

Properties of Water--Notes

Water is a molecule made up of two hydrogen atoms and one oxygen atom. It has the formula H_2O . When oxygen and hydrogen combine (H-O-H) they form a v-shaped triangular molecule. While water molecules are electrically neutral, the oxygen atom holds a small negative charge and the two hydrogen atoms hold small positive charges. Water molecules are attracted to each other, creating hydrogen bonds. These strong bonds determine almost every physical property of water and many of its chemical properties too. Scientists believe this unusual electrical balancing, called polarity, gives water some of its remarkable properties.

A large part of the mass of most organisms is simply water. In human tissues the percentage of water ranges from 20% in bones to 85% in brain cells. The water content is greater in embryonic and young cells and decreases as aging occurs. About 70% of our total body weight is water; as much as 95% of jellyfish or certain plants is water. Water is not only the major component of organisms but also one of the principal environmental factors affecting them. Many organisms live within the sea or in freshwater rivers, lakes, and puddles. The physical and chemical properties of water have permitted living things to appear, to survive, and to evolve on this planet. Water is the solvent, the medium and the participant in most of the chemical reactions occurring in our environment.

Water the Universal Solvent

Scientists often call water the “universal solvent” because water can **dissolve** more substances than any other liquid. Some substances, like common table salt (sodium chloride, $NaCl$), dissolve in water very easily. When placed in water, sodium chloride molecules fall apart. The positively charged sodium ion (Na^+) binds to oxygen, while the negatively charged chloride ion (Cl^-) attaches to hydrogen. This makes a very stable “salty” water molecule.

This property of water allows for the transport of nutrients vital to life in animals and plants.

A drop of rainwater falling through the air dissolves atmospheric gases. When rain reaches the earth, it affects the quality of the land, lakes and rivers.

Surface Tension

Water molecules at the surface (next to air) hold closely together, forming an invisible film. Water’s surface tension can hold weight that would normally sink. You can carefully float a paper clip on top of the water. Some aquatic insects such as the water strider or pond skater rely on surface tension to walk on water. Surface tension is essential for the transfer of energy from wind to water to create waves. Waves are necessary for rapid oxygen diffusion in lakes and seas. Next to mercury, water has the highest surface tension of all commonly occurring liquids.

Water is Sticky

Cohesion—Water molecules stick to each other. This is due to the hydrogen bonds among the molecules. Water molecules at the surface have a much greater attraction for each other than for molecules in the air. This cohesiveness creates a high surface tension at the surface of the water. The water molecules at the surface crowd together, producing a strong layer as they are pulled downward by the attraction of other water molecules beneath them.

Adhesion—Water molecules stick to other substances. You can see this property when water creeps up the inside of a drinking glass. Think of a sponge or a paper towel used to “soak up” spilled water. This is how water makes things wet. Water also clings to living things. Most plants have adapted to take advantage of water’s adhesion that helps move water from the roots to the leaves. This is called capillary action. This can also be seen as blood moves through our capillaries, carrying nutrients to each cell within our body.

One of the tallest plants is the redwood tree. Water moves from its roots to its leaves, more than 310 feet above the ground. As a plant loses water through pores in the leaves, more water moves up from roots and stems to replace the lost water. The process of water loss by leaves is known as **transpiration**.

Thermal Properties

Water absorbs or releases more heat than many substances for each degree of temperature increase or decrease. Because of this, it is widely used for cooling and for transferring heat in thermal and chemical processes. Differences in temperature between lakes and rivers and the surrounding air may have a variety of effects. For example, local fog or mist is likely to occur if a lake cools in the surrounding air enough to cause saturation—small water droplets are suspended in the air. Large bodies of water, such as the oceans or the Great Lakes, have a profound influence on climate. They are the world's great heat reservoirs and heat exchangers and the source of much of the moisture that falls as rain and snow over adjacent landmasses. When water is colder than the air, precipitation is curbed, winds are reduced, and fog banks are formed. These properties of water are crucial in stabilizing temperatures on earth.

Specific Heat—Water has a high specific heat. The amount of energy required to raise the temperature of water by one degree Celsius is quite large. Because so much heat loss or heat input is required to lower or raise the temperature of water, the oceans and other large bodies of water have relatively constant temperatures. Thus, many organisms living in the oceans are provided with a relatively constant environmental temperature. The high water content of plants and animals living on land helps them to maintain a relatively constant internal temperature (Ours is about 98.6°F).

The specific heat of water is 5 times greater than of sand. On a hot summer day, beach sand may quickly warm to the point that it is too hot to stand on while ocean water warms only a little. During the evening the temperature of sand will decrease while the temperature of the ocean remains relatively constant.

Heat of Vaporization—Water has a high heat of vaporization. Water absorbs heat as it changes from a liquid to a gas; the human body can dissipate excess heat by the evaporation of its sweat. A leaf can keep cool in the bright sunlight by evaporating water from its surface. Water's high heat conductivity makes possible the even distribution of heat throughout the body.

Boiling and Freezing—Pure water at sea level boils at 100°C (212°F) and freezes at 0°C (32°F), but extra energy is needed to push water molecules into the air. This is called latent heat—the heat required to change water from one phase to another. At higher elevations (lower atmospheric pressure) water's boiling temperature decreases. This is why it takes longer to boil an egg at higher altitudes. The temperature does not get high enough to cook the egg properly. If a substance is dissolved in water, then the freezing point is lowered. That is why we spread salt on streets in winter to prevent ice formation. Energy is lost when water freezes. A great deal of heat is released into the environment when liquid water changes to ice. It is lost when the high energy phase of liquid water moves to the low energy phase of ice. Nights when ice freezes often feel warmer than nights when ice melts.

Water density--Water is most dense at 4°C and then begins to expand again (becoming less dense) as the temperature decreases further. This expansion occurs because its hydrogen bonds become more rigid and ordered. As a result, frozen water (ice floats) upon the denser cold water. The expansion of water takes place even before it actually freezes. This explains why a pond freezes from the surface down, rather than from the bottom up. As water temperature drops, the colder water (0-4°C) where it is less dense—rises to the pond surface. It freezes to form a lid of ice. This ice insulates the water below from the wintry chill so that it is less likely to freeze. Organisms that inhabit the pond are able to survive the frigid winter below the icy surface.

Solid Expansion--For most substances, solids are denser than liquids. But the special properties of water make it less dense as a solid. Ice floats on water! Strong hydrogen bonds formed at freezing 0°C (32°F) lock water molecules away from each other. When ice melts, the structure collapses and molecules move closer together. Liquid water at 4°C (39.2°F) is about 9% denser than ice. This property plays an

important role in lake and ocean ecosystems. Floating ice often insulates and protects animals and plants living in the water below.

pH-- Water molecules have a tendency to ionize. They dissociate into ions (charged particles) hydrogen ions (H^+) and hydroxide ions (OH^-). In pure water a very small number of water molecules form ions in this way. The tendency of water to dissociate is balanced by the tendency of hydrogen ions and hydroxide ions to reunite to form water. A neutral solution contains an equal number of hydroxide ions and hydrogen ions. A solution with a greater concentration of hydrogen ions (H^+) is said to be acidic. A solution with a greater concentration of hydroxide (OH^-) ions is said to be alkaline or basic.

Name: _____

Exploring Properties of Water

Read each question thoroughly and answer. Make sure you follow directions for each activity. You may use the handout provided for more information.

1. Water as a solvent

- Fill a beaker with 200 mL of distilled water.
- Place 1 tsp. (10 mg) of sugar into the water.
- Stir the water for 20 seconds.
- Describe what happens to the sugar.
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2. Water is cohesive- Water molecules at the surface (next to the air) stick close together, forming an invisible film. The next two examples will demonstrate cohesion (surface tension).

Water on a Penny

- Using the dropper, place a few drops of water on a penny.
- What happens to the water?
- Add enough drops of water to cover the penny, but do not let the water spill over the penny.
- Describe what the water looks like. (you may use a drawing)

Float a Paper Clip

- Carefully float the following items on top of the water: a toothpick, a small paper clip, and a large paper clip. Describe what happens. What other objects might you try to float on top of the water?

3. Water has a high specific heat

- Imagine yourself out on the beach at 1:00 p.m. in July. It is a beautiful sunny day, with an air temperature of 89 degrees F. What would the sand feel like under your bare feet? What would the ocean water feel like?
- Using the information given to you about water, explain the temperature differences between the sand and the water.

4. Oil (a lipid) is a non-polar organic molecule (it contains carbon and hydrogen bonds). These compounds form interfaces with water molecules and will not dissolve.

- Place a few drops of oil into the test tube. Add 1 inch of water and replace the cap.
- Shake the test tube.
- Describe what you see.

5. Can a Solid Float on top of water?

- Place a couple of ice cubes into the beaker of water.
- Describe what you see.
- At what temperature is water a liquid? _____ At what temperature is water a gas? ____
At what temperature is water a solid? _____