

Properties of Water

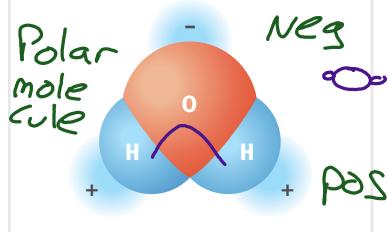
Gather Evidence

As you read, record evidence to answer this question: What characteristics of a water molecule make it unique?

When you're thirsty, you need to drink something that is mostly water. Why is water so necessary for life? Your cells, and those of every other living thing on Earth, are mostly water. The composition and structure of the water molecule gives it unique properties essential to living things.

Polar Molecules

FIGURE 9: In water molecules, the oxygen atom has a slightly negative charge, and the hydrogen atoms have slightly positive charges.



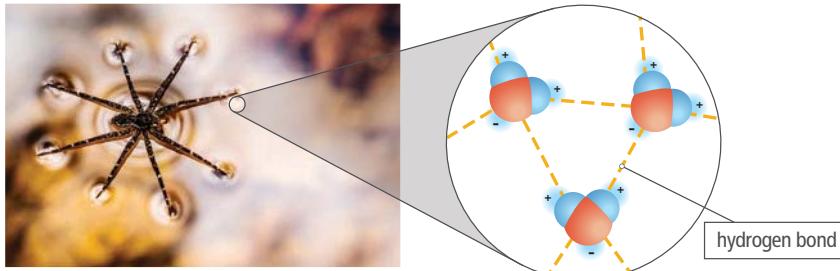
A water molecule has two covalent bonds. A water molecule is an example of a polar molecule. You can think about polar molecules similarly to how you think about the poles of a magnet. Just as magnets have a north and a south pole, polar molecules have a region with a slightly positive electric charge and a region with a slightly negative electric charge. Just like poles of magnets repel one another and opposite poles attract one another, so do the poles in polar molecules.

Polar molecules form when atoms in the molecule have unequal pulls on the electrons they share. In a molecule of water, the greater number of protons in the nucleus of an oxygen atom attracts the shared electrons more strongly than does the single proton in a hydrogen atom. Because electrons carry a negative charge, the oxygen atom gains a slight negative charge, and the hydrogen atoms gain slight positive charges. The more equally charged the atoms in chemical bond are, the less polar a bond is, because the atoms share the electrons more equally.

Hydrogen Bonds

When a hydrogen atom is part of a polar molecule, the hydrogen atom has a slight positive charge. This slightly positive atom is attracted to a slightly negative atom, often oxygen or nitrogen, forming a hydrogen bond. Life depends on hydrogen bonds. For example, hydrogen bonds are part of the structures of proteins and DNA molecules. Hydrogen bonding is important in other ways, as shown in Figure 10.

FIGURE 10: Water's surface tension comes from hydrogen bonds that cause water molecules to stick together, allowing this spider to walk across the surface of water.



Analyze

How are hydrogen bonds similar to ionic bonds?

Properties of Hydrogen Bonds

Individual hydrogen bonds are about 20 times weaker than typical covalent bonds, but they are strong enough to have an influence on water molecules. As a result, a large amount of energy is needed to overcome the interactions among water molecules. Water is a liquid at the temperatures that support most life on Earth because of hydrogen bonding among the water molecules. Without hydrogen bonds, water would boil at a much lower temperature than it does, because less energy would be needed to change liquid water into water vapor. Hydrogen bonds are responsible for other important properties of water.

High Specific Heat Hydrogen bonds give water an abnormally high specific heat. This means that water resists changes in temperature. This property is very important in cells. The processes that produce usable chemical energy in cells release a great deal of heat. Water absorbs the heat, which helps to regulate cell temperatures and maintain homeostasis.

Cohesion The attraction among molecules of a substance is called cohesion. Cohesion from hydrogen bonds makes water molecules “stick” to each other and produces surface tension.

Adhesion The attraction among molecules of different substances is called *adhesion*. For example, water molecules can stick to each other or to the sides of a glass tube. Adhesion helps plants transport water from their roots to their leaves, because water molecules stick to the sides of the tissues through which water passes.



Explain As shown in Figure 11, water sticks to the sides of a glass tube, but mercury forms a rounded, bubble-like surface at the top of the liquid. Which is probably greater in mercury—cohesion or adhesion? Explain your answer.

FIGURE 11: When water and mercury are placed in glass tubes, the water adheres to the sides of the tube. The mercury, by contrast, forms a rounded surface at the top of the liquid.



Water as a Solvent

Many substances dissolve in the water in your body. When one substance dissolves in another, a solution forms. A solution has two parts: the solvent and the solute. The substance in a solution that is present in the greater amount and that dissolves another substance is the solvent. A solute is a substance that dissolves in a solvent. The amount of solute dissolved in a certain amount of solvent is a solution’s concentration.

Although water is known as the “universal solvent,” not all substances dissolve in water. For example, nonpolar molecules, such as oil, will not dissolve in water. Substances that are similar in structure mix more readily. This phenomenon is also known as “like dissolves like.” For example, nonpolar molecules will dissolve in nonpolar solvents. Some vitamins, such as vitamin E, are nonpolar. They do not dissolve in water in the body, but they do dissolve in nonpolar substances such as the lipids that make up body fat. This is why vitamin E is classified as a fat-soluble vitamin.



Predict Why is the ability to dissolve many substances important for a solvent that is found in living things?



Analyze The liquid part of blood, called plasma, is about 95% water. Molecules such as sugars and proteins are dissolved in the water of blood plasma. What is the solute and what is the solvent in blood plasma?

Acids and Bases

Some compounds separate into ions when they dissolve in water. An acid is a compound that releases a proton—a hydrogen ion (H^+)—when it dissolves in water. An acid increases the concentration of H^+ ions in a solution. Bases are compounds that remove H^+ ions from a solution. When a base dissolves in water, the H^+ concentration decreases. A solution's acidity, or H^+ concentration, is measured by the pH scale.

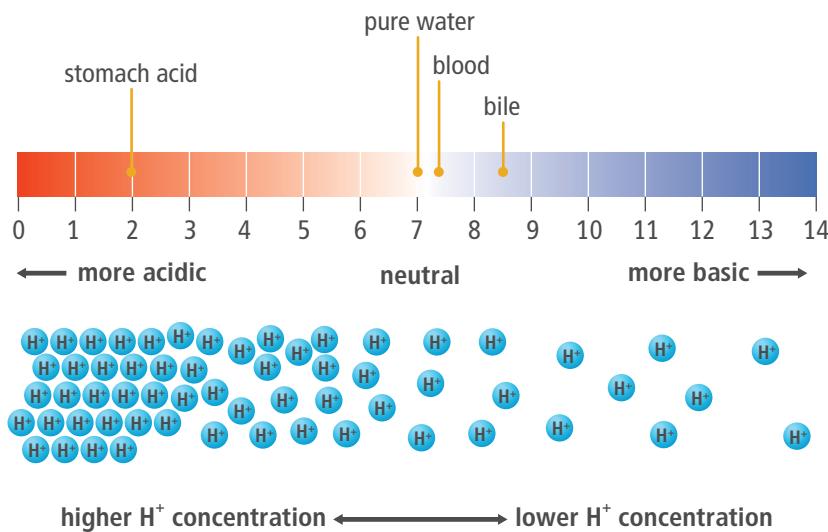
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Hands-On Lab



Investigating Acids and Bases Use different tools to measure the pH of various substances including foods and cleaning products.

FIGURE 12: The pH of a solution depends on the concentration of H^+ ions.



Analyze Lemon juice has a high hydrogen ion concentration. Where would you expect to find it on the pH scale?

In order to maintain homeostasis, most organisms need to keep their pH within a very narrow range around neutral (pH 7.0). However, some organisms require a pH outside this range. For example, the azalea plant thrives in acidic (pH 4.5) soil, and a microorganism called *Picrophilus* survives best at an extremely acidic pH of 0.7.

For all of these different organisms, pH must be regulated. One way pH is regulated in organisms is by substances called buffers. A buffer is a compound that can bind to an H^+ ion when the H^+ concentration increases, and can release an H^+ ion when the H^+ concentration decreases. The buffer maintains a more constant level of H^+ ions and helps to maintain homeostasis.



Explain Construct an explanation for how hydrogen bonds between water molecules contribute to the properties important for the survival of living things. In your explanation, discuss the structure of the water molecule, and explain how this structure contributes to the unique properties of water. Finally, explain how these properties are related to the proper functioning and survival of living things.