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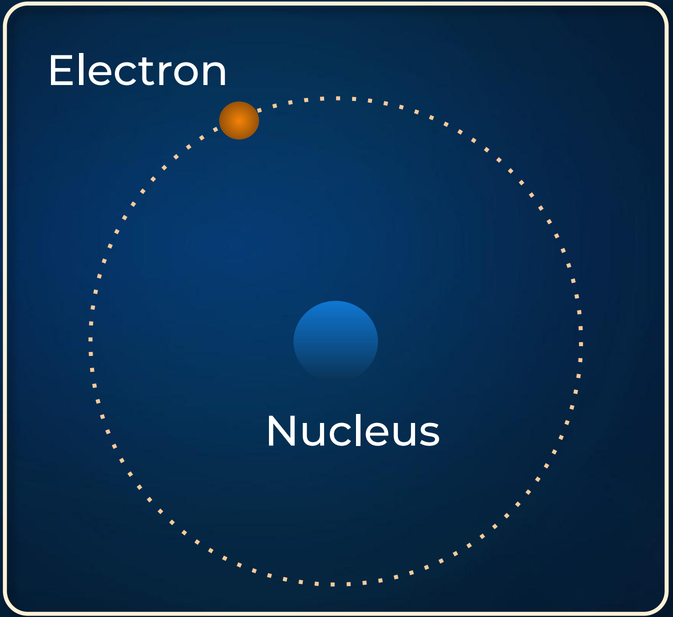
Hydrogen

Atomic Structure of Hydrogen

Electron = 1

Proton = 1

Neutron = 0



Hydrogen

Isotopes of Hydrogen

Name	Symbol	Atomic number	Mass number	Relative abundance
Protium or Hydrogen	H^{1}_{1}	1	1	99.985 %
Deuterium	H^{2}_{1}	1	2	0.0156 %
Tritium	H^{3}_{1}	1	3	10^{-15} %

Isotopic Effect

Same electronic configuration of isotopes

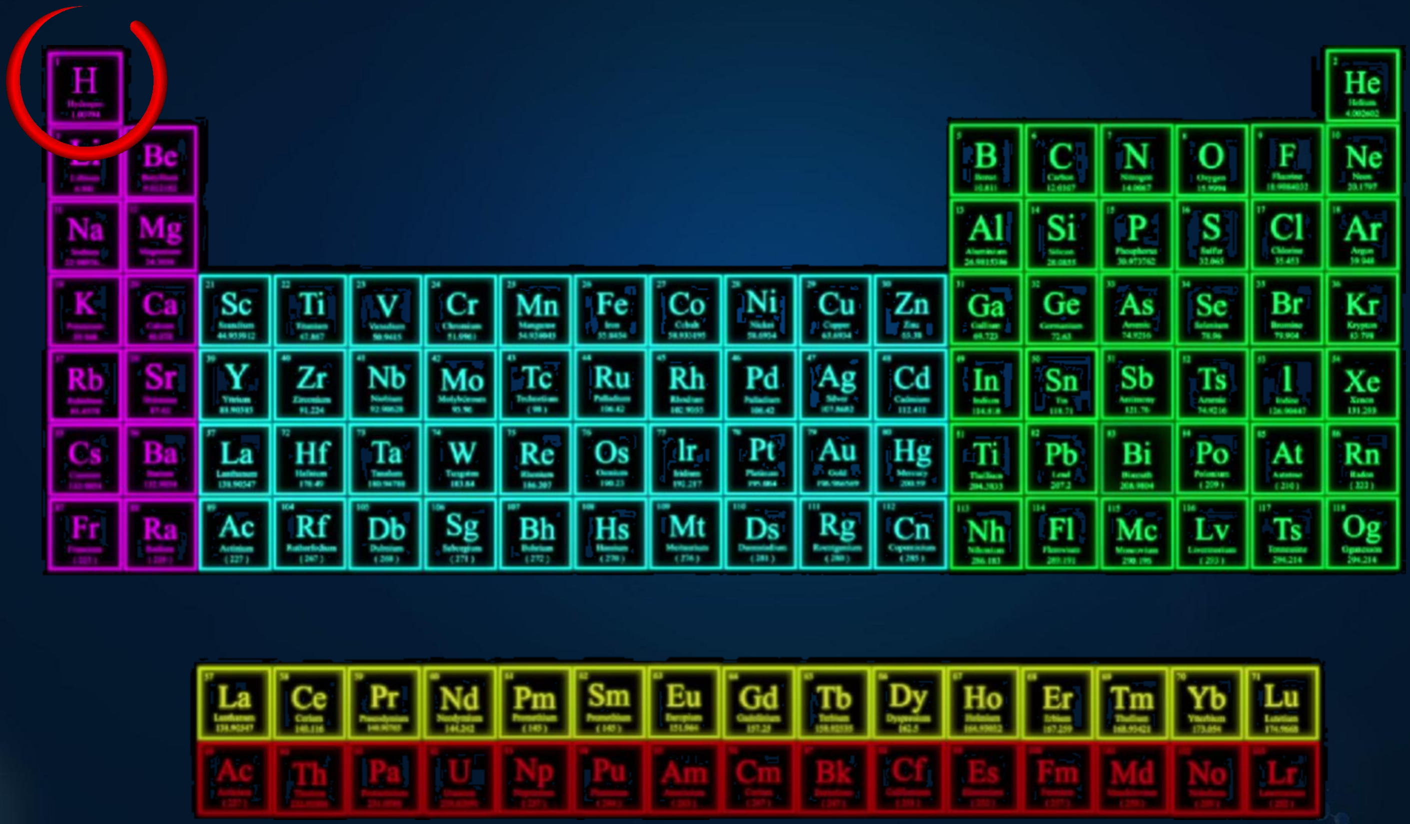
causes **similar** chemical properties

Difference in **bond enthalpies**

Results in difference in the **rate of reactions**

For example, the reaction between **H_2 and Cl_2** is almost **13** times faster than that between **D_2 and Cl_2** under similar conditions.

Position of Hydrogen in the Periodic Table



Position of Hydrogen in the Periodic Table

Hydrogen is the **first** element of the periodic table as its atomic number is **1.**

Electronic configuration **$1s^1$**

Hydrogen **resembles alkali metals** as well as **halogens** in many properties.

1 Resemblance with **alkali metals**

a One electron in its valence shell - **$1s^1$**

b Forms an **unipositive ion** H^+ (like Li^+, Na^+)

Position of Hydrogen in the Periodic Table

c Forms **oxides**, **halides,** and **sulphides** like alkali metals

Oxide	Halide	Sulphide
Na_2O	$NaCl$	Na_2S
H_2O	HCl	H_2S

d **Good reducing agent**

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

$$B_2O_3 + 6K \xrightarrow{\Delta} 3K_2O + 2B$$

Position of Hydrogen in the Periodic Table

Resemblance with **halogens**

a. **One electron less** than that of its preceding inert gas configuration

b. Forms a **diatomic molecule** H_2 (like Cl_2, Br_2, I_2)

c. Has **high ionisation enthalpy** like halogens

H	1312 kJ/mol
F	1680 kJ/mol
Cl	1255 kJ/mol

Position of Hydrogen in the Periodic Table

d Forms an **uninegative ion** like halogens

e Forms **compounds** like halogens

CCl_4	$SiCl_4$	$NaCl$
CH_4	SiH_4	NaH

Position of Hydrogen in the Periodic Table

3 Dissimilarities between **hydrogen and alkali metals**

I.E. of hydrogen (1312 kJ/mol) is **very high** compared to that of alkali metals.

Li	520 kJ/mol
Na	495 kJ/mol

Metallic character (under normal conditions)

- Alkali metals ✓
- Hydrogen ✗

Position of Hydrogen in the Periodic Table

4

Dissimilarities between
hydrogen and halogens

The **reactivity** of hydrogen is **very low** compared to that of halogens.

Oxides of **halogens** are **acidic,** while the oxide of **hydrogen** is **neutral.**

Occurrence

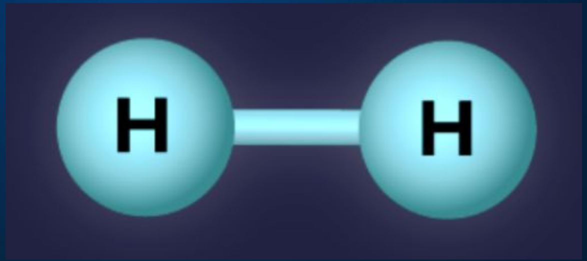
1. **Most abundant element** of the **universe** (70% of the total mass)

2. It is much **less abundant** (0.15 % by mass) in the **earth's atmosphere** due to its **light nature**

3. In combined form, it constitutes **15.4%** of the earth's crust and the oceans

Elemental Form of Hydrogen

Shared pair of electrons



Preparation of Dihydrogen

1 By the action of water with **metals**

1 Action of water with **Na, K, & Ca** at room temperature

$$2M + 2H_2O \xrightarrow{\Delta} 2MOH + H_2$$

M = Na, K

2 Action of water with **Mg, Al, & Zn** at the boiling temperature of water

$$2Al + 3H_2O \xrightarrow{\Delta} Al_2O_3 + 3H_2$$

$$Mg + H_2O \xrightarrow{\Delta} MgO + H_2$$

Preparation of Dihydrogen

3 By the reaction of **metals** like Zn & Al with **alkali**

4 **Laboratory method:** By the action of **granulated zinc** with **dilute HCl**

$$Zn + 2NaOH \xrightarrow{\Delta} Na_2ZnO_2 + H_2$$

Sodium zincate

$$Zn\ (\text{granulated}) + 2HCl \longrightarrow ZnCl_2 + H_2$$

$$2Al + 2H_2O + 2NaOH \xrightarrow{\Delta} 2NaAlO_2 + 3H_2$$

Sodium meta aluminate

Preparation of Dihydrogen

5 Preparation of **pure dihydrogen**

By the electrolysis of **warm aq. $Ba(OH)_2$** between **Ni** electrodes

Dihydrogen of high purity (> 99.95%) is obtained.

6 By the **electrolysis of acidified water** using **platinum** electrodes

$$2H_2O(l) \longrightarrow 2H_2(g) + O_2(g)$$

At cathode — $2H_2(g)$

At anode — $O_2(g)$

Preparation of Dihydrogen

7 Preparation from **hydrocarbons**

$$CH_4(g) + H_2O(g) \xrightarrow[Ni]{1270\ K} CO(g) + 3H_2(g)$$

8 Coal gasification

$$C(s) + H_2O(g) \xrightarrow{1270\ K} \underbrace{CO(g) + H_2(g)}_{\text{Water gas (Syngas)}}$$

Water gas
(Syngas)

Preparation of Dihydrogen

The yield of dihydrogen can be **increased** by reacting CO of the syngas mixture with steam in the presence of **iron chromate** as the catalyst.

Water-gas shift reaction

$$CO\,(g) + H_2O\,(g) \xrightarrow[\text{catalyst}]{673\ K} CO_2\,(g) + H_2\,(g)$$

Methods to separate CO_2 from H_2

1. CO_2 is dissolved in water under high pressure (20-25 atm) and the H_2 left undissolved is collected.

2. Carbon dioxide is removed by scrubbing with sodium arsenite solution.

Preparation of Dihydrogen

8

Commercial production of dihydrogen

As a **byproduct** in the manufacture of **NaOH and Cl_2** by the **electrolysis of brine solution**

At anode:

$$2Cl^- (aq) \longrightarrow Cl_2 (g) + 2e^-$$

At cathode:

$$2H_2O (l) + 2e^- \longrightarrow H_2 (g) + 2OH^- (aq)$$

Overall reaction:

$$2Na^+ (aq) + 2Cl^- (aq) + 2H_2O (l)$$

$$\downarrow$$

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

Physical Properties

Covalent radius (pm)	=	37
Ionic radius (H^-) (pm)	=	208
I.E. (kJ/mol)	=	1312
Electron gain enthalpy (kJ/mol)	=	- 73

It is a **colourless**, **tasteless,** and **odourless** gas. It is **insoluble in water**. It is **highly combustible.**

Chemical Properties of Dihydrogen

Dihydrogen is quite stable and dissociates into hydrogen atoms at high temperature in an electric arc.

$$H_2 \xrightarrow{\Delta} H + H$$

$$\Delta H \approx 440 \text{ kJ mol}^{-1}$$

Chemical Properties of Dihydrogen

1 **Reaction with metals** to form corresponding hydrides

$$2M\ (g) + H_2\ (g) \longrightarrow 2MH\ (s)$$

M = Alkali metal

2 **Reaction with halogens** to form hydrogen halides

$$H_2\ (g) + X_2\ (g) \longrightarrow 2HX\ (g)$$

X = F, Cl, Br, I

Order of reactivities

$F_2 > Cl_2 > Br_2 > I_2$

Chemical Properties of Dihydrogen

3 Reaction with **dioxygen**

$$2H_2\,(g) + O_2\,(g) \xrightarrow[\text{heating}]{\text{catalyst or}} 2H_2O\,(l)$$

$\Delta H^\circ \backsimeq -285\ kJmol^{-1}$

Chemical Properties of Dihydrogen

4 Reaction with **dinitrogen**

$$3H_2(g) + N_2(g) \xrightarrow[\text{Fe/Mo}]{\text{673 K, 200 atm}} 2NH_3(g)$$

$$\Delta H^\circ = -92.6\ \text{kJmol}^{-1}$$

5 **Hydrogenation** of unsaturated alkenes

$$CH_2{=}CH_2 + H_2 \xrightarrow[\text{473 K}]{\text{Ni or Pd}} CH_3{-}CH_3$$

$$HC{\equiv}CH + 2H_2 \xrightarrow[\text{473 K}]{\text{Ni or Pd}} CH_3{-}CH_3$$

Chemical Properties of Dihydrogen

6 Hydroformylation of olefins

It yields **aldehydes,** which further undergo **reduction** to give **alcohols**.

$$RCH{=}CH_2 + H_2 + CO \xrightarrow{\text{Catalyst}} RCH_2CH_2CHO$$

$$RCH_2CH_2CHO + H_2 \xrightarrow{\text{Catalyst}} RCH_2CH_2CH_2OH$$

Chemical Properties of Dihydrogen

7 Hydrogenation of **vegetable oils**

$$\text{Vegetable oil} + H_2 \xrightarrow[\text{Ni}]{473\text{ K}} \text{Edible fats}$$

(Margarine and vanaspati ghee)

8 Reaction with **metal ions** and **metal oxides**

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

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

Uses of Dihydrogen

- Reducing agent
- Used as a rocket fuel
- Preparation of many compounds like NH_3
- Oxy/atomic hydrogen torch for welding
- Used in fuel cells for generating electrical energy
- Hydrogenation of vegetable oils

Hydrides

Dihydrogen combines with a large number of **non-metals and metals**, except noble gases, under certain suitable reaction conditions to form **compounds** called hydrides.

Example: MgH_2, B_2H_6

Hydrides

- Ionic or Saline or Salt like hydrides
- Covalent or Molecular hydrides
- Metallic or Non-stoichiometric hydrides

Ionic or Saline Hydrides

These are stoichiometric compounds of dihydrogen with most of the s-block elements which are **highly electropositive** in nature.

Lighter metal hydrides such as LiH, BeH_2 and MgH_2 have significant **covalent character.**

BeH_2 and MgH_2 are **polymeric** in nature.

Ionic or Saline Hydrides

In solid state

- Crystalline
- Non-volatile
- Non-conducting

Ionic or Saline Hydrides

On **electrolysis**, molten saline hydrides liberates **H_2 gas** at **anode.**

$$2H^- \text{ (molten)} \longrightarrow H_2\text{ (g)} + 2e^- \text{ (at anode)}$$

Saline hydrides react violently with water liberating H_2.

$$NaH\text{ (s)} + H_2O\ (l) \longrightarrow NaOH\text{ (aq)} + H_2\text{ (g)}$$

Ionic hydrides are **powerful reducing agents**.

$$PbSO_4 + 2CaH_2 \longrightarrow PbS + 2Ca(OH)_2$$

Ionic or Saline Hydrides

LiH is used in the **synthesis** of other useful hydrides.

$$8LiH + Al_2Cl_6 \longrightarrow 2LiAlH_4 + 6LiCl$$

$$2LiH + B_2H_6 \longrightarrow 2LiBH_4$$

Covalent or Molecular Hydrides

These are the compounds of hydrogen with most of the **p-block elements** which have relatively **high electronegativity.**

Covalent hydrides involve the formation of **covalent bonds** between **H atoms** and other atoms by sharing of electrons.

Examples

HCl, H_2O, CH_4, PH_3, NH_3 etc.

Covalent or Molecular Hydrides

Molecular hydrides

- Volatile
- Soluble in organic solvents

1. Electron-deficient hydrides
2. Electron-precise hydrides
3. Electron-rich hydrides

Covalent or Molecular Hydrides

Electron deficient hydrides	Electron precise hydrides	Electron rich hydrides
Have **lesser number of electrons** than that required for writing the conventional Lewis structure.	Have the required number of electrons to write their **conventional Lewis structures.**	Have excess of electrons which are present as lone pairs around the central highly E.N. atom.
B_2H_6 and hydrides of group **13** elements	CH_4 and hydrides of group **14** elements	H_2O, NH_3, HF

Metallic/Interstitial Hydrides

Hydrides formed by many **d & f block** elements except the metals of group 7, 8, & 9.

They are almost always non-stoichiometric, being **deficient in hydrogen.**

$LaH_{2.87}$, $YbH_{2.55}$, $TiH_{1.5-1.8}$, $ZrH_{1.3-1.75}$, $VH_{0.56}$, $NiH_{0.6-0.7}$, $PdH_{0.6-0.8}$ etc.

The **inability** of metals of **groups 7, 8, & 9** of the periodic table to form hydrides is referred to as **hydride gap of d-block.**

Chromium - the only 6^{th} group metal which form metallic hydrides, (CrH).

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
H 1																	He 2
Li 3	Be 4											B 5	C 6	N 7	O 8	F 9	Ne 10
Na 11	Mg 12											Al 13	Si 14	P 15	S 16	Cl 17	Ar 18
K 19	Ca 20	Sc 21	Ti 22	V 23	Cr 24	Mn 25	Fe 26	Co 27	Ni 28	Cu 29	Zn 30	Ga 31	Ge 32	As 33	Se 34	Br 35	Kr 36
Rb 37	Sr 38	Y 39	Zr 40	Nb 41	Mo 42	Tc 43	Ru 44	Rh 45	Pd 46	Ag 47	Cd 48	In 49	Sn 50	Sb 51	Te 52	I 53	Xe 54
Cs 55	Ba 56	La 57	Hf 72	Ta 73	W 74	Re 75	Os 76	Ir 77	Pt 78	Au 79	Hg 80	Tl 81	Pb 82	Bi 83	Po 84	At 85	Rn 86
Fr 87	Ra 88	Ac 89	Rf 104	Db 105	Sg 106	Bh 107	Hs 108	Mt 109	Ds 110	Rg 111	Cn 112	Nh 113	Fl 114	Mc 115	Lv 116	Ts 117	Og 118

Ce 58	Pr 59	Nd 60	Pm 61	Sm 62	Eu 63	Gd 64	Tb 65	Dy 66	Ho 67	Er 68	Tm 69	Yb 70	Lu 71
Th 90	Pa 91	U 92	Np 93	Pu 94	Am 95	Cm 96	Bk 97	Cf 98	Es 99	Fm 100	Md 101	No 102	Lr 103

Metallic/Interstitial Hydrides

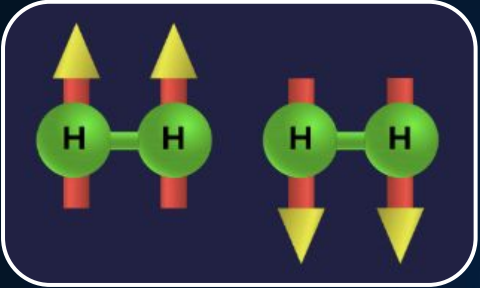
Earlier, it was thought that **hydrogen** occupies interstices in the metal lattice, producing distortion without any change in its type.

Recent studies have shown that except for **hydrides** of **Ni**, **Pd**, **Ce,** and **Ac**, others have different lattice from that of the parent metals.

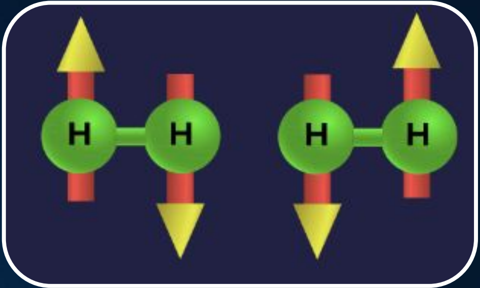
Applications

Property of absorption of hydrogen on transition metals is largely used in **catalytic reduction/hydrogenation reactions.**

Ortho and Para Hydrogen



H_2 has
two forms



Ortho hydrogen

Para hydrogen

Parallel nuclear spins

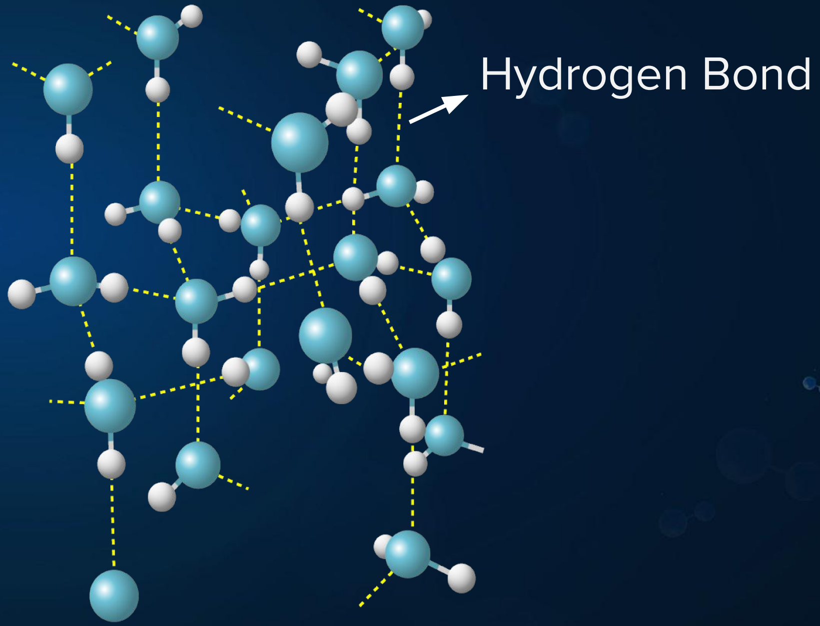
Paired nuclear spins

Did You Know?

Dihydrogen is used as **fuel**, as it liberates large amount of heat on combustion.

Water

Shape	Bent shape



Physical Properties of Water

Comparison to H_2S and H_2Se.

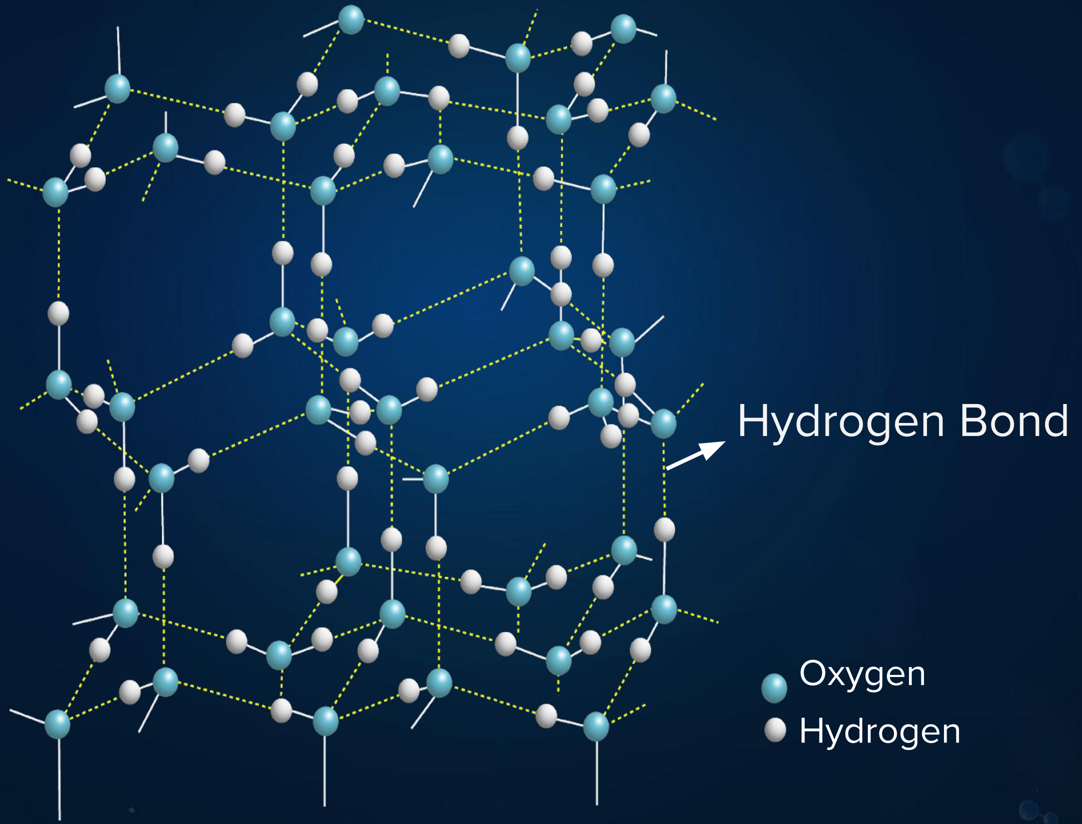
In comparison to H_2S and H_2Se, H_2O has high **freezing point**, high **b.p.**, high **heat of vapourisation**, and high **heat of fusion** due to H bonding.

Ice

At atmospheric pressure, ice crystallises in the **hexagonal form**, and at very low temperature, it condenses to **cubic form.**

Water is **denser** than ice

Structure of Ice



Chemical Properties of Water

$$H_2O\,(l) + NH_3\,(aq) \rightleftharpoons OH^-\,(aq) + NH_4^+\,(aq)$$

$$H_2O\,(l) + H_2S\,(aq) \rightleftharpoons H_3O^+\,(aq) + HS^-\,(aq)$$

$$H_2O\,(l) + H_2O\,(l) \rightleftharpoons H_3O^+\,(aq) + OH^-\,(aq)$$

1

Amphoteric nature

Chemical Properties of Water

2

Redox reaction

$$2Na\ (s) + 2H_2O\ (l) \longrightarrow 2NaOH\ (aq) + H_2\ (g)$$

Oxidising agent

$$2F_2\ (g) + 2H_2O\ (l) \longrightarrow 4H^+\ (aq) + 4F^-\ (aq) + O_2\ (g)$$

Reducing agent

Chemical Properties of Water

$$P_4O_{10}\,(s) + 6H_2O\,(l) \longrightarrow 4H_3PO_4\,(aq)$$

$$N^{3-}\,(s) + 3H_2O\,(l) \longrightarrow NH_3\,(g) + 3OH^-\,(aq)$$

$$SiCl_4\,(l) + 2H_2O\,(l) \xrightarrow{\Delta} SiO_2\,(s) + 4HCl\,(aq)$$

3

Hydrolysis reaction

Chemical Properties of Water

4

Hydrates formation

a **Coordinated water**

E.g.: $[Cr(H_2O)_6]^{3+}\ 3Cl^-$

b **Hydrogen bonded water**

E.g.: $[Cu(H_2O)_4]^{2+}SO_4^{\ 2-}.H_2O$ in $CuSO_4.5H_2O$

c **Interstitial water**

E.g.: $BaCl_2.2H_2O$

Hard and Soft Water

Soft water	Hard water
Gives lather with soap easily	Does not give lather with soap
Water **free from soluble salts of calcium and magnesium**	Water containing calcium & magnesium in the form of hydrogen carbonates, chlorides, and sulphates.
E.g., Distilled water, rain water	E.g., Sea water, river water, tap water

Causes of Hardness of Water

Presence of **bicarbonates, chlorides, and sulphates of calcium and magnesium.**

$$M^{2+}(aq) + 2C_{17}H_{35}COONa\ (aq) \longrightarrow (C_{17}H_{35}COO)_2M \downarrow + 2Na^{+}(aq)$$

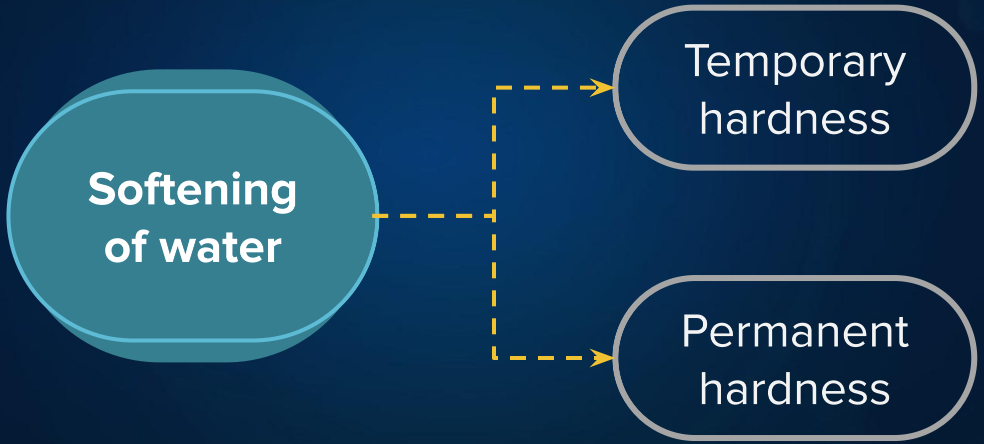
From hard water — M^{2+}

Sodium stearate (soap) — $C_{17}H_{35}COONa$

Metal stearate (ppt) — $(C_{17}H_{35}COO)_2M$

Where, **M = Ca or Mg**

Softening of Water



Hardness of water

Temporary hardness

Due to the presence of soluble **bicarbonates** of Ca & Mg.

Permanent hardness

Due to the presence of soluble **salts** of Ca & Mg in the form of chlorides and sulphates.

Removing Temporary Hardness

Softening of Water by Boiling

$$Ca(HCO_3)_2 \xrightarrow{\text{Boil}} CaCO_3 \downarrow + CO_2 \uparrow + H_2O$$

Soluble — Insoluble

$$Mg(HCO_3)_2 \xrightarrow{\text{Boil}} MgCO_3 \downarrow + CO_2 \uparrow + H_2O$$

Soluble — Insoluble

Softening of Water by Clark's method

$$Ca(HCO_3)_2 + Ca(OH)_2 \text{ (calculated amount)} \longrightarrow 2CaCO_3\downarrow + 2H_2O$$

Soluble — Lime water — Insoluble

$$Mg(HCO_3)_2 + 2Ca(OH)_2 \text{ (calculated amount)} \longrightarrow 2CaCO_3\downarrow + MgCO_3\downarrow + 2H_2O$$

Soluble — Lime water — Insoluble — Insoluble

Removal of Permanent Hardness

a Addition of **washing soda**

$$MCl_2 + Na_2CO_3 \longrightarrow \underset{\text{ppt}}{MCO_3}\downarrow + 2NaCl$$

$$MSO_4 + Na_2CO_3 \longrightarrow \underset{\text{ppt}}{MCO_3}\downarrow + Na_2SO_4$$

M = Ca, Mg

Removal of Permanent Hardness

b Ion-exchange method

Also called **zeolite/ permutit** method.

Hydrated sodium aluminium silicate, **$NaAlSiO_4$ (NaZ)**

$$2NaZ\,(s) + M^{2+}\,(aq) \longrightarrow MZ_2\,(s) + 2Na^{+}\,(aq)$$

$M^{2+} = Ca^{2+}/Mg^{2+}$

Exhausted zeolite is **regenerated** by treating with **NaCl (aq)**

$$MZ_2\,(s) + 2NaCl\,(aq) \longrightarrow 2NaZ\,(s) + MCl_2\,(aq)$$

Removal of Permanent Hardness

c **Calgon's** method

Calgon ($Na_6P_6O_{18}$ or $Na_2[Na_4(PO_3)_6]$) forms **soluble** complexes with Mg^{2+} and Ca^{2+} ions.

$$Na_6P_6O_{18} \longrightarrow 2Na^+ + Na_4P_6O_{18}^{2-}$$

$$M^{2+} + Na_4P_6O_{18}^{2-} \longrightarrow [Na_2MP_6O_{18}]^{2-} + 2Na^+$$

M = Mg, Ca

Removal of Permanent Hardness

d Synthetic resin method

Involves the use of **cation/anion exchange resin** for the softening of water.

Reactions with cation exchange resin,

$$RSO_3H + NaCl \longrightarrow RSO_3Na + HCl$$

$$2RNa\ (s) + M^{2+}\ (aq) \longrightarrow R_2M\ (s) + 2Na^{+}\ (aq)$$

$$M^{2+} = Ca^{2+}/Mg^{2+}$$

Removal of Permanent Hardness

Pure de-mineralised water (free from all soluble mineral salts) is obtained by passing water successively through

A **cation exchange** (in the H^+ form) and an **anion exchange** (in the OH^- form)

$$2RH\,(s) + M^{2+}\,(aq) \longrightarrow MR_2\,(s) + 2H^+\,(aq)$$

Removal of Permanent Hardness

In anion exchange process, **OH^- exchanges** anions like **Cl^-, HCO_3^-, SO_4^{2-}**, etc.

$$RNH_2\,(s) + H_2O\,(l) \rightleftharpoons RNH_3^+.OH^-\,(s)$$

$$RNH_3^+.OH^-\,(s) + X^-\,(aq) \rightleftharpoons RNH_3^+X^-\,(s) + OH^-\,(aq)$$

$$H^+\,(aq) + OH^-\,(aq) \longrightarrow H_2O\,(l)$$

Measurement of Hardness

Hardness is measured in terms of **ppm (parts per million)** of **$CaCO_3$** or equivalent to it.

$$\text{Hardness (in ppm)} = \frac{\text{Mass of } CaCO_3}{\text{Total mass of solution}} \times 10^6$$

Properties of D_2O

Colourless, tasteless, & odourless liquid

Values of all **physical constants** are higher than that of H_2O

Chemically, it is similar to H_2O

It's **chemical reactions** are **slower** than those of H_2O

Uses of Heavy Water

Moderator in nuclear reactors

Used in **exchange reactions** for the study of the reaction mechanism

For the preparation of other **deuterium** compounds

Preparation of Deuterium Compounds

$$CaC_2 + 2D_2O \longrightarrow C_2D_2 + Ca(OD)_2$$

$$SO_3 + D_2O \longrightarrow D_2SO_4$$

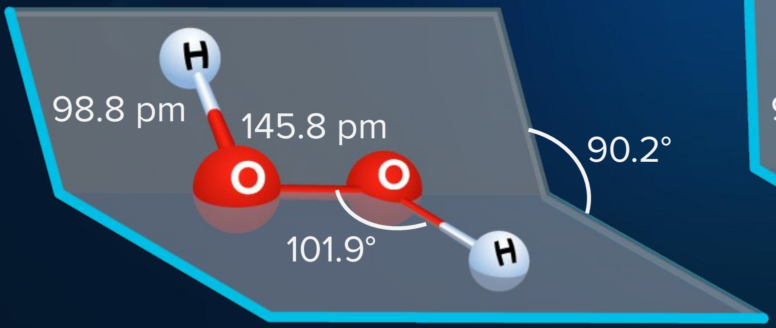
$$Al_4C_3 + 12D_2O \longrightarrow 3CD_4 + 4Al(OD)_3$$

Hydrogen Peroxide (H_2O_2)

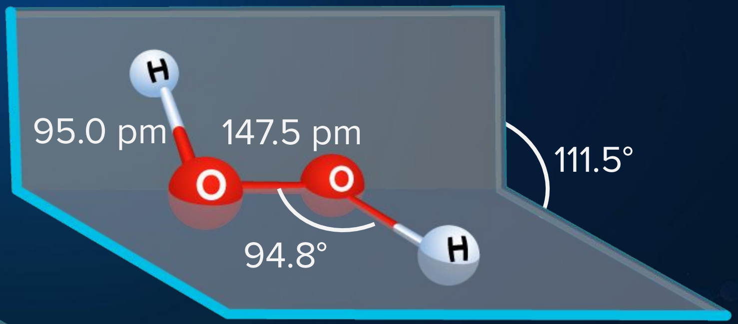
Non-linear, non-planar

Open book structure

-O-O- linkage is called **peroxy linkage**



Solid phase

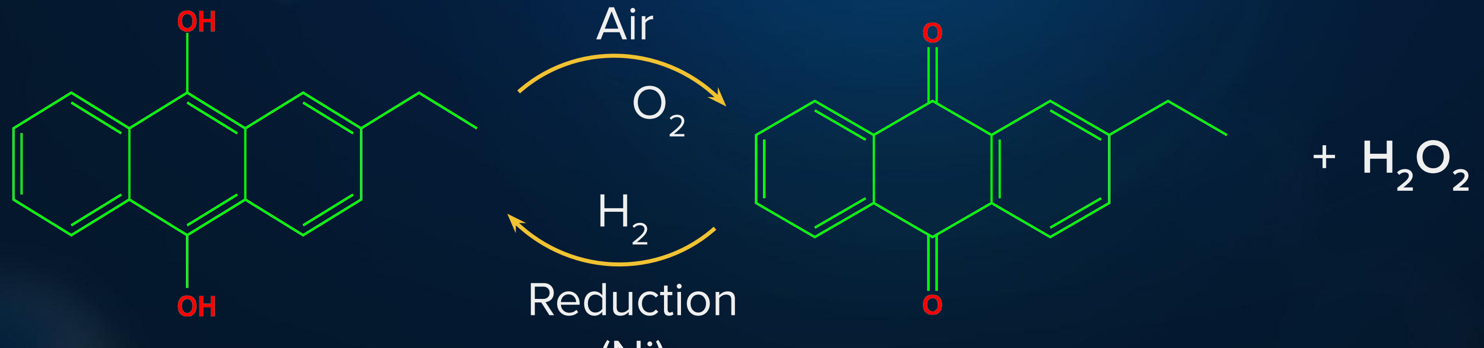


Gas phase

Preparation of H_2O_2

Acidifying barium peroxide and removing excess of water by evaporation under reduced pressure gives **H_2O_2.**

$$\underset{\text{Cold}}{BaO_2.8H_2O} + H_2SO_4 \longrightarrow \underset{\text{ppt.}}{BaSO_4\downarrow} + H_2O_2 + 8H_2O$$



2-Ethyl anthraquinol **2-Ethyl anthraquinone**

Preparation of H_2O_2

Prepared by the **electrolysis** of **50% H_2SO_4** solution at 0°C using inert electrodes.

Cathode	**Platinum**
Anode	**Graphite**

$$H_2SO_4 \rightleftharpoons H^+ + HSO_4^-$$

Preparation of H_2O_2

At anode:

$$2HSO_4^- \longrightarrow S_2O_8^{2-} + 2H^+ + 2e^-$$

At cathode:

$$H^+ + e^- \longrightarrow \frac{1}{2} H_2$$

$$H_2S_2O_8 + H_2O \xrightarrow[\text{distillation}]{80\text{-}90^\circ C} 2H_2SO_4 + H_2O_2$$

$$\downarrow BaCl_2$$

$$BaSO_4\downarrow + H_2O_2\,(aq)$$

Physical Properties of H_2O_2

01 Colourless viscous liquid which appears **blue in larger quantities.**

02 Miscible with water in all proportions.

03 b.p. (144°C) & density are more than that of water and F.P. (–4°C) is less than that of water.

Volume Strength of H_2O_2

Strength of H_2O_2 is represented as **10 V**, **20 V**, **30 V,** etc.

20 V H_2O_2 means **one litre** of this sample of H_2O_2 on decomposition gives **20 L of O_2 gas at STP**.

Chemical Properties

1 Oxidising action in acidic medium

$$2Fe^{2+}(aq) + 2H^{+}(aq) + H_2O_2(aq) \longrightarrow 2Fe^{3+}(aq) + 2H_2O\,(l)$$

$$PbS\,(s) + 4H_2O_2\,(aq) \longrightarrow PbSO_4\,(s) + 4H_2O\,(l)$$

2 Oxidising action in basic medium

$$2Fe^{2+} + H_2O_2 \longrightarrow 2Fe^{3+} + 2OH^{-}$$

$$Mn^{2+} + H_2O_2 \longrightarrow Mn^{4+} + 2OH^{-}$$

Chemical Properties

3 Reducing action in acidic medium

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

$$HOCl + H_2O_2 \longrightarrow H_3O^+ + Cl^- + O_2$$

Chemical Properties

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Reducing action in basic medium

$$I_2 + H_2O_2 + 2OH^- \longrightarrow 2I^- + 2H_2O + O_2$$

$$2MnO_4^- + 3H_2O_2 \longrightarrow 2MnO_2 + 3O_2 + 2H_2O + 2OH^-$$

Storage of H_2O_2

H_2O_2 decomposes slowly on exposure to light

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

Decomposition of **H_2O_2** is catalysed in the presence of **metal surfaces** or **traces of metal ions.**

Stored in **wax-lined glass** or plastic vessels in dark. **Urea** can be added as a **stabiliser**.

Uses of Hydrogen Peroxide

- Antiseptic
- Hair bleach & mild disinfectant
- Synthesis of hydroquinone, tartaric acid
- Bleaching agent
- Manufacture chemicals like sodium perborate
- Pollution control