6 STUDY OF THE FIRST ELEMENT — HYDROGEN

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, dilute acids and alkalis.

(a) Hydrogen from water."

- *The action of cold water on sodium, potassium and calcium.*
- *The action of hot water on magnesium.*
- *The action of steam on aluminium, zinc, and iron; (reversibility of reaction between iron and steam)*
- *The action of steam on non-metal (carbon).*

Application of activity series for the above mentioned reactions.

(b) Displacement of hydrogen from dilute acids:

- *The action of dilute sulphuric acid or hydrochloric acid on metals: Mg, Al, Zn and Fe*

(To understand reasons for not using other metals and dilute nitric acid)

(c) Displacement of hydrogen from alkalis:

- *The action of Alkalis ((NaOH, KOH) on Al, Zn and Pb – 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.

(iii) Industrial manufacture of hydrogen by Bosch process:

- Main reactions and conditions.
- Separation of CO_2 and CO from hydrogen.

(iv) Oxidation and reduction reactions

Differences in terms of addition and removal of oxygen/hydrogen.

Periodic Table

Period	1 IA	2	3-12	13	14	15	16	17	18 0
		IIA		IIIA	IVA	VA	VIA	VIIA	
1	H								He
2	Li	Be		B	C	N	O	F	Ne
3	Na	Mg		Al	Si	P	S	Cl	Ar
4	K	Ca	Transition Elements	Ga	Ge	As	Se	Br	Kr
5	Rb	Sr		In	Sn	Sb	Te	I	Xe
6	Cs	Ba		Ti	Pb	Bi	Po	At	Rn
7	Fr	Ra							

Hydrogen molecule

Symbol = H
Relative atomic mass =1
Molecular formula = H_2
Relative molecular mass =2
Valency = 1
Atomic number = 1
Electronic configuration : 1 (K shell)
Position in Periodic Table : 1st Period; 1A Group

6.1 POSITION OF HYDROGEN IN PERIODIC TABLE

Hydrogen is the first element in the periodic table. Its atomic number is 1, and it has only one electron in its valence shell. Therefore, **it belongs to the first group and the first period of the periodic table.**

It is expected that the properties of hydrogen should be similar to those of the other members of the Ist group, but this is not the case. Ever since Mendeleev presented his periodic table, the position of hydrogen in the table has been a matter of controversy and debate. This is mainly because some of the properties of hydrogen resemble the properties of the Group I A elements (alkali metals) while others are similar to those of the Group VII A (halogens) elements. Thompson suggested a separate position for hydrogen. He puts it at the top of the periodic table; that does not disturb the symmetry of the modern periodic table.

> ***Note*** **:** Hydrogen shows a *dual nature* since it resembles the alkali metals of Group IA and the halogens of Group VII A (17).

6.2 SIMILARITIES BETWEEN HYDROGEN AND ALKALI METALS

1. *Electronic configuration:* They have only one electron in their outermost orbits.

		K	L	M	N	O	P	(Shells)
H (1)	:	1						
Li (3)	:	2,	1					
Na (11)	:	2,	8,	1				
K (19)	:	2,	8,	8,	1			
Rb (37)	:	2,	8,	18,	8,	1		
Cs (55)	:	2,	8,	18,	18,	8,	1	
Fr (87)	:	2,	8,	18,	32,	18,	8,	1

2. *Valence electrons :* All elements have one electron in their outermost orbit, *i.e.* their valency shell and so all of them have one valence electron.
3. *Valency :* All alkali metals, including hydrogen, have valency 1.
4. *Ion formation :* Each of them can form cation, *i.e.* positive ion, by loss of an electron.

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

As such all these elements have electropositive character.

5. *Reducing power :* Both the alkali metals and hydrogen act as reducing agents.

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

6. *Burning :* Hydrogen burns in oxygen to form its oxide (water).

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

Hydrogen burns with a pop sound.

Alkali metals also burn vigorously when heated in oxygen to form their respective oxides.

Lithium forms monoxide

$$4Li + O_2 \rightarrow 2Li_2O$$

Sodium forms peroxide

$$2Na + O_2 \rightarrow Na_2O_2$$

while potassium, rubidium and caesium form superoxides having the general formula MO_2 (where M stands for metal).

$$K + O_2 \rightarrow KO_2$$

Action of air : Alkali metals are so reactive that they get rapidly tarnished when exposed to air. This is due to the formation of oxides and hydroxides, and finally, carbonates, on their surface.

Example :

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

Note : Due to their reactivity, alkali metals are always stored in an inert organic solvent, such as kerosene oil. This inert solvent prevents them from coming in contact with air and moisture.

7. *Combination with non-metals :* Hydrogen as well as alkali metals react with non-metals like oxygen, sulphur and chlorine to form respective compounds.

Hydrogen – forms H_2O; H_2S; HCl
Sodium – forms Na_2O; Na_2S; NaCl
and so on.

6.3 SIMILARITIES BETWEEN HYDROGEN AND HALOGENS

1. *Electronic configuration :* Hydrogen and halogens have one electron less than the nearest inert gas.

H = 1 [He = 2],
F = 2, 7 [Ne = 2, 8),
Cl = 2, 8, 7 (Ar 2, 8, 8)

2. *Valency :* Both have valency 1.

Thus, they accept one electron to attain the electronic configuration of the nearest inert gas.

3. *Formation of ions :* Both show a tendency to form anions since they are one electron short of the nearest inert gas configuration.

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

4. *Electronegative character :* Both halogens and hydrogen are non-metals. They show electronegative character.

$$H + e^- \rightarrow H^-$$
$$F + e^- \rightarrow F^-$$

5. *Physical state :* Like halogens (fluorine and chlorine), hydrogen too is a gas.
6. *Atomicity :* Hydrogen as well as halogens exist in the form of diatomic molecules (H_2, F_2, Cl_2, Br_2, I_2).

Properties of Hydrogen different from those of Alkali Metals and Halogens.

1. Hydrogen atom has only one shell but alkali metals and halogens have two or more shells.
2. Oxide of hydrogen, H_2O, is a neutral oxide. Oxides of halogens like Cl_2O, Cl_2O_7, etc., are acidic in nature, while oxides of alkali metals like Na_2O, K_2O, etc. are basic in nature.

6.4 DISCOVERY

The credit for the discovery of hydrogen goes to **Henry Cavendish** (1766), although **Robert Boyle** had prepared the gas in 1672. *Not only did Cavendish prepare the gas from iron and dilute acids, he also established its elementary nature and showed that water is formed when this gas burns in air.,* He called it **inflammable air** because of its combustible nature. It was on account of its ability to form water that **Lavoisier,** in 1783, named it *hydrogen* (Greek word meaning *water former*).

6.5 OCCURRENCE

Free state

In free state, hydrogen is found in traces in the earth's crust and atmosphere. Volcanic gases contain 0·025% of it, the earth's crust 0·98%, the earth's atmosphere 0·01% and the atmospheres of the Sun and the stars contain 1.1% hydrogen.

Combined state

(i) *Plant and animal tissues* are made up of compounds of hydrogen with carbon, oxygen and nitrogen.

(ii) Hydrogen is the characteristic *constituent of acids, alkalis,* hydrocarbons and proteins. In addition to these, sugar, starch, petroleum products, proteins, carbohydrates and also fats contain hydrogen.

(iii) In water, it is 11·1% by weight.

6.6 PREPARATION OF HYDROGEN

Since water, acids and alkalis contain hydrogen, they form the cheapest raw materials for preparation and manufacture of hydrogen.

6.6.1 Hydrogen from water

Hydrogen from cold water and metals

***Reactive metals** like potassium, sodium and calcium react with **cold water** forming their corresponding hydroxides and evolving hydrogen. Their reactions are exothermic.*

(a) Potassium :

1. Potassium when added to water, floats on water (density 0·86 g/cc).
2. It *melts* [at 62°C], forming a silver grey globule that *darts* about on the surface of the water.
3. Reaction : $2K + 2H_2O \longrightarrow 2KOH + H_2$

   The reaction is highly exothermic and vigorous.
4. It catches fire and burns with a *lilac-coloured flame*.
5. Bubbles of hydrogen gas are seen, and the solution formed is colourless, soapy and *alkaline*.

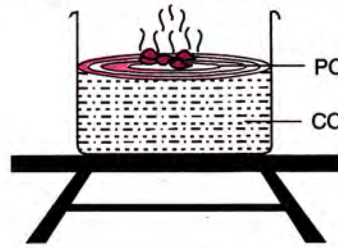

Fig. 6.1 Action of potassium on cold water

Although pure hydrogen burns with a pale blue flame, the colour of the flame is lilac due to the presence of traces of potassium vapour.

Caution! Potassium readily catches fire in air because it reacts with water vapour. So it is kept in kerosene oil and handled carefully. Do not touch it with your hand, rather use a pair of tongs.

(b) Sodium :

1. It floats on water; density 0.97 g/cc; melting point 97°C.
2. It melts, forming a silvery globule, which darts about on the surface of the water.
3. *Reaction :* $2Na + 2H_2O \longrightarrow 2NaOH + H_2$

   The reaction is less exothermic and less vigorous as compared to potassium.

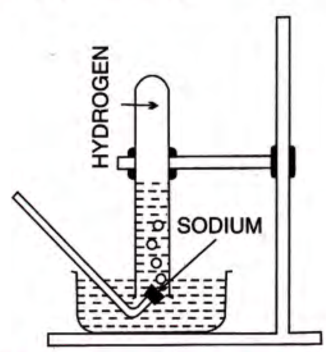

Fig. 6.2 Action of sodium on water

4. It catches fire and burns with a *golden yellow flame*.
5. Bubbles of hydrogen gas are produced, and the solution formed is colourless, soapy, slightly warm and *alkaline*.

Note : Sodium amalgam (alloy of sodium with mercury) and potassium amalgam react smoothly with water. Therefore *hydrogen can be safely prepared from these amalgams.*

(c) Calcium :

1. Calcium sinks in water.
2. Reaction : $Ca + 2H_2O \longrightarrow Ca(OH)_2 + H_2$
   Reaction is less vigorous than sodium.
3. Bubbles of hydrogen are liberated, and the solution turns milky, turbid and alkaline. *If red litmus is introduced in solution it turns blue.*

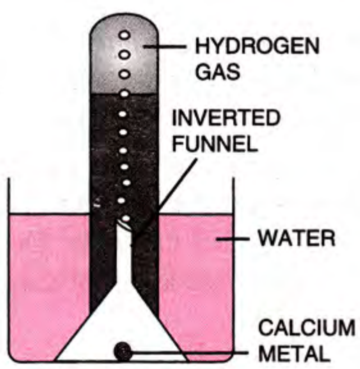

Fig. 6.3 Action of calcium on water

Action of hot water and steam on metals

(i) **Magnesium** reacts slowly with boiling water and forms a base, magnesium hydroxide liberating hydrogen gas.

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

(ii) **Magnesium** burns in steam with an **intense white light**, liberating hydrogen gas and white ash, *i.e.*, magnesium oxide.

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

Magnesium oxide crumbles down due to heating, further exposing magnesium to steam results in the liberation of hydrogen gas.

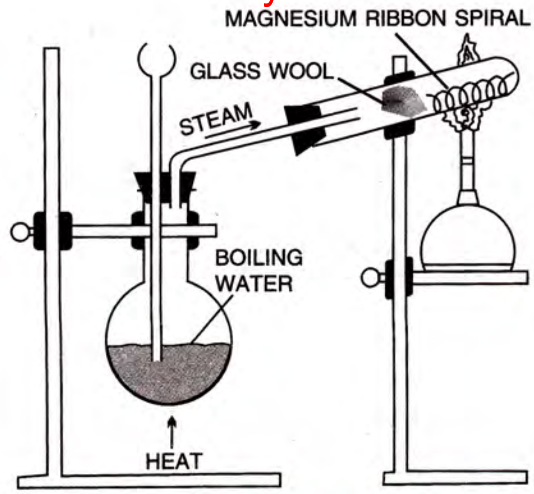

Fig. 6.4 Action of magnesium on steam

Action of steam on metals

(a) Aluminium :

1. It reacts with steam to liberate hydrogen.
2. It forms aluminium oxide, which makes it inactive, and liberates hydrogen. There is no further reaction due to the oxide coating.

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

3. At high temperature, however, the coating breaks and aluminium reacts with steam, liberating hydrogen.

(b) Zinc :

1. It is even less reactive *i.e.* it reacts only when it is *heated and steam* is passed over it.
2. Hydrogen is liberated and zinc is converted to white zinc oxide.

$$Zn + H_2O \rightarrow ZnO + H_2$$

3. Zinc oxide is *yellow* when it is hot but *white* when it is cold.

(c) Iron :

1. Iron is less reactive than zinc, but red hot iron reacts with steam, forming triferric tetra-oxide and hydrogen gas.
2. This reaction is *reversible*. If the hydrogen formed is not removed, the iron oxide formed is reduced back to iron.

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

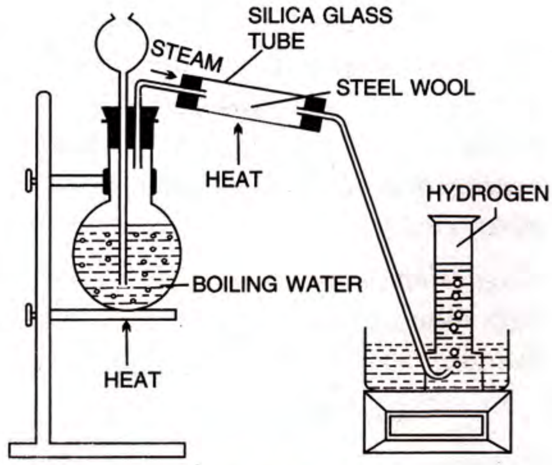

Fig. 6.5 Action of iron on steam

Note : In the beginning, the forward reaction is fast and the backward reaction is slow, since the speed of a reaction is directly related to the masses (or the concentrations) of the reacting substances. As the reactants get consumed, the forward reaction becomes slower. *In other words*, as the products are formed, the backward reaction becomes faster. There comes a time when the forward and backward reactions acquire the same speed. Thereafter, the reaction does not appear to move in a single direction, and the amounts of the reactants and the products do not change. This equilibrium stage is attained at 700°C.

An equilibrium, that is attained through a chemical change is known as a chemical equilibrium.

Note : When metals react with steam :

(i) rate of reaction is fastest in the case of magnesium but it progressively decreases in the cases of aluminium, zinc and iron.

(ii) in the case of magnesium, aluminium and zinc, **the reactions stop after some time**. This is because the oxides of these metals stick to the surfaces of the respective metals and thus do not allow steam to come into contact with the metal.

Action of steam on non-metals

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

$$C + H_2O \rightarrow \underbrace{CO + H_2}_{\text{Water gas}}$$

6.7 APPLICATION OF ACTIVITY SERIES IN THE PREPARATION OF HYDROGEN

Based on reaction with water, metals are arranged in decreasing order of reactivity.

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.

Thus, potassium being the most reactive metal is placed at the top of the list, and the least reactive metal being gold, is placed at the bottom of the list.

Hydrogen, though it is a non-metal, is included in this series because it can form a positive ion. It would occupy a position based on formation of its positive ion.

The ability of metals to reduce water to hydrogen decreases on going down the series.

K > Na > Ca > Mg > Al > Zn ....

Lead and the metals that are further below in the activity series : No reaction with water, even when the metal is hot and steam is used.

6.7.1 Salient features of the Activity Series

(i) Electropositive character decreases down the series.

(ii) Reducing power of metals decreases down the series. Thus, potassium is the strongest reducing agent.

(iii) Tendency of metals to lose valence electrons, *i.e.* tendency of metals to get oxidized, decreases down the series. Thus, potassium is the most readily oxidized metal.

(iv) Metals above hydrogen displace hydrogen from water and dilute acid, but metals below hydrogen do not.

$$2Na + 2H_2O \rightarrow 2NaOH + H_2$$
$$Cu + H_2O \rightarrow \text{No reaction}$$
$$Zn + 2HCl\ (\text{dil.}) \rightarrow ZnCl_2 + H_2$$
$$Cu + HCl\ (\text{dil.}) \rightarrow \text{No reaction}$$

(v) A metal higher up in the series displaces a metal below it from the salt solutions of the latter.

$$CuSO_4(aq) + Zn \rightarrow ZnSO_4(aq) + Cu$$

Larger the difference in the positions of the metals in the activity series, more rapidly the displacement occurs.

(vi) Oxides of metals K, Na, Ca, Mg and Al cannot be reduced by common reducing agents like H_2, CO or C. They can be reduced only by electrolysis. Metal oxides below aluminium can be reduced by heating them in the presence of reducing agents.

$$ZnO + C \rightarrow Zn + CO$$
$$PbO + C \rightarrow Pb + CO$$
$$PbO + CO \rightarrow Pb + CO_2$$
$$PbO + H_2 \rightarrow Pb + H_2O$$

(vii) Oxides and nitrates of less reactive metals like Hg, Ag and Au decompose on strong heating to give metals.

$$2HgO \rightarrow 2Hg + O_2$$
$$2AgNO_3 \rightarrow 2Ag + 2NO_2 + O_2$$

(viii) Metals below copper do not rust easily.

(ix) Since the reactivity series lists metals in decreasing order of electropositivity, it is expected that those at the top will combine with more electronegative elements in their minerals. *For example*, sodium and potassium occur mainly as their chlorides, aluminium as its oxide, and zinc, lead, copper, mercury and silver as their sulphides.

6.7.2 Displacement of hydrogen from dilute acids

Hydrogen is displaced from dilute hydrochloric acid and dilute sulphuric acid when the latter react with some metals which are more reactive than hydrogen.

The extent to which these reactions occur for a given metal is also based on the ***activity series of metals.***

K, Na, Ca	These displace hydrogen from dilute acids (HCl or H_2SO_4) with explosive violence
Mg, Al, Zn	These displace hydrogen from dilute acids (HCl or H_2SO_4) vigorously, but not violently forming their respective salts
F, Ni, Sn, Pb	These displace hydrogen from dilute acids (HCl or H_2SO_4) gently forming their respective salts
H	
Cu, Hg, Ag, Au	These do not displace hydrogen from dilute acids at all

- *When* ***dilute sulphuric acid*** *or* ***dilute hydrochloric acid*** *reacts with metals above hydrogen in the activity series, hydrogen is produced.* ***But in the case of metals below hydrogen in the activity series,*** *like copper, silver, etc., this does not happen.*
- *Magnesium, aluminium, zinc and iron* react with dilute HCl or dilute H_2SO_4, liberating *hydrogen* and forming their *respective salts.*

Metal		***Acid [dil.]***		***Salt***		***Hydrogen***
1. *Magnesium*						
Mg	+	2HCl	→	$MgCl_2$	+	H_2
2. *Aluminium*						
2Al	+	$3H_2SO_4$	→	$Al_2(SO_4)_3$	+	$3H_2$
3. *Zinc*						
Zn	+	H_2SO_4	→	$ZnSO_4$	+	H_2
4. *Iron*						
Fe	+	2HCl	→	$FeCl_2$	+	H_2

Zinc is the most preferred metal in laboratory preparation of hydrogen because of the following reasons :

(i) **Sodium** and **potassium** react violently with acid.

(ii) **Calcium** and **magnesium** are expensive.

(iii) **Aluminium** forms a protective coating of Al_2O_3 due to its great affinity for oxygen. So, it does not give hydrogen with acid after the reaction has occured for some time.

(iv) **Iron** has to be heated, but then the hydrogen thus produced contains impurities like hydrogen sulphide and sulphur dioxide.

(v) **Lead** reacts with dilute sulphuric or hydrochloric acid and **forms an insoluble coating of lead sulphate or lead chloride.** Therefore, further reaction is prevented.

(vi) Hydrogen cannot be prepared from metals that are below it in the activity series of metals, such as **copper** and **mercury**, **since *only*** *metals that are more reactive than hydrogen can displace it from acids.*

$$e.g.,\ Cu + \underset{(dil.)}{HCl} \rightarrow \text{No reaction}$$

6.7.3 Displacement of hydrogen by alkalis

Metals like zinc, lead and aluminium have a **unique nature**. *They react with acids and can even react with hot concentrated alkalis to form hydrogen and a soluble salt.*

Metal [powdered] Amphoteric		*Alkali [conc. soln.]*		*Salt*		*Hydrogen*
1. *Zinc*						
Zn	+	2NaOH	→	Na_2ZnO_2 (Sodium zincate)	+	H_2
Zn	+	2KOH	→	K_2ZnO_2 (Potassium zincate)	+	H_2
2. *Lead*						
Pb	+	2NaOH	→	Na_2PbO_2 (Sodium plumbite)	+	H_2
Pb	+	2KOH	→	K_2PbO_2	+	H_2

3. *Aluminium*

$$2Al + 6NaOH_{\text{(fused)}} \rightarrow \underset{\text{Sodium aluminite}}{2Na_3AlO_3} + 3H_2$$

$$2Al + 2NaOH + 2H_2O \rightarrow \underset{\text{Sodium meta aluminate}}{2NaAlO_2} + 3H_2$$

$$2Al + 2KOH + 2H_2O \rightarrow \underset{\text{Potassium meta aluminate}}{2KAlO_2} + 3H_2$$

Oxides and hydroxides of zinc, lead and aluminium are AMPHOTERIC, *i.e.*, they react with both bases and acids to give salt and water.

$$ZnO + 2HCl \rightarrow ZnCl_2 + H_2O$$

$$ZnO + \underset{\text{(Sodium hydroxide)}}{2NaOH} \rightarrow \underset{\text{(Sodium zincate)}}{Na_2ZnO_2} + H_2O$$

EXCERCISE 6(A)

1. Justify the position of Hydrogen in the periodic table.
2. Why does hydrogen show dual nature ?
3. Compare hydrogen with alkali metals on the basis of :
   (i) Ion formation (ii) Reducing power
   (iii) Reaction with oxygen (iv) Oxide formation
4. In what respect does hydrogen differ from :
   (i) alkali metals (ii) halogens ?
5. Give the general group study of hydrogen with reference to
   (i) valence electrons (ii) burning
   (iii) reducing power.
6. Why was hydrogen called 'inflammable air ?
7. State some sources of hydrogen.
8. Compare hydrogen and halogens on the basis of :
   (i) physical state (ii) ion formation
   (iii) valency (iv) reaction with oxygen
9. Which metal is preferred for preparation of hydrogen.
   (i) from water ? (ii) from acid ?
10. (i) Write the reaction of steam with red hot iron
    (ii) Why this reaction is considered as reversible reaction ?
    (iii) How the reaction can proceed continuously ?
11. Explain the unique nature of zinc and aluminium. Give balanced equations to support your explanation.
12. Write balanced equations for the following :
    (i) Iron reacts with dil HCl
    (ii) Zinc reacts with caustic soda solution
    (iii) Lead reacts with potassium hydroxide
    (iv) Aluminium reacts with fused sodium hydroxide.
13. Write balanced equations and give your observations when the following metals react :
    (i) Sodium with cold water
    (ii) Calcium with cold water
    (iii) Magnesium with boiling water
    (iv) Magnesium with steam.
14. (i) Under what conditions iron reacts wth water.
    (ii) Give the balanced equation of the reaction.
    (iii) What is noticed if the products are not allowed to escape ?
15. From the knowledge of activity series, name a metal which shows the following properties
    (i) It reacts readily with cold water
    (ii) It displaces hydrogen from hot water
    (iii) It displaces hydrogen from dilute HCl
    (iv) It forms a base which is insoluble in water.

6.8 LABORATORY PREPARATION OF HYDROGEN

Reactants :

Granulated zinc; dilute hydrochloric acid or dilute sulphuric acid.

Procedure :

Place some pieces of granulated zinc in a flat-bottom flask fitted with an air tight cork with two holes. Through one hole, pass a thistle funnel with a long stem, and through the other, a long delivery tube (Fig. 6.6).

Pour dilute hydrochloric acid (or dilute sulphuric acid) through the funnel.

Reaction :

$$\underset{\text{(dilute)}}{Zn + 2HCl} \rightarrow ZnCl_2 + H_2 \uparrow$$

OR

$$\underset{\text{(dilute)}}{Zn + H_2SO_4} \rightarrow ZnSO_4 + H_2 \uparrow$$

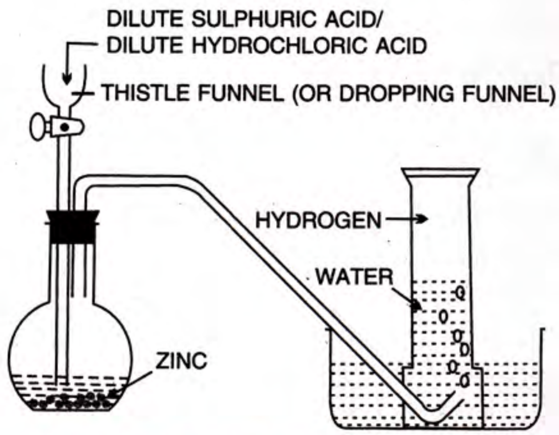

Fig. 6.6 Laboratory preparation of hydrogen

> Zinc granules are preferred for this reaction over pure zinc because the *impurity present in granulated zinc is copper, whose catalysing effect speeds up the rate of reaction.*

Observation :

Reaction will gradually start in the form of effervescence and evolution of gas. When all the air from the apparatus has been expelled, *collect the gas.*

Collection of hydrogen

Hydrogen is collected by the **downward displacement of water** because :

(i) it is virtually insoluble in water (20 mL of hydrogen disolves in 1litre of water under normal conditions).

(ii) it forms an explosive mixture with air and therefore cannot be collected by downward displacement of air even though it is lighter than it.

Impurities present with hydrogen :

(i) hydrogen sulphide (H_2S)

(ii) sulphur dioxide (SO_2)

(iii) oxides of nitrogen

(iv) phosphine (PH_3)

(v) arsine (AsH_3)

(vi) carbon dioxide

(vii) water vapour

Impurities can be removed from hydrogen by passing it through

1. **Silver nitrate solution** [to remove arsine and phosphine].

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

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

2. **Lead nitrate solution** [to remove hydrogen sulphide].

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

3. **Caustic potash solution** [to remove *sulphur dioxide, carbon dioxide and oxides of nitrogen].*

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

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

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

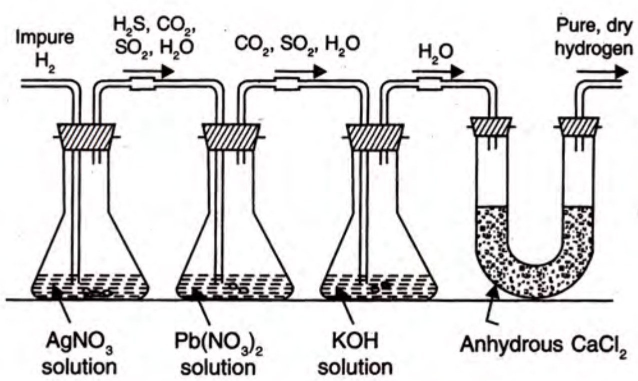

Fig. 6.4 Purification of hydrogen.

4. A **drying agent** used to dry the gas. Common drying agents like fused calcium chloride, caustic potash stick and phosphorous pentoxide remove water vapour.

Thus the gas is purified and dried, and then collected over mercury, because mercury has no reaction with it.

Concentrated sulphuric acid is a good drying agent but it is not used to dry hydrogen as it reacts with hydrogen, thus defeating the purpose of the reaction.

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

Precautions :

The following precautions must be taken while preparing the gas because *a mixture of hydrogen and air explodes violently when it is brought near a flame.*

1. The apparatus should be airtight and there should be no leakage of gas.
2. There should be no flame burning near the apparatus.
3. *The gas should be collected only after all the air in the apparatus has escaped.* This can be ascertained by collecting some amount of gas in a test tube and taking it to a flame. If the gas burns quietly, then there is no more air in the flask.
4. The end of the thistle funnel should be dipped under acid so as to prevent gas from escaping from the thistle funnel.

Note :

1. Nitric acid, even in its dilute form, is not used in preparation of hydrogen from metals because:

   Nitric acid is a powerful *oxidizing agent,* and the oxygen formed due to its decomposition *oxidizes the hydrogen to give water, thus defeating the purpose of the reaction.*

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

2. *Magnesium* [Mg] *and manganese* [Mn] are the only metals that react with *very dilute nitric acid (1% nitric acid) to* liberate hydrogen. The oxidizing action of the acid is much reduced due to its over-dilution.

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

3. Concentrated *sulphuric acid* is not used in preparation of hydrogen as it will produce sulphur dioxide.

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

TEST FOR HYDROGEN

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

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

   When it is premixed with air or oxygen, it explodes with a pop sound.

6.9 MANUFACTURE OF HYDROGEN

I. Bosch process :

It consists of the following steps :

(i) Steam is passed over hot coke (1000°C) in furnaces of a special design, called converters, giving **water gas.**

$$\underset{\text{hot coke}}{C} + \underset{\text{steam}}{H_2O} \xrightarrow{1000^\circ C} \underset{\text{water gas}}{(CO + H_2)} - \Delta$$

The reaction is endothermic.

(ii) Water gas is mixed with excess steam and passed over heated ferric oxide, which acts as a catalyst, and chromic oxide Cr_2O_3, which acts as a promoter.

$$\underset{\text{water gas}}{(CO + H_2)} + \underset{\text{steam}}{H_2O} \xrightarrow[450^\circ C]{Fe_2O_3} CO_2 + 2H_2 + \Delta$$

The reaction is exothermic.

(iii) **Separation of carbon dioxide**

The above mixture, *i.e.* $CO_2 + H_2$, is forced through cold water under pressure (30 atm), or through caustic potash solution, which dissolves the more soluble carbon dioxide, leaving hydrogen.

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

(iv) **Separation of carbon monoxide**

The mixture is passed through ammoniacal cuprous chloride solution in order to dissolve any uncombined carbon monoxide.

$$CuCl + CO + 2H_2O \rightarrow CuCl\,.\,CO\,.\,2H_2O$$

Thus, **hydrogen gas is left behind.**

II. By electrolysis of water :

Commercially hydrogen is also obtained by electrolysis of acidulated water.

Water is a poor conductor of electricity. In order to make it a conductor, a very small amount of less volatile acid, sulphuric acid (H_2SO_4), is added.

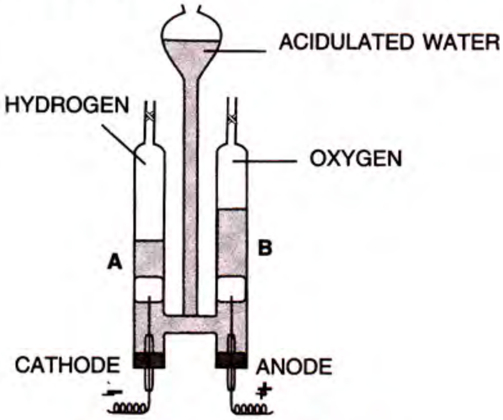

Fig. 6.5 Electrolysis of water.

On passing electric current through acidulated water, water dissociates.

$$H_2O \rightleftharpoons H^+ + OH^-$$

H^+ being positively charged, moves towards cathode (negatively-charged electrode).

At **cathode** $H^+ + e^- \rightarrow H$

$$H + H \rightarrow H_2$$

Hydrogen gas is evolved at the cathode.

OH^- being negatively charged, moves towards anode (positively-charged electrode).

Anode $OH^- - e^- \rightarrow OH$

$$OH + OH \rightarrow H_2O + O$$

$$O + O \rightarrow O_2$$

Oxygen is evolved at the anode.

Thus, water dissociates to give hydrogen and oxygen with the help of electric current.

$$\underset{\text{(acidulated)}}{2H_2O} \xrightarrow[\text{current}]{\text{electric}} \underset{\text{(at cathode)}}{2H_2} + \underset{\text{(at anode)}}{O_2}$$

The main advantage of this process lies in the fact that oxygen is simultaneously produced at the anode and both the gases are pure.

EXCERCISE 6(B)

1. Hydrogen can be prepared with the metal zinc by using :
   (i) acid (ii) alkali (iii) water
   Give an equation in each case.
2. For laboratory preparation of hydrogen, give the following :
   (a) materials used (b) method of collection
   (c) chemical equation (d) fully-labelled diagram
3. (a) Name the impurities present in hydrogen prepared in the laboratory.
   (b) How can these impurities be removed.
4. Which test should be made before collecting hydrogen in a gas jar ?
5. Why nitric acid is not used in the preparation of hydrogen.
6. Why hot concentrated sulphuric acid is not used in preparation of hydrogen ?
7. Hydrogen is manufactured by 'Bosch Process'.
   (a) Give the equations with conditions.
   (b) How can you obtain hydrogen from a mixture of hydrogen and carbon monoxide ?
8. Give equations to express the reaction between :
   (a) steam and red hot iron
   (b) calcium and water
9. A small piece of calcium metal is put into a small trough containing water. There is effervescence and white turbidity is formed.
   (a) Name the gas formed in the reaction. How would you test the gas ?
   (b) Write an equation for the reaction.
   (c) What do you observe when a few drops of red litmus solution are added to the turbid solution ?
   (d) What happens if dilute hydrochloric acid is added to the turbid solution ? Write the equation for the reaction.
10. Thin strips of magnesium, copper and iron are taken.
    (a) Write down what happens when these metals are treated as follows :
    (i) Heated in presence of air
    (ii) Heated with dil. HCl
    (iii) Added to an aqueous solution of zinc sulphate
    (b) Arrange these metals in descending order of reactivity.

6.10 PROPERTIES OF HYDROGEN

6.10.1 Physical properties

1. *Colour* : Colourless.
2. *Odour* : Odourless.
3. *Taste* : Tasteless.
4. *Physiological nature* : Non-toxic.
5. *Density* : 0·0899 g/mL. It is the lightest known gas. It is 14·4 times less dense than air.
6. *Solubility* : Very slightly soluble in water. [1 L of water dissolves about 20 mL of the gas under normal conditions].
7. *Liquefaction* : Liquefies at below –240°C under pressure of about 20 atmosphere.

Occlusion : Hydrogen is readily adsorbed by *palladium* or *platinum* or *nickel* at room temperature. *For example*, one volume of finely divided palladium takes up 900 volumes of hydrogen at room temperature. This phenomenon is called **occlusion** or **adsorption**.

To prove that hydrogen is a very light gas

Experiment : Take soap solution in a beaker and allow hydrogen to pass through it.

On passing hydrogen gas through the soap solution, soap bubbles filled with hydrogen fly higher and burst out. This behaviour proves that hydrogen is lighter than air.

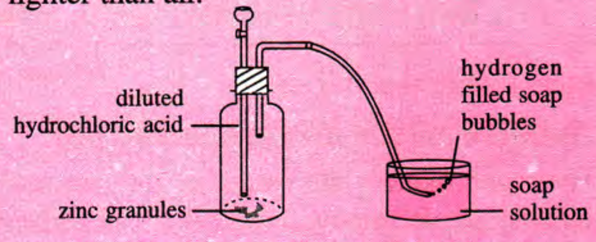

Fig. 6.9 : Hydrogen filled soap bubbles rise upwards in the air

6.10.2 Chemical properties

Hydrogen is a reactive element; it reacts with non-metals, metals, metallic oxides and even organic compounds under appropriate conditions. It does not support combustion.

1. Reaction of hydrogen with non–metals

Reactants	*Equations* Reactants		Products	*Condition and observations*
1. Oxygen [air] and hydrogen	$2H_2 + O_2$	$\longrightarrow$	$2H_2O$ (water)	Hydrogen burns (in presence of electric spark) with a 'pop' sound in oxygen, and with a pale blue flame, forming water. Pure hydrogen burns *quietly* in air (Fig. 6.10).
2. Chlorine and hydrogen	$H_2 + Cl_2$	$\longrightarrow$	2HCl (hydrogen chloride)	Equal volumes of hydrogen and chlorine react slowly in diffused sunlight but **explosively in direct sunlight.** This is because a spontaneous reaction takes place, with release of a large amount of energy. However, hydrogen continues to burn in chlorine.
3. Nitrogen and hydrogen **(Haber Process)**	$N_2 + 3H_2$	$\rightleftharpoons$	$2NH_3$ (ammonia)	Three volumes of hydrogen and one volume of nitrogen react at ***temperature*** of 450-500°C, ***pressure*** 200-900 atm, in presence of ***catalyst*** finely divided iron with molybdenum as ***promoter.***
4. Sulphur and hydrogen	$H_2 + S$	$\longrightarrow$	H_2S	Hydrogen gas, when passed through molten sulphur, reacts to give another gas (hydrogen sulphide).

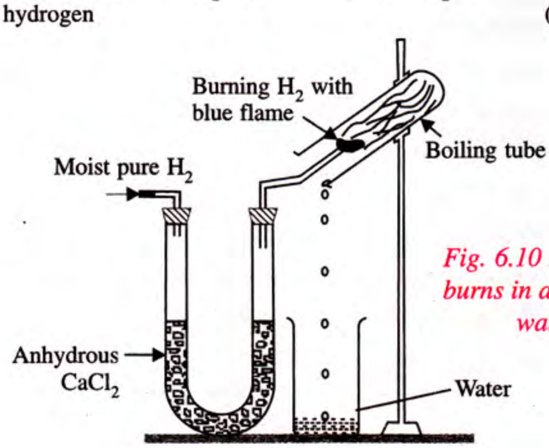

Fig. 6.10 Hydrogen burns in air to form water.

Note : Hydrogen forms an explosive mixture with air (due to the oxygen present in air). If the amount of air is less in the mixture, the explosion is not dangerous, *i.e.* the gas burns with a pop sound only. But a large volume of mixture causes a dangerous explosion leading to serious damage and injuries. (*Hydrogen-oxygen mixture is called* **detonating mixture**).

2. Reaction of hydrogen with metals

Reactants	Equation		Observation
Hydrogen and :	**Reactants**	**Products**	
1. Potassium	$2K + H_2$	$\xrightarrow{\Delta} 2KH$	Dry hydrogen, when it is passed over heated metals [K, Na, Ca]
2. Sodium	$2Na + H_2$	$\xrightarrow{\Delta} 2NaH$	reacts to give their corresponding hydrides, *i.e.*
3. Calcium	$Ca + H_2$	$\xrightarrow{\Delta} CaH_2$	potassium or sodium or calcium hydride.
	$CaH_2 + 2H_2O$	$\longrightarrow Ca(OH)_2 + 2H_2$	**The hydrides thus formed further react with water to form hydrogen.**

3. Reaction with metallic oxides

(i) *Hydrogen gas is a strong reducing agent.*

Hydrogen reduces the oxides of the less active metals, *i.e.* it removes oxygen from *strongly heated metal oxides* when passed over them and itself gets oxidized to water.

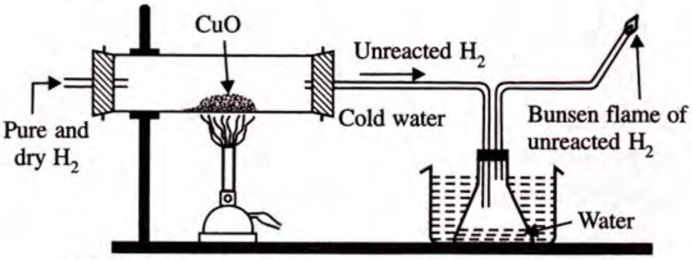

Fig. 6.8 Reduction of copper oxide to copper metal

Metallic oxide	+	***Hydrogen***	$\xrightarrow{\Delta}$	***Metal + Water***	***Colour changes as metal oxide changes to metal***
Fe_2O_3	+	$3H_2$	$\xrightarrow{\Delta}$	$2Fe + 3H_2O$	Brown to grey
Fe_3O_4	+	$4H_2$	$\xrightarrow{\Delta}$	$3Fe + 4H_2O$	Brown to grey
PbO	+	H_2	$\xrightarrow{\Delta}$	$Pb + H_2O$	Yellow to silvery grey
CuO	+	H_2	$\xrightarrow{\Delta}$	$Cu + H_2O$	Black to reddish brown (see Fig. 6.11)

4. In the presence of a catalyst like nickel, hydrogen directly combines with organic compounds that have double or triple bonds between two carbon atoms. This process is known as hydrogenation.

$$\underset{\text{ethylene}}{H_2C=CH_2} + H_2 \rightarrow \underset{\text{ethane}}{C_2H_6} \qquad \underset{\text{acetylene}}{HC\equiv CH} + 2H_2 \rightarrow \underset{\text{ethane}}{C_2H_6}$$

6.11 USES OF HYDROGEN

1. ***As a fuel :*** Because of its high heat of combustion, hydrogen is used as a fuel in the form of :
   (i) Coal gas,
   (ii) Water gas ($CO + H_2$),
   (iii) Liquid hydrogen (non-polluting and easy to store).
2. ***Oxy-hydrogen torch :*** A mixture of hydrogen and oxygen is burnt in a specially-designed apparatus called an oxy-hydrogen torch to produce temperatures touching 2500°C. *The flame is used for cutting and welding metals, for melting platinum and quartz, and for fusing alumina to produce synthetic rubies and sapphires that are used as jewels in watches.*
3. ***Atomic hydrogen torch : Creates high temperature (2800°C), which is used for welding alloys containing metals*** like tungsten, manganese and chromium.
4. ***In self-lighting gas jets and automatic lighters.***
5. For manufacture of ammonia ***(Haber Process)***, hydrogen chloride, ***methyl alcohol :***

$$CO + 2H_2 \rightarrow \underset{\text{(Methyl alcohol)}}{CH_3OH}$$

6. ***For hydrogenation of vegetable oil :*** Hydrogen is used in preparation of solid *vanaspati ghee* from liquid vegetable fats like groundnut oil, coconut oil, etc. This process is called **catalytic hydrogenation of oils** because it takes place in the presence of finely-divided nickel or platinum or palladium acting as catalyst. This process occurs at high pressure and at a temperature of about 200°C.
7. ***For producing artificial petrol from coal***
   Passage of hydrogen under high pressure over powdered coal in presence of a catalyst is known as *hydrogenation of coal.* It produces a product similar to petroleum but containing a higher proportion of hydrogen.
8. ***In extraction of metals :*** Hydrogen reduces heated metallic oxide to metals (less active metal oxides).

$$Fe_2O_3 + 3H_2 \rightarrow 2Fe + 3H_2O$$

$$\underset{\text{black}}{CuO} + H_2 \rightarrow \underset{\text{red/brown}}{Cu} + H_2O$$

Note : Oxides of active metals like sodium, potassium, aluminium, calcium and magnesium have great affinity towards oxygen. These oxides do not get reduced by hydrogen into their corresponding metals.

9. ***In meteorological balloons to study weather conditions :*** Hydrogen is the lightest gas but inflammable; thus helium is preferred.

EXCERCISE 6(C)

1. (a) State the position of hydrogen in the periodic table.
   (b) Explain its resemblance to the other members of its group.
2. Comment on the dual position of hydrogen in the periodic table.
3. (a) Where does hydrogen occur in free state ?
   (b) How did the name 'hydrogen' originate ?
4. Hydrogen can be prepared with the help of cold water. Give a reaction of hydrogen with :
   (a) a monovalent metal
   (b) a divalent metal.
5. Why are the following metals not used in the lab. preparation of hydrogen ?
   (a) calcium (b) iron (c) aluminium (d) sodium
6. What is the activity series of metals ?
7. Under what conditions can hydrogen be made to combine with
   (a) nitrogen ? (b) chlorine ?
   (c) sulphur ? (d) oxygen ?
   Name the products in each case and write the equation for each reaction.
8. Hydrogen may be prepared in the laboratory by the action of a metal on an acid.
   (a) Which of the metals copper, zinc, magnesium or sodium would be the most suitable ?
   (b) Which of the acids dilute sulphuric, concentrated sulphuric, dilute nitric and concentrated nitric would you choose ? Explain why you would not use the acids you reject.
   (c) How would you modify your apparatus to collect dry hydrogen ? Which drying agent would you employ for this purpose ?
9. If the following are kept in closed vessels at over 400°C, what would happen to them ?
   (a) iron filings and steam,
   (b) hydrogen and magnetic oxide of iron ?
10. (a) A metal in the powdered form reacts very slowly with boiling water, but it decomposes in steam. Name the metal.
    (b) Write a balanced equation for the reaction occurring in (a).
11. When hydrogen is passed over a black solid compound A, the products are 'a colourless liquid' and 'a reddish brown metal B.'
    Substance B is divided into two parts, each placed in separate test tubes.
    Dilute HCl is added to one part of substance B and dilute HNO_3 to the other.
    (a) Name the substances A and B.
    (b) Give two tests for the colourless liquid formed in the experiment.
    (c) What happens to substance A when it reacts with hydrogen ? Give reasons for your answer.
    (d) Write an equation for the reaction between hydrogen and substance A.
    (e) Is there any reaction between substance B and dilute hydrochloric acid ? Give reasons for your answer.
12. Hydrogen is evolved when dilute HCl reacts with magnesium, but nothing happens in the case of mercury and silver. Explain.
13. What do you observe when hydrogen gas is passed through soap solution ?
14. *Bosch Process* is used for large-scale production of hydrogen. Give necessary
    (a) Balanced equations (b) Conditions
15. Which metal is preferred for collecting hydrogen from :
    (a) cold water ?
    (b) hot water ?
    (c) steam ?
    Write balanced equation for each case.
16. Steam can react with metal and non-metal to liberate hydrogen. Give necessary conditions and equations for the same.
17. Hydrogen is obtained by displacement from :
    (a) dilute sulphuric acid
    (b) dilute hydrochloric acid
    Write equations using zinc and Iron.
    Why does copper not show similar behaviour ?
18. Name two alkalies that can displace hydrogen. Give balanced equations for the same. Why are the metals you have used considered to have *unique nature.*

19. Complete and balance the following reactions.

(a) $Na + H_2O \rightarrow$ _______ + _______

(b) $Ca + H_2O \rightarrow$ _______ + _______

(c) $Mg + H_2O \rightarrow$ _______ + _______

(d) $Zn + H_2O \rightarrow$ _______ + _______

(e) $Fe + H_2O \rightarrow$ _______ + _______

(f) $Zn + HCl \rightarrow$ _______ + _______

(g) $Al + H_2SO_4 \rightarrow$ _______ + _______

(h) $Fe + HCl \rightarrow$ _______ + _______

(i) $Zn + NaOH \rightarrow$ _______ + _______

(j) $Al + KOH + H_2O \rightarrow$ _______ + _______

20. Give reason for the following :

(a) Though lead is above hydrogen in the activity series, it does not react with dilute hydrochloric acid or dilute sulphuric acid.

(b) **Potassium and sodium** are not used for reaction with dilute hydrochloric acid or dilute sulphuric acid in laboratory preparation of hydrogen.

6.12 OXIDATION AND REDUCTION

6.12.1 Oxidation

In **the electronic concept**, oxidation is defined as a ***process in which an atom or an ion loses electron(s).***

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

Oxidation is also defined as a *chemical process that involves* :

(i) **Addition of oxygen :**

$$\textit{Element} + \textit{oxygen} \rightarrow \textit{oxide}$$
$$C + O_2 \rightarrow CO_2$$
$$2Mg + O_2 \rightarrow 2\,MgO$$

In the above reactions, by gaining oxygen carbon and magnesium, are oxidised to carbon dioxide, and magnesium oxide respectively.

(ii) **Addition of electronegative ion :**

$$2FeCl_2 + Cl_2 \rightarrow 2FeCl_3$$
$$Zn + 2HCl \rightarrow ZnCl_2 + H_2$$

Ferrous chloride and zinc are oxidized to ferric chloride and zinc chloride, respectively, by gain of electronegative ion Cl^-.

(iii) **Removal of hydrogen :**

$$H_2S + Cl_2 \rightarrow 2HCl + S$$

Hydrogen sulphide is oxidized to sulphur by loss of hydrogen.

(iv) **Removal of electropositive ion (element) :**

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

Potassium iodide is oxidized to iodine by loss of electropositive ion K^+.

Oxidizing agents

An oxidizing agent is one that oxidizes other substances either by accepting electrons or by providing oxygen or an electronegative ion, or by removing hydrogen or an electropositive ion. Thus, in the above examples (given in oxidation), oxygen, chlorine, hydrochloric acid and hydrogen peroxide are oxidizing agents.

Some examples of oxidizing agents.

(i) Solids : Manganese dioxide, red lead, lead dioxide, potassium permanganate ($KMnO_4$), potassium dichromate ($K_2Cr_2O_7$), bleaching powder, etc.

(ii) Liquids : Hydrogen peroxide, conc. nitric acid, conc. sulphuric acid, bromine, etc.

(iii) Gaseous : Oxygen, ozone, chlorine, etc.

Tests for oxidizing agents

Most oxidizing agents respond to the following tests:

(i) On heating strongly, they *liberate oxygen,* which rekindles a glowing splinter.

(ii) They may form a *yellow precipitate of sulphur when hydrogen sulphide is bubbled* through their solutions.

(iii) On warming *with conc. hydrochloric* acid, *they liberate chlorine,* that bleaches moist litmus paper.

(iv) On treating *with acidified potassium iodide solution*, they *liberate iodine,* which imparts a blue colour to a freshly-prepared starch solution (an oxidizing agent also turns potassium iodide paper brown due to liberation of iodine).

6.12.2 Reduction

*In **the electronic concept**, reduction is defined as a **process in which an atom or an ion gains electrons.***

$$Cu^{2+} + 2e^- \rightarrow Cu$$

Reduction is also defined as a *chemical process that involves* :

(i) **Removal of oxygen :**

$$\textit{Oxide} + \textit{element} \rightarrow \textit{metal}$$
$$CuO + H_2 \rightarrow Cu + H_2O$$
$$ZnO + C \rightarrow Zn + CO$$

Copper (II) oxide and zinc (II) oxide are reduced to copper and zinc respectively, by losing oxygen.

(ii) **Addition of electropositive ion :**

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

Mercuric chloride is reduced to mercurous chloride by gain of electropositive ion Hg^+.

(iii) **Addition of hydrogen :**

$$Cl_2 + H_2S \rightarrow 2HCl + S$$
$$2NH_3 + 3Cl_2 \rightarrow N_2 + 6HCl$$

Chlorine is reduced to hydrogen chloride by gain of hydrogen.

(iv) **Removal of electronegative ion :**

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

Ferric chloride is reduced to ferrous chloride by loss of electronegative ion Cl^-.

Reducing agents

A reducing agent is one that reduces other substances either by providing electrons, or by providing hydrogen or an electropositive ion, or by removing oxygen or an electronegative ion. Thus, in the above examples (given in reduction), hydrogen sulphide, ammonia, stannous chloride, hydrogen and carbon are reducing agents.

Some examples of reducing agents.

(i) ***Solids :*** Carbon, metals like Zn, Al, Cu and Na, stannous chloride, glucose, etc.

(ii) ***Liquids:*** Hydrogen peroxide, hydrogen iodide, hydrogen bromide, etc.

(iii) ***Gaseous:*** Hydrogen sulphide, carbon monoxide, etc.

Tests for reducing agents

Reducing agents generally respond to the following tests :

(i) They give out brown fumes of *nitrogen dioxide*, when warmed with nitric acid.

(ii) They change black copper (II) oxide, on heating, to a red copper metal.

(iii) They decolourise the pink colour of dilute potassium permanganate solution.

(iv) They change the colour of acidified potassium dichromate solution from orange to green.

(v) They change the light yellow colour of iron (III) salts in solution to a light green colour [due to the formation of iron (II) salts].

REDOX (OXIDATION-REDUCTION) REACTIONS

In a chemical reaction, if one substance is oxidized, the other substance must necessarily be reduced. This is because the electrons lost during oxidation are simultaneously gained during reduction, and vice versa.

For example : When zinc reacts with copper sulphate solution to form zinc sulphate and copper:

$$CuSO_4 + Zn \rightarrow ZnSO_4 + Cu$$
$$Cu^{2+}SO_4^{2-} + Zn \rightarrow Zn^{2+}SO_4^{2-} + Cu$$

Writing half reaction

$$Zn \rightarrow Zn^{2+} + 2e^- \text{(oxidation)}$$
$$Cu^{2+} + 2e^- \rightarrow Cu \text{ (reduction)}$$

They occur simultaneously as

$$Cu^{2+} + Zn \rightarrow Zn^{2+} + Cu$$

Oxidation

Reduction

Thus, oxidation and reduction always go side by side.

> A reaction in which oxidation and reduction take place simultaneously is known as REDOX REACTION.

Examples of redox reactions

(1)

Oxidized

$$\underset{\text{Oxidizing agent}}{CuO} + \underset{\text{Reducing agent}}{H_2} \rightarrow Cu + H_2O$$

Reduced

In this reaction, hydrogen, the reducing agent, reduces the oxidizing agent Cu (II) oxide to copper. On the other hand, oxidation reaction is the oxidation of the reducing agent, hydrogen, to water, by the oxidizing agent, Cu (II) oxide. Thus the net reaction is a redox reaction.

(2) In the reaction between hydrogen sulphide and chlorine, hydrogen sulphide loses its hydrogen to chlorine and is thereby oxidized to sulphur; and chlorine, which gains hydrogen, is reduced to hydrochloric acid.

Oxidized

$$\underset{\text{Reducing agent}}{H_2S} + \underset{\text{Oxidizing agent}}{Cl_2} \rightarrow 2HCl + S$$

Reduced

Table 6.2: Differences between oxidation and reduction

Oxidation involves	*Reduction involves*
1. Addition of oxygen	Removal of oxygen
2. Removal of hydrogen	Addition of hydrogen
3. Addition of electro-negative atom or ion	Removal of electro-negative atom or ion
4. Removal of electro-positive atom or ion	Addition of electro-positive atom or ion
5. Increase in positive valency	Decrease in positive valency
6. Decrease in negative valency	Increase in negative valency
7. Loss of electrons	Gain of electrons

CHAPTER AT A GLANCE

- Hydrogen is placed in the 1st period and IA group of the periodic table. It shows dual nature as it resembles the alkali metals of group IA and also the halogens of Group VII A (17).
- Hydrogen is found in traces in the earth's crust; the sun and the stars contain 1·1% hydrogen. It is present in plant and animal tissues, acids, alkalies, water and hydrocarbons.
- Hydrogen is prepared from water by reacting active metals like potassium, sodium and calcium with cold water, magnesium with boiling water and zinc and red hot iron with steam.
- Dilute sulphuric acid and dilute hydrochloric acid displace hydrogen when they react with any metal above hydrogen in the activity series.
- Zinc, lead, aluminium are unique metals. They produce hydrogen by reacting with acids as well as alkalies.
- Hydrogen is prepared in the lab by reacting granulated zinc with dilute hydrochloric acid or dilute sulphuric acid, and it is collected by the downward displacement of water. This hydrogen contains impurities that are then removed.

  Impurities like H_2S are removed by passing hydrogen through lead nitrate solution, CO_2, SO_2 and oxides of nitrogen through KOH solution, PH_3 and AsH_3 through silver nitrate solution, and water vapour through a drying agent like fused calcium chloride.
- Magnesium and manganese are the only two metals that can react with very dilute nitric acid to produce hydrogen.
- On a large scale, hydrogen is obtained by

  (i) electrolysis of water; acidulated water (water + sulphuric acid) is electrolysed to get hydrogen at cathode and oxygen at anode.

  (ii) passing steam over red hot coke (Bosch process).
- Hydrogen is the lightest gas. It burns with a pop sound and is absorbed by metals like palladium.
- It reacts with metals and non-metals under appropriate conditions.
- It is a reducing agent and thus reduces metallic oxides to metals. *For example*, black copper oxide is reduced to brown copper and yellow lead oxide is reduced to silvery grey lead.
- Hydrogen is used as a fuel as well.

EXCERCISE 6(D)

1. Describe briefly the ionic concept of oxidation and reduction. Give an equation to illustrate.
2. Is it essential that oxidation and reduction must occur side by side in a chemical reaction ? Explain.
3. State, giving reasons, whether the substances printed in bold letters have been oxidised or reduced.
   (a) $\mathbf{PbO} + CO \rightarrow Pb + CO_2$
   (b) $\mathbf{H_2S} + Cl_2 \rightarrow 2\,HCl + S$
4. State whether the following conversions are oxidation or reduction.
   (a) $PbO_2 + SO_2 \rightarrow PbSO_4$
   (b) $K \rightarrow K^+ + e^-$
5. In the following reaction : $A^+ + B \rightarrow A + B^+$. Write half reactions for this reaction and name :
   (a) oxidizing agent
   (b) substance oxidized
   (c) reducing agent.
6. Give a chemical test for :
   (a) an oxidizing agent
   (b) a reducing agent.
7. Complete the following word equations :
   (a) Sodium hydroxide + zinc → hydrogen + ...
   (b) Calcium + water → calcium hydroxide + ...
8. Give reasons :
   (a) Hydrogen is collected by the downward displacement of water and not of air, even though it is lighter than air.
   (b) A candle brought near the mouth of a jar containing hydrogen gas starts burning but is extinguished when pushed inside the jar.
   (c) Oxy-hydrogen flame is used for welding and cutting metals.
   (d) Apparatus for laboratory preparation of hydrogen should be air tight and away from a naked flame.
9. Select the odd one out and justify your answer.
   (a) Zn, Fe, Mg and Na
   (b) SO_2, H_2S, NH_3 and CO_3
   (c) Fe, Zn, Cu and Mg
   (d) Fe, Pb, Al and Zn
10. (a) Helium is preferred to hydrogen for filling balloons because it is :
    (i) lighter than air (ii) almost as light as hydrogen
    (iii) non-combustible (iv) inflammable.

    (b) Reacting with water, an active metal produces
    (i) oxygen (ii) nitric acid
    (iii) a base (iv) none of these.

    (c) A metal oxide that is reduced by hydrogen is
    (i) Al_2O_3 (ii) CuO
    (iii) CaO (iv) Na_2O

    (d) Which of the following statements about hydrogen is incorrect ?
    (i) It is an inflammable gas
    (ii) It is the lightest gas.
    (iii) It is not easily liquefied.
    (iv) It is a strong oxidizing agent.

    (e) For the reaction $PbO + H_2 \rightarrow Pb + H_2O$, which of the following statements is wrong ?
    (i) H_2 is the reducing agent.
    (ii) PbO is the oxidizing agent.
    (iii) PbO is oxidized to Pb
    (iv) H_2 is oxidized to H_2O.

    (f) Which metal gives hydrogen with all of the following : water, acids, alkalis ?
    (i) Fe (ii) Zn
    (iii) Mg (iv) Pb

    (g) Which of the following metals does not give hydrogen with acids ?
    (i) Iron (ii) Copper
    (iii) Lead (iv) Zinc
11. Choose terms from the options given in brackets to complete these sentences.
    (a) When CuO reacts with hydrogen, ... is reduced and .... is oxidized to ....
    (CuO, H_2, Cu, H_2O)
    (b) Hydrogen is .... soluble in water.
    (sparingly, highly, moderately)
    (c) Metals like .... , ... and .... give H_2 with steam.
    (iron, magnesium, aluminium, sodium, calcium)
    (d) Sodium .... reacts smoothly with cold water.
    (metal, amalgam, in the molten state)
    (e) A metal .... hydrogen in the activity series gives hydrogen with .... acid or .... acid.
    (above, below, dilute hydrochloric, concentrated hydrochloric, dilute sulphuric).

12. Correct the following statements :

(a) Hydrogen is used as a fuel for rocket propulsion.

(b) All metals react with acids to give hydrogen.

(c) Metals adsorb hydrogen.

(d) The reaction between hydrogen and oxygen is exothermic.

(e) Conc. H_2SO_4 reacts with zinc to liberate hydrogen.

13. Name :

(a) an oxidizing agent that does not contain oxygen.

(b) a substance that oxidizes concentrated HCl to chlorine.

(c) a substance that will reduce aqueous Iron (III) ions to Iron (II) ions.

(d) a liquid that is an oxidizing as well as a reducing agent.

(e) a gas that is an oxidizing as well as a reducing agent.

(f) a solid that is an oxidizing agent.