

Without water, life would not exist on Earth. All chemical reactions in living organisms take place in water, all living cells contain water, and most organisms are largely composed of water. For example, the human body is about 70% water. On a larger scale, water provides habitats for billions of living things, and controls the climate of the entire planet.

What properties of water make it so unique? And how do these properties affect chemical and biological systems?

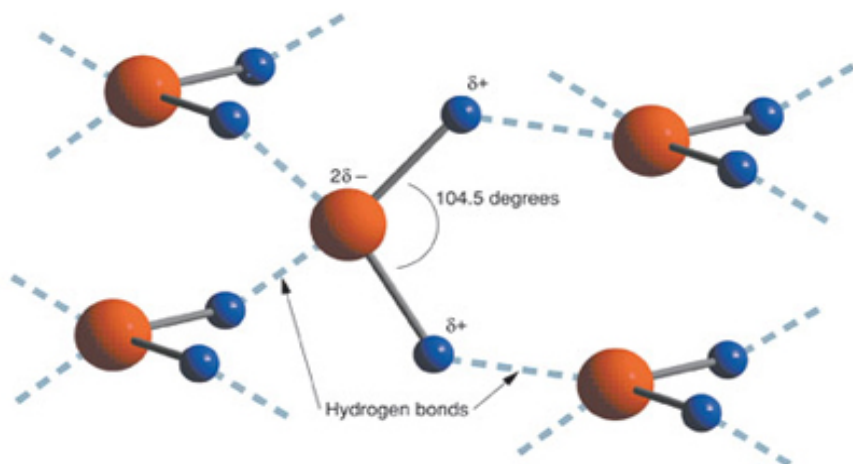
Properties of the Water Molecule

The properties of water start with the properties of the water molecule, H_2O . Oxygen atoms are much more electronegative (“electron-loving”) than hydrogen atoms. As a result, the oxygen atom in a water molecule has a slight negative charge, and the two hydrogen atoms have slight positive charges.

Water molecules have a bent shape, due to the presence of two nonbonding electron pairs on the oxygen atom. As a result, one side of the molecule (the side with the oxygen atom) is slightly negative, while the other side (the side with both hydrogen atoms) is slightly positive. In other words, water is a **polar** molecule.



All living things need water.



Hydrogen bonds are responsible for water's properties.

Water molecules are also able to form **hydrogen bonds** with each other and with certain other compounds. A hydrogen bond is an intermolecular bond that forms between the oxygen atom on one water molecule and the hydrogen atom on another water molecule. Because each oxygen atom has two nonbonding electron pairs, each oxygen can form

two hydrogen bonds.

Although many compounds can form hydrogen bonds, water is the only compound that can simultaneously bond to two hydrogen atoms through covalent bonds, and two hydrogen atoms through hydrogen bonds. Because of its hydrogen bonding ability, water can form unique three-dimensional structures when it freezes.

Essential Properties of Water

The properties of the water molecule make water unique in the following ways:

- **Universal solvent:** The polarity of water makes it an excellent solvent. Ionic and polar compounds dissolve in water, because positive and negative ions can be stabilized, or *hydrated*, by being surrounded by water molecules. Because of the ability of water to dissolve so many compounds, water is often referred to as the *universal solvent*. Water is used as the solvent in a wide range of chemical reactions performed in research and in industry.
- **Cohesion:** Because of hydrogen bonding, water molecules tend to stick to each other more than the molecules of other liquids do. This property allows water in plants to rise from the roots to the leaves where it is used in photosynthesis. This property also causes the surface of water to have a very high surface tension.
- **Density:** When water freezes, it forms three-dimensional structures due to hydrogen bonding. As a result, water molecules are further apart in ice than in

liquid water, and ice is less dense than water. As a lake or pond freezes, ice floats to the top, leaving liquid water below. This property allows aquatic organisms to survive the winter, living in the liquid water that remains under the surface of a frozen lake.



Because of hydrogen bonding, water molecules have cohesion. The attractive forces between water molecules cause them to form spherical droplets.

- **Heat capacity:** Due to hydrogen bonding, water has an unusually high heat capacity. This means that it requires a lot of energy to heat water. The high heat capacity of water allows living organisms to maintain constant body temperatures. This is essential for the enzymes that are involved in the chemical reactions of metabolic processes to function properly. The high heat capacity of water also allows water to moderate local climate: during the day, water absorbs heat energy and decreases the local temperature. During the night, water releases stored heat energy, and increases local temperature. The heat capacity of water, along with its other properties, is also essential to the water cycle and the greenhouse effect, which control weather and climate on Earth.
- **Boiling and freezing points:** Due to hydrogen bonding, water has unusually an unusually high boiling point and an unusually high freezing point. If it behaved like other liquids with similar molecular sizes, water would naturally occur on Earth only as a gas—and oceans, lakes, and bodily fluids would not exist.