

Hydrogen Bonding

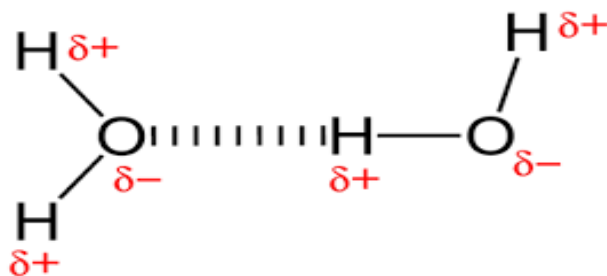
The attractive electrostatic force which binds hydrogen atom (positive end) of one molecule with an electronegative atom (F, O, N) (negative end) of another molecule is known as hydrogen bond. The strength of a hydrogen bond varies from 10-40kJ/mol while that of a covalent bond is 400kJ/mol. Thus, hydrogen bond is much weaker than a covalent bond

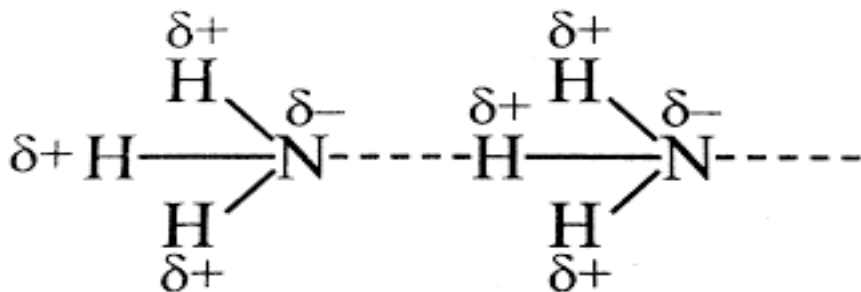
Example of molecules exhibiting hydrogen bonding are HF, H₂O, NH₃

In HF, F atom is highly electronegative; hence it pulls the covalently bonded electron pair towards the nucleus and away from the hydrogen atom. The hydrogen atom is then left with a partial positive charge and the F atom with a slight negative charge. This phenomenon of charge separation makes the HF molecule polar and the molecule behaves as a dipole. The electrostatic force of attraction causes one molecule of HF to get attached to another HF molecule. This attractive force between H atom of HF molecule and F atom of another HF molecule is hydrogen bond.

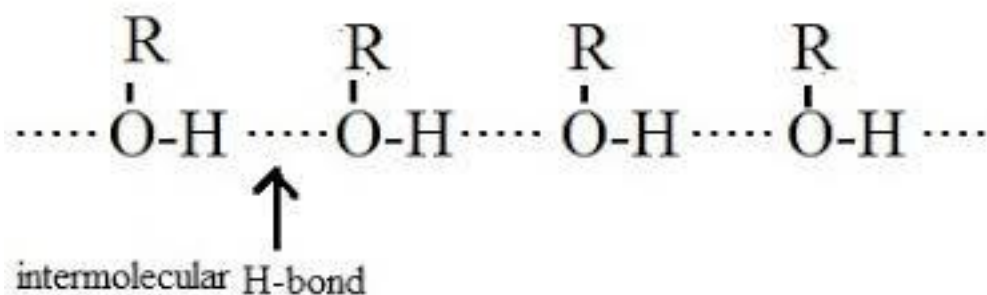
**hydrogen bonding in HF (dotted line shows hydrogen bonding)**

H₂O molecule too exhibits hydrogen bonding because it is polar molecule and because of its bent shape, is also a dipole; Oxygen end carrying a negative charge and hydrogen end carrying a positive charge.

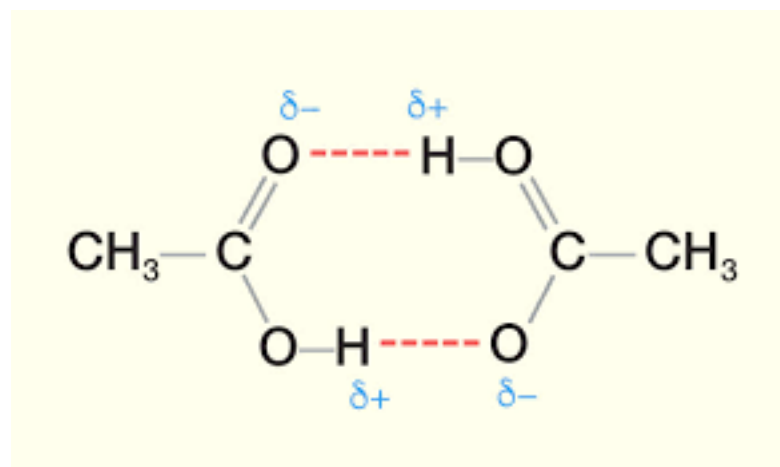
**Hydrogen bonding in H₂O (dotted line shows hydrogen bonding)**



Hydrogen bonding in NH_3 (dotted line shows hydrogen bonding)



Hydrogen bonding in alcohols (dotted line shows hydrogen bonding)



Hydrogen bonding in carboxylic acids (dotted line shows hydrogen bonding)

Types of hydrogen bonds

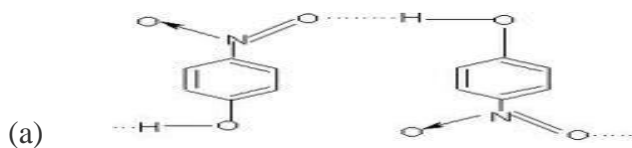
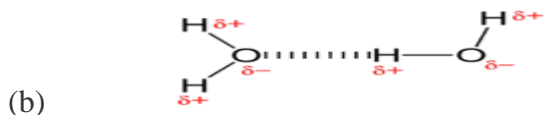
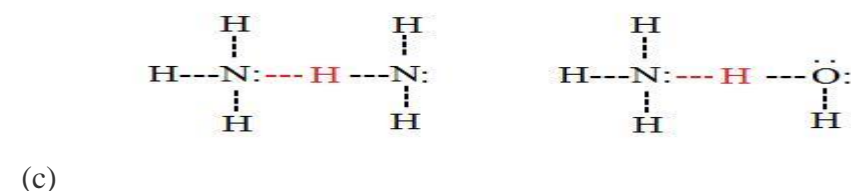
Hydrogen bonds can occur within one single molecule, between two like molecules, or between two unlike molecules.

1. Intramolecular hydrogen bonds:

- Intramolecular hydrogen bonds are those which occur within one single molecule.
- This occurs when hydrogen and an electronegative element like O, N, F is present in the same molecule.
- Example is o-nitro phenol, o-Cl-phenol

**2. Intermolecular hydrogen bonds**

- Intermolecular hydrogen bonds occur between hydrogen atom of one molecule and an electronegative atom of another molecule of the same substance.
- Example, NH_3 , H_2O molecules alone, or between NH_3 and H_2O molecules.

p-nitro phenol H_2O  NH_3 alone NH_3 and H_2O

Consequences of hydrogen bonding**1. Melting and boiling points:**

Compounds exhibiting hydrogen bonding have strong intermolecular force of attraction and hence require high energy to break the bonds in order to separate the molecules. Consequently such molecules have high melting point and boiling point.

Also, boiling point of liquids increases because hydrogen bonding leads to increase in intermolecular attractions which lead to increase in heat of vaporization.

The abnormal boiling point of water is due to hydrogen bonding.

2. Association of molecules:

Due to hydrogen bonding, two or more molecules of a compound get associated to form bigger units. For example, 2 molecules of carboxylic acid get associated to form a dimer.

3. Solubility

The solubility of organic compounds in water is attributed to hydrogen bonding.

For example, a. CH_3OCH_3 (dimethyl ether) is completely miscible in water but CH_3SCH_3 (dimethyl sulphide) is partially miscible. This is because dimethyl ether is capable of hydrogen bonding with H_2O molecule.

The high solubility of sugar in water is due to hydrogen bonding.

4. Viscosity:

Intermolecular hydrogen bonding increases attraction between molecules in different layers of hydrogen bonded liquids. This results in increase in viscosity. Compounds exhibiting strong hydrogen bonding are highly viscous and have high surface tension.

Example: concentrated sulphuric acid, glycerol etc are highly viscous due to extensive hydrogen bonding

5. Unique properties of water:

- Density of water in solid state is less than that in liquid state. This is unusual because in most substances, density in solid state is more than in liquid state. This is due to intermolecular hydrogen bonding.
- Water contracts when heated between 0°C and 4°C . This is again unusual because most substances expand when heated in all temperature ranges.
- Water is liquid over wide temperature range (0 - 100°C)
- known as universal solvent: can dissolve many substances

- water has high heat of evaporation thereby sweating leads to cooling
- adhesion and cohesion: strong forces of attraction between molecules allows water to rise up inside plants from roots to leaves
- water conducts heat more easily than any other liquid except mercury