

THE CHEMISTRY OF THE ELEMENTS

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- A progression through the periodic table concentrating on group trends

Hydrogen: inert , tasteless, colourless **gas** at room temperature

As a gas: **London forces** exist between **molecules**. These are instantaneous electric dipoles and give rise to the fact that H₂ is less dense than air and low boiling

Three **isotopes** exist :

	mm g/mol	Abundance
Hydrogen (H ¹)	1.008	99.88%
Deuterium (H ²)	2.014	0.02%
Tritium (H ³)	3.016	radioactive β-emitter, half life 12.4 years

Deuterium

- obtained by fractional distillation or electrolysis of H₂O.

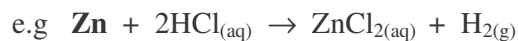
Often used as a moderator in nuclear reactors.

Chemical reactions of isotopes are identical but the **rate** of reaction is different

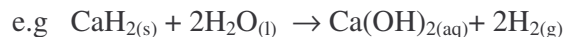
e.g C-H bond cleavage occurs 5-8 times faster than C-D bond cleavage

Preparation of hydrogen:

In laboratory , hydrogen can be obtained by reduction of H^+ .



Or by the oxidation of H^- :



[**Remember:** Hydride (H^-) oxidation number = -1 (H in the presence of an electropositive metal atom)]

Formation of atomic hydrogen requires electric arcs, discharge tubes or UV irradiation

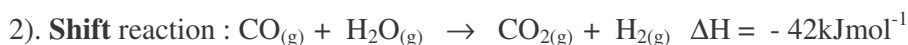
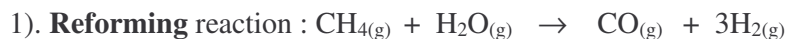
Atomic hydrogen is used in welding as the reformation of H_2 generates heat :



Preparation of Hydrogen in industry:

Petroleum industry – **cracking** e.g $\text{C}_{12}\text{H}_{26(\text{g})} \rightarrow \text{C}_5\text{H}_{10(\text{g})} + \text{C}_4\text{H}_{8(\text{g})} + \text{C}_3\text{H}_{6(\text{g})} + \text{H}_{2(\text{g})}$

Shift reaction two-step process :



The carbon dioxide can be removed by “scrubbing” (K_2CO_3)

Uses of Hydrogen .

(i) Haber- Bosch Process : Synthesis of ammonia: $\text{N}_{2(\text{g})} + 3\text{H}_{2(\text{g})} \rightarrow 2\text{NH}_3$

(ii) Formation of methanol - a starting material for plastics and synthetic fibres .



(iii) Hydrogenation - addition of H_2 to $\text{C}=\text{C}$ bond generating a solid-fat from an unsaturated oil.

Binary compounds of hydrogen

Three main categories exist;

1. **Non-stoichiometric compounds:** Interstitial/metallic hydrides

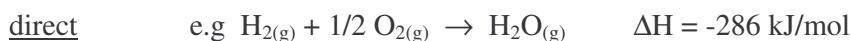


Metallic hydrides can be thought of as hydrogen atoms occupying interstitial holes in metal lattices

2. **Molecular compounds** : Consist of discrete molecules e.g

SnH_4 (metal), SiH_4 (metalloid), NH_3 , HF , (non-metals), B_2H_6 (diborane)

Preparation of molecular hydrides:



Hydrogen bonding - An important characteristic of molecular compounds.



___ Covalent bond $\Delta H = 200 \text{ kJmol}^{-1}$ ----- Hydrogen bond $\Delta H = 20-30 \text{ kJmol}^{-1}$

Responsible for H_2O being more dense than ice and raising surface tension of water.

It is also responsible for **hydrates** (solid containing a compound and water),

clathrates (solid in which one component crystallises in an open structure into which a second small component can be trapped e.g $[\text{R}_4\text{N}] [\text{C}_6\text{H}_5\text{CO}_2] \cdot 39.5\text{H}_2\text{O}$. **In cellulose**

H-bonding gives cross-linking between glucose-like chains. **In DNA** protein structures of peptides held together by H bonds .

Group 1 Alkali Metals :

Li , Na, K, Rb, Cs, Fr.- all the elements are **soft**, silvery metals which give basic (alkali) solutions.

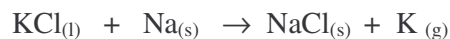
M-M bonding is weak and involves the delocalisation of e^- around a 'sea' of cations.

Preparation of the elements

Na - electrolysis of the molten salt (NaCl) (Down's Process). Chlorine gas is given off at the graphite anode (chlorine would react with steel) and molten sodium collects at the steel cathode .

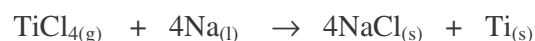
(See fig 17.26 "Atkins and Beran "). CaCl_2 is added to the NaCl to lower the melting point from 800 to about 630°C .

K - more volatile metal (melt reaction)



Uses :

1 . They readily form M^+ ions (low 1st ionisation energies) - good reducing agents.



2. **Alloys** of Na and K (mixture of the elements) are used in nuclear reactors as coolants. The packing of atoms with different metallic radii is poor so these alloys are liquids.

2. **Biological** -

Francium –Radioactive tracer experiments

Na^+ , K^+ - physiological importance

Li^+ - used in treatment of bipolar disorder (manic depression) .