# CHAPTER 9

# Study of the First Element - Hydrogen

***LATEST SYLLABUS – SCOPE OF SYLLABUS* – Study of the First Element -Hydrogen**

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 dil. sulphuric acid or hydrochloric acid by zinc or iron [no reaction with copper].*

*Displacement of hydrogen from alkalis [NaOH, KOH] by Zn, Al – unique nature of these elements.*

ii) 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.*

## A. POSITION OF THE NON-METAL – *Hydrogen in the periodic table*

| GROUPS → | 1 IA | 2 IIA |
|---|---|---|
| PERIOD 1 | 1 H | |
| PERIOD 2 | 3 Li | 4 Be |
| PERIOD 3 | 11 Na | 12 Mg |

| PERIOD | ELEMENT | ATOMIC NUMBER | ELECTRONIC CONFIGURATION |
|---|---|---|---|
| 1 | HYDROGEN [H] | 1 | 1 |
| 2 | LITHIUM [Li] | 3 | 2, 1 |
| 2 | FLUORINE [F] | 9 | 2, 7 |

| 13 IIIA | 14 IVA | 15 VA | 16 VIA | 17 VIIA | 18 0 |
|---|---|---|---|---|---|
| | | | | 1 H | 2 He |
| 5 B | 6 C | 7 N | 8 O | 9 F | 10 Ne |
| 13 Al | 14 Si | 15 P | 16 S | 17 Cl | 18 Ar |

**ELEMENTS OF GROUP 1 [IA]** - *alkali metals*

- Lithium [Li]
- Sodium [Na]
- Potassium [K]
- Rubidium [Rb].

**ELEMENTS OF GROUP 17 [VIIA]** - *halogens*

- Fluorine [F]
- Chlorine [Cl]
- Bromine [Br]
- Iodine [I].

### POSITION OF HYDROGEN – IN THE PERIODIC TABLE

- *Atomic number of hydrogen* = one;
- *Number of valence electrons* = one
- *1st element* of the periodic table placed in **Group 1 [IA]** [period - 1] of the periodic table.

*DUAL NATURE OF HYDROGEN*

- Hydrogen has the simplest electronic configuration of 'one' and hence:
  - Either *loses one electron* behaving like electropositive alkali metals [group 1 (IA)]
    e.g. $H - 1e^- \rightarrow H^{1+}$, $Li - 1e^- \rightarrow Li^{1+}$, $Na - 1e^- \rightarrow Na^{1+}$.
  - *Gains one electron* behaving like electronegative halogens [group 17 (VIIA)]
    e.g. $H + 1e^- \rightarrow H^{1-}$, $F + 1e \rightarrow F^{1-}$, $Cl + 1e^- \rightarrow Cl^{1-}$.

*RESULTANT POSITION OF HYDROGEN*

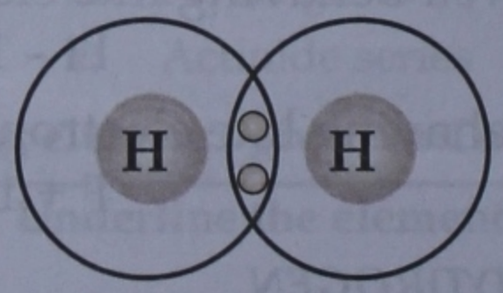
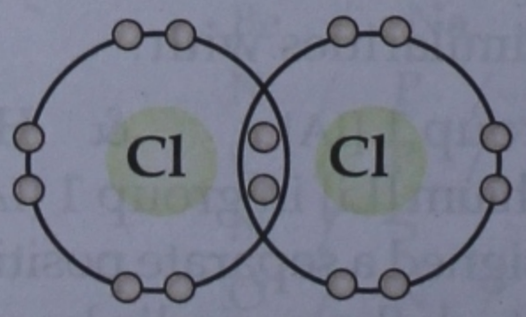
- Hydrogen thus show similarities with:
  - **Alkali metals** of group 1 [IA] & **Halogens** of group 17 [VIIA]
    & is placed above Lithium [Li] in group 1 [IA] or above Fluorine [F] in group 17 [VIIA].
    [Thompson had assigned a separate position to hydrogen on top of the periodic table which does not disturb the periodic law or the symmetry of the table].

# B. GENERAL GROUP CHARACTERISTICS – First element Hydrogen

## SIMILARITY OF HYDROGEN WITH – *Alkali Metals* – [GROUP 1 (IA)]

| | |
|---|---|
| • **ELECTRONIC CONFIGURATION** | **Valency electrons – One valence electron**<br>**H** = ① ; **Li** = 2, ① ; **Na** = 2, 8, ① ; **K** = 2, 8, 8, ① |
| • **CHARACTER [Ion formation]** | **Electropositive character exhibited**<br>$H - 1e^- \rightarrow H^{1+}$ ; $Li - 1e^- \rightarrow Li^{1+}$ ; $Na - 1e^- \rightarrow Na^{1+}$ |
| • **VALENCY** | **Electrovalency of 'one' exhibited**<br>$H^{1+}$ , $Li^{1+}$ , $Na^{1+}$ , $K^{1+}$ |
| • **REACTIONS** | **Strong affinity for non-metals –** [e.g. O, S, Cl]<br>*Hydrogen* – forms $H_2O$; $H_2S$, HCl<br>*Sodium* – forms $Na_2O$; $Na_2S$, NaCl |
| • **REDUCING AGENT** | **Act as reducing agents**<br>*Hydrogen* – $CuO + H_2 \rightarrow Cu + H_2O$<br>*Sodium* – $CuO + 2Na \rightarrow Cu + Na_2O$ |

## SIMILARITY OF HYDROGEN WITH – *Halogens* – [GROUP 17 (VIIA)]

| | |
|---|---|
| • **ELECTRONIC CONFIGURATION** | **One electron less than the nearest noble gas**<br>**H** = 1 [He = 2]; **F** = 2, 7 [Ne = 2, 8]; **Cl** = 2, 8, 7 [Ar = 2, 8, 8] |
| • **CHARACTER [Ion formation]** | **Electronegative character exhibited**<br>$H + 1e^- \rightarrow H^{1-}$ ; $F + 1e^- \rightarrow F^{1-}$ ; $Cl + 1e^- \rightarrow Cl^{1-}$ |
| • **VALENCY** | **Electrovalency and covalency exhibited**<br>*Hydrogen* – forms NaH [electrovalent]; $CH_4$ [covalent]<br>*Chlorine* – forms NaCl [electrovalent]; $CCl_4$ [covalent] |
| • **ATOMICITY** | **Diatomic molecules formed –** *[two atoms linked by a single bond]*<br>*Hydrogen*   H : H or H – H → $H_2$<br>*Chlorine*   Cl : Cl or Cl – Cl → $Cl_2$ |

# C. DISCOVERY AND OCCURRENCE – Of Hydrogen

## DISCOVERY

**Hydrogen was initially called 'inflammable gas'.**

- *Robert Boyle* – in 1672 - established the elementary character of hydrogen.
- *Henry Cavendish* – in 1776 - first prepared hydrogen in the pure state and also described its properties and recognized it as an *element*.
  He found that the gas was *inflammable* and that it *burnt in air to produce water*.
- *Lavoisier* – in 1783 - established its name *'hydrogen'* meaning *'water producer'*
  [Greek word ***Hydro*** = water, ***gen*** = producer].

## OCCURRENCE

***In the free state***

- Hydrogen stands ninth in abundance [by mass] – among the elements present in the earth's crust.
  It makes up approximately 1% of the earth's crust.
- Hydrogen is seldom found in the free state on the planet earth.
- It exists upto 0.01% in the earth's atmosphere.
- It is also found in minute traces , in volcanic gases and to a higher extent around the sun & the stars.

| **In the free state** | |
|---|---|
| Earth's crust | 0.98% |
| Earth's atmosphere | 0.01% |
| Volcanic gases | 0.025% |
| Atmosphere – around the sun and the stars | 01.1% |

***In the combined state***

Hydrogen is distributed in combination with other elements in the combined state.

It occurs in the combined state :

- *In plant and animal tissues* –
  which are made of compounds of hydrogen along with carbon, oxygen & nitrogen.
- *In water* –
  about one ninth by mass of water is hydrogen.
- *As a constituent of different substances* –
  i.e. acids, alkalis, petroleum products & organic substances.
  Combined with carbon, hydrogen is found in –
  a] natural gas, b] kerosene, c] gasoline, d] petroleum products
  It is a constituent of most organic substances including –
  a] proteins, b] carbohydrates, c] fats which are essential for all living matter.

# D. PREPARATION OF HYDROGEN – General Methods

## I. GENERAL METHODS FROM – *Cold water, Boiling water, Steam* – with metals

| *Metal* | *Cold water* | *Metallic hydroxide* | *Hydrogen* | *Reason why method is not preferred* |
|---|---|---|---|---|
| • *Potassium*<br>$2K$ + | $2H_2O$ → [cold water] | $2KOH$ + | $H_2$ | • The reaction is – *violent & exothermic.*<br>• The liberated heat – ignites the hydrogen. |
| • *Sodium*<br>$2Na$ + | $2H_2O$ → [cold water] | $2NaOH$ + | $H_2$ | • The reaction is *violent* – but comparatively – *less than* potassium.<br>The sodium melts into a globule and darts about in the water - hence the collection of hydrogen is difficult.<br>The sodium is therefore wrapped – in a wire gauze and used in the above preparation. |
| • *Calcium*<br>$Ca$ + | $2H_2O$ → [cold water] | $Ca(OH)_2$ + | $H_2$ | • The reaction is *slightly vigorous*– but calcium is comparatively more expensive. |
| *Metal [heated]* | *Boiling water/Steam* | *Metallic oxide* | *Hydrogen* | *Observations* |
| • *Magnesium*<br>$Mg$ + | $H_2O$ → [boiling water] | $MgO$ + | $H_2$ | • Mg, Al, Zn, Fe – *do not react with cold water* to liberate hydrogen.<br>Magnesium reacts with – *boiling water* liberating hydrogen but the reaction is *slow.* |
| • *Aluminium*<br>$2Al$ + | $3H_2O$ → [steam] | $Al_2O_3$ + | $3H_2$ | |
| • *Zinc*<br>$Zn$ + | $H_2O$ → [steam] | $ZnO$ + | $H_2$ | • Mg, Al, Zn and Fe react with – *steam* in the heated state and – form the corresponding – *oxide and hydrogen.* |
| • *Iron*<br>$3Fe$ + | $4H_2O \rightleftharpoons$ [steam] | $Fe_3O_4$ + [magnetic oxide of iron] | $4H_2$ | • Iron reacts with – *steam* & the reaction is *reversible.* |

# D. PREPARATION OF HYDROGEN – General Methods [Contd.]

## II. GENERAL METHODS FROM – *Acids* – with Magnesium, Aluminium, Zinc, Iron

| *Metal* | *Acid [dil.]* | *Salt* | *Hydrogen* | *Observations* |
|---|---|---|---|---|
| • Mg + | $2HCl \rightarrow$ | $MgCl_2$ + | $H_2$ | • K, Na & Ca – react with – dil. $H_2SO_4$ or dil. HCl – but the reaction is highly – *explosive* & practically *not feasible*. |
| • 2Al + | $3H_2SO_4 \rightarrow$ | $Al_2(SO_4)_3$ + | $3H_2$ | |
| • Zn + | $H_2SO_4 \rightarrow$ | $ZnSO_4$ + | $H_2$ | • Mg, Al, Zn & Fe – react with – dil. $H_2SO_4$ or dil. HCl –forming – *hydrogen* & the *respective salt*. |
| • Fe + | $2HCl \rightarrow$ | $FeCl_2$ + | $H_2$ | |

**Nitric acid – [dilute] is not used in the preparation of hydrogen from metals.**

- Nitric acid is a powerful ***oxidizing agent*** & the nascent oxygen formed on its decomposition – ***oxidizes the hydrogen to water***. Magnesium & manganese however, react with *very dil.* $HNO_3$ – at *low temperatures* liberating $H_2$, since oxidizing action of the acid is much reduced due to dilution.

**Lead – cannot be used in the preparation of hydrogen using dilute acids.**

- Lead reacts with dil. HCl & dil. $H_2SO_4$ forming an insoluble coating of – *lead chloride* [$PbCl_2$] & *lead sulphate* [$PbSO_4$] respectively & hence further reaction comes to a stop.

## III. GENERAL METHODS FROM – *Alkalis* – with Zinc, Lead, Aluminium

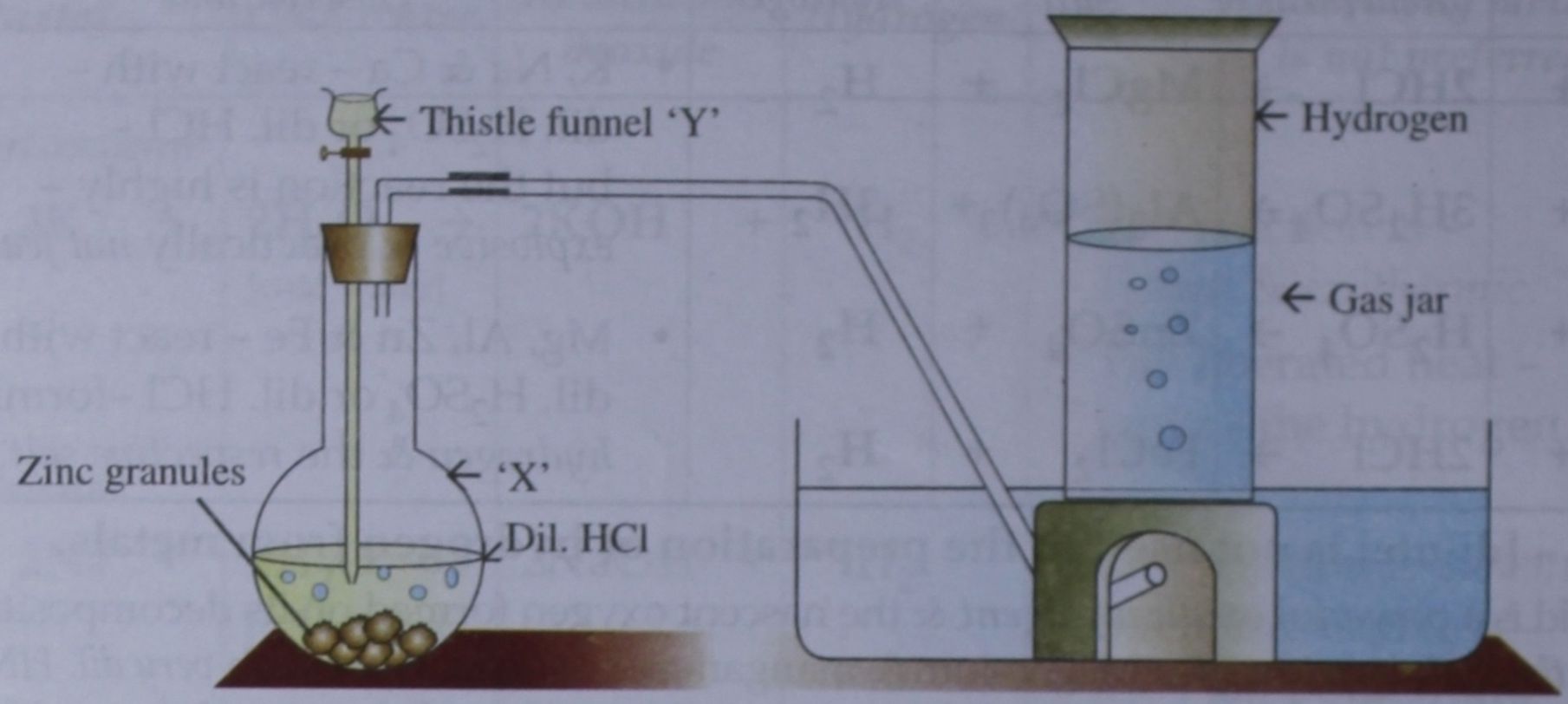
| *Metal* | *Alkali [conc. soln.]* | *Salt* | *Hydrogen* | *Observations* |
|---|---|---|---|---|
| • Zn + | $2NaOH \rightarrow$ | $Na_2ZnO_2$ + [sodium zincate] | $H_2$ | • Zn , Pb or Al – react with – with hot conc. alkali i.e. NaOH or KOH – forming– *hydrogen* & the *respective salt*. |
| Zn + | $2KOH \rightarrow$ | $K_2ZnO_2$ + [potassium zincate] | $H_2$ | |
| • Pb + | $2NaOH \rightarrow$ | $Na_2PbO_2$ + [sodium plumbite] | $H_2$ | |
| • 2Al + | $2NaOH+2H_2O \rightarrow$ | $2NaAlO_2$ + [sodium aluminate] | $3H_2$ | |

**Unique nature of Zn, Pb and Al** – Zinc, lead and aluminium form oxides e.g. ZnO & hydroxides e.g. $Zn(OH)_2$ which are – ***amphoteric*** in nature i.e. react with base & acids to give salt & water.

| **Activity series of metals – Reaction with *water*** | | **Activity series of metals–Reaction with *dilute acids*** | |
|---|---|---|---|
| K | Reacts vigorously – *with cold water* | K | Reacts highly explosively – *with dil. acids* |
| Na | Reacts less vigorously – *with cold water* | Na | Reacts less explosively – *with dil. acids* |
| Ca | Reacts slowly – *with cold water* | Ca | |
| Mg | Heated metal reacts – *with boiling water* | Mg | |
| Al | Heated metal reacts – *with steam* | Al | Ca, Mg, Al, Zn, Fe react – with decreasing vigour – *with dil. acids* liberating $H_2$. |
| Zn | Red hot metal reacts – *with steam* | Zn | |
| Fe | Red hot metal reacts slowly – *with steam* | Fe | |
| Pb | **Metals below hydrogen –** | Pb | **Metals below hydrogen –** |
| [H] | ***[including lead]*** | [H] | ***[including lead]*** |
| Cu | **– have no reaction** | Cu | **– have no reaction** |
| Hg | **with water.** | Hg | **with dilute acids.** |
| Ag | | Ag | |
| Pt | | Pt | |
| Au | | Au | |

# D. PREPARATION OF HYDROGEN – Laboratory Method

## LABORATORY METHOD – By action of dilute acid on zinc




**Laboratory preparation of hydrogen by action of dil. HCl on zinc.**

**REACTION** $Zn + 2HCl$ [dil.] $\rightarrow ZnCl_2 + H_2$ [g]

**REACTANTS:**
- *Granulated zinc* - in flat bottom flask [X].
- *Dilute hydrochloric acid* - added through thistle funnel [Y].

**PROCEDURE:**
- Granulated zinc is placed in the flat bottom flask and – hydrochloric acid [or dil. sulphuric acid] is added slowly – from the thistle or dropping funnel.
- A brisk effervescence is seen with the evolution of – hydrogen gas.

**PURIFICATION:**
- Granulated zinc being impure, on treatment with – dilute HCl or $H_2SO_4$ evolves in traces– gaseous *impurities.*

  These impurities may be further removed by – passage of the impure gas through three washer bottles & a U-tube.

  – Washer bottle 1 - Contains $AgNO_3$ solution which absorbs – *Impurity* – Arsine [$AsH_3$] and phosphine [$PH_3$]

  – Washer bottle 2 - Contains $Pb(NO_3)_2$ solution which absorbs – *Impurity* – Hydrogen sulphide [$H_2S$]

  – Washer bottle 3 - Contains KOH solution which absorbs – *Impurity* – $NO_2$, $CO_2$, $SO_2$

  – U-Tube 4 - Contains anhydrous $CaCl_2$ which absorbs – *Impurity* – Moisture

**PRECAUTIONS:**
- No leakage of gas should take place & no flame must be near the apparatus.
- Hydrogen is collected after all the air in the apparatus is allowed to escape [pure hydrogen burns quietly in air, hence its purity can be tested].
- The end of the thistle funnel should dip below the level of the dil. acid in the flask 'X' or the hydrogen gas may escape out through the thistle funnel 'Y'.

**COLLECTION :**
- Hydrogen gas is collected by – *the downward displacement of water.*

# D. PREPARATION OF HYDROGEN – Laboratory Method [Contd.]

## APPARATUS

**In the above laboratory preparation of hydrogen an airtight apparatus is used.**

- Hydrogen forms an *explosive mixture with air* –
  hence the complete apparatus is *airtight* preventing any leakage of the gas.
- A *naked flame* should not be brought near the apparatus since –
  it may be the cause of *an explosion* which may take place if the gas leaks.
- The *lower end of the thistle funnel* should dip below the level of the dilute acid –
  in the flask thereby minimizing the chance of any leakage of the hydrogen gas through the thistle funnel.

## REACTANTS

**Granulated zinc on reaction with dilute acid evolves hydrogen.**

- Granulated zinc is *commercial zinc* obtained from molten zinc.
  It may contain *traces of impurities* which has a *slight catalyzing* effect on the reaction.
- Addition of traces of *copper* [II] *sulphate* to the reaction medium –
  also *enhances the speed of the reaction.*
- The preferred acid is *dilute hydrochloric or sulphuric acid.*
  Nitric acid being a strong oxidizing agent – oxidizes the hydrogen formed to water & is not used as the acid in the reaction with zinc.

## COLLECTION OF HYDROGEN

**Hydrogen is collected by the downward displacement of water.**

- Hydrogen is almost insoluble in water –
  [100 vols. of water dissolve about 2 vols. of hydrogen at s.t.p.].
- Even though *hydrogen is lighter than air* – [1 litre of $H_2$ weighs 0.09 g. at s.t.p.]
  it is *not collected by downward displacement of air* since –
  it forms an explosive mixture with air.
- Pure dry hydrogen is collected over mercury –
  or in a flask previously evacuated thereby having absence of air.

## PURIFICATION OF HYDROGEN

**Hydrogen is purified by passage through different solutions.**

- Granulated zinc on reaction with dilute acids imparts traces of –
  gaseous impurities which are removed by passage through different solutions.
- Arsine [$AsH_3$] & phosphine [$PH_3$] – through *silver nitrate* solution,
  Hydrogen sulphide [$H_2S$] – through *lead nitrate* solution,
  Nitrogen dioxide, carbon dioxide & sulphur dioxide – through KOH solution
  Moisture using a – drying agent i.e. *fused calcium chloride.*

# D. PREPARATION OF HYDROGEN – Industrial Methods

## INDUSTRIAL METHOD – Bosch Process

**STEP I** *Reaction* : **Production of – water gas**

$$\underset{\text{[coke]}}{C} + \underset{\text{[steam]}}{H_2O} \xrightarrow{1000^oC} \underbrace{CO + H_2}_{\text{water gas}} - \Delta$$

*Reactants* : White hot coke & steam

*Temperature* : Around 1000°C

*Process* : Passage of steam over white hot coke [carbon]

*Chamber* : Specially designed *convertor*

**STEP II** *Reaction* : **Reduction of steam to hydrogen – by carbon monoxide.**

$$\underbrace{CO + H_2}_{\text{[water gas]}} + \underset{\text{[excess steam]}}{H_2O} \xrightarrow[Fe_2O_3]{450^oC} CO_2 + 2H_2 + \Delta$$

*Reactants* : Water gas & excess steam

*Temperature* : Around 450°C

*Catalysts* : Iron [III] oxide [$Fe_2O_3$], promoter chromic oxide [$Cr_2O_3$]

*Process* : Excess steam is mixed with water gas & – passed over a catalyst at elevated temperatures. [CO is converted to $CO_2$ with a further yield of hydrogen].

**STEP III** *Reaction* : **Separation of – Carbon dioxide [$CO_2$] & unreacted Carbon monoxide [CO] from – the above mixture.**

*Process* :

| *Removal of* | *Method* |
|---|---|
| • $CO_2$ | By dissolving mixture in –<br>– *water under pressure* [30 atmospheres], or<br>– *caustic potash solution*<br>[$2KOH + CO_2 \rightarrow K_2CO_3 + H_2O$] |
| • CO | By dissolving mixture in –<br>– *ammoniacal cuprous chloride solution.*<br>[$CuCl + CO + 2H_2O \rightarrow CuCl.CO.2H_2O$] |

## INDUSTRIAL METHODS – *By electrolysis of water or brine & from natural gas or $CaH_2$*

***By electrolysis of* – Water :**
Acidified water on electrolysis– liberates hydrogen at the cathode.

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

***Electrolysis of brine*** [NaCl soln.] – Very pure hydrogen is obtained as a by-product during electrolysis of brine.

***From natural gas & from calcium hydride – $CaH_2$***
Methane present in natural gas [obtained from petroleum ] – reacts with steam to give hydrogen

$$\underset{\text{[methane]}}{CH_4} + \underset{\text{[steam]}}{H_2O} \xrightarrow[800^oC]{Ni} CO + 3H_2$$

*Unreacted CO* – removed similarly as in – Bosch process.

$$\underset{\text{[calcium hydride]}}{CaH_2} + 2H_2O \rightarrow Ca(OH)_2 + 2H_2$$

# E. SUMMARY OF PREPARATIONS OF – Hydrogen

**SUMMARY OF PREPARATIONS – Of hydrogen – from**

**1. *WATER***

- cold water

- *Metals reacting with – cold water* – K, Na, Ca.

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

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

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

- *Method not preferred* – reaction is violent and exothermic in case of K & Na slightly vigorous in case of Ca but Ca is more expensive.

- boiling water/steam

- *Metals reacting with – boiling water/steam* – Mg, Al, Zn, Fe

$Mg + H_2O \rightarrow MgO + H_2$

$2Al + 3H_2O \rightarrow Al_2O_3 + 3H_2$

$Zn + H_2O \rightarrow ZnO + H_2$

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

**2. *DILUTE ACIDS***

- *Metals reacting with – dilute acids* – Mg, Al, Zn, Fe [active metals].

- dil. HCl

$Mg + 2HCl\ [dil.] \rightarrow MgCl_2 + H_2$

$Zn + 2HCl\ [dil.] \rightarrow ZnCl_2 + H_2$

- dil. $H_2SO_4$

$2Al + 3H_2SO_4\ [dil.] \rightarrow Al_2(SO_4)_3 + 3H_2$

$Fe + H_2SO_4\ [dil.] \rightarrow FeSO_4 + H_2$

[Copper which is below hydrogen in the activity series does not react]

**3. *CONC. ALKALIS***

- *Metals reacting with – conc. alkalis* – Zn, Pb or Al.

- conc. KOH soln.

$Zn + 2KOH \rightarrow K_2ZnO_2 + H_2$

$Pb + 2NaOH \rightarrow Na_2PbO_2 + H_2$

- conc. NaOH soln.

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

$2Al + 2KOH + 2H_2O \rightarrow 2KAlO_2 + 3H_2$

- ***LABORATORY***

- active metal/dil. acid

- *By action of dil. HCl on – granulated zinc*

$Zn + 2HCl\ [dil.] \rightarrow ZnCl_2 + H_2$

*Removal of impurities* – impurities obtained are removed- by passage through washer bottles containing – $AgNO_3$, $Pb(NO_3)_2$ & KOH solns. to remove – arsine, $H_2S$ & $NO_2$, $CO_2$, $SO_2$ impurities – respectively.

*Collection of gas* – downward displacement of water.

**The product – Hydrogen**

- Colourless, odourless, tasteless, non-poisonous gas.
- Lightest gas known [14.4 times less dense than air]; Very slightly soluble in water.
- Difficult to liquefy; Combustible [burns in air]; Non-supporter of combustion.
- Neutral to litmus [i.e. neither acidic nor alkaline]

# F. TESTS AND USES OF HYDROGEN

| *TESTS – For Hydrogen* | |
|---|---|
| | ***Observations*** |
| • Colour, odour, density | Colourless, odourless, lighter than air. |
| • Combustibility of | |
| i] Pure hydrogen | Burns quietly in air – with a pale blue flame forming water. $2H_2 + O_2 \rightarrow 2H_2O$ |
| ii] Hydrogen-air mixture. | Burns with a characteristic 'pop sound'. |
| ***USES – Of Hydrogen*** | |
| | ***Reasons/conditions for use*** |
| **GENERAL USES** | |
| • **As a fuel –** in the form of | |
| – *Coal gas*<br>– *Water gas* | *Combustion of hydrogen* – is a highly exothermic reaction. |
| – *Liquid hydrogen* | *Liquid hydrogen* – is non-polluting and easy to store. |
| • **In meteorological balloons** | |
| – *To study weather conditions.* | *Hydrogen is – lighter than air.* Being inflammable – it is now replaced by helium. |
| **MANUFACTURE OF –** | |
| • *Ammonia* $N_2 + 3H_2 \rightleftharpoons 2NH_3 + \Delta$ | *Temp.:* 450–500°C *Pressure:* 200–900 atmos. *Catalyst:* Iron *Promoter:* Molybdenum |
| • *Hydrogen chloride* $H_2 + Cl_2 \rightarrow 2HCl$ | *Reaction slow in diffused sunlight* – and explosive in direct sunlight. |
| **IN THE CONVERSION OF HYDROGEN TO –** | |
| • *Water* $2H_2 + O_2 \rightarrow 2H_2O + \Delta$ | *Hydrogen burns quietly in air* – forming water. |
| • *Hydrogen sulphide* $H_2 + S \rightarrow H_2S$ | *Hydrogen reacts with sulphur vapours* – forming hydrogen sulphide. |

# F. TESTS AND USES OF HYDROGEN [Contd.]

| *USES OF HYDROGEN* | *Reasons/Conditions for use* |
|---|---|
| **IN HYDROGENATION REACTIONS** | |
| • **Hydrogenation of oil** | |
| Addition of hydrogen to organic compounds in presence of catalyst e.g. Pt or Ni under high pressure at about 200°C is called – *hydrogenation*. | Certain metals like – platinum, nickel, gold & palladium readily adsorb – large volumes of hydrogen on their surface. |
| Vegetable oils [palm oil] turn to – semi solid fats by *hydrogenation*. | The phenomenon is called – ***occlusion*** a property useful for *hydrogenation*. |
| • **Hydrogenation of coal** | |
| Passage of hydrogen under high pressure over powdered coal in presence of catalyst at a suitable temperature. | Hydrogenation of coal leads to – conversion of coal to a product similar to *petroleum* containing – a higher percentage of hydrogen. |
| **IN EXTRACTION OF METALS** | |
| • Hydrogen when passed over heated metal oxides of less active metals e.g. zinc, iron, lead & copper, reduces the oxides of the metals to free metals, a process useful in – *metallurgy*. | Hydrogen acts as a – *reducing agent*<br>$ZnO + H_2 \rightarrow Zn + H_2O$<br>$Fe_2O_3 + 3H_2 \rightarrow 2Fe + 3H_2O$<br>$CuO + H_2 \rightarrow Cu + H_2O$ |
| **IN WELDING AND CUTTING METALS** | |
| • Oxygen burns in an atmosphere of hydrogen to produce an – oxy-hydrogen flame. The flame is used for *welding* & *cutting*. | *Hydrogen-oxygen* mixture on burning produces an ***exothermic reaction*** and the temperature of the flame is around 2800°C, which makes it useful for welding or cutting. |
| **OXIDATION - REDUCTION REACTIONS.** | |
| • *Oxidation* involves – removal of hydrogen from a substance. | $H_2S + Cl_2 \rightarrow S$ [*oxidised product*] $+2HCl$ |
| • *Reduction* involves – addition of hydrogen to a compound. | $Br_2 + H_2S \rightarrow 2HBr$ [*reduced product*] $+ S$ |

# EQUATION WORKSHEET

Complete and balance the equations

## HYDROGEN

**a. Preparation of hydrogen**
[General Methods]

*Reactions of active metals - cold water*

| | |
|---|---|
| **1. Potassium** | $K + H_2O \rightarrow$ _____ + _____ [g] |
| **2. Sodium** | $Na + H_2O \rightarrow$ _____ + _____ [g] |
| **3. Calcium** | $Ca + H_2O \rightarrow$ _____ + _____ [g] |

*Reactions of metals with steam*

| | |
|---|---|
| **4. Magnesium** | $Mg + H_2O \rightarrow$ _____ + _____ [g] |
| **5. Aluminium** | $Al + H_2O \rightarrow$ _____ + _____ [g] |
| **6. Zinc** | $Zn + H_2O \rightarrow$ _____ + _____ [g] |
| **7. Iron** | $Fe + H_2O \rightleftharpoons$ _____ + _____ [g] |

*Reactions of metals with dilute acids*

| | |
|---|---|
| **8. Magnesium** | $Mg + HCl \rightarrow$ _____ + _____ [g] |
| **9. Aluminium** | $Al + H_2SO_4 \rightarrow$ _____ + _____ [g] |
| **10. Zinc** | $Zn + HCl \rightarrow$ _____ + _____ [g] |
| **11. Iron** | $Fe + HCl \rightarrow$ _____ + _____ [g] |

*Reactions of metals - alkali [conc. soln.]*

| | |
|---|---|
| **12. Zinc** | $Zn + NaOH \rightarrow$ _____ + _____ [g] |
| | $Zn + KOH \rightarrow$ _____ + _____ [g] |
| **13. Lead** | $Pb + NaOH \rightarrow$ _____ + _____ [g] |
| **14. Aluminium** | $Al + NaOH + H_2O \rightarrow$ _____ + ____ [g] |
| | $Al + KOH + H_2O \rightarrow$ _____ + ____ [g] |

**b. Preparation of hydrogen**
[Laboratory method]

*By action of dilute acid on zinc*

| | |
|---|---|
| **15. Zinc** | $Zn + HCl \rightarrow$ _____ + _____ [g] |

**Preparation of hydrogen**
[Industrial method - Bosch process]

| | |
|---|---|
| **16. Step I - Production of water gas** | $C + H_2O \xrightarrow{1000^oC}$ [ _____ + _____ ] - Δ |
| **17. Step II - Reduction of steam to hydrogen by carbon monoxide** | $CO + H_2 + H_2O \xrightarrow[Fe_2O_3]{450^oC}$ _____ + _____ [g] |
| **18. Step III - Removal of unreacted carbon dioxide and carbon monoxide from the above mixture** | $KOH + CO_2 \rightarrow$ _____ + _____<br>$CuCl + CO + H_2O \rightarrow$ _____ |

| | |
|---|---|
| **c. Tests and uses of hydrogen** | |
| *Conversion of hydrogen to –* | |
| **19. Water** | $H_2 + O_2 \rightarrow$ _____ |
| **20. Hydrogen chloride** | $H_2 + Cl_2 \rightarrow$ _____ |
| **21. Ammonia** | $N_2 + H_2 \rightleftharpoons$ _____ |
| **22. Hydrogen sulphide** | $H_2 + S \rightarrow$ _____ |
| *Hydrogen in metallurgy – reduction of* | |
| **23. Zinc oxide** | $ZnO + H_2 \rightarrow$ _____ + _____ |
| **24. Iron [III] oxide** | $Fe_2O_3 + H_2 \rightarrow$ _____ + _____ |

For additional questions on **Chp. 9** - Refer
**'OBJECTIVE WORKBOOK FOR SIMPLIFIED I C S E CHEMISTRY' FOR STD. IX BY DR. VIRAF J. DALAL**
[A Supplementary work book for "Simplified I. C. S. E. Chemistry for Std. IX"]

## Questions

### 1984

1. Name an element which reacts violently with water at room temperature.
2. What do the following symbols [or formula] denote : 2H ; $H_2$ ; $H^+$. [two atoms, molecule, ion]
3. Write correctly balanced equation for the following "word equation" :
   calcium + water → calcium hydroxide + hydrogen.
4. When steam is passed over red-hot iron, magnetic oxide of iron and hydrogen are obtained. "The reaction between steam and red-hot iron is a *Reversible Reaction*." What is meant by this statement.
5. How can you obtain hydrogen from sodium hydroxide [not by electrolysis].

### 1985

1. Write balanced equation for the following reaction : magnesium + dil. hydrochloric acid →

### 1986

1. Name a gas which burns in air or oxygen forming water.
2. Write correctly balanced equation for the following : *When steam is passed over red hot iron.*
3. Explain the following : Two jars of $H_2$ are collected - *"one burns quietly and the other does not"*.

### 1987

1. Write correctly the balanced equation for the following : *'When zinc filings are added to a concentrated solution of sodium hydroxide'*.
2. Describe one chemical test applied to the following gases, which would enable you to distinguish between them : *'carbon monoxide and hydrogen'*.

**1988**

1. Write down the "word equation" for the following reaction : *sodium hydroxide solution + zinc* →
2. Explain briefly how hydrogen is manufactured on a large scale, from steam.

**1989**

1. State the products of the reaction *"when steam is passed over red-hot iron"*.

**1990**

1. How can you obtain hydrogen from a mixture of hydrogen and carbon monoxide.
2. What do you observe when a piece of sodium is dropped into cold water?
3. Give reasons for the following : *'Though hydrogen is lighter than air, it is not collected by the downward displacement of air'*.
4. Complete the following word equations:
   i) Sodium hydroxide + zinc → hydrogen + .....
   ii) Calcium + water → calcium hydroxide + .....

**1991**

1. How would you obtain *'hydrogen from sodium hydroxide'* solution other than by electrolysis?

**1992**

1. Complete and balance the following equations : Al + NaOH + ..... → ..... + .....
2. What do the following symbols represent : 2H and $H_2$. [two atoms, molecule]

**1993**

1. Write balanced equation of the reaction in the preparation of : *hydrogen from a solution of potassium hydroxide* [other than by electrolysis].
2. Describe briefly, with equations, the *Bosch Process* for the large scale production of hydrogen.
3. Account for the following facts :
   i] Though lead is above hydrogen in the activity series, it does not react with dilute hydrochloric acid or dilute sulphuric acid. [$PbCl_2$, $PbSO_4$ formed - insoluble]
   ii] Potassium and sodium are not used to react with dilute hydrochloric acid or dilute sulphuric acid in the laboratory preparation of hydrogen.

**1994**

1. Place the metals *calcium, iron, magnesium* and *sodium* in order of their activity with water, placing the most active first. Write the equation for each of the above metals which react with water.
2. Why is copper not used to prepare hydrogen by the action of dilute hydrochloric acid or dilute sulphuric acid on the metal. [copper [Cu] below hydrogen - no reaction]

**1995** [discontinued]

## Additional Questions

1. State the electronic configuration of hydrogen [at. no. 1].
   Give a reason why hydrogen can be placed in group 1 [IA] and group 17 [VIIA] of the periodic table.

2. Give the general group characteristics applied to hydrogen with respect to similarity in properties of hydrogen with –
   a] alkali metals of group 1 [IA] b] halogens of group 17 [VIIA].
   with special reference to valency electrons & ion formation.

3. How did the name 'hydrogen' originate. How does hydrogen occur in the combined state.

4. Give balanced equations for obtaining hydrogen from cold water using –
   a] A monovalent active metal b] A divalent active metal

5. Give balanced equations for obtaining hydrogen from –
   a] Boiling water using a divalent metal b] Steam using a trivalent metal
   c] Steam using a metal – and the reaction is reversible.

6. State why hydrogen is not prepared in the laboratory by the action of –
   a] Sodium with cold water
   b] Calcium with dilute sulphuric acid
   c] Lead with dilute hydrochloric acid.

7. Give balanced equations for the following conversions.
   a] Sodium zincate from zinc
   b] Sodium plumbite from lead
   c] Sodium aluminate from aluminium.

8. In the laboratory preparation of hydrogen from zinc and dil. acid. Give reasons for the following :
   a] The complete apparatus is air-tight.
   b] Dilute nitric acid is not preferred as the reactant acid.
   c] The lower end of the thistle funnel should dip below the level of the acid in the flask.'
   d] Hydrogen is not collected over air.

9. 'Magnesium reacts with very dilute nitric acid at low temperatures liberating hydrogen.' Give reasons.

10. State the conditions and give balanced equations for the conversion of –
    a] coke to water gas, b] water gas to hydrogen – in the Bosch process.

11. How are the unreacted gases separated out in 'Bosch process' in the manufacture of hydrogen.

12. Compare the combustibility of – a] pure hydrogen b] hydrogen-air mixture.

13. State the reactant added to hydrogen to obtain the respective product in each case.
    a] Ammonia b] Hydrogen chloride c] Water d] Hydrogen sulphide

14. State the use of hydrogen –
    a] As a fuel b] In hydrogenation of oil & coal c] In extraction of metals

# Unit Test Paper 9 — Hydrogen

30 marks

**Q.1 Select from A to G the reactant added, to give the products 1 to 5, in the preparation of hydrogen gas.**
**A : dilute acid, B : dilute alkali, C : cold water, D : conc. alkali, E : boiling water, F : conc. acid, G : steam** **[5]**

1. $Ca(OH)_2 + H_2$ 2. $MgO + H_2$ 3. $Fe_3O_4 + H_2$ 4. $Al_2(SO_4)_3 + H_2$ 5. $NaAlO_2 + H_2$

**Q.2 Give balanced equations for the following conversions, 1 to 5.** **[5]**

1. $MgCl_2 \leftarrow \boxed{HCl} \rightarrow FeCl_2$.
2. $KAlO_2 \leftarrow \boxed{KOH} \rightarrow K_2ZnO_2$.
3. $ZnO \leftarrow \boxed{H_2O} \rightarrow Fe_3O_4$
4. $CO + H_2 \leftarrow \boxed{H_2O} \rightarrow CO_2 + H_2$
5. $NH_3 \leftarrow \boxed{H_2} \rightarrow H_2S$

**Q.3 Give reasons for the following.** **[5]**

1. Nitric acid in the dilute form is not used in the laboratory preparation of hydrogen from metals.
2. Granulated zinc is preferred to metallic zinc in the preparation of hydrogen using dilute acid.
3. Hydrogen and alkali metals of group 1 [IA] react with copper [II] oxide to give copper.
4. Hydrogen is collected by the downward displacement of water and not air even though – it is lighter than air.
5. A mixture of hydrogen and chlorine can be separated by passage through a porous pot.

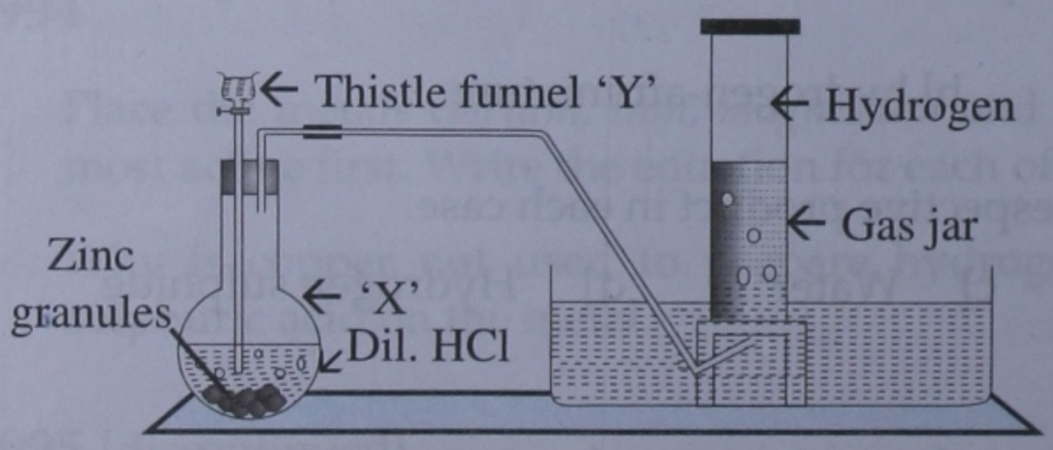
**Q.4 Name the following.** **[5]**

1. A metal below iron but above copper in the activity series of metals which has no reaction with water.
2. A metal which cannot be used for the preparation of hydrogen using dilute acids.
3. The salt formed when aluminium reacts with potassium hydroxide, during the preparation of hydrogen from alkalis.
4. A metal which reacts with very dilute nitric acid at low temperatures liberating hydrogen.
5. A compound formed between hydrogen and an element from group 17 [VIIA] – period 3.

**Q.5 Select the correct answer from the symbols in bracket.** **[5]**

1. The element placed below hydrogen in group 1 [IA]. [Na, Li, K, F].
2. The element other than hydrogen, which forms a molecule containing a single covalent bond. [Cl, N, O]
3. The element, which like hydrogen has one valence electron. [He, Na, F, O]
4. The element, which like hydrogen is a strong reducing agent. [Pb, Na, S, Cl]
5. The element which forms a diatomic molecule. [C, Br, S, P]

**Q.6 The diagram represents the preparation & collection of hydrogen by a standard laboratory method.** **[5]**




1. State what is added through the thistle funnel 'Y'.
2. State what difference will be seen if pure zinc is added in the distillation flask 'X' instead of granulated zinc.
3. Name a solution which absorbs the impurity – $H_2S$.
4. State why hydrogen is collected after all the air in the apparatus is allowed to escape.
5. Name a gas other than hydrogen collected by the same method.