Hydrogen bonds in water

The structure of water molecules and how they can interact to form hydrogen bonds.

Introduction to the properties of water

You are a talking, tool-making, learning bag of water. Okay, that's not completely fair, but it's close since the human body is 60 to 70% water. And it's not just humans—most animals and even tiny bacteria are made up mostly of water1^11start superscript, 1, end superscript. Water is key to the existence of life as we know it. That may sound dramatic, but it's true—and dramatic things that are true are what make life interesting! Most of an organism's cellular chemistry and metabolism occur in the water-based "goo" inside its cells, called cytosol.

Water is not only very common in the bodies of organisms, but it also has some unusual chemical properties that make it very good at supporting life. These properties are important to biology on many different levels, from cells to organisms to ecosystems. You can learn more about the life-sustaining properties of water in the following articles:

- Solvent properties of water: Learn how and why water dissolves many polar and charged molecules.
- Cohesion and adhesion of water: Water can stick to itself (cohesion) and other molecules (adhesion).
- Specific heat, heat of vaporization, and density of water: Water has a high heat capacity and heat of vaporization, and ice—solid water—is less dense than liquid water.

Water owes these unique properties to the polarity of its molecules and, specifically, to their ability to form hydrogen bonds with each other and with other molecules. Below, we'll look at how this hydrogen bonding works.

Polarity of water molecules

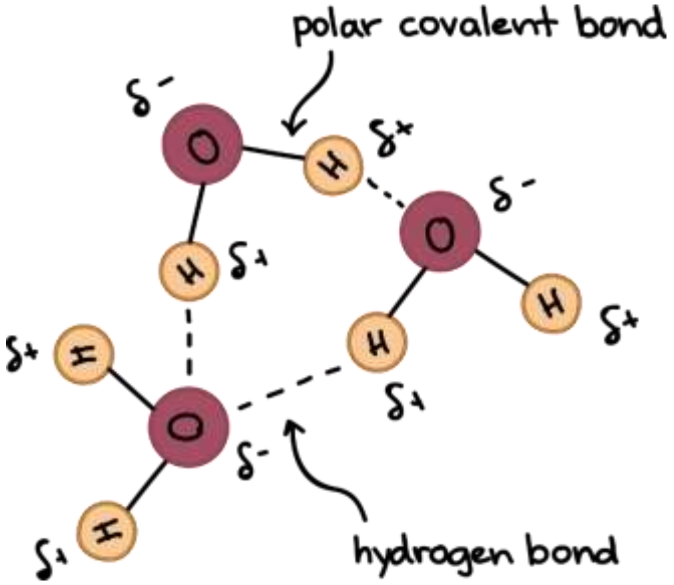
The key to understanding water's chemical behavior is its molecular structure. A water molecule consists of two hydrogen atoms bonded to an oxygen atom, and its overall structure is bent. This is because the oxygen atom, in addition to forming bonds with the hydrogen atoms, also carries two pairs of unshared electrons. All of the electron pairs—shared and unshared—repel each other.

The most stable arrangement is the one that puts them farthest apart from each other: a tetrahedron, with the $\text{O}-\text{H}$ bonds forming two out of the four "legs". The lone pairs are slightly more repulsive than the bond electrons, so the angle between the $\text{O}-\text{H}$ bonds is slightly less than the 109° of a perfect tetrahedron, around 104.5°.[2]

Because oxygen is more electronegative—electron-greedy—than hydrogen, the O atom hogs electrons and keeps them away from the H atoms. This gives the oxygen end of the water molecule a partial negative charge, while the hydrogen end has a partial positive charge. Water is classified as a **polar molecule** because of its polar covalent bonds and its bent shape $2,^3$.

Hydrogen bonding of water molecules

Thanks to their polarity, water molecules happily attract each other. The plus end of one—a hydrogen atom—associates with the minus end of another—an oxygen atom.
These attractions are an example of **hydrogen bonds**, weak interactions that form between a hydrogen with a partial positive charge and a more electronegative atom, such as oxygen. The hydrogen atoms involved in hydrogen bonding must be attached to electronegative atoms, such as O, N or F.



Water molecules forming hydrogen bonds with one another. The partial negative charge on the O of one molecule can form a hydrogen bond with the partial positive charge on the hydrogen's of other molecules.

Water molecules are also attracted to other polar molecules and to ions. A charged or polar substance that interacts with and dissolves in water is said to be **hydrophilic**: *hydro* means "water," and *philic* means "loving." In contrast, nonpolar molecules like oils and fats do not interact well with water. They separate from it rather than dissolve in it and are called **hydrophobic**: *phobic* means "fearing." You may have noticed this as a not-so-handy feature of oil and vinegar salad dressings. Vinegar is basically just water with a bit of acid.