HYDROGEN ENERGY

- potential sources of fuel

Advantages: abundantly available
compatability with fuel cell
high efficiency [65-9%]

Disadvantages: cost ↑
flammable
dependent on fossil fuels.

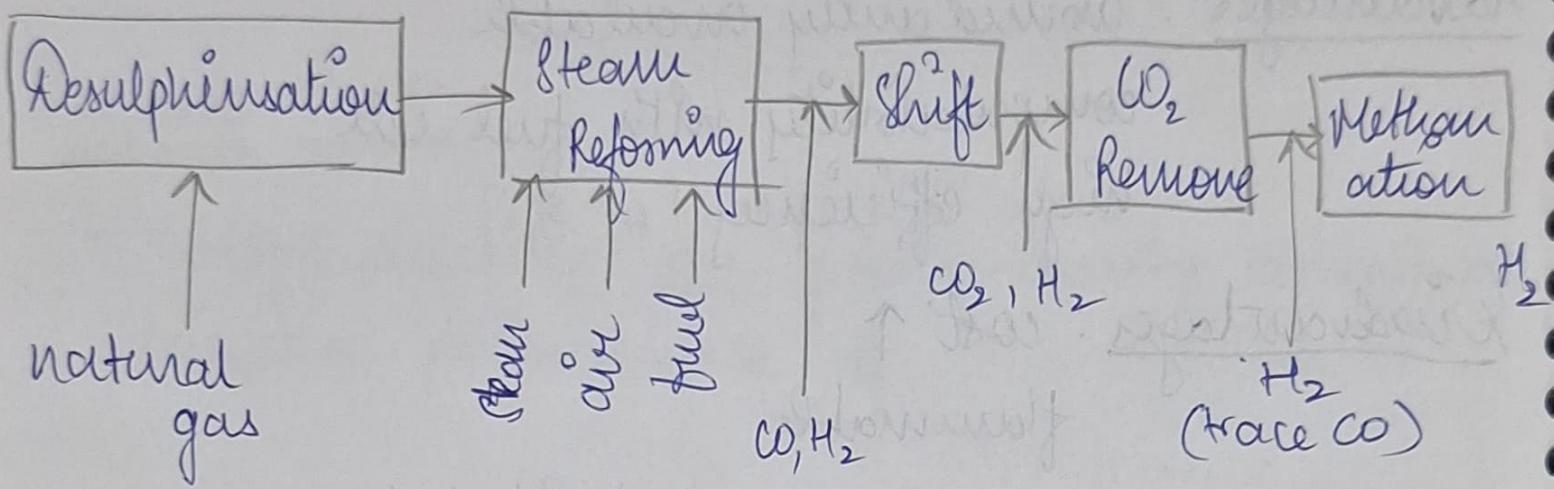
- Hydrogen economy is a vision of an energy delivery infrastructure based on H as carbon free energy carrier.

Hydrogen Production

- Steam Reforming (grey hydrogen)
- Photolysis (green)
- Gasification (black hydrogen)
- Electrolysis (green)
- Thermolysis (green)

Steam Reforming:

- Has four important steps.



Desulphurisation: removal of sulphur from feedstock as it poisons catalyst.

Steam Reforming: steam + fuel + air with catalyst in chamber make syngas at 800°C to 900°C

catalyst: Nickel

reaction: endothermic [T↑, P↓]

$$CH_4 + H_2O \longrightarrow CO + 3H_2$$

Shift: $CO + H_2O \longrightarrow CO_2 + H_2$

catalyst: Fe_3O_4 / Cr_2O_3

reaction: exothermic [T↓, P↑]

Temp: 350°C

Purification: $CO + 3H_2O \longrightarrow CH_4 + H_2O$

CO_2 is removed to make pure H_2

methanation removes CO traces.

350 - 450°C.

Advantages: high yield [50%]

heat generated is recycled

Stable

Disadvantages: carbonaceous materials formed ↑

external heat needed to start rxn

Alkaline Electrolysis:

- zero CO_2 emissions
- green hydrogen is produced.
- Aqueous solution of KOH / NaOH at 20-40% conc.

Anode : Nickel and alloys

Cathode : Cd, Pb, Cu, Ag, Pt

Electrolyte : KOH, $NaOH_2$

Catalyst : Ni_2-Zn, Ni-Co-Au, RuO_2, $LaCoO_3$

Temp : 343 - 363 K

Pressure : 3 MPa.

- H_2SO_4 is added to increase conductivity of water.

Anode : $2OH^- \longrightarrow \frac{1}{2}O_2 + H_2O + 2e^-$

Cathode : $2H_2O + 2e^- \longrightarrow H_2 + 2OH^-$

Overall : $H_2O \longrightarrow H_2 + \frac{1}{2}O_2$

Advantages : no harmful emmissions, clean H_2 fuel cells

Disadvantages : cost ↑
efficiency ↓
high power source needed.

HYDROGEN STORAGE

Physical Methods : Comprensed Gas [350-700 bar]
Cryo pressed
liquid H_2 [cryogenic temp needed]

Material Based : Adsorbent [MOF-5]
liquid Organic [BN-methylcyclopentane]
Intersetial Hydride [$LaNi_5H_6$]
Complex Hydride [$NaAlH_4$]
Chemical Hydrogen. [NH_3BH_3]

Solid State Storage:

Chemisorption
- Hydrogen atoms are bound to the surface into
- Absorption into matter

Physisorption
- Adsorption on surface
- bound onto the surface of adsorbent.

Metal Organic Frame : [MOF]

- As adsorbent,
- novel class of porous materials with unique pore structure.
- high density storage

Zn-MOF : MOF5, one of the best due to balanced gravimetric & volumetric H_2 uptake

Liquid Organic Hydrogen Carriers: [LOHC]

- organic compounds that can absorb and release H_2 through chemical reactions.
- safe, economical transportation & storage

Methyl cyclopentane
Dibenzyl Toulene

Interstitial Hydride:

- more H_2 than same volume liq. H_2
- $LiNi_5H_6$

Complex Hydrides:

- metal cations and hydrogen containing coordination anions that decompose on heating

$$3NaAlH_4 \longrightarrow Na_3AlH_6 + 2Al + 3H_2$$

Chemical Hydrogen:

- Hydrogen released from a material through a chemical reaction.

  Ammonia borane $[NH_3-BH_3]$

Challenges:→ All materials have surface area ↑ but weak binding forces with H_2

→ Hydrogen spillover is migration of hydrogen atom from metal surface to non metal support / absorbent.

NANOMATERIALS

- nano comes from greek word dwarf.
- $1nm = 10^{-9} m$
- lie between bulk and atoms / molecules
- Materials which have atleast one external dimension between 1 and 100 nm.

Classification

0D
- all dimensions within nano range
- quantum dot
- fullerene
- carriers confined in all directions

1D
- One dimension outside nano range
- nanowires
- nanotubes
- carriers move in one direction (up, down)

2D
- 2 dimensions outside nano range
- nanofilms
- nanocoatings
- carriers are free to move in a plane

3D
- 3 dimensions out of nano range
- bundles of nanowires
- carriers are free in all directions

Spatial confinement.

- Properties of nano materials are different due to the following reasons
  - → large volume of surface atoms
  - → large surface energy
  - → spatial confinement.
  - → lesser imperfections

PROPERTIES :

Surface Area: surface area is increased
catalytic activity ↑
surface energy ↑
chemical reactivity ↑
gas adsorption ↑

Bulk Au → catalytically inactive
Nano Au → catalytically active for some redox

Electrical: conductivity of nanoparticles ↓
- due to spacial confinement, energy gap ↑
  bands become discrete
- conductors in bulk
  semiconductors in nano.

- surface scattering reduces conductivity due to inelastic scattering when e^- loses velocity.

Optical : Colour depends on size of particle
Increase in band gap [blue shift]
Surface Plasmon Resonance
- collective oscillation of polarised surface electrons is called plasmon.
- when plasmon f = radiation f, resonance occurs.
- as size of particles decreases, energy gap ↑ ∴ λ absorbed moves towards smaller values. (BLUE SHIFT)

Mechanical : strength of nano > strength of bulk
as area of cross section is small in nano lattices which decreases possibility of defects.
- Bulk Cu → malleable + ductile
Nano Cu → super hard material

Thermal : thermal conductivity ↓ [phonon scattering]
melting pt ↓, transition temp ↓ [more atoms, lesser bonds to be broken]

Magnetic: if ferromagnetic in bulk, become paramagnetic in nano.

[surface energy ↑, domains can flip directions in magnetic fields, easily magnetised with high susceptibilities]

bulk Au | Pt → non magnetic

nano Au | Pt → magnetic particles.

APPLICATIONS: Catalyst

Medicine [targeted drug delivery]

Cosmetics [ZnO, TiO_2, sunscreens]

Energy Storage [fuel cell, supercapacitor]

Consumer Electronics [HDTV, LED]

Environment [catalytic converters, water purifiers]