ST. LAWRENCE HIGH SCHOOL

A JESUIT CHRISTIAN MINORITY INSTITUTION

STUDY MATERIAL FOR CHEMISTRY (CLASS-11)

TOPIC- HYDROGEN (PART-2)

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SET NUMBER-13

DATE: 06.02.2021

It was discovered by Henry Cavendish in 1766 by the action of dilute H_2O_4 on iron. It was named 'inflammable air', Lavoisier gave it the name hydrogen (Creek: Hydra = water, gennas = producer]. It occurs in free state as well as in combined state.

Position of Hydrogen in the Periodic Table

Hydrogen resembles with alkali metals (group I) as well as halogens (group 17), At the same time, it differs from both in certain characteristics. That is why hydrogen if; called "rogue element".

However. it has been placed in group 1 on the basis of its configuration $1s^1$, which is the basis of modern classification of elements.

Isotopes of Hydrogen

Hydrogen exists in the form of three Isotopes :

Name	Symbol	Atomic number	Relative atomic mass	Density	Relative abundance	Nature
Protium	^1_1H or H	1	1.0078	0.09	99.98%	Non-radioactive
Deuterium	^2_1H or D	1	2.0141	0.18	0.0156%	Non-radioactive
Tritium	^3_1H or T	1	3.016	0.27	10^{-15}%	Radioactive (emits β-rays, $t_{1/2}$ = 12.33 year)

Dihydrogen [H_2]

Methods of Preparation

(a) Lab methods

(i) $Zn + \underset{\text{dilute}}{H_2SO_4(aq)} \longrightarrow ZnSO_4(aq) + H_2(g)$

Metals which have reduction potential lesser than H, can liberate H_2 from acids.

Pure zinc is not used because it reacts slowly. The presence of some impurities increases the rate of reaction due to the
formation of electrochemical couples Cone sulphuric acid is also not used because it oxidises, H_2 formed into H_2O.

$Zn + 2H_2SO_4(conc.) \rightarrow ZnSO_4 + SO_2 + 2H_2O$

(ii) It can also be prepared by the reaction of zinc with aqueous alkali.

$$Zn + 2NaOH \xrightarrow{\Delta} \underset{\text{sodium zincate}}{Na_2ZnO_2} + H_2$$

b) Commercial production of dihydrogen

(i) By the electrolysis of acidified water

$$H_2O \rightleftharpoons H^+ + OH^- \qquad \text{(Ionisation)}$$

At cathode,
$$H^+ + e^- \longrightarrow H^\bullet \qquad \text{(Reduction)}$$
$$H^\bullet + H^\bullet \longrightarrow H_2$$

At anode,
$$4OH^- \longrightarrow 4OH + 4e^- \qquad \text{(Oxidation)}$$
$$4OH \longrightarrow 2H_2O + O_2$$

ii) From water gas (Bosch process)

$$\underbrace{CO + H_2}_{\text{water gas}} + \underset{\text{steam}}{H_2O} \xrightarrow[773K]{Fe_2O_3 + Cr_2O_3} CO_2\uparrow + 2H_2$$

Carbon dioxide is removed by dissolving it in water under pressure (20-25 atm) and hydrogen left behind is collected.

(iii) From steam (Lane's process) Super heated steam is passed over iron filings heated to about 1023-1073 K when hydrogen is
formed.

$$3Fe + 4H_2O\ (steam) \xrightarrow{1023-1073\ K} Fe_3O_4 + 4H_2$$

(iv) Highly pure (> 99.95%)dihydrogen is obtained by electrolysing warm aqueous barium hydroxide solution between nickel
electrodes.

(v) From hydrocarbons by partial oxidation

$$\underset{\text{natural gas}}{CH_4} + \underset{\text{steam}}{H_2O} \xrightarrow[1270\ K]{\text{Ni-Cr catalyst}} CO + 3H_2$$

vi) It is also obtained as a by-product in the manufacture of NaOH and chlorine hy the electrolysis of brine solution.

During electrolysis, the reactions that take place are

$$\text{At anode,} \quad 2\bar{Cl}(aq) \longrightarrow Cl_2(g) + 2e^-$$

$$\text{At cathode,} \quad 2H_2O(l) + 2e^- \longrightarrow H_2(g) + 2OH^-(aq)$$

The overall reactions by adding spectator Na^+ ions,

$$2Na^+(aq) + 2\bar{Cl}(aq) + 2H_2O(l) \longrightarrow$$

$$Cl_2(g) + H_2(g) + 2Na^+ + 2OH(aq)$$

Physical Properties of Dihydrogen

Dihydrogen is a colourless, odourless, tasteless, combustible gas. It is lighter than air and insoluble in water. It is neutral to litmus.

Chemical Properties of Dlhydrogen

(i) Reactivity The relative inertness of dihydrogen at room temperature is because of Its high enthalpy of H-H bond i.e..high bond dissociation energy. So its reactions take place under specific conditions only (at high temperature).

(ii) Action with non-metals

$$2H_2 + O_2 \xrightarrow[\text{or Electric discharge}]{970\ K} 2H_2O(l);\ \Delta H^\circ = -285.9\ kJ\ mol^{-1}$$

$$N_2 + 3H_2 \xrightarrow[Fe\ (Mo)]{673\ K/200\ atm} 2NH_3(g);\ \Delta H^\circ = -92.6\ kJ\ mol^{-1}$$

$$H_2 + X_2 \xrightarrow{Dark} 2HX \text{ (where, } X \text{ represents halogens)}$$

Order of reactivity of halogens:

$$F_2 > Cl_2 > Br_2 > I_2$$

(iii) Reaction with metals Here H_2 acts as oxidising agent.

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

$$Ca + H_2 \xrightarrow{\Delta} CaH_2 \text{ (Hydrolith)}$$

(iv) Reducing action of dihydrogen

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

(v) Reactions with metal ions and metal oxides

$$H_2(g) + Pd^{2+}(aq) \longrightarrow Pd(s) + 2H^+(aq)$$

$$yH_2(g) + M_xO_y(s) \longrightarrow xM(s) + yH_2O(l)$$

(vi) Reaction with organic compounds

$$\text{(i) Veg. oil} + H_2 \xrightarrow{\text{Ni/400K}} \text{Veg. ghee}$$

$$\text{(ii) } R\text{—CH} = CH_2 + H_2 + CO \xrightarrow{[Co(CO)_4]_2} RCH_2CH_2CHO$$

$$RCH_2CH_2CHO + H_2 \xrightarrow[\Delta]{Ni} RCH_2CH_2CH_2OH$$

Uses of Dihydrogen

1. It is used in the manufacture of CH_3OH.

$$CO(g) + 2H_2(g) \xrightarrow{Co} CH_3OH(l)$$

2. It produces temperature of 2850°C and oxy-atomic hydrogen flame produces a temperature of 4000°C, so it is used in oxy-hydrogen flame.
3. The largest single use of H_2 is in the synthesis of NH_3 which is used in the manufacture ofHNO_3 and fertilizers.
4. Liquid hydrogen (LH_2) is used as rocket fuel.
5. H_2 is used as a reducing agent in extraction of metals.
6. H_2 is used in fuel cell for generating electrical energy.
7. Hydrogen is used in the manufacture of synthetic petrol.

(By heating H_2 with coal and heavy oils under very high pressure in the presence of catalyst.)

Different Forms of Hydrogen

Atomic Hydrogen

$$H_2 \xrightarrow{\text{Electric arc}} 2H; \qquad \Delta H = 105.4 \text{ kcal mol}^{-1}$$

It is very reactive and its half-life period is 0.33 s.

Nascent Hydrogen

Freshly prepared hydrogen is known as nascent hydrogen and is more reactive than ordinary hydrogen. It causes the reduction of certain compounds which IS not possible with ordinary hydrogen. It can never be isolated.

$$Zn + H_2SO_4 \longrightarrow ZnSO_4 + 2[H]$$

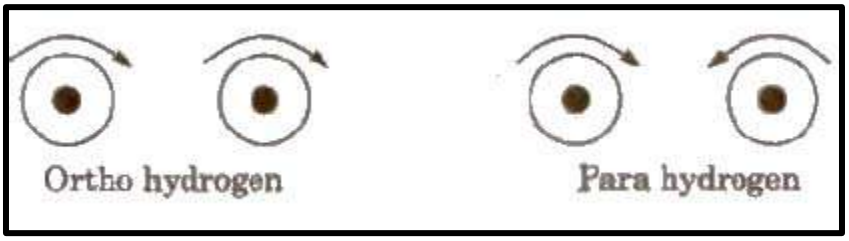
Activity of nascent H depends upon the reaction by which it is obtained.

Adsorbed Hydrogen

Adsorption of hydrogen at the metal surface is called occlusion. This hydrogen brings out many chemical changes such as reduction and hydrogenation. Occlusion decreases with rise in temperature.

Ortho and Para Hydrogen

When in hydrogen molecule, the nuclear spins are in the same direction, it is known as ortho hydrogen. On the other hand when the nuclear spins arc in tho opposite direction. it is known as para hydrogen. At room temperature hydrogen consists of 75% ortho and 25% para hydrogen.



Hydrogen Economy

Hydrogen economy is the use of liquid hydrogen as an alternate source of energy. The technology involves the production, transportation and storage of energy in the form of liquid hydrogen. Large scale production of hydrogen can be done by electrolysis of water or by thermochemical reaction cycle. Storage of hydrogen in liquid form can be done in vacuum insulated cryogenic tanks or in a metal or in all alloy like iron-titanium alloy as interstitial hydride. Hydrogen fuel has many advantage over conventional fuels in that it is non-polluting and it liberates large amount of energy on combustion.

Pbotohydrogen is used to obtain renewable energy from sunlight by using microscopic organism such as bacteria or algae.

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