Hydrogen (H) – The Lightest and Most Abundant Element in the Universe

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1. General Information

- Symbol: H
- Atomic Number: 1
- Atomic Mass: 1.008 u
- Group: 1 (Non-metal)
- Period: 1
- Block: s-block
- Electron Configuration: $1s^1$
- Valence Electrons: 1
- Phase at Room Temperature: Gas

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2. Isotopes of Hydrogen

Isotope	Protons	Neutrons	Name	Abundance
^{1}H	1	0	Protium	99.98%
^{2}H	1	1	Deuterium (^{2}H or D)	0.02%
^{3}H	1	2	Tritium (^{3}H or T)	Trace

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3. Physical Properties

- Color: Colorless
- Odor: Odorless
- Density: 0.08988 g/L (at 0°C and 1 atm)
- Melting Point: -259.16°C
- Boiling Point: -252.87°C
- State at STP: Gas

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4. Chemical Properties

- Highly reactive – Readily forms compounds with most elements.
- Diatomic Molecule (H_2): Exists as H_2 gas under standard conditions.
- Flammable – Combines explosively with oxygen to form water (H_2O).
- Reacts with Non-metals – Forms acids (e.g., HCl) when combined with halogens.
- Reduces Metal Oxides – Can extract metals from ores.

Combustion Reaction (Hydrogen + Oxygen):

$2H_2 + O_2 \rightarrow 2H_2O + Energy$

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5. Occurrence and Abundance

- Most abundant element in the universe (about 75% by mass).
- On Earth:

- Exists in water (H_2O).
- Found in organic compounds, hydrocarbons, and fossil fuels.
- Present in stars and the Sun (nuclear fusion).

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6. Production Methods

Method	Description
Steam Reforming	$CH_4 + H_2O \rightarrow CO + 3H_2$ (from methane)
Electrolysis of Water	$2H_2O \rightarrow 2H_2 + O_2$ (splitting water using electricity)
Biological Processes	Hydrogen from algae or bacteria.
Gasification	From coal or biomass.

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7. Uses of Hydrogen

Application	Description
Fuel	Hydrogen fuel cells ($H_2 + O_2 \rightarrow$ Electricity + H_2O)
Industrial	Production of ammonia (Haber Process).
Rocket Fuel	Used in liquid form for rocket propulsion.
Chemical Feedstock	Used to refine petroleum and in metallurgy.
Welding	Hydrogen is used in oxyhydrogen torches.
Cooling	Used as a coolant in power plants.

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8. Hydrogen as a Fuel

- Hydrogen Fuel Cells – Generate electricity by combining hydrogen and oxygen.
- Eco-Friendly – Only by-product is water.
- Challenges:
  - Storage (requires high-pressure tanks or liquefaction).
  - Infrastructure (limited hydrogen fueling stations).
  - Production can be energy-intensive.

9. Hydrogen Bonding

- Definition: Attraction between hydrogen and electronegative atoms (O, N, F).
- Example: Hydrogen bonding in water (H_2O), contributing to high boiling point and surface tension.

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10. Role in the Universe

- Stars and Fusion:
  - Hydrogen nuclei fuse to form helium in stars, releasing energy (nuclear fusion).
  - The Sun’s energy comes from hydrogen fusion.
- Building Block of Life:
  - Essential in organic molecules (proteins, DNA, carbohydrates).

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11. Safety and Handling

- Highly Flammable – Handle with caution.
- Explosive Limits in Air: 4% to 75% by volume.
- Storage: Stored in pressurized tanks or as a liquid at very low temperatures.

Fun Facts About Hydrogen:

- Hydrogen is the simplest element – One proton, one electron.
- The hydrogen atom is the only element whose energy levels are described exactly by quantum mechanics.
- Hydrogen fuel cells powered the Apollo missions to the Moon.