# Study of the First Element Hydrogen.

Symbol : H
Molecular Formula : $H_2$
Valency : 1
Electronic Configuration : 1 (K Shell)
Position in Periodic Table : 1st Period, 1A Group.
Relative Atomic Mass : 1
Relative Molecular Mass : 2
Atomic Number : 1

## Position of Hydrogen in Periodic Table

Hydrogen is the first element in the periodic table. It belongs to first group and first period of the periodic table.

Hydrogen shows dual nature as it resemble alkali metals of Group IA and halogens of Group VII A (17).

## larity between Hydrogen and Alkali

ydrogen and alkali metals have 1 $e^-$ ir outermost orbit.

2. Both hydrogen and alkali metals have 1 valence electron.

3. Both hydrogen and alkali metals have a valency 1.

4. Both hydrogen and alkali metals loose 1 $e^-$ and form a cation.

$$H \longrightarrow H^+ + e^-$$
$$Li \longrightarrow Li^+ + e^-$$
$$Na \longrightarrow Na^+ + e^-$$

5. Both hydrogen and alkali metals acts as a reducing agent.

$$CuO + H_2 \longrightarrow Cu + H_2O$$
$$CuO + 2Na \longrightarrow Cu + Na_2O$$

6. Both hydrogen and alkali metals reacts with oxygen to form their respective oxides. Hydrogen burns with a pop sound.

$$2H_2 + O_2 \longrightarrow 2H_2O$$
$$4Li + O_2 \longrightarrow 2Li_2O \quad \text{— monoxide}$$
$$2Na + O_2 \longrightarrow Na_2O_2 \quad \text{— peroxide}$$
$$H_2 + O_2 \longrightarrow H_2O_2 \quad \text{— peroxide}$$

K, Rb, Cs forms superoxide with general formula $MO_2$.

$$K + O_2 \longrightarrow KO_2$$

Alkali Metals are so reactive that they get rapidly tarnished when exposed to air. They

form oxide, hydroxide and finally carbonate on their surface.

$$4Na + O_2 \longrightarrow 2Na_2O$$
$$Na_2O + H_2O \longrightarrow 2NaOH$$
$$2NaOH + CO_2 \longrightarrow Na_2CO_3 + H_2O$$

Due to their reactivity, alkali metals are always stored in inert organic solvent, such as kerosene oil.

7 Both hydrogen and alkali metals react with non-metals to form respective compounds.

Hydrogen: $H_2O$, $H_2S$, HCl
Sodium: $Na_2O$, $Na_2S$, NaCl.

## Similarity between Hydrogen and Halogen

1. Both hydrogen and halogen have 1 $e^-$ less than nearest inert gas.
2. Both hydrogen and halogen have valency 1.
3. Both hydrogen and halogen gain 1 $e^-$ and form anion.

$$H + e^- \longrightarrow H^-$$
$$Cl + e^- \longrightarrow Cl^-$$

4. Both hydrogen and halogen are non-metals. They show electronegative character.
5. Both hydrogen and halogen are gases.

6. Both hydrogen and halogen exist in the form of diatomic molecule. ($H_2$, $F_2$, $Cl_2$, $Br_2$)

## Difference in the properties of Hydrogen and Halogen

1. Hydrogen atom has one shell but alkali metal and halogen have two or more shells.
2. Oxide of hydrogen is neutral but oxide of alkali metals are basic and oxide of halide acidic.

## Occurence of Hydrogen.

In free state,

- Traces in earth's crust and atmosphere
- 0.025% in volcanic gases.
- 0.98% in earth's crust
- 0.01% in earth's atmosphere
- Atmosphere of sun and star contain hydrogen in large amounts.

In combined state,

- Plant and animal tissues are made of compound of hydrogen with carbon oxygen and nitrogen.
- Acids, alkalis, hydrocarbons, proteins, sugar, starch, protein, carbohydrates, fats, petroleum products contains hydrogen.
- Water has 11.1% by weight hydrogen.

# Preparation of Hydrogen:

## - Action of Cold Water on Metals:

Reactive metals like potassium, sodium and calcium react with cold water to form corresponding hydroxide and evolving hydrogen gas.

### 1. Potassium

a. Potassium when added to water floats on water (density 0.86 g/cc).

b. It melts (at 62°C), forming silver grey globule that darts on the surface of water.

c. Reaction is highly exothermic and vigorous.

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

d. It catches fire and burns with lilac colour flame.

e. Hydrogen gas bubbles are observed and the solution formed is colourless, soapy, and alkaline.

### 2. Sodium

a. It floats on water; density 0.97 g/cc. MP: 97°C

b. It melts forming a silver globule which darts on the surface of water.

c. Reaction is less exothermic and less vigorous compared to ~~sodium~~ potassium.

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

d. It catches fire and burns with a golden yellow flame.

e. Hydrogen gas bubbles are produced.

f. Solution formed is colourless, soapy, slightly warm, and alkaline.

Note: Sodium Amalgam (Na + Hg) & Potassium Amalgam (K + Hg) react smoothly with water to produce hydrogen gas safely.

3. Calcium

a. Calcium sinks in water.

b. Calcium reaction is less vigrous than sodium.

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

c. Hydrogen gas bubbles are liberated, and solution turns milky, turbid, and alkaline.

Note: Solution of metal hydroxide of sodium, potassium, and calcium turn red litmus blue depicting their alkaline nature.

- Action of Hot Water on Metals

Magnesium react slowly with boiling water and form magnesium hydroxide (base) and hydrogen gas.

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

Magnesium burns in steam with an intense white light forming $Mg(OH)_2$ (white ash) and hydrogen gas.

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

## Action of Steam on Metals

1. Aluminium:

a. It reacts with steam to liberate hydrogen gas.

b. It forms aluminium oxide which makes it inactive.

$$2Al + 3H_2O \xrightarrow{800^\circ C} Al_2O_3 + 3H_2$$

c. At high temperature, the coating breaks and aluminium reacts with steam to liberate hydrogen gas.

2. Zinc:

a. It reacts when zinc is heated and steam is passed over it.

b. Zinc reacts with water to form zinc oxide and liberate hydrogen gas.

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

c. Zinc Oxide is yellow when hot and white when cold.

3. Iron:

a. Red Hot Iron reacts with steam to form triferric tetraoxide and hydrogen gas.

b. Reaction is reversible. If hydrogen formed is not removed, iron oxide reduce back to iron.

$$3Fe + 4H_2O \rightleftharpoons Fe_3O_4 + 4H_2\uparrow$$

Note: In the beginning, forward reaction is fast, but as the products are formed, the backwards reaction becomes faster.

Rate of reaction is fastest in magnesium, but it progressively decreases in aluminium, zinc, and iron.

In magnesium, aluminium, and zinc, reaction stops after some time as oxides of these metals stick to surface of respective metals.

## Action of steam on Non-Metals

1. Carbon: When steam is passed over red hot coke, water gas ($CO + H_2$) is formed.

$$C + H_2O \longrightarrow \underbrace{CO + H_2}_{\text{Water Gas}}$$

# Application of Activity series in Preparation of Hydrogen

K
Na
Ca
Mg
Al
Zn
Fe
Pb
[H]
Cu
Hg
Ag
Au

Arrangement of metals in decreasing order of reactivity in the form of a series is called the activity or reactivity series of metals.

Hydrogen, a non-metal is included in series because it can form the ion. It occupy position based on that.

Lead and metals below it shows no reaction with water.

## Displacement of Hydrogen from dilute acid

- K, Na, Ca — Displaces $H_2$ explosively
- Mg, Al, Zn — Displace $H_2$ vigorously, but not violently
- Fe, Ni, Sn, Pb — Displaces $H_2$ gently
- H
- Cu, Hg, Ag, Au — Do not displace $H_2$

$Mg + 2HCl \longrightarrow MgCl_2 + H_2$

$2Al + 6HCl \longrightarrow 2AlCl_3 + 3H_2$

$Zn + H_2SO_4 \longrightarrow ZnSO_4 + H_2$

$Fe + H_2SO_4 \longrightarrow FeSO_4 + H_2$

Zinc is preferred to prepare hydrogen gas Other metals are not prefered because:

1. Na & K reacts violently
2. Ca & Mg are expensive
3. Al form protective coating of $Al_2O_3$
4. Iron has to be heated, and it contains impurity of $H_2S$ and $SO_2$.
5. Lead form insoluble coating of lead sulphate or lead chloride.
6. $H_2$ can not be prepared from metals below it.

## Displacement of Hydrogen from Alkali

Metals like Zn, Al, and Pb reacts with alkali to liberate hydrogen gas.

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

$$Pb + 2KOH \longrightarrow K_2PbO_2 + H_2$$

$$2Al + 6NaOH\ (fused) \longrightarrow 2Na_3AlO_3 + 3H_2$$

$$2Al + 2NaOH + 2H_2O \longrightarrow 2NaAlO_2 + 3H_2$$

Oxide and hydroxide of zinc, lead, and aluminium are amphoteric. They react with both acids and base to form salt and water.

# Laboratory Preparation of Hydrogen

Hydrogen is prepared by reaction of granulated zinc with HCl.

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

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

Note: Zinc granules are preferred over pure zinc because impurity present in granulated zinc speeds up reaction rate.

## Collection of Hydrogen

Hydrogen is collected by downward displacement of water because:

i) It is virtually insoluble in water.

ii) It forms explosive mixture with air and can't be collected by downward displacement of air.

## Impurities with Hydrogen

$H_2S$, $SO_2$, N-oxides, $PH_3$, $AsH_3$, $CO_2$, Water Vapour.

Impurities can be removed by:

→ Arsine and Phosphine are removed by silver nitrate solution.

$$AsH_3 + 6AgNO_3 \longrightarrow Ag_3As + 3AgNO_3 + 3HNO_3$$

$$PH_3 + 6AgNO_3 \longrightarrow Ag_3P + 3AgNO_3 + 3HNO_3$$

→ Hydrogen sulphide is removed by lead nitrate solution.

$$Pb(NO_3)_2 + H_2S \longrightarrow PbS + 2HNO_3$$

→ $SO_2$, $CO_2$, N- oxides are removed by caustic potash solution.

$$SO_2 + 2KOH \longrightarrow K_2SO_3 + H_2O$$

$$CO_2 + 2KOH \longrightarrow K_2CO_3 + H_2O$$

$$2NO_2 + 2KOH \longrightarrow KNO_2 + KNO_3 + H_2O$$

→ Drying agent are used to remove water vapour.

Gas is purified and dried, and then collected over mercury.

Note: Conc $H_2SO_4$ is good drying agent but it is not used to dry hydrogen as it reacts with it.

$$H_2SO_4 + H_2 \longrightarrow 2H_2O + SO_2$$

## Precautions

1 Apparatus should be air tight.

2. There should be no flame nearby apparatus.

3 Gas should be only collected after all air in the apparatus has escaped.

1 End of the thistle funnel should be dipped under acid.

Note: 1. $HNO_3$ even in its dilute form is not used to prepare hydrogen as it oxidizes it into water.

$$3Zn + 8HNO_3 \longrightarrow 3Zn(NO_3)_2 + 4H_2O + 2NO\uparrow$$

2. Mg and Mn react with very dilute $HNO_3$ to liberate $H_2$ gas.

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

3. Conc $H_2SO_4$ is not used to prepare as it strong oxidiser and produce $SO_2$.

$$Zn + H_2SO_4 \longrightarrow ZnSO_4 + SO_2 + 2H_2O$$

## Test for Hydrogen

1. Hydrogen is combustible but does not support combustion.
2. It burns silently in air with pale blue flame forming water.

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

It explodes with a pop sound.

## Manufacture of Hydrogen

1. **Bosch Process**: It is used to prepare on hydrogen on large scale.

i) Steam is passed over hot coke (1000°C) in converters.

$$C + H_2O \xrightarrow{1000^\circ C} \underbrace{CO + H_2}_{\text{Water Gas}} - \Delta$$

(ii) Water Gas is mixed with steam and passed over heated $Fe_2O_3$ (catalyst) and $Cr_2O_3$ (promoter).

$$CO + H_2 + H_2O \xrightarrow[450°C]{Fe_2O_3} CO_2 + 2H_2 + \Delta$$

(iii) Separation of $CO_2$.

a) Water Gas is forced through cold water under 30 atm. which dissolves $CO_2$ leaving behind $H_2$.

b) Pass water gas through KOH (caustic potash solution) which reacts with $CO_2$ leaving behind $H_2$.

$$2KOH + CO_2 \longrightarrow K_2CO_3 + H_2O$$

(iv) Separation of CO:

Mixture of water gas and steam is passed through ammoniacal cuprous chloride solution. It reacts with uncombined CO leaving behind $H_2$.

$$CuCl + CO + 2H_2O \longrightarrow CuCl.CO.2H_2O$$

Oxidation: Process in which an atom or an ion loses electrons.

$$Zn \longrightarrow Zn^{2+} + 2e^-$$

Oxidation is defined as the chemical process that involves:

i) Addition of Oxygen: $C + O_2 \longrightarrow CO_2$

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

ii) Addition of Electronegative Ion:

$$FeCl_2 + Cl_2 \longrightarrow 2FeCl_3$$

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

iii] Removal of Hydrogen: $H_2S + Cl_2 \longrightarrow 2HCl + S$

iv] Removal of Electropositive Ion:

$$2KI + H_2O_2 \longrightarrow 2KOH + I_2$$

Oxidizing Agent: Substance that oxidizes other substances either by accepting electrons or by providing oxygen or electronegative ion or by removing hydrogen or an electropositive ion.

Examples.

i) Solid: $MnO_2$, Red Lead, $PbO_2$, $KMnO_4$, $K_2Cr_2O_7$, Bleaching Powder.

ii] Liquid: $H_2O_2$, Conc $HNO_3$, Conc $H_2SO_4$, Bromine

iii] Gas: Oxygen, Ozone, Chlorine, Sulphur dioxide.

Reduction: Process in which an atom or an ion gains electrons.

$$Cu^{2+} + 2e^- \longrightarrow Cu.$$

Reduction is defined as a chemical process that involves

i] Removal of Oxygen: $CuO + H_2 \longrightarrow Cu + H_2O$

$$ZnO + C \longrightarrow Zn + CO$$

ii] Addition of Electropositive Ion:

$$2HgCl_2 + SnCl_2 \longrightarrow Hg_2Cl_2 + SnCl_4$$

iii) Addition of Hydrogen: $Cl_2 + H_2S \longrightarrow 2HCl + S$

$2NH_3 + 3Cl_2 \longrightarrow N_2 + 6HCl$

iv) Removal of electronegative Ion:

$2FeCl_3 + H_2S \longrightarrow 2FeCl_2 + 2HCl + S$

Reducing Agent: Substance that reduces other substances either by providing electrons or by providing hydrogen or an electropositive ion or by removing oxygen or electronegative ion.

Examples:

i) Solids: Carbon, Metals like Zn, Al, Cu, and Na. Stannous chloride, Glucose, etc.

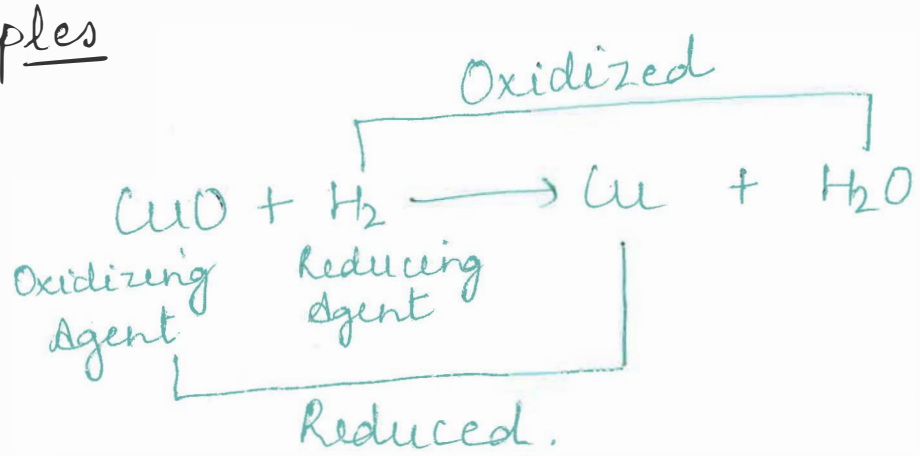
ii) Liquids: $H_2O_2$, HI, HBr.

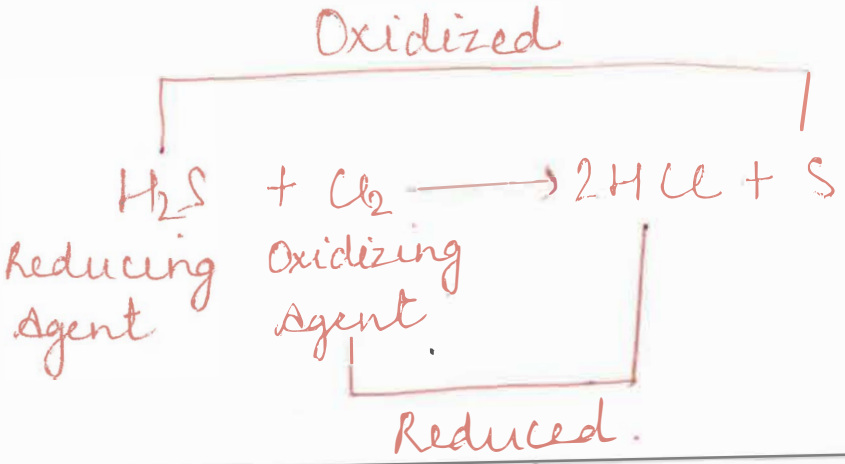
iii) Gases: $H_2S$, CO, $SO_2$, $NH_3$.

Redox (Oxidation - Reduction) Reaction

A reaction in which oxidation and reduction take place simultaneously.

Examples






| Oxidation involves | Reduction involves |
|---|---|
| 1 Addition of oxygen. | 1. Removal of oxygen. |
| 2. Removal of hydrogen. | 2. Addition of hydrogen. |
| 3. Addition of electronegative atom or ion. | 3. Removal of electro negative atom or ion. |
| 4. Removal of electropositive atom or ion. | 4. Addition of electropositive atom or ion. |
| 5 Loss of electrons | 5. Grain of electrons. |