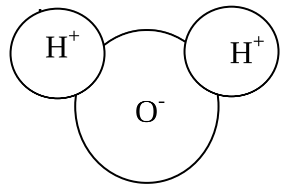
The Properties of Water

If you could see molecules of water and how they act, you would notice that each water molecule electrically attracts neighboring molecules. Each molecule has two hydrogen atoms and one oxygen atom, H_20. A simple diagram of the asymmetrical shape of a water molecule resembles a “Mickey Mouse” head.



The “stickiness” of water is due to the two hydrogen atoms which are arranged on one side of the molecule and are attracted to the oxygen atoms of other nearby water molecules in a state known as **"hydrogen bonding."** (If the molecules of a liquid did not attract one another, then the constant thermal agitation of the molecules would cause the liquid to instantly boil or evaporate.) See the “Explain the Lab” page for a diagram of hydrogen bonding.

The hydrogen atom has one valence electron and an electronegativity value of 2.2. Oxygen has six valence electrons with an electronegativity value of 3.44. Electronegativity is the tendency an element has to attract electrons. The higher the electronegativity of an atom, the greater its tendency is to attract electrons in a shared pair. This means that oxygen has a greater tendency to attract electrons. Therefore, the valence electron on each hydrogen atom tends to be pulled toward the oxygen atom, leaving an uneven distribution of electrons called polarity.

Since opposite charges attract, it is no surprise that the hydrogen atoms of a water molecule like to point toward the oxygen atom of other molecules. Of course, in the liquid state, the molecules have too much energy to become locked into a fixed pattern; nevertheless, the numerous temporary "hydrogen bonds" between molecules make water an extraordinarily sticky fluid.

Cohesion and Adhesion

The property that causes water molecules to be attracted to other water molecules is called **cohesion.** When water is attracted to molecules of other materials it is referred to as **adhesion**. Because of the unequal charge distribution, the hydrogen of one water molecule is attracted to the oxygen of other molecules. This gives water its cohesive and adhesive properties. These two properties of water can help explain how water can bulge upward from the rim of a glass filled with water. **Surface tension** is the name given to this phenomenon.

Adhesion and cohesion explain what happens when you dip one end of a piece of paper towel into a glass of water. The water will climb up the fibers of the paper, getting it wet above the level of the water in the glass. We know gravity is pulling down on the water, so why is the water moving up? The water molecules' positive and negative charges are attracted to the positive and negative charges in the cellulose molecules in the paper. The water molecules also "stick" to each other, causing an upward movement.

Surface Tension

Within a body of water, every molecule is engaged in a tug of war with its neighbors on every side. For every "up" pull there is a "down" pull, and for every "left" pull there is a "right" pull, and so on, so that any given molecule feels no net force at all.

At the surface things are different. There is no up pull for every down pull, since of course there is no liquid above the surface; thus the surface molecules tend to be pulled back into the liquid. It takes work to pull a molecule up to the surface. If the surface is stretched - as when you blow a bubble - it becomes larger in area, and more molecules are dragged from within the liquid to become part of this increased area. This "stretchy skin" effect is called **surface tension**. Surface tension plays an important role in the way liquids behave. If you fill a glass with water, you will be able to add water above the rim of the glass because of surface tension. Try this and you will notice the water “piling up” above the rim of the glass.

There are many simple experiments that can be performed with surface tension, and many real world examples that can be used to illustrate its effects. A water strider can “scoot” rapidly across the surface of a pond without breaking the surface tension. You will notice a dimpling of the water’s surface where each leg touches the surface.

You can float a paper clip or a sewing needle on the surface of water. Place the paper clip on a fork (or another paper clip that is unfolded) and lower it slowly onto the water’s surface. The paper clip is supported by the surface-tension “skin” of the water.

Surfactants and Surface Tension

Soaps and detergents have a polar “head” to which water is attracted, known as the hydrophilic end. It also has a non-polar “tail” that is hydrophobic or water fearing (repelling). When these substances are added to water, they weaken the strength of the surface tension by interfering with hydrogen bonding between water molecules. At the surface the non-polar tails stick out away from the water reducing the surface tension.

To illustrate this, sprinkle grains of black pepper over the surface of a bowl of water. Dip a swab in detergent and touch it to the middle of the water’s surface. The pepper grains will rapidly move to the side of the bowl when the detergent “breaks down” the surface tension. This effect can also be simulated by a group performing a tug of water with a rope. As long as tension is equal in both directions nothing happens; but if the rope is cut, both groups will suddenly fall down.