogen occupy the holes in the crystal structure of the metal.

On the basis of their constituents or elements, alloys can be of two types. They are as follows:

(a) Ferrous alloy: Alloys which contain iron as the base metal are known as ferrous alloys. For example steel, alnico (used for making magnets), etc.

(b) Non-ferrous alloy: Alloys which does not contain iron as the base metal are known as non-ferrous alloy. For example brass, bronze, duralumin, etc.

Uses of different alloys:

Bell metal	**Copper: 77 %**	**Casting of bells**
Duralumin	Aluminium: 95% Copper: 4% Manganese: Less than 1 % Magnesium: 0.5%	Aircraft parts, boats, railroad cars, ships and nails
Brass	Mainly copper Zinc: Up to 50%	Hose nozzles, screws, inexpensive jewellery, window and door fittings
Bronze	Mainly copper Tin: Up to 12%	Coins, medals, heavy gears, statues, machine parts
Solder	Lead: 50% Tin: 50%	In electrical and plumbing industries to join two metals together
Steel	Iron, carbon, chromium, nickel and tungsten	Cooking utensils, household articles, construction of bridges and buildings
Sterling silver	Silver: 92.5% Copper: 7.5%	jewellery, art objects
Alnico	Iron, aluminium, nickel and cobalt	Magnets which are much stronger than ordinary magnets

Do you know? Certain elements are added to steel to enhance its properties. Some of them are mentioned in the table below.		
Alloying Agent	**Property**	**Use**
Nickel	It increases strength and hardness. It also makes steel resistant to corrosion.	Turbine blades, engine parts, etc.
Chromium	It resists wear and tear and enhances its resistance to corrosion. It also enhances the hardness and toughness of steel.	This alloy is known as stainless steel. It is mainly used for making kitchen utensils and surgical instruments.
Vanadium	Increases strength and toughness of steel, including its resistance to wear and tear.	Crankshaft, hand tools, surgical instruments, etc.