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Introduction

This is a learning as well as an exam preparation video.

At the end of the video are practice assignments for you to attempt.

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Chapter 3:Metals & Non-Metals

Chapter 3:Metals & Non-Metals

Physical Properties of Metals

- Physical State: With the exception of mercury and gallium, which are liquids at room temperature, metals are solids at room temperature.
- Lustre: The property of metals which makes the light reflect from their surfaces is called lustre. This property of the metals can be due to the polished metal surfaces. Eg., gold and silver.
- Malleability: Metals may be formed into thin sheets known as foils and can withstand hammering. With the exception of Zinc, which is fragile.

Chapter 3:Metals & Non-Metals

Physical Properties of Metals

- Ductility: Wires can be made out of metals. With the exception of Zinc, which is fragile.
- Hardness: Except for sodium and potassium, which are soft and can be cut with a knife, all metals are hard.
- Conduction: Because metals have free electrons, they are good conductors. Silver and copper are the best heat and electricity conductors. Lead is the least efficient heat conductor. Iron, bismuth, and mercury are likewise poor conductors.

Chapter 3:Metals & Non-Metals

Physical Properties of Metals

- Density: Metals have a high density and weigh a lot. The densities of iridium and osmium are the greatest, whereas lithium has the lowest density.
- Melting and Boiling Point: Metals are known for their high melting and boiling points.
- The melting point of tungsten is the highest, while the boiling point of silver is the lowest. The melting values of sodium and potassium are both low.
- Alloy Formation: Metals combine to create an alloy, which is a homogeneous combination of metals. Brass is a copper and zinc alloy.

Chapter 3:Metals & Non-Metals

Physical Properties of Non- Metals

- Physical State: At ambient temperature, the majority of non-metals exist in two of the three states of matter: gases (oxygen) and solids (iodine, carbon, sulphur). There is no metallic sheen to them (save iodine) and they do not reflect light. (With the exception of carbon in the form of diamond).
- Nature: Non-metals are extremely fragile, and they can't be coiled into wires or hammered into sheets. Except for diamond, which is the world's hardest substance.
- Conduction: Non-metals are poor heat and electrical conductors. (Except graphite conducts heat, both graphite and gas carbon conduct electricity.)

Chapter 3:Metals & Non-Metals

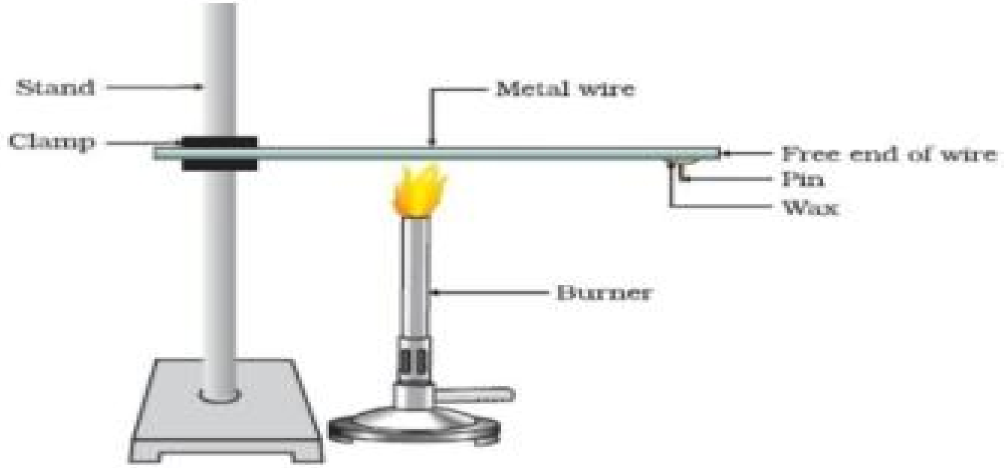
Physical Properties of Non- Metals

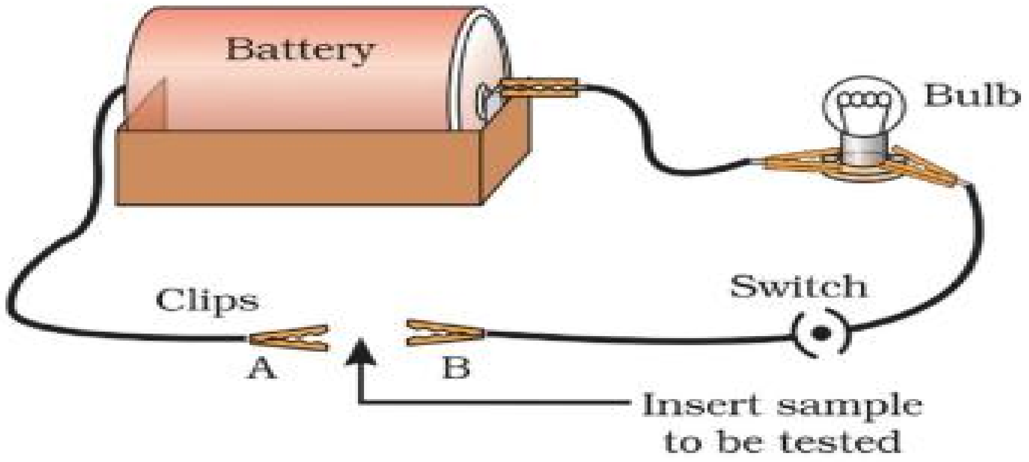
- Electronegative Character: Non-metals have a proclivity for gaining or sharing electrons with neighbouring atoms. Hence, non-metals are known for their electronegative nature.
- Reactivity: When they come into contact with oxygen, they produce acidic or neutral oxides. Hence, non-metals are reactive.

Chapter 3:Metals & Non-Metals

Difference in Physical Properties of Metals and Non-Metals:

Metals	Non-metals
1. Metals are good conductors of heat and electricity.	1. Non-metals are bad conductors of heat and electricity.
2. Metals are malleable that is they can be beaten into sheets.	2. Non-metals are not malleable.
3. Metals are ductile that is they can be drawn into wires.	3. Non-metals are not ductile.
4. Metals are sonorous.	4. Non-metals are not sonorous.
5. Metals have high tensile strength due to high attraction between molecules.	5. Non-metals have low tensile strength due to low attraction between molecules.
6. Metals have high density.	6. Non-metals have low density.





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Chemical Properties of Metals

Almost all metals react with oxygen to form metal oxides.

Metal + Oxygen → Metal oxide (basic)

- Sodium and potassium are the most reactive and react with oxygen present in the air at room temperature to form the oxides. It is kept immersed in kerosene oil as they react vigorously with air and catch fire.

$4K(s)+O_2(g) \rightarrow 2K_2O(s)$ (vigorous reaction)

Chapter 3:Metals & Non-Metals

Chemical Properties of Metals

- Magnesium does not react with oxygen at room temperature, but on heating, it burns in the air with intense light and heat to form magnesium oxide.

$2Mg(s)+O2(g) \rightarrow 2MgO(s)$ (Mg burns with white dazzling light)

- Silver, platinum and gold don’t burn or react with air.

Chapter 3:Metals & Non-Metals

Chemical Properties of Metals

Reaction of Metals with Water

Metals react with water and produce a metal oxide and hydrogen gas. Metal oxides that are soluble in water dissolve in it to further form metal hydroxide. But all metals do not react with water.

Metal + Water → Metal oxide + Hydrogen

Metal oxide + Water → Metal hydroxide

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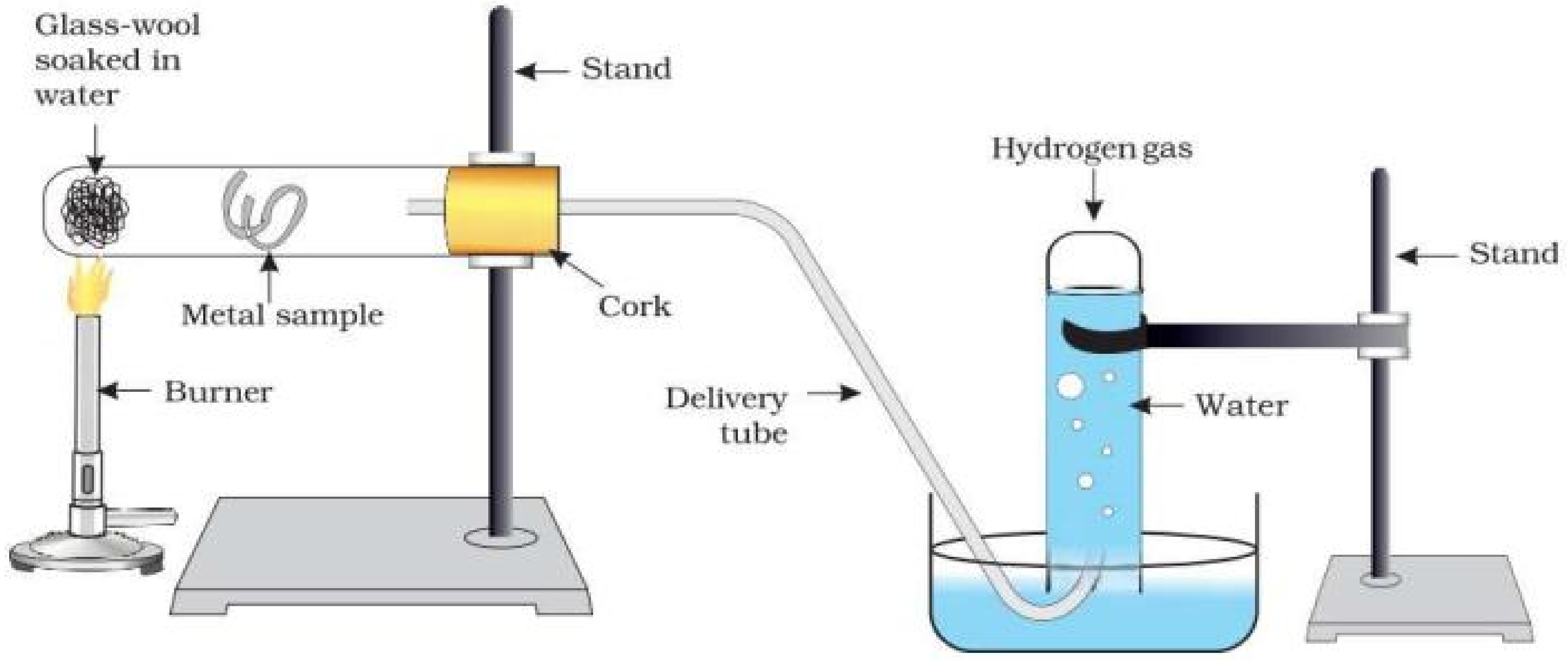
Chemical Properties of Metals



Action of steam on a metal

Chapter 3:Metals & Non-Metals

Chemical Properties of Metals

- Metals such as sodium and potassium react vigorously with cold water to lead to evolution of hydrogen, which immediately catches fire producing a large quantity of heat.

$2K(s) + 2H_2O(l) \rightarrow 2KOH(aq) + H_2(g)$ + heat energy
$2Na(s) + 2H_2O(l) \rightarrow 2NaOH(aq) + H_2(g)$ + heat energy

- Metals such as aluminium, zinc and iron do not react with cold or hot water, but they react with steam to form metal oxides and hydrogen.

Chapter 3:Metals & Non-Metals

Chemical Properties of Metals

$2Al(s) + 3H_2O(g) \rightarrow Al_2O_3(s) + 3H_2(g)$
$3Fe(s) + 4H_2O(g) \rightarrow Fe_3O_4(s) + 4H_2(g)$

- Metals such as lead, copper, silver and gold do not react with water at all

Reactions of Metals with Acids

Metals react with acids to form salt and hydrogen gas.
Metal + Dilute acid → Salt + Hydrogen

- 1. Metals react with dilute hydrochloric acid to give metal chloride and hydrogen gas.

$Mg + 2HCl \rightarrow MgCl_2 + H_2$

Chapter 3:Metals & Non-Metals

Chemical Properties of Metals

2. Metals react with sulphuric acid to form metal sulphate and hydrogen gas.

$$Fe + H_2SO_4 \rightarrow FeSO_4 + H_2$$

3. Metals react with nitric acid, but hydrogen gas is not evolved since nitric acid is a strong oxidising agent. So, it oxidises the hydrogen to water and itself gets reduced to a nitrogen oxide.

But magnesium and manganese react with dilute nitric acid to evolve hydrogen gas.

$$Mg + 2HNO_3 \rightarrow Mg(NO_3)_2 + H_2$$

$$Mn + 6HNO_3 \rightarrow Mn(NO_3)_2 + H_2$$

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Chemical Properties of Metals

Reactivity Series

The arrangement of metals in the order of decreasing reactivities is called the reactivity series of metals.

K	Potassium	Most reactive
Na	Sodium	
Ca	Calcium	
Mg	Magnesium	
Al	Aluminium	
Zn	Zinc	Reactivity decreases
Fe	Iron	
Pb	Lead	
H	Hydrogen	
Cu	Copper	
Hg	Mercury	
Ag	Silver	
Au	Gold	Least reactive

Activity series: Relative reactivities of metals

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Chemical Properties of Metals

Reactions of Metals with Solutions of Other Metal

A more reactive metal displaces a less reactive metal from its salt solution.

For example:

When an iron nail is placed in a copper sulphate solution, the blue colour of $CuSO_4$ fades away slowly and a reddish brown copper metal is formed.

$CuSO_4(aq) + Fe(s) \rightarrow FeSO_4(aq) + Cu(s)$

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Chemical Properties of Metals

Reaction of Metals with Chlorine

Metals react with chlorine to form metal chlorides. For example:

- Sodium readily reacts with chlorine to form ionic chloride called sodium chloride.
  $2Na(s) + Cl2(g) \rightarrow 2NaCl(s)$
- Calcium reacts vigorously with chlorine to form calcium chloride.
  $Ca(s) + Cl2(g) \rightarrow 2CaCl2(s)$

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Chemical Properties of Metals

Properties of Ionic Compounds

- Ionic compounds are hard solids, due to the strong force of attraction between the positive and negative ions.
- They are generally brittle and break into pieces when pressure is applied.
- Ionic compounds have high melting and boiling points, since a large amount of energy is required to break the strong intermolecular attractions.

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Chemical Properties of Metals

Properties of Ionic Compounds

- They are soluble in water, but insoluble in solvents such as kerosene, petrol, etc.
- They do not conduct electricity in a solid state, because electrostatic forces of attraction between ions in the solid state are very strong but conduct electricity in the fused (or in the aqueous state) because these forces weaken in the fused (or in solution) state so that their ions become mobile.

Chapter 3:Metals & Non-Metals

Metallurgy

- **Minerals: The naturally occurring compounds of metals, along with other impurities are known as minerals.**
- **Ores: The minerals from which metals are extracted profitably and conveniently are called ores.**
- **Gangue: Earthly impurities including silica, mud, etc. associated with the ore are called gangue.**
- **Metallurgy: The process used for the extraction of metals in their pure form from their ores is referred to as metallurgy.**

Chapter 3:Metals & Non-Metals

Metallurgy

Extraction of Metals

- The reactivity of elements differs for different metals.
- Three major steps involved in the extraction of metals from their ores are:

Conversion of Concentrated Ore into Metal

- The extraction of a metal from its concentrated ore is essentially a process of reduction of the metal compound present in the ore.
- The method of reduction to be used depends on the reactivity of the metal to be extracted.

Chapter 3:Metals & Non-Metals

Metallurgy

- **Extraction of Less Reactive Metals**

Metals at the bottom of the reactivity series are not very reactive and the oxides of these metals can be reduced by heating the ore itself.

Extraction of Mercury

Cinnabar, an ore of mercury is first heated in the air and is converted into mercuric oxide.

$$2HgS_{(s)} + 3O_{2(g)} \xrightarrow{Heat} 2HgO_{(s)} + 2SO_{2(g)}$$

$$2HgO_{(s)} \xrightarrow{Heat} 2Hg_{(s)} + O_{2(g)}$$

Chapter 3:Metals & Non-Metals

Metallurgy

- **Extraction of Moderately Reactive Metals**
- **The moderately reactive metals in the middle of the reactivity series are extracted by the reduction of their oxides with carbon, aluminium, sodium or calcium.**
- **It is easier to obtain metals from their oxides (by reduction) than from carbonates or sulphides. So, before reduction can be done, the ore is converted into a metal oxide.**
- **The concentrated ores can be converted into metal oxides by the process of calcination or roasting.**

Chapter 3:Metals & Non-Metals

Metallurgy

Calcination is the process in which a carbonate ore is heated strongly in the absence of air to convert it into a metal oxide. The ore is heated to a high temperature in the absence of air, or when air is not present throughout the reaction. Carbonate ores, as well as ores containing water, are usually calcined to remove carbonate and moisture impurities.

Chapter 3:Metals & Non-Metals

Metallurgy

For example:

$$ZnCO_{3(s)} \xrightarrow{Calcination} ZnO_{(s)} + CO_{2(g)}$$

Roasting is the process in which a sulphide ore is strongly heated in the presence of air to convert it into a metal oxide.

$$2ZnS_{(s)} + 3O_{2(g)} \xrightarrow{Roasting} 2ZnO_{(s)} + 2SO_{2(g)}$$

Chapter 3:Metals & Non-Metals

Metallurgy

The metal oxides are converted to free metal by using reducing agents such as carbon, aluminium, sodium or calcium.

For example:

- **The metal zinc is extracted by the reduction of zinc oxide with carbon. Thus, when zinc oxide is heated with carbon, zinc is produced.**
- **Aluminium reduces iron oxide to produce the metal iron with the evolution of heat.**

Due to this heat, the iron is produced in the molten state.

Chapter 3:Metals & Non-Metals

Metallurgy

$Fe_2O_3(s) + 2Al(s) \rightarrow 2Fe(l) + Al_2O_3(s) + Heat$

The reaction of iron (III) oxide with aluminium is used to join railway tracks or cracked machine parts. This reaction is known as the thermite reaction.

- Extraction of Highly Reactive Metals

Metals high up in the reactivity series are very reactive. These metals have a strong affinity for oxygen. So, oxides of sodium, magnesium, calcium and aluminium cannot be reduced by carbon.

Chapter 3:Metals & Non-Metals

Metallurgy

These metals are obtained by electrolytic reduction.
Sodium, magnesium and calcium are obtained by the electrolysis of their molten chlorides.
For example:
Sodium metal is extracted by the electrolytic reduction of molten sodium chloride.

$$2NaCl_{(l)} \xrightarrow{Electrolytic} 2Na_{(s)} + Cl_{2(g)}$$

At Cathode: $Na^+ + e^- \rightarrow Na$

At Anode: $2Cl^- \rightarrow Cl_2 + 2e^-$

Chapter 3:Metals & Non-Metals

Metallurgy

Refining of Metals

- The most widely used method for refining impure metals is electrolytic refining.
- Electrolytic refining means refining by electrolysis. Metals such as copper, zinc, tin, lead, chromium, nickel, silver and gold are refined electrolytically.

Chapter 3:Metals & Non-Metals

Metallurgy

Electrorefining

Electrolysis can be used to recover metals that cannot be separated via a chemical reduction technique, as well as to purify metals acquired through other means. The anode in the electrorefining process is a block of impure metal, while the cathode is a thin sheet of pure metal. An aqueous solution of the metal salt is included in the electrolytic cell. When an electric current of a sufficient voltage is passed via the anode, impure metal is dissolved and pure metal is deposited at the cathode.

Chapter 3:Metals & Non-Metals

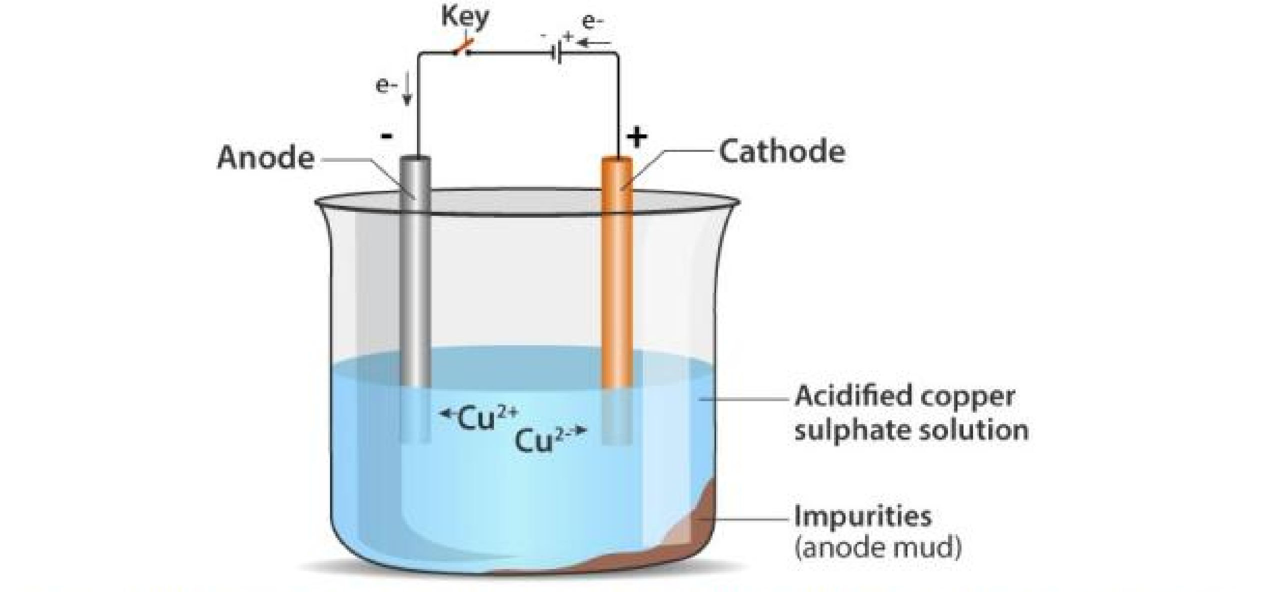
Metallurgy

The following is how metal ions from the anode enter the electolyte:

$M \rightarrow M^{+n} + ne^-$

These ions get deposited on the cathode in the following manner

$M^{+n} + ne^- \rightarrow M$



Electrolytic refining of copper. The electrolyte is a solution of acidified copper sulphate. The anode is impure copper, whereas, the cathode is a strip of pure copper. On passing electric current, pure copper is deposited on the cathode.

Chapter 3:Metals & Non-Metals

Metallurgy

This technique is used to refine volatile metals with lower boiling points than their impurities, such as copper, silver, tin, and nickel. For example: Mercury and Zinc.

- An electrolyte is a substance (salt, acid, or base) that transmits an electric current in solution or in a molten form while also being decomposed by it. The current is carried by ionised electrolytes, which are electrically charged ions.

Chapter 3:Metals & Non-Metals

Metallurgy

- Charged ions migrate towards oppositely charged electrodes in order to lose their electric charge and form atoms, which are then either released or deposited at the electrolyte.

Chapter 3:Metals & Non-Metals

Corrosion

- Most of the metals keep on reacting with the atmospheric air. This leads to the formation of a layer over the metal. In the long run, the underlying layer of metal keeps on getting lost due to conversion into oxides or sulphides or carbonate, etc. As a result, the metal gets eaten up. The process is called Corrosion.

Chapter 3:Metals & Non-Metals

Corrosion

- Rusting of Iron: Rusting of iron is the most common form of corrosion. When iron articles like the gate, grill, fencing, etc. come in contact with moisture present in the air, the upper layer of iron turns into iron oxide. Iron oxide is brown-red in colour and is known as Rust. The phenomenon is called Rusting of Iron.

Chapter 3:Metals & Non-Metals

Corrosion

- If rusting is not prevented in time, the whole iron article would turn into iron oxide. This is also known as Corrosion of Iron. Rusting of iron gives a huge loss every year.

Conditions necessary for rusting of iron

i. Presence of air (or oxygen)
ii. Presence of water (or moisture)

Chapter 3:Metals & Non-Metals

Corrosion

- Prevention of Corrosion
- Galvanising: It is the process of giving coating a thin layer of zinc on iron or steel to protect them from corrosion. Example: shiny nails, pins. etc.
- Tinning: It is a process of coating tin over other metals.
- Electroplating: In this method, a metal is coated with another metal using electrolysis.

Example: silver plated spoons, gold plated jewellery etc.

Chapter 3:Metals & Non-Metals

Corrosion

- **Alloying: An alloy is a homogeneous mixture of two or more metals or a metal and a non-metal in a definite proportion. The resultant metals, called alloys do not corrode easily.**

For example: Brass (copper and zinc), Bronze (copper and tin) and Stainless steel (iron, nickel, chromium and carbon)

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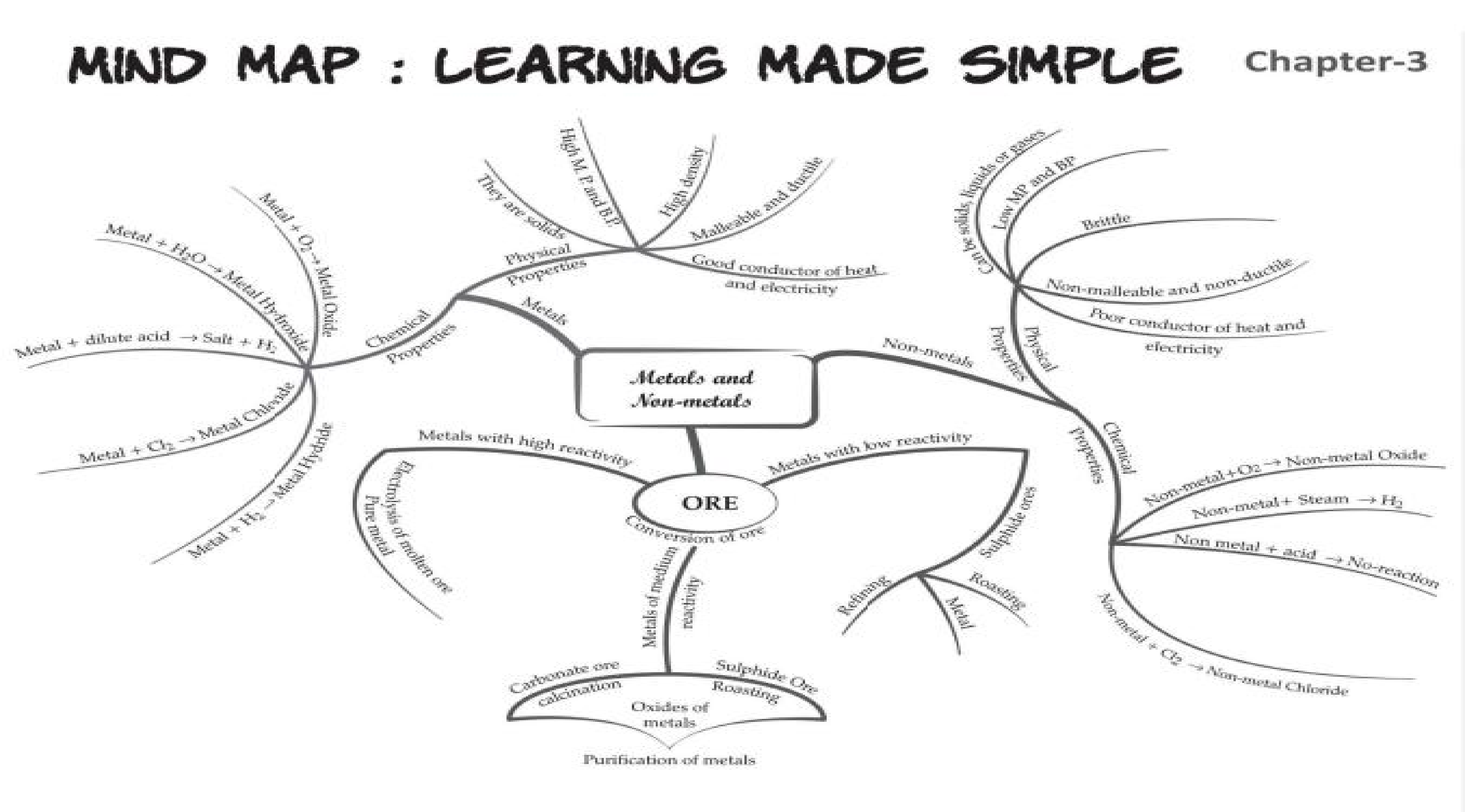

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