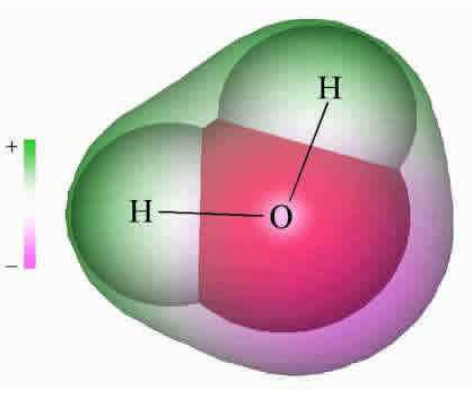
Water – properties and importance

Water is the most important molecule on the Earth. It provides a basis for all living life and makes up between 75%-90% of the total mass of a cell. Some animals such as jellyfish are made up of 96% water. 75% of the total of Earth's surface is covered with water.

Water is a simple molecule made of 2 hydrogen atoms and one oxygen atom, H_20. The hydrogen and oxygen atoms are bonded covalently. Water is not a linear molecule; the two hydrogen atoms form a bond with the oxygen at the angle of 104.5 degrees.



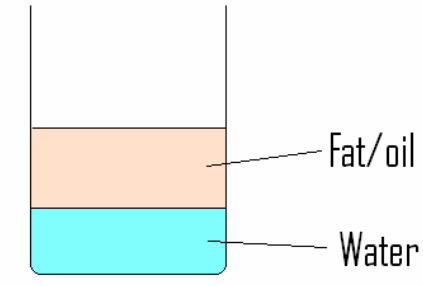
Its properties allow it to act as a solvent, a reactant, as a molecule with a consistent properties, as an environment and as a temperature stabiliser.

With water, the large number of protons in the oxygen nucleus have a stronger attraction for these shared electrons than the comparatively tiny hydrogen nuclei. This pulls the electrons slightly closer to the oxygen nucleus and away from the hydrogen so that the oxygen develops a slight negative charge and the hydrogen's a slight positive charge. This makes the molecules slightly polar.

Water can dissolve polar or ionic substances and can keep them in solution because of water's own polar properties. Substances that dissolve in water are known as hydrophilic substances (eg: sugar). Ionic substances such as sodium chloride (NaCl) are made up of positive and negative ions. Sodium chloride is held in it's structure by the strong attraction between it's positive sodium ions and negative chloride ions. Normally these ionic attractions require a large amount of energy to break but when put into water the negative oxygen side of the water molecules cluster around the positive sodium ions Na+ and the positive hydrogen atoms cluster around the negative chloride ions Cl-. The attraction between the Na+ and Cl- ions is weakened as the ions are separated.

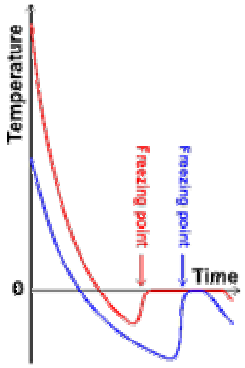
Water can also separate covalently bonded molecules such as glucose and sucrose because the polar hydroxyl groups (-OH) in its structure forms hydrogen bonds with the water separating the molecules from each other.

Water's properties as a solvent are vital to life as most biochemical reactions such as respiration occur in solution. This is why cell cytoplasm contains about 90% water. Water cannot dissolve hydrophobic substances such as fats and oils (see diagram), these are used by organisms as cell membranes to separate cells and also as waterproofing as they prevent water from entering the organism if it is covered in a hydrophobic substance.



Water also has many thermal properties as a temperature stabiliser. Water has a boiling point of 100oC and a melting point of 0oC, this is unusual for a molecule of it's size because other molecules of a similar size such as carbon dioxide CO2 are all gaseous at room temperature whereas water is a liquid. This is because of the hydrogen bonds which hold the water molecules in a liquid state.

Water also has a high specific heat capacity, the result of this is that it takes 4.2 Joules of energy to raise one gram of water by 1oC. This means that it takes a lot of heat energy to raise the temperature of water significantly, but once warm it cools slowly. This is essential to life where internal body temperature has to be maintained at a constant temperature and fluctuations can result in a breakdown of essential processes. Large bodies of water will remain at an almost constant temperature with only very gradual changes which makes temperature regulations for organisms far more straightforward.



Due to the large number of bonds holding water molecules together, it takes 2 kJ per gram of water which is a considerable amount of energy to separate the bonds and turn the liquid to vapour. Water is therefore described as having a high latent heat of evaporation. Animals use this property of water by using excess body heat to evaporate water from their surfaces, resulting in them transferring a lot of energy into the environment, but only losing a little water. Sweating and panting are based on this principle.

Water also has a high latent heat of fusion from solid to liquid. It requires 300 J per gram of ice to melt it to water. This means that water stays liquid. This is vital in the case of cytoplasm in cells which is made of a high percentage of water because once frozen the cell would be irreparably damaged. The freezing point of water is also lowered by solutes because the soluble molecules disrupt the hydrogen bonds making the water freeze at a lower temperature and it easier to melt ice. As there are many solutes in cytoplasm the water will not freeze until well below 0oC and the cells are protected until the temperature gets extremely low.

As water cools its density increases and the hydrogen bonds between the water molecules take on a more latticed formation as ice. Yet ice floats on the surface of water which means its density must be lower than that of water. Water is at its most dense at 4oC which is when its bonds are closest together. When water freezes, the lattice arrangement of its structure move apart slightly and it floats on the surface. This means that the layer of ice insulates the water below which stays at 4oC and aquatic life can continue (eg: the ice at North Pole floats on Arctic Ocean).

Water is the key in condensation reactions where water is removed from molecules to bond them together, this occurs with many sugars and carbohydrates (eg: sucrose and maltose).

By adding water, molecules can be split up, this is called hydrolysis and is essential to animals and plants because it allows them to utilise stored foods which are in long chains by breaking off smaller molecules (eg: glycogen to glucose).

Respiration produces water as a by-product. A large amount of energy is produced by oxidising hydrogen, which contains so much energy it is an explosive gas, into water. Photosynthesis uses water as a source of hydrogen atoms which are needed to produce glucose which is then stored in the plant cells as starch or used for respiration. Without water these two essential reactions would not occur and life would not be able to continue on earth.

An important property of water is also its transparency, it allows sunlight to pass through it so aquatic plants can photosynthesis and on a larger scale, allow life on earth to begin, since life started in the oceans with small organisms which relied on sunlight for the reaction photosynthesis to take place.

Water molecules are highly cohesive because of the hydrogen bonds between the molecules. Water forms spherical droplets which have the maximum inner area and least surface area when in contact with a hydrophobic material. The cohesive properties of water allows plants to pull up water through xylem vessels from the roots to the leaves, this is called the transpiration stream. It also means that the water molecules where the water meets the air will be tightly held together and the water molecules below them to form an ‘elastic film’ known as surface tension (also how contact lenses stay in). Small creatures can get stuck in the surface water because they cannot break the water surface tension, creatures like water skaters can move across the surface of the water without sinking as they have hydrophobic feet which stops them from breaking the surface tension.

Another of water's properties is that is has a strong hydrostatic force, meaning water is incompressible. This provides support for soft bodied creatures such as worms, slugs and jellyfish which therefore do not require a supporting skeletal system. Water allows cells filled with water to become turgid and due to its incompressibility plants can support themselves.

General surfactants, such as soap, have a hydrophylic end and a hydrophobic end. The soap (or surfactant) tends to ‘float’ on the surface of water so that the hydrophylic end is directed toward the water and the hydrophobic end is oriented toward air or whatever hydrophobic surface is in contact with the aqueous solution. This surface orientation of soap, greatly changes the surface properties of the water.

To conclude, water's unique properties make it perhaps the most biologically important substance on the planet. No other substance shares similar properties to water and in the way that one single molecule can possess such varied and essential characteristics.