MODULE 11

AIM

The aim of this module is to provide students with an introduction to water and its properties.

CONTENTS AND OBJECTIVES

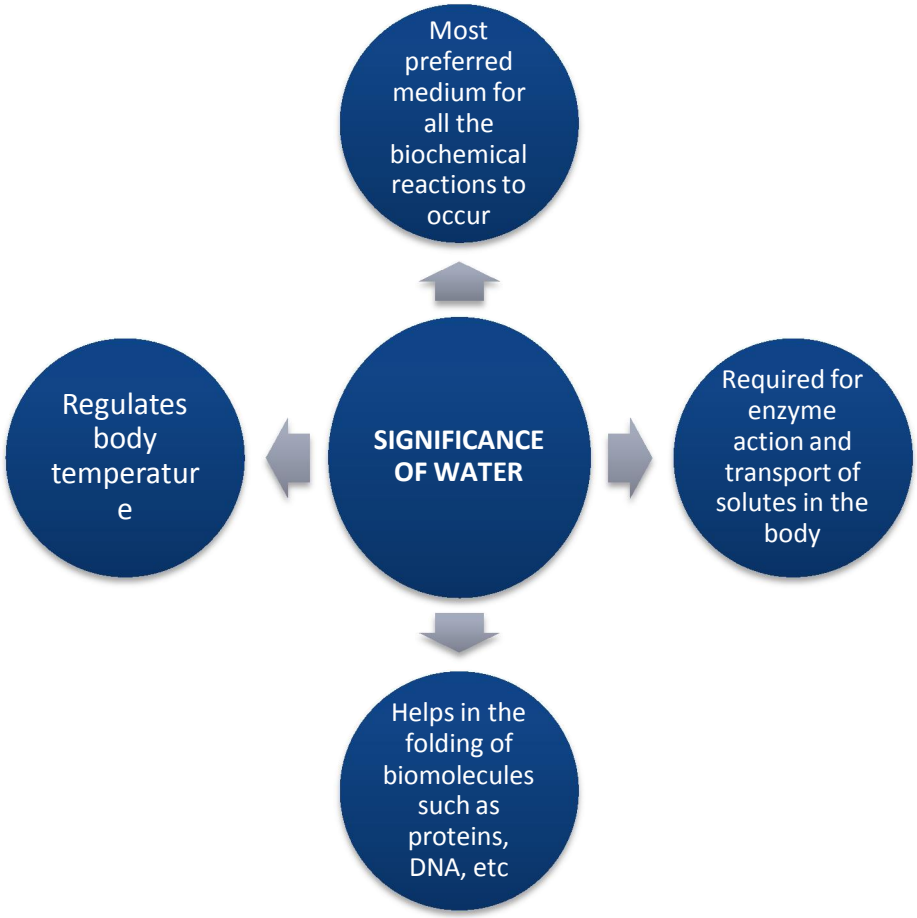
- Introduction
- Significance of water
- Molecular structure of water
- Dissociation of water
- The concept of pH

WATER

INTRODUCTION

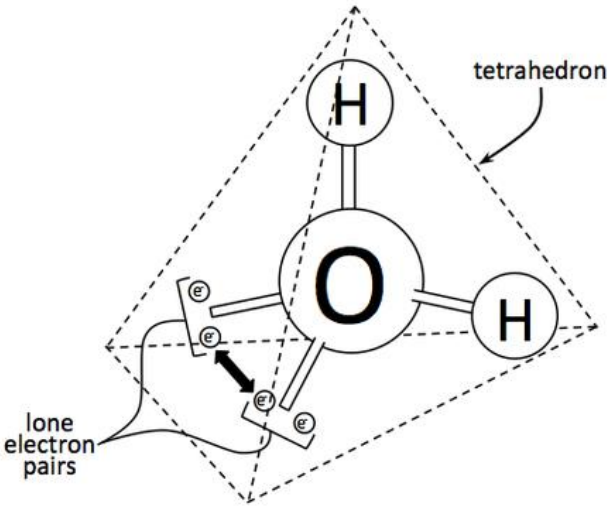
- During the origin of life, water served as the only medium for the movement and interactions of biomolecules.
- About 3.8 billion years ago, life originated in water as a result of these interactions, gradually spreading to land, and has invariably been tied to water since then.
- About three-fourth of the Earthôs surface is covered with water which happens to be an essential constituent of all forms of life.
- Almost all biochemical reactions happen in aqueous milieu.
- Approximately two-thirds of an organismôs body is composed of water and no organism can grow or reproduce in any but a water-rich environment. It is no coincidence that tropical rainforests are bursting with life, while deserts appear almost lifeless except after a rainstorm.

IMPORTANCE OF WATER



MOLECULAR STRUCTURE OF WATER

- The molecular formula of water is H2O. A water molecule consists of two hydrogen atoms bonded with one oxygen atom by two single covalent bonds. The oxygen atom bears two unshared electrons.
- In a water molecule, the angle between the two hydrogen atoms is 104.5° forming a slightly skewed tetrahedral structure.
- The oxygen atom, in a water molecule, is slightly more electronegative than hydrogen atom. In other words, the oxygen atom is negatively charged and the hydrogen atoms are positively charged making the entire water molecule dipolar in nature.
- Negatively charged oxygen of one molecule and positively charged hydrogen atom of the next molecule come together to form a hydrogen bond between the two molecules of water.



The bent structure of a water molecule.

- In this manner, each water molecule can form hydrogen bonds with four different water molecules at the same time.
- Water can exist in three different states- Liquid, solid and gas (or vapour). In the liquid state, there is dynamic hydrogen bonding between the water molecules, whereas, in solid state the water molecules present in the same state form hydrogen bonds among each other.

DISSOCIATION OF WATER

- Water has a limited tendency to get reversibly ionized into hydrogen ion (H+) and hydroxide ion (OH-).

$$H2O \longrightarrow H+ + OH-$$

- The tendency of water to dissociate is expressed as follows:

$$K = [H+]\,[OH-]/\,[H2O]$$

Where, the bracketed terms represent the molar concentration of hydrogen ions, hydroxyl ions and un-dissociated water molecules and **K** is termed as the **dissociation constant**.

The concentration of pure water [H2O] is 55.5M and K, as calculated from electrical conductivity measurement, is $1.8x10^{-16}$ M.

Therefore, $[H+][OH-] = \mathbf{k_W} = 1.0x10^{-14}\,M^2$

In pure water, $H+ = \sqrt{k_W} = \sqrt{1.0x10^{-14}}$ i.e., $[H+] = [OH-] = 10^{-7}$ M.

THE CONCEPT OF pH

- pH is defined as the negative log of hydrogen ion concentration.

$$pH = -\log [H+]$$

- It ranges from 1-14. A solution with pH=7 is **neutral**, whereas a solution with pH above 7 is **basic** and a solution with pH below 7 is **acidic**.
- Hence the ability of any acid to dissociate to give [H+] ion or a base to give [OH-] ion define the acid or alkali as strong or weak acid.
- In order to know the pH of a solution:
  1. Calculate hydrogen ion concentration [H+] in the solution.
  2. Calculate the base 10 logarithm of [H+].
  3. pH is negative of the value found in step 2.

     Eg- for pure water-

     $pH = -\log[H+] = -\log 10^{-7} = -(7) = \mathbf{7.0}$
- pH values below 7 correspond to high concentration of H+ and pH values above 7 correspond to low H+ concentrations.
- Thus, acids are considered as **proton donors** and bases are **proton acceptors**.