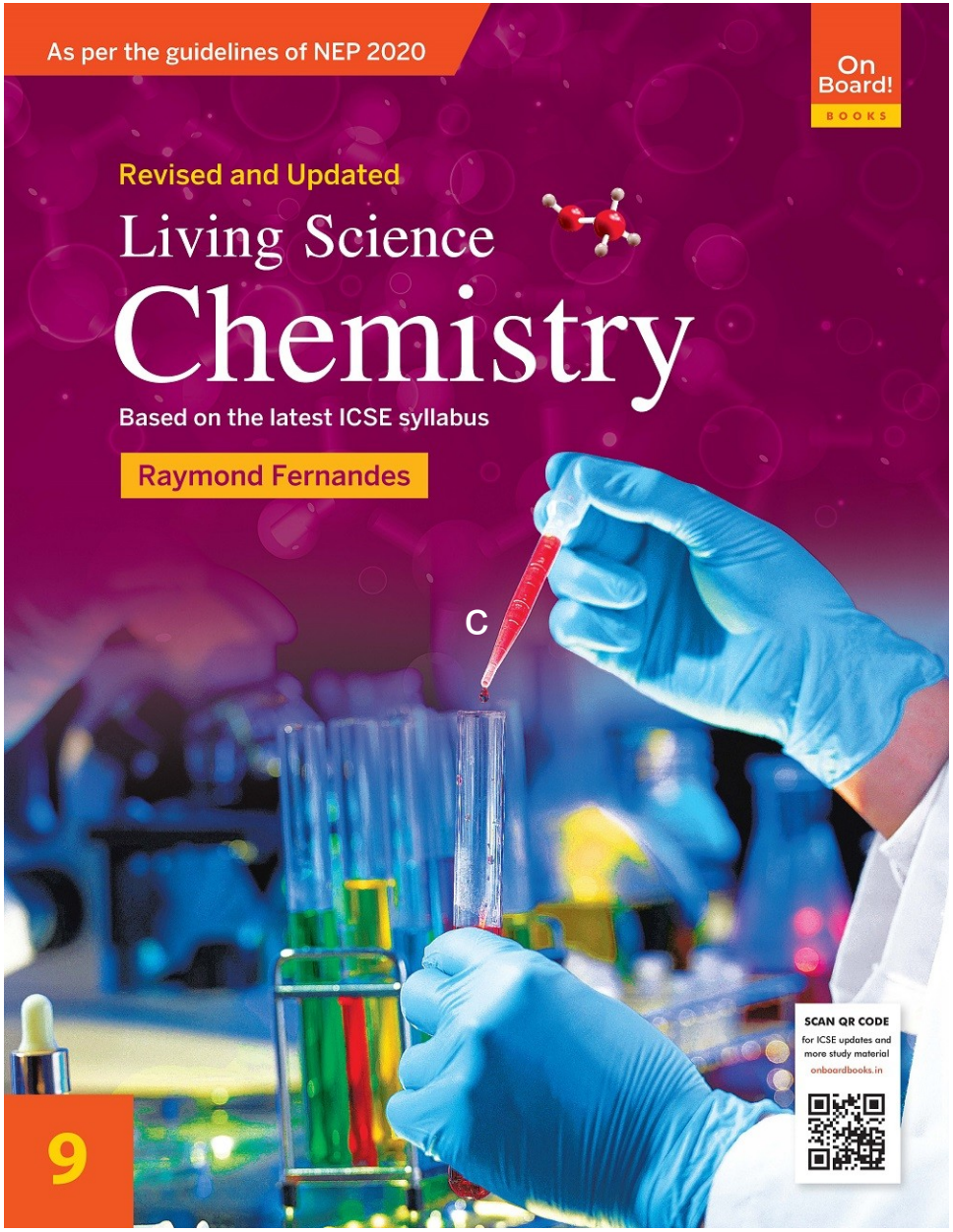
On Board! BOOKS

On Board!

BOOKS



Living Science

Chemistry

Class 9

Chapter 6 Study of the First Element – Hydrogen

LEARNING OBJECTIVES

Important Characteristics

- The position of hydrogen in the Periodic Table
- Resemblance with alkali metals
- Properties of hydrogen different from those of alkali metals
- Resemblance with halogens

Preparation of Hydrogen

- General methods of preparation
- Laboratory preparation
- Industrial preparation

Properties of Hydrogen

- Physical properties
- Chemical properties

Use of Hydrogen

Oxidation and Reduction Reactions

What is the position of hydrogen in the Periodic Table?

Hydrogen is the first element in the Periodic Table having atomic number 1. It has its one electron in the *K* shell. Hydrogen shows resemblance in properties with alkali metals of Group 1 as well as the halogens of Group 17 of the Periodic Table.

Hydrogen as an Element

Symbol: H

Atomic Number: 1

Electronic Configuration: (K – 1)

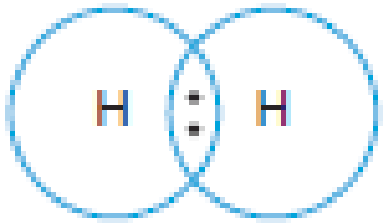
Molecular Formula: H_2

Molecular Mass: 2

Vapour Density: 1

Nature: Neutral gas

Solubility: Sparingly soluble in water

Structure: 

Two atoms of hydrogen combine covalently to form a molecule of hydrogen.

Resemblance with alkali metals

1. Electronic configuration: Like alkali metals, hydrogen has only one electron in its outermost shell or valence shell.

2. Valency: The valency of hydrogen as well as alkali metals is 1.

3. Like alkali metals hydrogen also forms positive ions by losing one electron. These elements, therefore, have electropositive character.

4. Action of air/burning: Hydrogen burns in air to form water.

$$2H_2 + O_2 \longrightarrow 2H_2O$$

Alkali metals burn vigorously in air or oxygen forming oxides.

Sodium burns in air to form sodium peroxide, Na_2O_2.

$$2Na + O_2 \longrightarrow Na_2O_2$$

5. Reducing agent: Alkali metals and hydrogen both are good reducing agents.

$$CuO + H_2 \xrightarrow{Heat} Cu + H_2O$$

$$CuO + 2Na \longrightarrow Cu + Na_2O$$

6. Combination with non-metals: Like alkali metals, hydrogen combines with non-metals such as oxygen, sulphur and halogens to form their corresponding compounds like H_2O, H_2S, HCl, HF, HBr and HI.

Properties of hydrogen different from those of alkali metals

1. Hydrogen shows little tendency to lose its electron but shows greater tendency to share the electron.

2. Hydrogen is a gas but alkali metals are solids.

3. Oxide of hydrogen, H_2O, is neutral but oxides of alkali metals are basic.

Resemblance with halogens

1. Electronic configuration: Hydrogen and halogens need an electron each to acquire stable noble gas configuration.

2. Valency: Both hydrogen and halogens have valency 1.

3. Atomicity: Like halogens, hydrogen also exists as a diatomic molecule. For example, H_2, Cl_2, Br_2, F_2, etc.

4. Ion formation: Like halogens, hydrogen behaves as an electronegative element and forms negative ion H^- as well.

5. Physical state: Like halogens, hydrogen is also a gas.

6. Oxidising agent: Hydrogen can oxidise Group I and Group II metals to form hydrides. Halogens are also good oxidising agents.

7. Non-metallic character: Like halogens, hydrogen is non-metallic in nature.

Properties of hydrogen different from those of halogens

1. Hydrogen is univalent but halogens show variable valency.

2. Oxide of hydrogen, H_2O, is a neutral oxide but oxides of halogens are acidic in nature.

Preparation of Hydrogen

General methods of preparation

Hydrogen from cold water and metals

Active metals like sodium, potassium and calcium react with cold water forming hydroxides and evolving hydrogen.

- **Potassium**

$$2K + 2H_2O \longrightarrow 2KOH + H_2\uparrow$$

The above reaction is not preferred due to the following reasons:

a. The reaction is vigorous and exothermic.

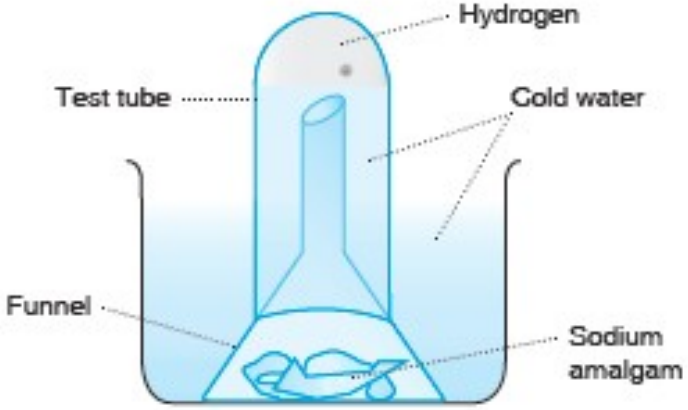
b. The heat produced by the reaction ignites hydrogen that is evolved.

- **Sodium**

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

The above reaction is not preferred due to the following reasons:

a. Sodium melts to form a ball that moves around on the surface. It darts about vigorously and catches fire. It is difficult to collect the liberated gas.



Reaction of cold water with sodium amalgam to liberate hydrogen

b. The reaction is violent but with potassium it is less violent. If sodium amalgam is reacted with water then the alloy sinks and stays under water. The reaction is slower and can be controlled and hydrogen gas can be collected.

Hydrogen from hot water and metals

- **Magnesium**

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

a. Magnesium does not react with cold water but it decomposes with hot water to liberate hydrogen.

b. Magnesium forms a protective layer of oxide so the reaction slows down. The reaction can be made fast by removing the oxide layer by amalgamating with mercury.

Hydrogen from steam and metals

- **Aluminium**

Aluminium reacts with steam to form aluminium oxide and hydrogen gas.

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

Aluminium does not react with water under ordinary conditions. When exposed to air, aluminium develops a thin layer of oxide on its surface which prevents further reaction.

- **Zinc**

Zinc reacts with steam to form zinc oxide, and hydrogen is liberated.

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

• **Action of steam on non-metal (Carbon)**

When steam is passed over red-hot coke, carbon monoxide and hydrogen are produced. This 1 : 1 mixture of CO and H_2 is called **water gas**.

$$C + H_2O \longrightarrow CO\uparrow + H_2\uparrow$$

Displacement of hydrogen from dilute acids

Metals react with dilute acids to form corresponding metal salt, and hydrogen gas is liberated.

• **Sodium**

Sodium metal reacts violently with dilute hydrochloric acid to form sodium chloride and hydrogen gas.

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

Reaction with dilute nitric acid

When metals react with dilute nitric acid, hydrogen gas is not evolved.

• Nitric acid is an oxidising agent and hydrogen is a reducing agent. So, dilute nitric acid oxidises the hydrogen produced to water and itself reduces to any of the nitrogen oxides like N_2O, NO_2, N_2 and NH_3.

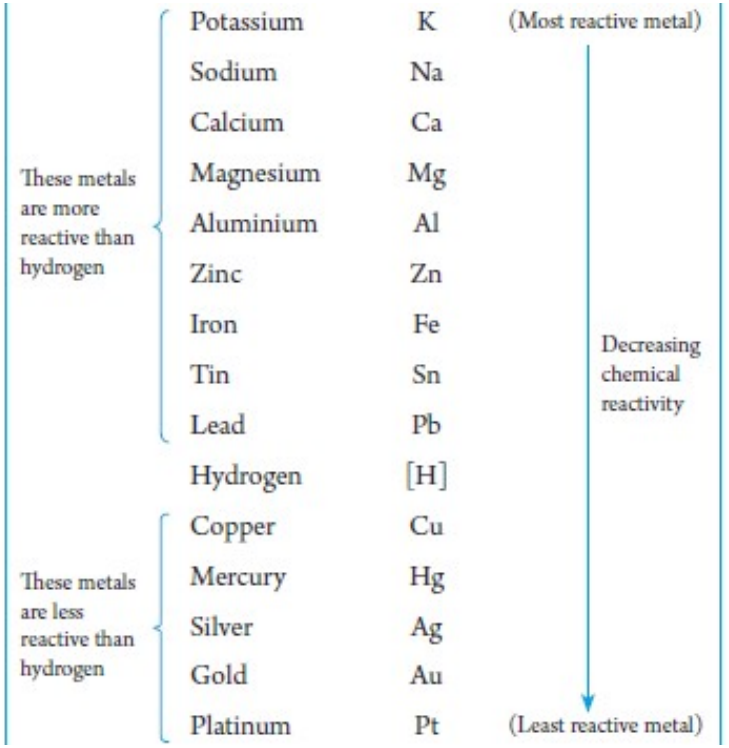
• Only magnesium and manganese react with very dilute nitric acid to produce corresponding nitrate and hydrogen gas.

$$Mg + 2HNO_3 \longrightarrow Mg(NO_3)_2 + H_2\uparrow$$

Activity series of metals

Some metals are chemically very active while some are less reactive or unreactive. **The arrangement of metals in a vertical column in the order of decreasing reactivity is called the activity series of metals.**

Hydrogen is not a metal but it is included in the activity series of metals. This is because, similar to metals, hydrogen loses an electron to form positive ion H^+.



1. Potassium is the most reactive metal and it has been placed at the top in the activity series.

2. Platinum is the least reactive metal and it has been placed at the bottom of the activity series.

3. If a metal is placed above hydrogen in the activity series, then it will displace hydrogen from water or acids.

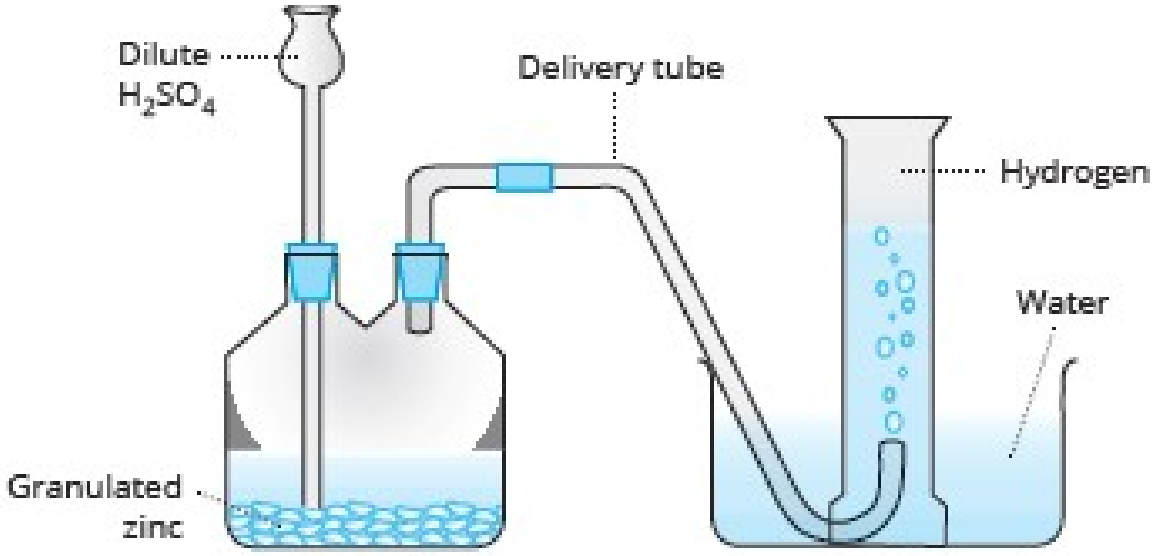
4. If a metal is placed below hydrogen in the activity series, it will not displace hydrogen from water or acids.

Laboratory preparation

In the laboratory, hydrogen is prepared by the action of dilute sulphuric acid or hydrochloric acid on granulated zinc.

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

$$Zn + 2HCl \longrightarrow ZnCl_2 + H_2$$



If pure zinc is used, this reaction becomes very slow because the layer of gas insulates the metal from the acid. Granulated zinc is therefore preferred. Granulated zinc is placed in a flask fitted with a two holed rubber stopper and dilute sulphuric acid is added into it through the funnel.

Hydrogen gas is liberated, which is transferred through a delivery tube and is collected by the downward displacement of water. This is possible because of the following reasons:

- Hydrogen is practically insoluble in water.
- Although hydrogen is lighter than air it cannot be collected over air because the air–hydrogen mixture is explosive in nature.

Precautions

The following precautions should be taken while preparing hydrogen as it is a highly inflammable gas.

1. Care must be taken to seal any leakage of the gas.

2. No flame must be brought near the apparatus because hydrogen is a combustible gas.

3. The end of the thistle funnel must be below the level of the acid in the flask so as to prevent the gas from escaping through the funnel.

Industrial preparation

On a large scale, hydrogen is prepared by the following methods:

1. Bosch process

When steam is passed over white hot coke, a mixture of hydrogen and carbon monoxide called water gas is formed.

The water gas is mixed with more steam and passed over a catalyst at 450 °C. CO is converted into CO_2 and more hydrogen is produced.

$$C + H_2O \longrightarrow \underset{\text{water gas}}{CO + H_2} - \Delta$$

$$CO + H_2 + H_2O \longrightarrow CO_2 + 2H_2$$

2. Electrolysis

Acidified water, when electrolysed, liberates hydrogen gas at the cathode and oxygen gas at the anode.

$$2H_2O \xrightarrow{\text{electric current}} \underset{\text{cathode}}{2H_2\uparrow} + \underset{\text{anode}}{O_2\uparrow}$$

3. From methane

Methane is mixed with steam and limited supply of oxygen and passed over nickel catalyst at 900 °C.

$$CH_4 + H_2O \longrightarrow CO + 3H_2$$

4. As a by-product

Hydrogen of high purity is obtained as a by-product in the manufacture of sodium hydroxide by electrolysing brine.

5. By the action of water on hydrides

This method is not important because of its high cost.

$$CaH_2 + 2H_2O \longrightarrow Ca(OH)_2 + 2H_2\uparrow$$

calcium hydride

Properties of Hydrogen

Physical properties

1. It is a colourless, tasteless and odourless gas.
2. It is the lightest gas known and is practically insoluble in water.
3. It is difficult to liquefy.
4. Hydrogen is absorbed on heating with certain transition metals such as palladium, platinum and nickel. This phenomenon is called **occlusion** or adsorption of hydrogen.

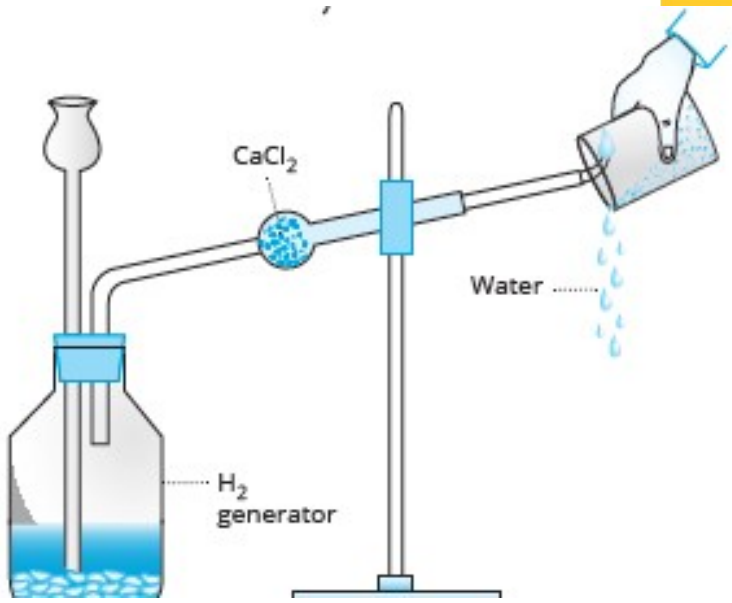
Chemical properties

1. Action of litmus: It is neutral to litmus.
2. Combustion: Hydrogen is a combustible gas but it is not a supporter of combustion. The gas burns with a pale blue flame.
3. Reaction with metals: Hydrogen reacts with many metals at high temperatures to form corresponding hydrides.

$2K + H_2 \xrightarrow{heat} 2KH$

$2Na + H_2 \xrightarrow{heat} 2NaH$

4. Reaction with non-metals: Hydrogen combines with many non-metals at high temperature, usually in the presence of a catalyst.
It combines with oxygen to form water. The reaction is exothermic.



Burning of hydrogen to form water

$$2H_2 + O_2 \longrightarrow 2H_2O$$

5. Reducing property of hydrogen: Hydrogen is a strong reducing agent. When hydrogen is passed over oxides of less active metals like Cu, Pb, Fe, etc., it removes oxygen from them and itself gets oxidised to water.

$CuO + H_2 \xrightarrow{heat} Cu + H_2O$

$PbO + H_2 \xrightarrow{heat} Pb + H_2O$

Hydrogenation of vegetable oils: When hydrogen is passed through edible vegetable oils like soyabean oil or cotton-seed oil in the presence of finely divided nickel at 200 °C, they undergo hardening and change into edible fats. This process is called **hydrogenation** or **hardening of oils**.

Uses of Hydrogen

1. **As a fuel**:

- It is a constituent of many fuel gases like coal gas and water gas.
- Liquid hydrogen is used as rocket fuel in space research.

2. In the hydrogenation of vegetable oil to produce vanaspati ghee.
3. **In extraction of metals**: Hydrogen reduces metal oxides to metals.
4. In the manufacture of ammonia, hydrogen chloride, methyl alcohol, etc.

$$CO + 2H_2 \longrightarrow CH_3OH$$

5. **For filling airships and balloons**: Since hydrogen is a very light gas, it is used for filling airships and balloons. As the gas is inflammable, nowadays a non-inflammable mixture of hydrogen and helium is used.
6. **For producing high temperature flame**: The oxy-hydrogen torch gives a very hot flame (2000–2500 °C). These flames are used for welding and cutting metals.

Oxidation and Reduction Reactions

A process which involves addition of oxygen or removal of hydrogen is called **oxidation.**

Elements burn in the presence of oxygen and combine with oxygen to form oxides of elements. Therefore, burning is an oxidation reaction.

$$C + O_2 \longrightarrow CO_2$$

Removal of hydrogen from compounds containing hydrogen leads to the oxidation of the compounds. For example,

Oxidation of hydrogen sulphide by bromine:

$$H_2S + Br_2 \xrightarrow{\text{oxidation}} 2HBr + S$$

Since in this reaction hydrogen is removed from hydrogen sulphide, this is an oxidation reaction.

A process which involves removal of oxygen or addition of hydrogen is called **reduction**. Metals are usually prepared by the removal of oxygen from metal oxides. This process involves reduction.

Oxidising and reducing agents

A substance which causes addition of oxygen or removal of hydrogen from other substances is called **oxidising agent.** Some examples of oxidising agents are oxygen, fluorine, chlorine, hydrogen peroxide, etc.

A substance which causes addition of hydrogen or removal of oxygen from other substances is called **reducing agent.** Some examples of reducing agent are hydrogen, carbon, sodium, magnesium, etc.

Relation between oxidation and reduction

A reaction in which oxidation and reduction take place simultaneously is called oxidation–reduction or redox reaction. In redox reactions, the oxidising agent is reduced and the reducing agent is oxidised.

$$CuO + H_2 \xrightarrow{\text{heat}} Cu + H_2O$$

a. CuO gives oxygen and therefore, CuO is the oxidising agent.
b. H_2 gains oxygen and therefore, H_2 is the reducing agent.

Differences between oxidation and reduction

Oxidation is a chemical reaction which involves addition of oxygen or any other electronegative atom or ion to a substance. It is a chemical reaction which involves removal of hydrogen or any other electropositive atom or ion from a substance.

Reduction is a chemical reaction which involves removal of oxygen or any other electronegative atom or ion from a substance. It is a chemical reaction which involves addition of hydrogen or any other electropositive atom or ion to a substance.

SUMMARY..

1. Preparation of Hydrogen

a. From water

Hydrogen is liberated when water reacts with metals or by electrolysis.

- Hydrogen from cold water and metals

$$2K + 2H_2O \longrightarrow 2KOH + H_2\uparrow$$

- Hydrogen from hot water and metals

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

- Hydrogen from steam and metals

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

b. Action of steam on non-metal (carbon)

$$C + H_2O \longrightarrow CO\uparrow + H_2\uparrow$$

c. Displacement of hydrogen from dilute acids

$$Mg + 2HCl \longrightarrow MgCl_2 + H_2\uparrow$$

d. Reaction with dilute nitric acid

$$Mg + 2HNO_3 \longrightarrow Mg(NO_3)_2 + H_2\uparrow$$

e. Displacement of hydrogen from alkalis

$$Zn + 2NaOH \longrightarrow Na_2ZnO_2 + H_2\uparrow$$

2. Activity series of metals

The arrangement of metals in a vertical column in the order of decreasing reactivity is called the activity series of metals.

3. Laboratory preparation of hydrogen

In the laboratory, hydrogen is prepared by action of dilute sulphuric acid or hydrochloric acid on granulated zinc.

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

$$Zn + 2HCl \longrightarrow ZnCl_2 + H_2\uparrow$$

4. Industrial preparation of hydrogen

On a large scale, hydrogen is prepared by

- Bosch Process
- Electrolysis

SUMMARY..

5. Physical properties

• It is a colourless, tasteless, odourless, sparingly soluble in water and lightest gas known.

• Occlusion: Hydrogen is absorbed on heating with certain transition metals such as palladium, platinum and nickel. This phenomenon is called occlusion or adsorption of hydrogen.

6. Chemical properties

• It is neutral to litmus.

• Hydrogen burns with a pale blue flame but does not support combustion.

• Hydrogen reacts with many metals at high temperatures to form corresponding hydrides.

• Hydrogen combines with many non-metals at high temperature, usually in the presence of a catalyst.

• Reacts with unsaturated hydrocarbons in the presence of appropriate catalyst to form saturated hydrocarbons. This process is called **hydrogenation**.

SUMMARY..

7. Hydrogen is used in the manufacture of ammonia, vegetable oils and hydrochloric acid.

8. A process which involves addition of oxygen or removal of hydrogen is called **oxidation**.

9. A process which involves removal of oxygen or addition of hydrogen is called **reduction**.

10. A substance which causes addition of oxygen or removal of hydrogen from other substances is called **oxidizing agent**.

11. A substance which causes addition of hydrogen or removal of oxygen from other substances is called **reducing agent**.

12. A reaction in which oxidation and reduction take place simultaneously is called redox reaction.

THANK
YOU