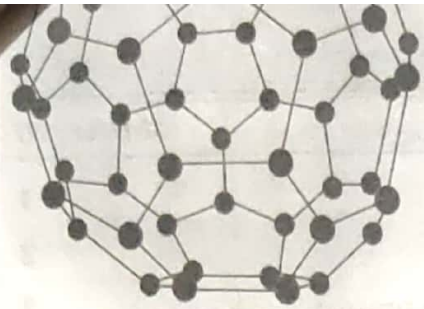


9 STUDY OF THE FIRST ELEMENT – HYDROGEN

SCOPE OF SYLLABUS

Position of the non-metal (Hydrogen) in the periodic table and general group characteristics with reference to valency electrons, burning, ion formation applied to the above mentioned element.

(i) Hydrogen from water

(ii) Hydrogen from dilute acids

(iii) Hydrogen from alkalies.

Hydrogen from water : Cold water and metals; hot water and metals; steam and metals; steam and non-metals. Application of activity series for the above mentioned preparations. Displacement of hydrogen from dilute sulphuric acid or hydrochloric acid by zinc or iron (no reaction with copper). Displacement of hydrogen from alkalies (NaOH, KOH) by Zn, Al – unique nature of these elements.

(iv) The preparation and collection of hydrogen by a standard laboratory method other than electrolysis.

In the laboratory preparation, the reason for using zinc, the impurities in the gas, their removal and the precautions in the collection of the gas must be mentioned.

Industrial manufacture of hydrogen by Bosch process with main reactions and conditions; separation of CO_2 and CO from it.

IMPORTANT POINTS TO REMEMBER

1. The **first element** that existed in the universe was **hydrogen**.
2. **Hydrogen** in the **sun** undergoes the process of **nuclear fusion** to form **helium** with the liberation of **energy** in the form of **heat** and **light**.
3. The **credit** of **discovery** of **hydrogen** goes to **Henry Cavendish.**
4. **Antoine Lavoisier** named the gas as **hydrogen**, *i.e.*, **water producer**.
5. **Hydrogen** is the **first element** present in the **periodic table**.
6. **Position** of **hydrogen** is **controversial** as it is placed in **group 1** (alkali metals) and **group 17** (halogens).
7. **Hydrogen resembles** the **alkali metals** in the following ways :

   (*i*) **Electronic configuration :** Like alkali metals, hydrogen has also got one electron in its valence shell.

   (*ii*) **Formation of cations :** Like alkali metals, hydrogen loses electron and forms cation.

   $H - e^- \longrightarrow H^+$ (Hydrogen)

   $Na - e^- \longrightarrow Na^+$ (Alkali metal)

   (*iii*) **Formation of compounds :** Hydrogen readily forms stable compounds with oxygen, sulphur and chlorine.

H_2O = Water
H_2S = Hydrogen sulphide
HCl = Hydrogen chloride

In the similar way the alkali metals form oxides, sulphides and chlorides
Na_2O = Sodium oxide
Na_2S = Sodium sulphide
NaCl = Sodium chloride

(*iv*) **Hydrogen** burns in **oxygen** to form **water** (neutral oxide).

$$2H_2 + O_2 \rightarrow 2H_2O.$$

8. **Hydrogen resembles halogens** in the following ways :

(*i*) **Electronic configuration :** Both hydrogen and halogen require one electron to complete their duplet and octet respectively, hence they gain electrons to acquire stable configuration. Therefore, they are electronegative and monovalent.

$$\underset{1}{H} + e^- \longrightarrow \underset{2}{H^-}$$

$$\underset{2,8,7}{Cl} + e^- \longrightarrow \underset{2,8,8}{Cl^-}$$

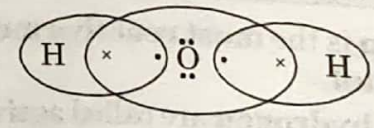
(*ii*) **Atomicity :** It is the number of atoms present in one molecule of an element. Both hydrogen and halogens are diatomic, *i.e.*, having two atoms in its one molecule.

Hydrogen — H_2
Fluorine — F_2
Chlorine — Cl_2
Bromine — Br_2
Iodine — I_2

9. **Hydrogen** has **three isotopes**, *i.e.*, these are the **atoms** of **same element** having **same atomic number** but **different mass number**.
Isotopes differ in **number** of **neutrons**.

Name of the Isotope	*Symbol*	*Mass Number*	*Atomic Number*	*Protons*	*Neutrons*	*Electrons*
Protium	${}_1^1H$	1	1	1	0	1
Deuterium	${}_1^2D$ or ${}_1^2H$	2	1	1	1	1
Tritium	${}_1^3T$ or ${}_1^3H$	3	1	1	2	1

10. **Protium** has **no neutron**.
11. **Hydrogen** in **combined state** occurs in the form of **water (H_2O)**.



$$H—\ddot{\underset{\cdot\cdot}{O}}—H$$

Formation of polar covalent bond in water

Water forms **polar covalent bond**.

12. All plants and animals have **hydrogen** in the form of **carbohydrates, fats** and **proteins**.
13. **Organic compounds** essentially contain **hydrogen** in **combination** with **carbon**.
14. **General methods of preparation of Hydrogen.**

(*i*) **By action of metals with cold water : Sodium, potassium** and **calcium** react with **cold water** to form its respective **metallic hydroxides** (soluble) with the **liberation** of **hydrogen**. It is not a safe method to prepare hydrogen gas in laboratory as the reaction sometimes proceeds with an explosion.

$$\text{Metal} + \text{Cold water} \longrightarrow \text{Metallic hydroxide} + \text{Hydrogen}$$

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

Sodium + Water ⟶ Sodium hydroxide + Hydrogen

$$\underset{\text{Potassium}}{2K} + \underset{\text{Water}}{2H_2O} \longrightarrow \underset{\text{Potassium hydroxide}}{2KOH} + \underset{\text{Hydrogen}}{H_2}$$

$$\underset{\text{Calcium}}{Ca} + \underset{\text{Water}}{2H_2O} \longrightarrow \underset{\text{Calcium hydroxide}}{Ca(OH)_2} + \underset{\text{Hydrogen}}{H_2}$$

Both **sodium** and **potassium** react **vigorously** with **cold water.** The **solution** thus **produced as a result** of **reaction turns red litmus blue** showing that the **solution formed** is **basic** or **alkaline** in nature.

***(ii)* By the reaction of metals with steam :**

Heated metal + Steam ⟶ Metallic oxide + Hydrogen

$$Mg + \underset{\text{Steam}}{H_2O} \longrightarrow MgO + H_2$$

$$Zn + \underset{\text{Steam}}{H_2O} \longrightarrow ZnO + H_2$$

$$\underset{\text{Heated}}{3Fe} + 4H_2O \rightleftharpoons Fe_3O_4 + 4H_2$$

***(iii)* By the reaction of dilute acids with active metals :**

(*a*) **Activity series :** The series in which the metals are arranged in the decreasing order of their reactivity is called activity series.

K	Potassium	Reactivity Increases ↑	Reactivity Decreases ↓
Ca	Calcium		
Na	Sodium		
Mg	Magnesium		
Al	Aluminium		
Zn	Zinc		
Fe	Iron		
Pb	Lead		
[H]	Hydrogen		
Cu	Copper		
Hg	Mercury		
Ag	Silver		
Au	Gold		
Pt	Platinum		

(*b*) The **metal** lying at the **top** is the **most reactive metal** and the **metal** present at the **bottom** is the **least reactive metal**.

(*c*) The **metals** placed **above hydrogen** are called **active metals** as they can displace **hydrogen** readily from **water** and **dilute acids**.

(*d*) Highly reactive metals like **sodium, potassium** and **calcium** react **vigorously** at ordinary temperature with **dilute acids** liberating **hydrogen**.

$$2Na + \underset{\text{dil.}}{2HCl} \longrightarrow 2NaCl + H_2$$

$$2K + \underset{\text{dil.}}{2HCl} \longrightarrow 2KCl + H_2$$

$$Ca + \underset{\text{dil.}}{2HCl} \longrightarrow CaCl_2 + H_2$$

(*e*) Metals like **magnesium, zinc, aluminium, iron,** etc. react **moderately** at ordinary temperature with **dilute acids** to liberate **hydrogen**.

Metal	+	Dil. acid	⟶	Salt	+ Hydrogen
Mg	+	2HCl (dil.)	⟶	$MgCl_2$	+ H_2
Mg	+	H_2SO_4 (dil.)	⟶	$MgSO_4$	+ H_2
Zn	+	2HCl (dil.)	⟶	$ZnCl_2$	+ H_2
Zn	+	H_2SO_4 (dil.)	⟶	$ZnSO_4$	+ H_2
2Al	+	6HCl (dil.)	⟶	$2AlCl_3$	+ $3H_2$
2Al	+	$3H_2SO_4$ (dil.)	⟶	$Al_2(SO_4)_3$	+ $3H_2$
Fe	+	2HCl (dil.)	⟶	$FeCl_2$	+ H_2
Fe	+	H_2SO_4 (dil.)	⟶	$FeSO_4$	+ H_2

(*f*) **Nitric acid** reacts with only **magnesium** and **manganese** to liberate **hydrogen**. With **rest** of the **metals** it produces **oxides** of **nitrogen** or **ammonium nitrate** and **not hydrogen** as it is an **oxidising agent**.

Mg	+	$2HNO_3$ (V. dil.)	⟶	$Mg(NO_3)_2$	+	H_2
Mn	+	$2HNO_3$ (V. dil.)	⟶	$Mn(NO_3)_2$	+	H_2

(*g*) **Lead** is **not used** for the **preparation** of **hydrogen** by using **dilute hydrochloric acid** and **dilute sulphuric acid** because the **products** are **insoluble lead chloride** and **lead sulphate** which **settle** on **fresh lead metal** and thus, **prevents** the **reaction** of **metal** with **acid**.

(*iv*) **By the action of alkalies with metals : Metals** like **zinc**, **aluminium** and **lead** in powder form **dissolve** when boiled with **concentrated sodium hydroxide** or **concentrated potassium hydroxide** to form their **respective soluble complex salts** with the **liberation** of **hydrogen**.

Zn	+	2NaOH (conc.)	boiled ⟶	Na_2ZnO_2 (Sodium zincate)	+	H_2
Zn	+	2KOH (conc.)	boiled ⟶	K_2ZnO_2 (Potassium zincate)	+	H_2
2Al	+	$2NaOH + 2H_2O$ (conc.)	boiled ⟶	$2NaAlO_2$ (Sodium aluminate)	+	$3H_2$
2Al	+	$2KOH + 2H_2O$ (conc.)	boiled ⟶	$2KAlO_2$ (Potassium aluminate)	+	$3H_2$

15. **Laboratory Preparation of Hydrogen.**

In laboratory, **hydrogen** is **prepared** by the **reaction** of **dilute sulphuric acid** with **granulated zinc**.

Zn	+	H_2SO_4 (dil.)	⟶	$ZnSO_4$	+	H_2

(*i*) **Zinc** is **preferred** to **other metals** because **sodium** and **potassium react explosively** or **violently** with **cold water** or **dilute acids**. In **calcium** and **magnesium**, the **liberation** of **hydrogen** is **very rapid** that it **cannot** be **collected**.

Aluminium gets **coated** with the **thin** but **tough layer** of **oxide** which **prevents** the **reaction** of **metal** with **water** and **dilute acids**.