

Biological molecules

Water

Objectives :

- Describe the structure of water.
- Explain the term electronegativity.
- Explain that water molecules are polar and hydrogen bonds form between them.
- Explain How hydrogen bonding is responsible for the cohesive, adhesive, thermal and solvent properties of water.
- Explain the properties of water
- Describe and explain the functions of water in the body

Resources :

Book pages 25 , 26 , 27

<https://www.youtube.com/watch?v=3jwAGWky98c> properties of water

Water is of major importance to all living organisms. Most of the body weight of living organisms comes from water. In humans, it constitutes 60% of an adult's body weight.

The structure of water

The water molecule (H₂O) is composed of one oxygen atom linked by a single bond to two hydrogen atoms. Each hydrogen atom shares a pair of electrons with the oxygen atom. Therefore, the bond between each hydrogen atom and the oxygen atom is a covalent bond. The two hydrogen atoms are bound to the oxygen atom at an angle of 104.5° to each other. This gives the water molecule a "bent" structure.

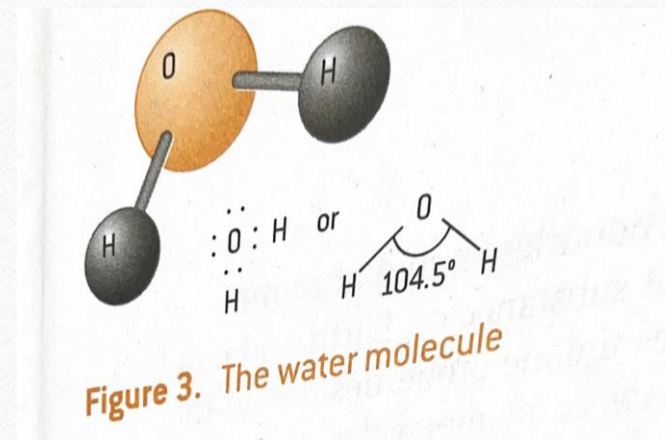


Figure 3. The water molecule

The oxygen atom has a greater electronegativity than a hydrogen atom which means that the oxygen atom will pull the shared electrons more towards it. This will cause the oxygen atom to have a partial negative charge (δ^-) and the hydrogen atoms to have a partial positive charge (δ^+). Therefore, the bond between the hydrogen and oxygen atoms is a polar covalent bond, which makes the water molecule polar

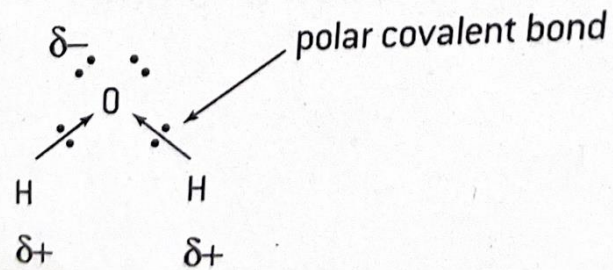


Figure 4. Polar covalent bond in water molecule

Due to the opposite charges at the two ends, the positive hydrogen end of one molecule is attracted to the negative oxygen end of another molecule. This bond is called a hydrogen bond, which is approximately ten times weaker than the average covalent bond. Each water molecule binds to four other water molecules by hydrogen bonding. The hydrogen bond between water molecules gives water its unique properties.

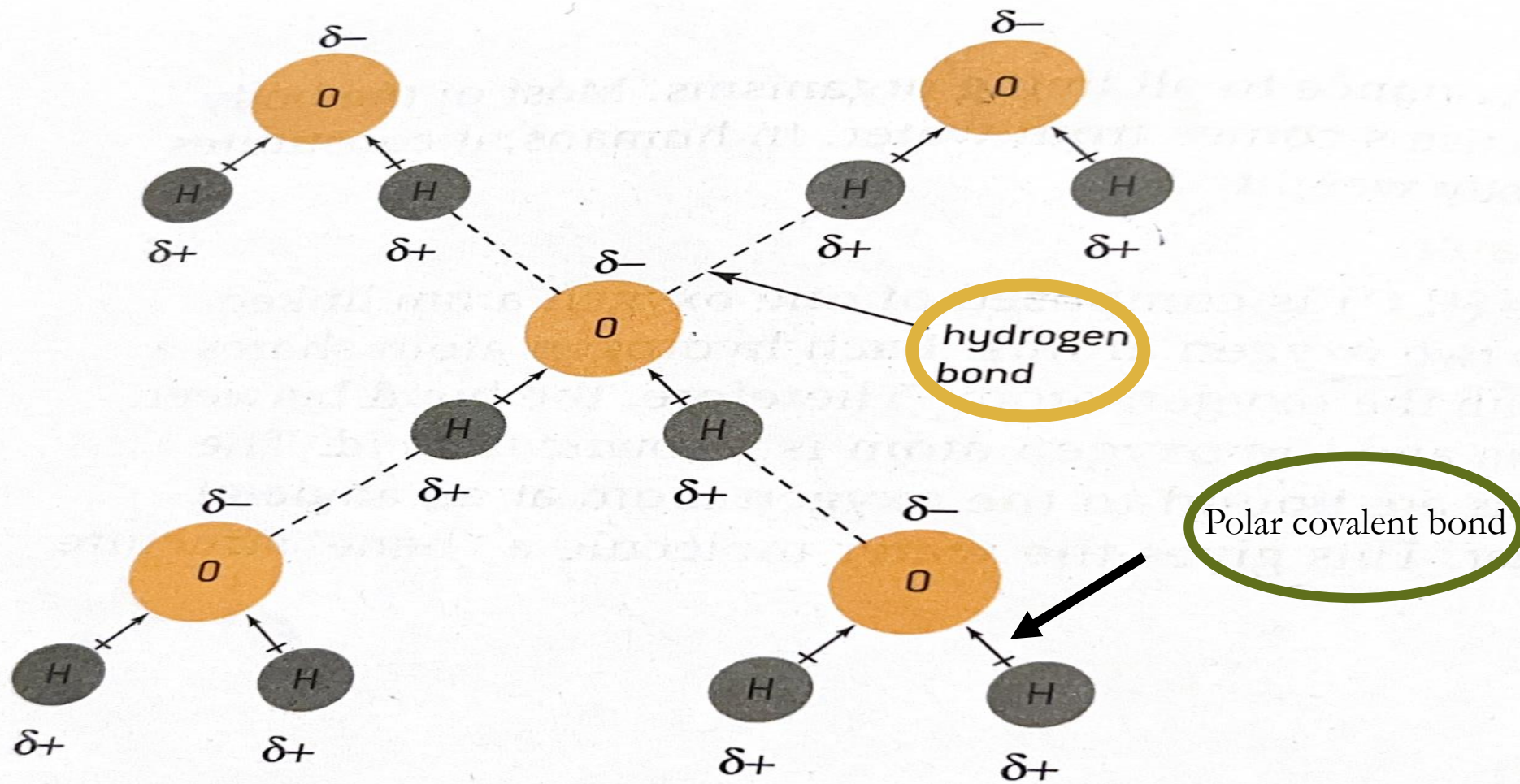


Figure 5. Hydrogen bonding between water molecules

Properties of water :

- ❖ Water is a transparent, tasteless and odorless liquid at room temperature.
- ❖ It is the most abundant substance on Earth and can be found as a solid, liquid or gas.
- ❖ It has unique properties due to the presence of the hydrogen bonds between its molecules.
- ❖ Its melting point is 0°C and its boiling point is 100°C .
- ❖ When water is in its solid form, ice, it is less dense than liquid water, which explains why glaciers float in water.
- ❖ It is described as the «universal solvent» because of its ability to dissolve many substances.
- ❖ It has a high specific heat capacity, which means that it would require high amounts of energy to increase its temperature.
- ❖ It also has a high latent heat of vaporization, which means that it needs to absorb a high amount of heat to evaporate.
- ❖ Water is cohesive, which means that water molecules tend to bond to itself by forming hydrogen bonds.
- ❖ Water is adhesive, which means that water molecules are attracted to other types of molecules due to its polarity .

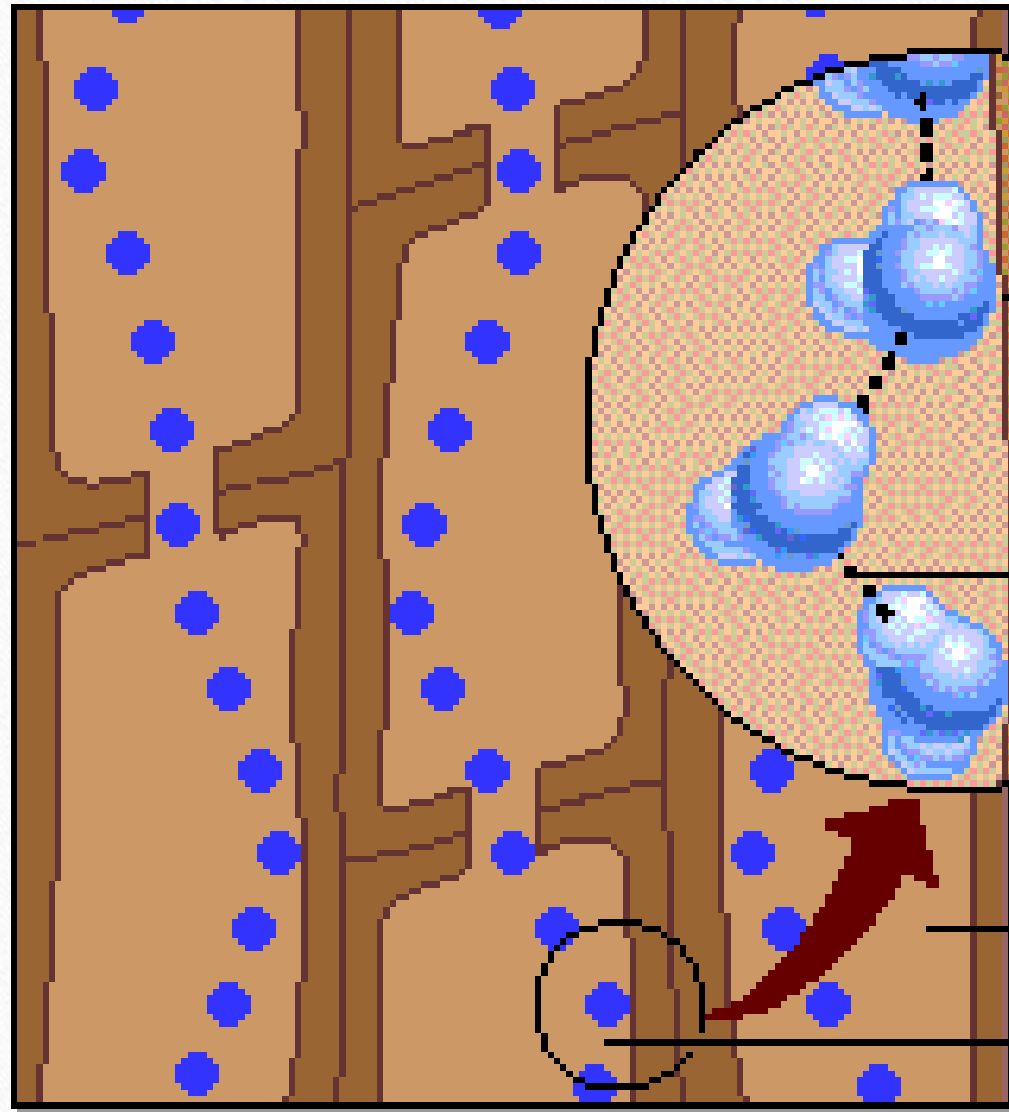
Cohesion and adhesion

Hydrogen bonds between water molecules hold them together in a network, resulting in a phenomenon known as cohesion. Cohesive forces give water many of its biologically important properties. For example, they enable water to be drawn up inside the xylem of a plant stem in a continuous column. Strong pulling forces, produced as water evaporates from the leaves at the top of tall trees, draw water and dissolved minerals up great distances to the tips of branches high above the ground.

Cohesion is also responsible for surface tension, which enables some small organisms to walk on water', and contributes to the thermal properties of water too.

Water also tends to be attracted and adhere to the walls of its container.

There are forces of attraction, known as adhesive forces, which occur between water molecules and different molecules in vessels that contain the water. Adhesion attracts water molecules to the sides of the xylem and is important as water is drawn up the stem of a plant.



Xylem cell wall

Adhesion

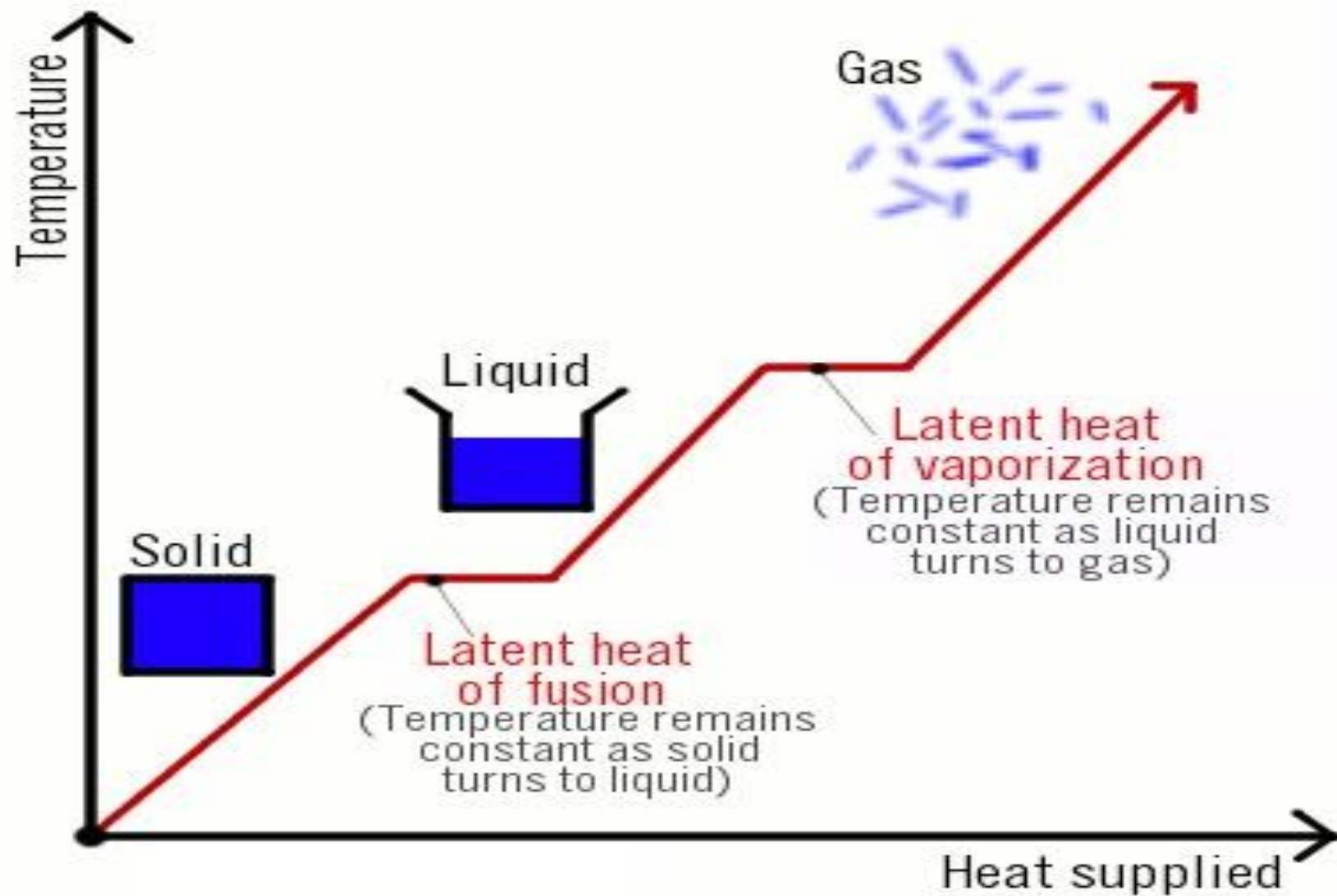
Cohesion

Xylem cell

Water molecule

Thermal properties

Water also has unusual thermal properties. It is unusual among small molecules because it is a liquid at a normal range of temperatures. A large amount of energy is needed to break the many weak hydrogen bonds between the water molecules. This gives water a high specific heat capacity - it can absorb or give out a great deal of heat energy without its temperature changing very much. A stable temperature is important to living things because the range of temperatures in which biological reactions can occur is quite narrow. The thermal properties of water allow it to keep an organism's temperature fairly constant.



Solvent properties

Water is sometimes known as a universal solvent. Its polarity makes it an excellent solvent for other polar molecules. Most inorganic ions, such as sodium, potassium and chloride ions, dissolve well as their positive or negative charges are attracted to the charges of water molecules .

Polar organic molecules, such as amino acids and sugars, are also soluble in water. Water is the medium in which most biochemical reactions take place since almost all the substances involved dissolve well in it. **Protein synthesis and most of the reactions of photosynthesis and respiration take place in an aqueous (water) solution.**

Substances are classified into two groups according to their solubility in water.

- ✓ Hydrophilic substances such as sugars and salts dissolve well, as do amino acids with polar side groups.
- ✓ Hydrophobic or water-hating' substances do not dissolve in water. They are usually uncharged, and examples include fats and oils, and large proteins that do not carry any polar groups.

The functions of water :

Water has several important functions in the body:

- ❖ **Cell life:** Water makes up most of the cell and therefore it is a vital nutrient to the life of every cell.
- ❖ **Transport medium:** Some substances are hydrophilic (water loving) and so they dissolve in water. For example, oxygen and nutrients such as glucose are transported to the cells whereas waste products such as urea are eliminated from the body through urine.
- ❖ **Metabolic reactions:** Many chemical reactions in the body require water. For instance, water is involved in hydrolysis reactions in which macromolecules such as proteins, lipids and carbohydrates are broken down into simpler molecules. Such reactions cannot take place without water.
- ❖ **Temperature regulation:** Water regulates our internal body temperature by sweating. When sweat evaporates, the body cools down and constant body temperature is maintained.

Property	Reason	Consequence / Benefits to living organisms
cohesion	Hydrogen bonds hold water molecules together.	Water can travel in continuous columns – for example, in the stems of plants – and act as a transport medium.
adhesion	Water molecules are attracted to other different molecules.	A column of water can be held up in the narrow xylem of a plant.
solvent	The polar molecules of water can interact with other polar molecules.	Ions dissolve easily. Large molecules with polar side groups, such as carbohydrates and proteins, can also dissolve. So water acts as an excellent transport medium and as a medium for metabolic reactions.
thermal	Water has a high heat capacity. Large amounts of energy are needed to break hydrogen bonds and change its temperature.	The temperature of organisms tends to change slowly. Fluids such as blood can transport heat round their bodies.
	Water has a high boiling point compared with other solvents because hydrogen bonds need large amounts of energy to break them.	Water is liquid at most temperatures at which life exists, so is a useful medium for metabolic reactions.
	Water evaporates as hydrogen bonds are broken and heat from water is used.	Sweating and transpiration enable animals and plants to lose heat. Water acts as a coolant.