S-BLOCK ELEMENTS

1. HYDROGEN

1.1 ATOMIC AND MOLECULAR PROPERTIES OF HYDROGEN

Atomic Properties		Molecular Properties	
Ionisation enthalpy, (kJ mol^{-1})	1312	Melting point, (K)	13.8
Electron gain enthalpy (earlier electron affinity), (kJ mol^{-1})	–72.8	Boiling point, (K)	20.4
Electronegativity	2.1	Density, (g/cm^3)	0.0899
Atomic radius, (pm)	37	Bond length, (pm)	74.2
Ionic radius (H^-), (pm) H^+, (pm)	210 $\approx 1.5 \times 10^{-3}$	Bond enthalpy, (kJ mol^{-1})	435.9

Hydrogen in the gaseous state exist as a diatomic species H_2. The diatomic H_2 molecule is also termed as dihydrogen to distinguish it from the hydrogen atom.

1.2 RESEMBLANCE WITH ALKALI METALS

Hydrogen resembles alkali metals in the following respects.

(i) Electronic configuration:

The hydrogen atom has one electron in the outermost shell like the alkali metals.

Element	H	Li	Na
Atomic number	1	3	11
Electronic configuration	$1s^1$	$1s^2, 2s^1$	$1s^2, 2s^2, 2p^6, 3s^1$

(ii) Cation formation:

Hydrogen like alkali metals forms singly charged cation by losing the outermost electron.

$$H(1s^1) \longrightarrow H^+ + e^-$$

$$Na(1s^2, 2s^2, 2p^6, 3s^1) \longrightarrow Na^+(1s^2, 2s^2, 2p^6) + e^-$$

(iii) Affinity for non–metals:

Both hydrogen and alkali metals combine with halogens to form halides, with oxygen to give oxides and with sulphur to give sulphides. For example,

HCl	H_2O	H_2S
NaCl	Na_2O	Na_2S

(iv) Electropositive nature:

Hydrogen is displaced from acids by metals. In this reaction hydrogen behaves as an electropositive element. For example,

$$Zn + \text{dil. } H_2SO_4 \longrightarrow ZnSO_4 + H_2(g)$$

It is further supported by the fact that when an aqueous solution of hydrogen chloride or a molten alkali metals halide is electrolysed, both hydrogen and alkali metals are liberated at the cathode.

$HCl \longrightarrow H^+ + Cl^-$ $\quad$ $NaCl \longrightarrow Na^+ + Cl^-$

At cathode: $H^+ + e^- \longrightarrow \frac{1}{2} H_2(g)$ $\quad$ $Na^+ + e^- \longrightarrow Na$

(v) Reducing character:

$CuO + H_2 \longrightarrow Cu + H_2O$

$B_2O_3 + 6K \longrightarrow 2B + 3K_2O$

potassium (an alkali metal)

1.3 RESEMBLANCE WITH HALOGENS

Hydrogen resembles halogens in the following respects

(i) Electronic configuration:

Both hydrogen and halogens are one electron short of saturation in their outermost shell. After gaining one electron they acquire stable configuration of the nearest noble gas. Thus, both behave as univalent non–metals as shown below.

$H + e^- \longrightarrow H^-$ (This corresponds to He)

$1s^1 \qquad\qquad 1s^2$

$Cl + e^- \longrightarrow Cl^-$ (This corresponds to Ar)

$1s^2, 2s^2 2p^6, 3s^2 3p^5 \qquad 1s^2, 2s^2 2p^6, 3s^2 3p^6$

$Br + e^- \longrightarrow Br^-$ (This corresponds to Kr)

2, 8, 18, 7 $\qquad$ 2, 8, 18, 8

(ii) Hydrides and halides:

Hydrogen combines with alkali and alkaline earth metals to form hydrides similar to halides.

$H_2 + 2Na \longrightarrow 2NaH$ $\quad$ $Cl_2 + 2Na \longrightarrow 2NaCl$

$H_2 + Ca \longrightarrow CaH_2$ $\quad$ $Cl_2 + Ca \longrightarrow CaCl_2$

The fused hydrides on electrolysis produce hydrogen at anode, like chlorine from fused chlorides.

$H^- \xrightarrow{\text{at anode}} \frac{1}{2} H_2(g) + e^-$ $\quad$ $Cl^- \xrightarrow{\text{at anode}} \frac{1}{2} Cl_2(g) + e^-$

(iii) Ionisation enthalpy:

The ionisation enthalpy of hydrogen is closer to halogens and much different from alkali metals.

	Hydrogen	Alkali metals					Halogens			
Element	H	Li	Na	K	Rb	Cs	F	Cl	Br	I
Ionisation enthalpy / kJ mol^{-1}	1301	520	496	419	408	375	1680	1256	1142	1008

(iv) Formation of covalent compounds:

Like halogens, hydrogen readily combines with non–metals such as carbon, silicon, nitrogen etc. to form covalent compounds.

With hydrogen:	CH_4	SiH_4	NH_3
	Methane	Silane	Ammonia
With halogens:	CCl_4	$SiCl_4$	NCl_3
	Carbon tetrachloride	Silicon tetrachloride	Nitrogen trichloride

1.4 PROPERTIES OF HYDROGEN IN WHICH IT DIFFERS FROM BOTH THE ALKALI METALS AS WELL AS HALOGENS

Hydrogen has some properties which neither resemble alkali metals nor halogens. For example,

(i) The oxide of hydrogen, H_2O is neutral, while the oxides of halogens, e.g., Cl_2O, ClO_2, Cl_2O_7 etc. are acidic and the oxides of alkali metals, e.g. Na_2O, K_2O etc are basic.

(ii) Hydrogen atom has no inner electrons and no unshared electrons.

1.5 ISOTOPES OF HYDROGEN

Hydrogen has three isotopes. The most abundant and stable isotope is that of protium ($_1^1H$).

The stable isotope deuterium ($_1^2H$ or D) is also called heavy hydrogen. The third isotope called tritium ($_1^3H$ or T) is radioactive. ($t_{1/2}$ = 12.33 year). It emits low energy β–particles but no γ–radiations.

$$_1^3H \longrightarrow {}_2^3He + {}_{-1}^0e$$

It is prepared artificially by the bombardment of nitrogen or an isotope of lithium with neutron.

$$_7^{14}N + {}_0^1n \longrightarrow {}_6^{12}C + {}_1^3H$$

$$_3^6Li + {}_0^1n \longrightarrow {}_2^4He + {}_1^3H$$

The relative abundance of these three isotopes in nature are,

$$1 : 1.56 \times 10^{-2} : 1 \times 10^{-17}$$

Deuterium is usually prepared from heavy water (D_2O). Heavy water (D_2O) is obtained by electrolytic enrichment of ordinary water. Heavy water is used as a coolant and moderator in nuclear reactors. It is also used for the preparation of deuterated compounds.

$$\underset{\text{aluminium carbide}}{Al_4C_3} + 12D_2O \longrightarrow \underset{\text{deuterated methane}}{3CD_4} + 4Al(OD)_3$$

	Properties	Ordinary water (H_2O)	Heavy water (D_2O)
1.	Molecular mass	18.02	20.03
2.	Melting point	0.00°C	3.79°C
3.	Boiling point	100.00°C	101.41°C
4.	Density (20°C)	8.97×10^2 kg/m^3	11.08×10^2 kg/m^3
5.	Specific heat capacity (20°C)	4.186 J g^{-1} °C^{-1}	4.261 J g^{-1} °C^{-1}
6.	K_w (25°C)	1.0×10^{-14}	0.3×10^{-14}
7.	Surface tension	72.7 mN m^{-1}	67.8 mN m^{-1}

All the three isotope of hydrogen have the same electronic configuration. So, all the three isotopes give similar chemical reactions. However, due to the mass difference, there is significant difference in their physical properties and also in the rates of their reactions. Ordinary hydrogen undergoes reactions more rapidly than deuterium.

1.6 PREPARATION OF HYDROGEN OR DIHYDROGEN

Hydrogen can be prepared by various methods. Some of them are described below:

(i) By electrolysis of water:

This process is suitable for places where cheap electric supply is available. Since water is a bad conductor of electricity, it is made conducting by the addition of small quantity of sulphuric acid or sodium hydroxide. Hydrogen so obtained is 99.9% pure.

$$H_2SO_4 \longrightarrow 2H^+ + SO_4^{2-}$$

The SO_4^{2-} does not get involved in the electrode reaction. The ion, which gets oxidised at the anode in preference to SO_4^{2-} is OH^- (coming from the ionisation of water).

At cathode:
$$H^+ + e^- \longrightarrow H$$
$$H + H \longrightarrow H_2(g)$$

At anode:
$$H_2O \longrightarrow OH^- + H^+] \times 4$$
$$OH^- \longrightarrow OH + e^-] \times 4$$
$$2OH \longrightarrow H_2O + O] \times 2$$
$$O + O \longrightarrow O_2(g)$$

Net reaction:
$$2H_2O \longrightarrow 4H^+ + O_2(g) + 4e^-$$

(ii) By the action of metals on water:

Metals occurring above hydrogen in the electrochemical series displace hydrogen from water under the conditions depending upon their reactivity.

(a) Action of metals on cold water:

Elements like sodium, potassium, calcium etc., displace hydrogen from water at room temperature. With alkali metals the reaction is explosive.

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