

Properties of Water

Guided Notes – Student Edition

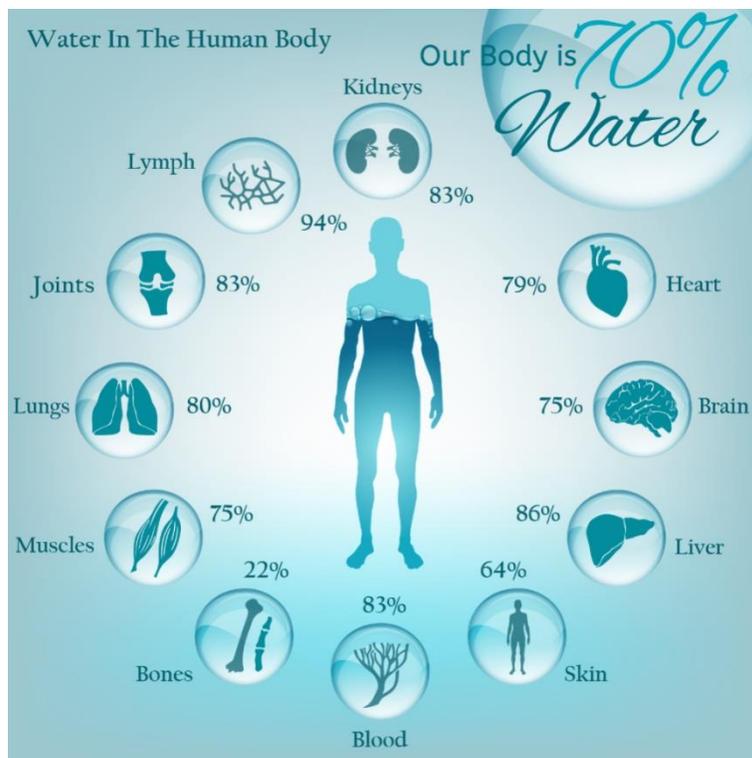
Why is Water Necessary?

Water is found everywhere on Earth; it covers around _____ of the Earth's surface in the form of rivers, lakes, oceans and underground water. Of these, the oceans represent approximately _____ of the total water present on the planet. Everywhere that water is found on Earth; _____ is also found. Therefore, there is little wonder that between 50% and 80% of all life forms exist in the ocean.

Water is needed for almost all of life's processes, including:

- digestion
- circulation
- respiration
- transport
- controlling internal body temperature and
- maintaining the internal environment

The human body is made up of approximately _____ water. This value is an average measure of all the main areas of the body. The image below depicts the concentration of water in these areas.



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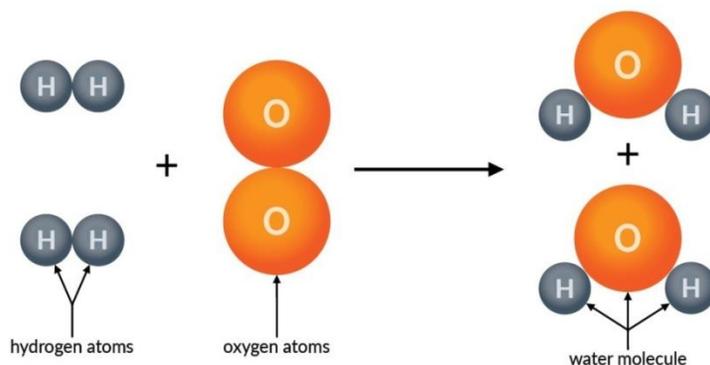
Even those organisms which seem to be able to survive in very hot, dry climates still require water and have mechanisms which enable them to conserve this vital liquid.

The Properties of Water

There are several properties of water which make it essential to living things. These properties include its structure and its ability to act as a solvent for almost any substance.

1. The Structure of Water

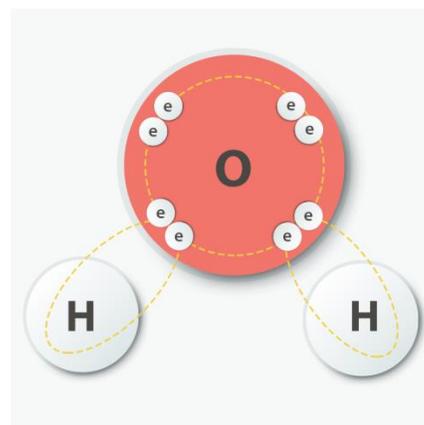
The water molecule contains three atoms; two _____ atoms joined to one _____ atom; this gives it the chemical formula of _____. The chemical equation for the formation of water is shown below:



The hydrogen atoms are bonded to the oxygen atom with _____. In these bonds, the _____ electron on each hydrogen atom is shared with oxygen, so that all three atoms can complete their valence shells. Each water molecule is bonded to other water molecules through _____ bonding. These are _____ bonds which keep the water molecules together as a substance.

Covalent bonding – the details

Oxygen has _____ electrons in its valence shell. This shell is only _____ full and can fit up to eight. This means that oxygen must add two more electrons or find another atom which it can share its electrons with in order to become _____.



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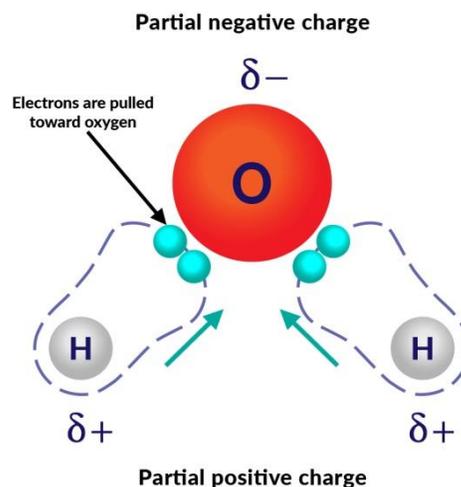
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Hydrogen, in contrast, only has _____ valence electron. This means that in order to complete its valence shell it needs either lose that one electron or share it with another atom. In the case of water, hydrogen and oxygen _____ their electrons, completing each other's valence shells and forming a single _____ bond. This can be seen in the diagram to the right.

The Polarity of Water

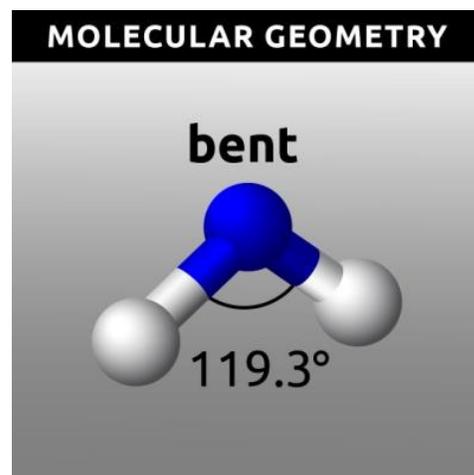
The electronegativity of an atom is the measure of its ability to _____ electrons towards itself. Oxygen is _____ electronegative than hydrogen. This means that in the water molecule, the electrons which belong to hydrogen will be much closer to the _____ atom than the _____ atom.

Since electrons have a _____ charge, and they are closer to the oxygen atom, oxygen acquires this negative charge. This also means that hydrogen acquires a partial positive charge since the electrons are further away from it. The difference in charge across the chemical bonds in water, therefore, make it a polar molecule.



Molecular Geometry of Water

Water molecules show a _____ molecular geometry. This shape occurs due to the arrangement of electrons around the central _____ atom. Oxygen has two pairs of electrons in its valence shell and two single (unpaired) electrons. These two unpaired electrons are _____ with two hydrogen atoms to form the covalent bonds in the water molecule. Since electrons are negative, they _____ each other. This results in the electrons in the molecule spacing themselves out so that they have the least repulsion between each electron pair, resulting in the bent conformation.



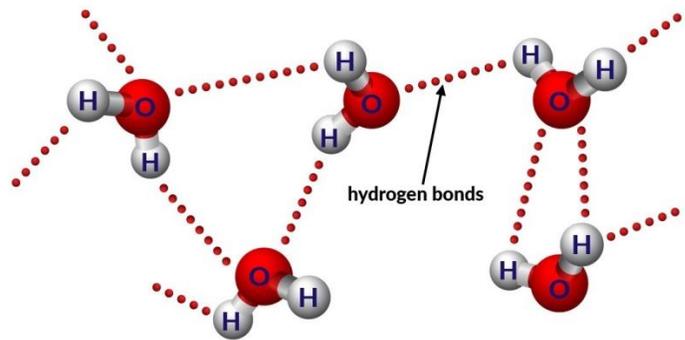
Hydrogen bonds between water molecules

Not only are there bonds between the atoms _____ the water molecule, but there are also bonds which exist between the _____. These are called hydrogen bonds and exist as a result of the _____ charges on the atoms mentioned in the section above.

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The hydrogen atoms partially positive charge makes it attractive to the partially _____ charge of the oxygen on another water molecule. This enables a _____ bond to form and holds the water together, with each water molecule being bonded to four other water molecules.



It is the hydrogen bonding as well as the molecular _____, and the polarity or the high difference in electronegativity in the water molecule which gives water some its unique properties.

2. The Phases of Water

In nature, water exists as three states - _____ ice, _____ water and as a _____ - water vapor or steam. These states occur within a very narrow temperature range, all of which occur on Earth. Other substances may occur as a liquid or vapor on Earth but, their other states only occur in temperatures or pressures which would be too extreme for living organisms to survive in.

- *Example 1: Methane*

Methane (CH_4) was initially thought to play a similar role to water as a universal solvent. However, methane only exists as a liquid in very cold temperatures (182 degrees Celsius) which much too cold for living organisms.

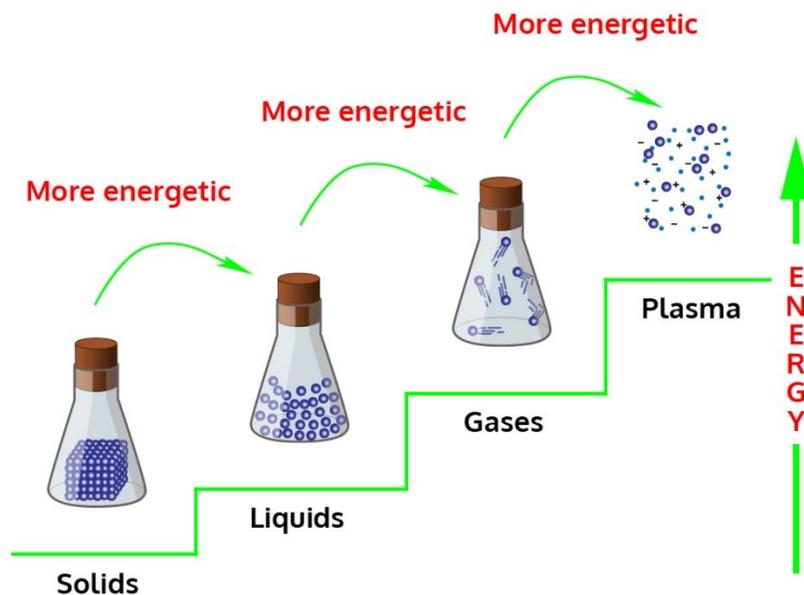
- *Example 2: Ammonia*

Ammonia, like water, is relatively abundant in the universe and is polar like water. However, scientists are yet to find any large amounts of ammonia anywhere in our solar system; therefore this has been ruled out as a universal solvent.

In general, as a substance cools and then solidifies, its atoms and molecules move _____ .
The closer the particles are, the less energy they possess.

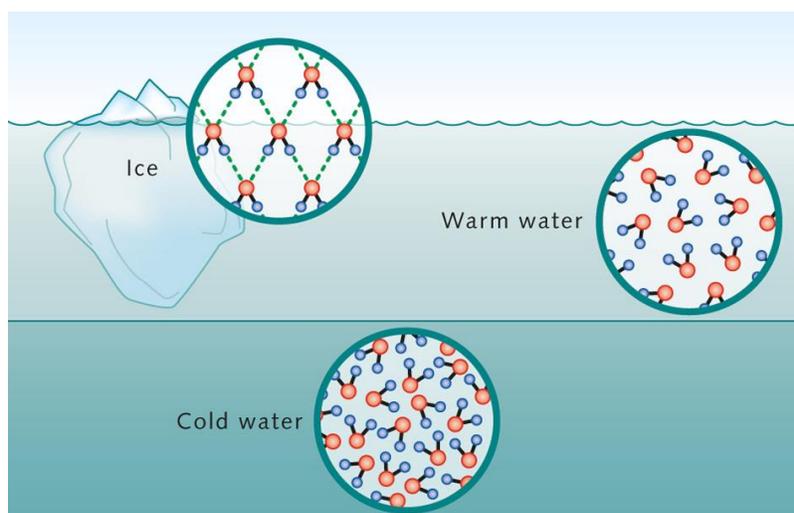
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Water behaves differently:

In the solid phase, water _____, and the particles move further apart. Cold water, at 4 degrees Celsius is very dense and shows particles in more tightly-packed conformation than seen in solid ice. As heat is added, the water expands once more, and the molecules spread out. This property explains why icebergs are partially seen floating on top of the water.



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While freezing, molecules of water lose a certain amount of heat energy and move very slowly, making it easier for them to form _____ bonds. Their crystalline shape now is open and hexagonal which causes their increase in volume. The volume and density of water are inversely proportional. Therefore, as density decreases, the volume increases.

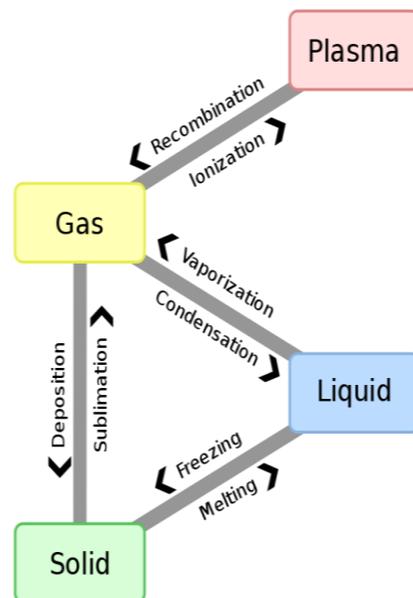
High boiling point and melting point

Melting point is temperature at which a substance changes from a solid to a liquid.

Boiling point is the temperature at which a substance changes from a liquid to a vapor or gas.

Oxygen is found in group _____ of the periodic table. In general, elements found in the same group show similar properties.

The table below shows the boiling and melting points for other group 16 elements when bonded to hydrogen.



Compound	Boiling point	Melting point
Hydrogen Telluride	-4°C	-49°C
Hydrogen Selenide	-42°C	-64°C
Hydrogen Sulfide	-62°C	-84°C
Water	100°C	0°C

Using this information, water should have a boiling point of less than _____°C and a melting point less than _____°C. However, water, at normal atmospheric pressure, boils at 100°C and ice melts at 0°C, which does not follow the pattern seen in other group 16 hydrides.

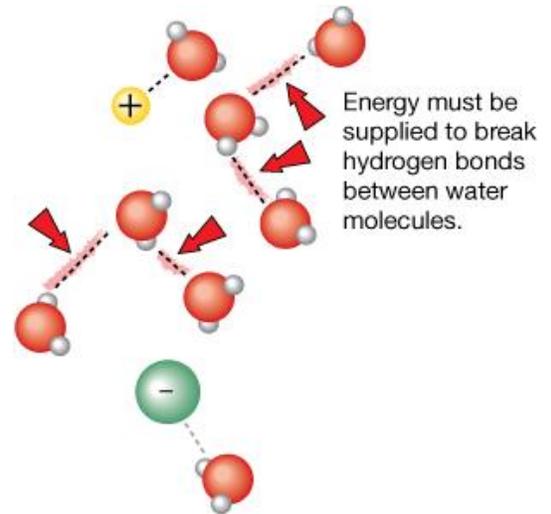
The abnormal boiling and melting points of water are due to the presence of the _____ bonds. These bonds require additional energy and must be broken before the individual water molecules gain sufficient heat energy to move apart and change state from ice to water (melting) or from water to steam (boiling).

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Latent and Specific Heat Capacity

The amount of energy that needs to be added to 1 gram of a substance to break its bonds and change its state is called its _____. This property makes water very resistant to changes in temperature and explains why it's so useful for putting out fires. Therefore we can say that water has a high latent heat of melting and evaporation.



Specific heat is the amount of _____ one gram of a substance must gain or lose to change its temperature by one degree Celsius. For water, this value is one calorie or 4.184 Joules which is the highest specific heat capacity of any liquid.

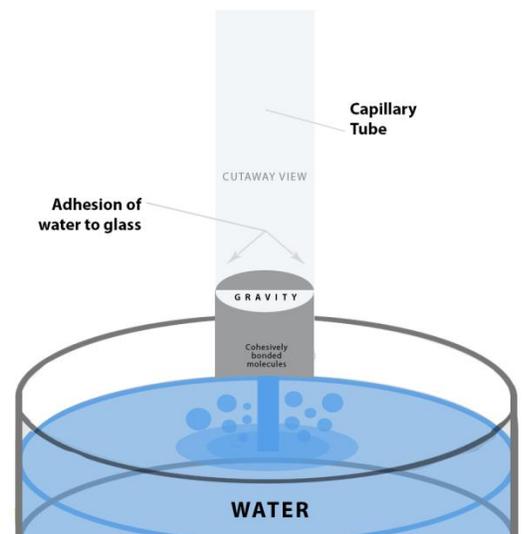
Relevance to Biology

A high specific heat capacity enables the bodies of _____ organisms such as humans to maintain their body temperature in different environments. It also allows large bodies of water e.g. the ocean to absorb large amounts of energy from the sun without changing temperature. Many organisms rely on a constant temperature in order to maintain their food supply, oxygen levels etc.

Cohesion

Water molecules stick together. This is called _____.

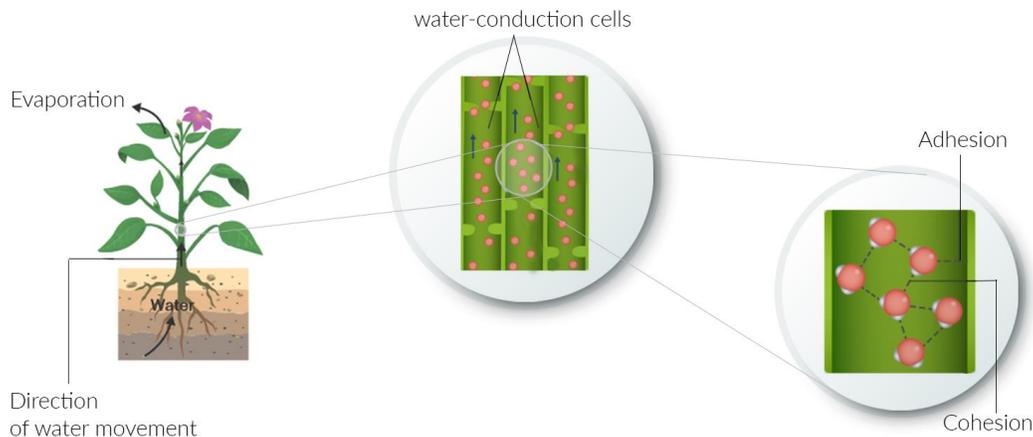
This is the attraction between molecules of the same substance. The cohesive properties of water cause the molecules on the surface of water to be drawn _____, which is why drops of water form beads on a smooth surface. Cohesion also explains why some insects and spiders can walk on a pond's surface. This property also allows water to move through narrow spaces such as the roots and shoots of plants and the smallest capillaries in the human body as cohesion holds the column of water together as it moves.



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ADHESION & COHESION OF WATER MOLECULES

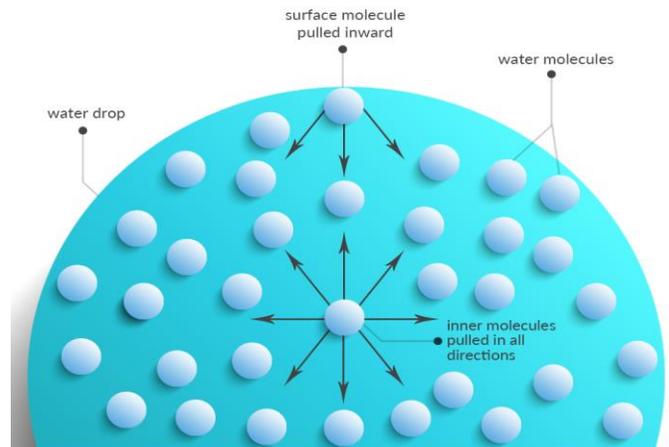


Cohesion and Surface Tension

The cohesiveness of water is due to its hydrogen bonding. This gives it the highest surface tension of any liquid. Surface tension describes the ability of a liquid to _____ into the minimum surface area possible and explains why water exists as _____ rather than a thin layer.

The water molecules on the surface of a water droplet are attracted to the molecules which are directly _____ them. In contrast, the water molecules underneath the top layer are attracted to molecules in _____ direction. Surface tension explains why certain organisms such as water striders can walk on the surface of water.

SURFACE TENSION IN A WATER DROPLET



Adhesion

Water also shows _____. This is the attraction between molecules of different substances and can be seen by the _____ of a volume of water in a measuring cylinder. The surface of the water in the measuring cylinder shows a gentle curve in the center due to the adhesion between liquid and glass molecules. The curve appears because the adhesion between the _____ substances is stronger than cohesion between the water molecules.

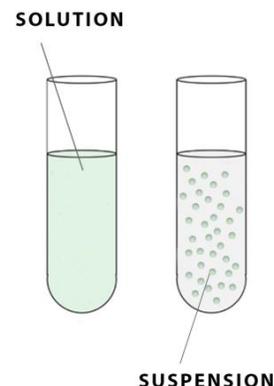
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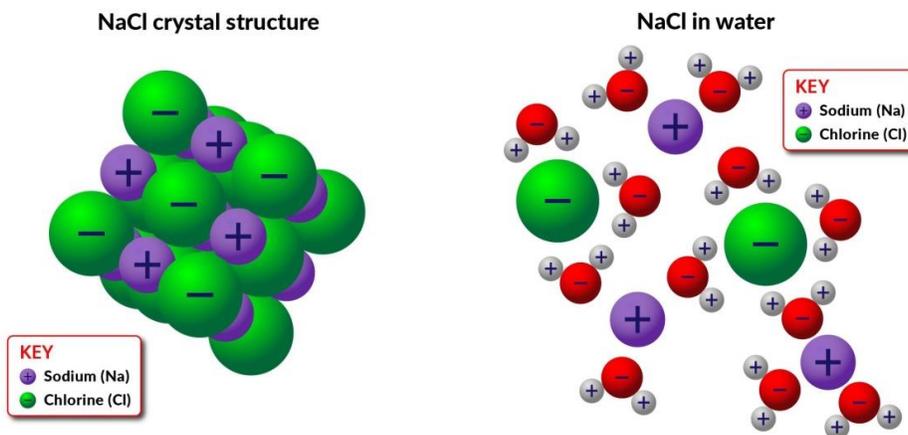
Adhesion between water and glass also allows water to rise in a narrow tube against the force of _____. This effect is called _____ and is responsible for pulling water out of the roots of a plant and up into its stems and leaves.

3. Water as a universal polar solvent

Water is not always found in its pure form, often occurring as a part of a mixture. A mixture is defined as the combination of two substances that are not _____ bonded together. Water forms two types of mixtures, a solution and a suspension. A solution has its components _____ distributed throughout, whereas a suspension shows an _____ distribution. In many cases, the suspension must be shaken to redistribute the components as the solute (dissolved solids) will settle on the bottom of the container over time.



If a spatula of table salt (NaCl) is placed in a beaker of warm water, the sodium and chloride ions on the surface of the crystal are attracted to the polar water molecules. This causes the ions to break away from the crystal structure and become surrounded by _____ molecules. The ions gradually become dispersed in the water, forming a salt-water _____. In this example, the table salt is the _____, since it is the substance being dissolved. Water is the _____—the substance in which the solute dissolves. Water’s polarity gives it the ability to dissolve both ionic compounds and other polar molecules, such as sugar. It is for this reason that water is often called the _____. Being the universal solvent enables water to carry substances such as essential ions (electrolytes) into and out of the cell.

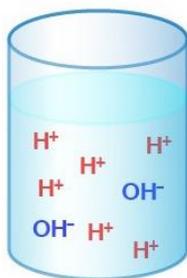


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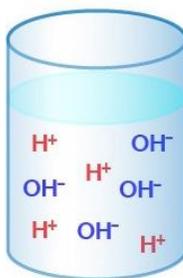
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Water is a Neutral Substance.

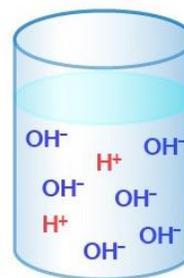
Water is a neutral substance which means that it is neither an acid nor a base and has a pH of _____. Therefore, it does not affect blue or red litmus paper. This effect is due to the positive hydrogen ions being present in equal proportions to the negative OH ions.



Acidic solution



Neutral solution



Basic solution