Hydrogen Element:

Atomic number = Mass Number = 1

Isotopes of hydrogen:

- $^{1}H_{1}$: Protium , Most abundant in nature
- $^{2}H_{1:}$ Deuterium (D), Component of heavy water.
- $^{3}H_{1}$: Tritium (T) , Radioactive in nature

Dihydrogen:

a. Laboratory preparation:

Reaction of metals with acids. $Zn + H^{+} \rightarrow Zn^{2+} + H_2$

b. Commercial Preparation:

Electrolysis of acidified water

Electrolysis of warm aqueous Ba(OH) 2 between nickel electrodes.

By-product in the manufacture of NaOH and Cl2 by electrolysis of brine solution.

Reaction of steam and hydrocarbons at high temperatures

c. Properties:

Reaction with halogen: $H_2 + X_2 \rightarrow 2HX$ [X= F, Cl, Br, I]

Reaction with oxygen: $H_2(g) + O_2(g) + \Delta \rightarrow 2H_2O(l)$ $\Delta H^0 = -285.9\ kJ\ mol^{-1}$

Reaction with nitrogen: $3H_2(g) + N_2(g) + \Delta \rightarrow 2NH_3(l)$ $\Delta H^0 = -92\ kJ\ mol^{-1}$

Reaction with alkali metals: $3H_2(g) + 2M(g) + \Delta \rightarrow 2MX(s)$

Uses of Hydrogen:

Used for synthesis of ammonia and vanaspati fat and many other products.

Used as rocket fuel.

Used in hydrogen fuel cells.

Hard Water:

a) Water containing carbonate, chloride and sulphate salts of calcium and magnesium.

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Temporary hardens is due to the presence of carbonate salts and can be removed by boiling or by adding lime water.

$Ca(HCO3)_2 + Ca(OH)_2 \rightarrow 2CaCO_3\downarrow + 2H_2O$

$Ca(HCO_3)_2 + \Delta \rightarrow 2CaCO_3\downarrow + 2H_2O + CO_2\uparrow$

Permanent hardness is due to presence of sulphate and chloride salts and can be removed by treatment with washing soda.

$MCl_2 + Na_2CO_3 \rightarrow MCO_3 \downarrow + 2NaCl$ (M= Mg, Ca)

$MSO_4 + Na_2CO_3 \rightarrow MCO_3 \downarrow + Na_2SO_4$ (M= Mg, Ca)

b)Hard water forms scum/precipitate with soap:

$$2C_{17}H_{35}COONa\,(aq) + M^{2+}\,(aq) \rightarrow$$
$$(C_{17}H_{35}COO)_2\,M\downarrow + 2Na^{+}\,(aq);\ M \text{ is } Ca/Mg$$

Heavy water:

Molecular formula: D_2O

10.68% denser than ordinary water

Freezing point 3.8 ^0C

Unfit for drinking and causes sterility.

Hydrogen peroxide :

a. Preparation :

Lab Method :

$Na_2O_2\,(s) + H_2SO_4(aq) \dashrightarrow H_2O_2(aq) + Na_2SO_4(s)$

$BaO_2.8H_2O + H_2SO_4(aq) \dashrightarrow H_2O_2\,(aq) + BaSO_4(s)$

Anhydrous barium oxide is not used because the precipitated $BaSO_4$ forms a protective layer on the unreacted barium peroxide and thus prevents its further participation in the reaction. However it can be overcome by using phosphoric acid.

By Electrolysis:

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$$2H_2SO_4(aq) \xrightarrow{\text{electrolysis}} H_2S_2O_8\,(aq) + H_2(g)$$

$$H_2S_2O_8(aq) \xrightarrow{2H_2O} 2H_2SO_4(aq) + H_2O_2(aq)$$

By the auto-oxidation of 2-ethyl anthraquinol. The net reaction is a catalytic union of H_2 and O_2 to yield hydrogen peroxide.

$$\text{2-ethyl anthraquinol} \underset{H_2(Pd)}{\overset{O_2(air)}{\rightleftharpoons}} (\text{oxidised product}) + H_2O_2$$

b. Properties

i) Unstable liquid, decomposes to give water and dioxygen and the reaction is slow in the absence of catalyst. It is catalysed by certain metal ions, metal powders and metal oxides.

$2H_2O_2\,(l) \rightarrow 2H_2O\,(l) + O_2\,(g)$

ii) It is a very powerful oxidising agent and poor reducing agent.

As oxidising agent

In acidic medium: $H_2O_2 + 2H^+ + 2e^- \rightarrow 2H_2O$

In basic medium :$H_2O_2 + OH^- + 2e^- \rightarrow 3OH^{--}$

As reducing agent

In acidic medium: $H_2O_2 \rightarrow 2H^+ + O_2 + 2e^-$

In basic medium : $H_2O_2 + 2OH^- \rightarrow 2H_2O + O_2 + 2e^-$

$2Fe^{2+} + H_2O_2 + 2H^+ \rightarrow 2Fe^{3+} + 2H_2O$

$2MnO_4^- + 5H_2O_2 + 6H^+ \rightarrow 2Mn^{2+} + 8H_2O + 5O_2$

$Mn^{2+} + H_2O_2$ --> $Mn^{+4} + 2OH^-$

$2Fe^{3+} + H_2O_2 + 2OH^- \rightarrow 2Fe^{2+} + 2H_2O + O_2$

The oxidising property of hydrogen peroxide is put to use in the **restoration of old paintings**, where the original white lead paint has been converted to black PbS by the H_2S in the atmosphere. Hydrogen peroxide oxidises the black PbS into white $PbSO_4$.

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$PbS(s) + 4H_2O_2\ (aq) \rightarrow PbSO_4(s) + 4H_2O$

black white

c. Tests :

It liberates iodine from potassium iodide in presence of ferrous sulphate

Acidified solution of dichromate ion forms a deep blue colour with H_2O_2 due to the formation of CrO_5. ,

$Cr_2O_7^{2-} + 4H_2O_2 + 2H^+ \rightarrow 2CrO_5 + 5H_2O$

With a solution of titanium oxide in conc.H_2SO_4, it gives orange colour due to the formation of pertitanic acid.

$Ti^{4+} + H_2O_2 + 2H_2O \rightarrow H_2TiO_4 + 4H^+$

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