

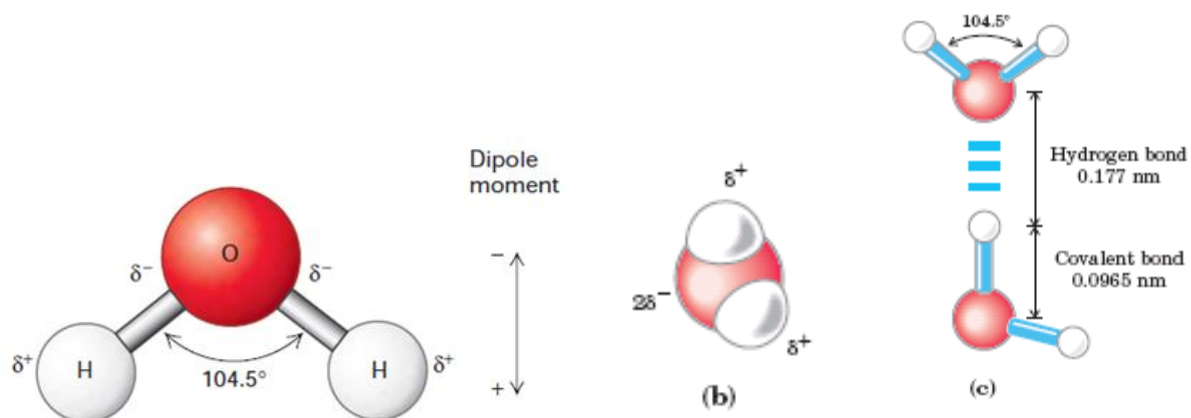
## 2. WATER

### 2.1 INTRODUCTION

- Water is the most abundant compound in living organisms, making up 60-95% fresh mass of all living organisms.
- Water is important to living organisms because (i) it is an important chemical constituent of living cells and (ii) it provides a habitat for aquatic organisms.
- Water has special physical and chemical properties because of its small size, its polarity and due to hydrogen-bonding between its molecules.

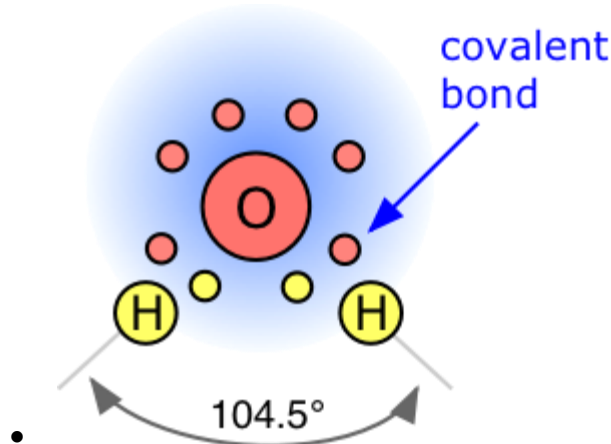
### 2.2 DIPOLAR NATURE OF WATER

- Polarity is the unequal charge distribution over a molecule.
- In water one end of the molecule is slightly positive and the other slightly negative. This is known as dipole.
- The electronegative oxygen atom (on one water molecule) attracts the electrons of the hydrogen atoms (of surrounding water molecules); Water molecules therefore have an electrostatic attraction for each other.
- Each oxygen atom has two partial negative charges while each hydrogen atom has one partial positive charge. Hydrogen bonds are longer and weaker than covalent O-H bonds.



**Figure 2.1** The dipolar nature of the water molecule is shown by (a) ball-and-stick and (b) space-filling models. In (c) a hydrogen bond is formed between the oxygen of the upper and hydrogen of the lower molecule.

- Because the two non-bonding pairs remain closer to the oxygen atom, these exert a stronger repulsion against the two covalent bonding pairs, effectively pushing the two hydrogen atoms closer together. The result is a distorted tetrahedral arrangement in which the H—O—H angle is **104.5°**.

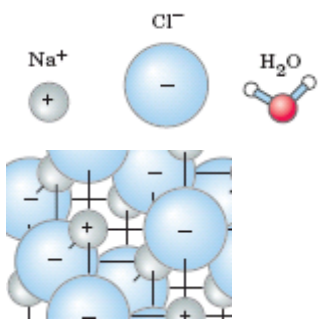
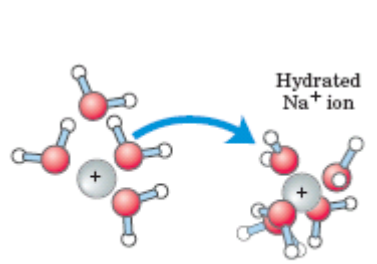
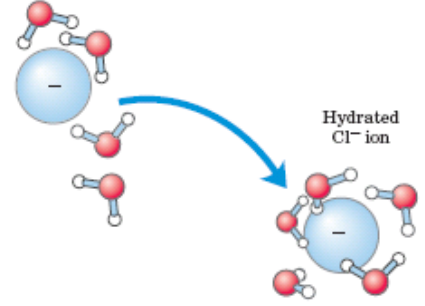


## 2.4 HYDROGEN BOND FORMATION

- The attractions between hydrogen and oxygen atoms of different water molecules are called hydrogen bonds.
- These weak bonds are also formed between (i) the oxygen atoms of water molecules and hydrogen atoms of different molecules such as acids and (ii) the hydrogen atoms of water and OH groups of other molecules such as alcohols.

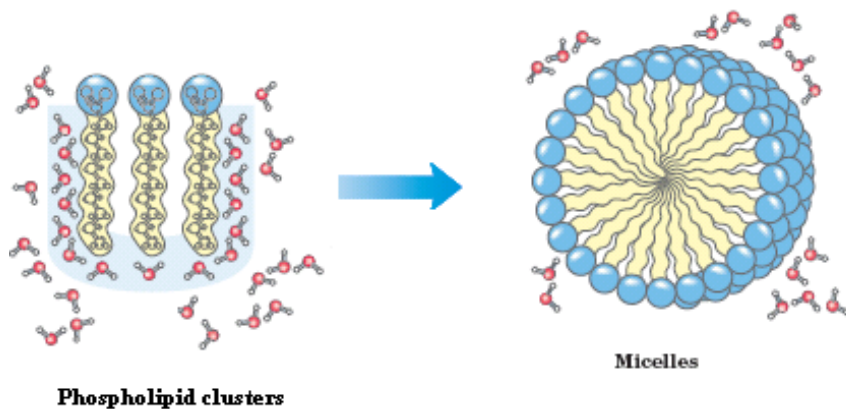
## 2.5 IMPORTANCE OF WATER AS A SOLVENT

- Water is a good solvent for ionic substances like salts whose charged particles dissociate in water and for some non-ionic substances like sugars and simple alcohols which contain charged (polar) groups such as the hydroxyl (-OH) within the molecules.
- When substances dissolve in water they become more chemically reactive than when they are in the solid form.
- Therefore, the majority of cellular reactions take place in aqueous solution.
- The solvent properties of water make it act as a transport medium, in blood, lymphatic system, excretory system and the alimentary canal of animals as well as in xylem and phloem tissues of plants.

		
Sodium ion, chloride ion , water molecule and sodium chloride crystal	Hydration of the sodium ion by water molecules	Hydration of the chloride ion by water molecules

**Figure 2.2** The ionic charges of sodium chloride are partially neutralized and the electrostatic attractions needed for crystal formation are weakened.

- Non-polar substances such as lipids are immiscible with water (insoluble) and are said to be hydrophobic (water-hating).
- Hydrophobic interactions exist between different non-polar molecules which are mixed with water and these are important in maintaining the stability of membranes, many protein molecules, nucleic acids and other sub-cellular structures.



**Figure 2.3** The formation of micelles by phospholipid molecules in water

## 2.6 ROLE RELATED TO WATER'S HIGH SPECIFIC HEAT CAPACITY

- The specific heat capacity of water is the amount of heat, in joules, that is required to raise the temperature of 1 kg of water by 1°C.

- Water has a high heat capacity, meaning that a large increase in heat energy results in a relatively small rise in temperature.
- This is because much of the energy is used in breaking the hydrogen bonds between the water molecules.
- This means that temperature fluctuations in water are minimised as a result of its high heat capacity.
- Biochemical processes in living cells, therefore take place within a narrow temperature range, at constant rates and are usually not affected by changes of temperature of the environment.
- Water therefore provides a very constant external environment for many cells and organisms.

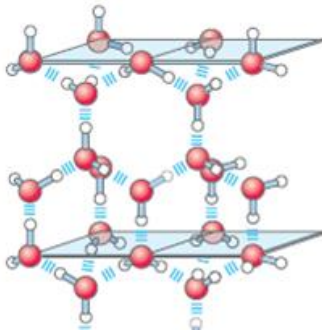
## **2.7 ROLE RELATED TO WATER'S HIGH LATENT HEAT OF VAPORIZATION**

- Latent heat of vaporisation is the amount of the heat energy required to vaporise a liquid. Water has a high latent heat of vaporisation meaning that a large amount of heat can be lost with minimal loss of water from the organism.
- This heat is used to overcome the cohesive (forces (hydrogen bonds) between water molecules so that they can escape as a gas.
- As a result, water has an unusually high boiling point for such a small molecule.
- The energy absorbed by water molecules to evaporate results in the loss of energy from their surroundings thus causing a cooling effect in the surroundings.
- Through sweating and panting mammals cool themselves while leaves are cooled down during transpiration.

## **2.8 ROLE RELATED TO WATER'S DENSITY**

- The density of water decreases at temperatures below 4°C and because of this ice tends to float.
- Each water molecule, in ice, forms the maximum of four hydrogen bonds, creating a regular lattice.

- The crystal lattice of ice makes it less dense than liquid water, thus ice floats on liquid water.
- In liquid water, at room temperature and atmospheric pressure, each water molecule forms an average of 3.4 bonds with other water molecules.
- Since ice floats, it forms at the surface of water first and at the bottom last.
- Therefore, ice insulates the water below it, increasing the chances of survival of organisms in the water during the cold season in temperate climates.
- The fact that water below 4 °C tends to rise to the surface also helps to maintain circulation in large bodies of water (lakes and oceans).
- This helps in bringing nutrients from the sediments (floor) of lakes and oceans to the surface (nutrient cycling) and helps organisms (living things) to reach and stay at greater depths.



**Figure 2.4.** Hydrogen bonding in ice.

## 2.9 ROLE RELATED TO WATER'S COHESION AND SURFACE TENSION

- Cohesion is the force which makes similar molecules stick together.
- At the surface of a liquid, such as water, a force called surface tension exists between the molecules as a result of cohesion.
- This creates a 'thin skin' over the water surface. Water has a higher surface tension than any other liquid.
- The high cohesion of water molecules helps in the movement of water in cells especially in the translocation of water through the xylem in plants.
- In addition, many small aquatic organisms are able to float or skate on water because of its high surface tension.

## 2.10 ROLE RELATED TO WATER'S ADHESION PROPERTIES

- The attraction between water molecules and other different substances is called adhesion.
- Water, through adhesion, makes things wet by sticking to their surfaces.
- Adhesion is important in the movement of water along the walls of vascular tissues in plants and along blood vessels in mammals.

## 2.11 CAPILLARITY IN WATER

- This is the ability of water to flow upwards in narrow vessels without the assistance of external forces like gravity or air pressure.
- Capillarity action is due to the action of cohesion and adhesion which together cause the liquid to work against gravity and it occurs when forces of adhesion to the vessel walls are stronger than the forces of adhesion between the liquid molecules.

## 2.12 REVISION EXERCISE

1. Draw three water molecules interacting via hydrogen bonding showing the partial positive and negative charges .
2. Describe three different properties of water that make it very important for life.
3. Explain the amphoteric property of water.
4. Suggest how you would test the high surface tension of water using plants.
5. Why are the temperature ranges of water in which it remains a liquid important for living organisms?

## 2.13 SUMMARY

Water has many chemical properties that make it very essential for life support. These include the dipolar nature of the molecule and the hydrogen bonds that hold several water molecules together. These properties make it an excellent solvent, a good biochemical reaction medium, a buffer and a chemical that supports plant life in various ways including offering structural support, as a cooling agent and as a reactant in photosynthesis