3D Molecular Designs™

...where molecules become real™

10 ways to use Water Kit©

3D Water Makes Learning Sensational!

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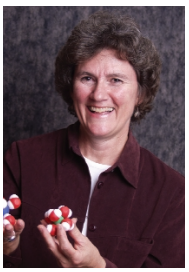

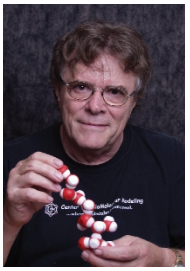

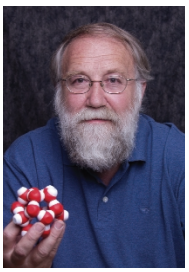

Ask the Professor

If you have questions about water or other molecules, be sure to contact us through our ***Ask the Professor*** link on the Water Resource pages of the 3D Molecular Designs website 3dmoleculardesigns.com

Pictured from top to bottom:
Mary Gruhl, Ph.D., University of Wisconsin - Milwaukee
Michael Patrick, Ph. D., University of Wisconsin - Madison
Tim Herman, Ph. D., Milwaukee School of Engineering

Q. Why is Water a Liquid?

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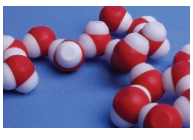
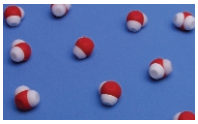
A. Like other compounds, water can be converted between solid, liquid, and gas phases. **The remarkable property of water is that it is a liquid over a very large temperature range.**

Use the Water Kit© to show what water molecules look like when they are in the solid, liquid and gas states.

- As a solid, the molecules are held close together in a tight, orderly fashion, with little freedom of motion.



- As a liquid, the molecules are close together but are not tightly or rigidly held. Each molecule can move with respect to other molecules.



- As a gas, the molecules are in random motion. Distances separating each molecule are large compared with the size of the molecules.

Q. What Holds Water Molecules Together?

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A. Water molecules interact with each other by forming ***hydrogen bonds.*** That is, the positive hydrogrens are attracted to and "stick to" the negative oxygens. This phenomenon is called ***cohesion,*** which means attraction between like molecules. Hydrogen bonds are different from the ***covalent bonds*** that hold together the hydrogen and oxygen in single water molecule.

Use the Water Kit© to:

- Examine the way two water molecules interact. The magnets simulate the polar nature of the water molecule. Unequal sharing of electrons in the ***covalent bond*** between hydrogen and oxygen pulls more electrons to the oxygen, making it slightly negative and leaving the hydrogens slightly positive.

- Hydrogen bonds are formed when the slightly positive hydrogen is aligned close enough to the slightly negative oxygen. One water molecule can form hydrogen bonds with four other water molecules — 1 through each of the hydrogens and 2 through the oxygen.

- Compare the difference in effort it takes to pull 2 water molecules apart with that needed to pull 1 of the hydrogen atoms from the oxygen of a single water molecule. Simulate the constantly changing bonding patterns by putting the water models in a clear container and shake. Hydrogen bonds are roughly 20 times weaker than covalent bonds. They rapidly form, break and re-form. Each bond lasts only a few trillionths of a second as the water molecules constantly form new bonds with a succession of partners.

Q. How Does Water Boil? How Does Water Freeze?

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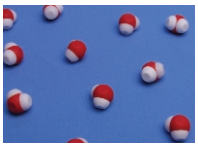
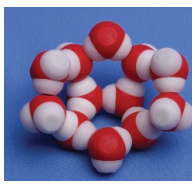
A.



At sufficiently high temperatures (100°C), the average ***kinetic energy*** of water molecules is great enough to overcome the attraction of one molecule to another by breaking the hydrogen bonds as water transitions from liquid to gas.



As temperature decreases, the average kinetic energy of the water molecules decreases. Beginning at 0°C, there is not enough energy to break hydrogen bonds and water molecules become fixed in space, forming a crystal.

Q. Why Does Ice Float?

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A. There are several ways water forms the highly ordered, 3-D structure, ***ice***. The most common form of ice is created when 1 water molecule rigidly remains bonded to 4 other water molecules. These rigid ice crystals have more open space than in their liquid form, which means there are fewer molecules per unit volume than water as a liquid. Thus ice is less dense than water as a liquid and floats in the liquid form of water.

Use the Water Kit© to make an ice crystal and compare it with randomly bonded water molecules.
Note that additional water molecules could be placed in the holes that are present in the ice lattice.

Eco-notes: *What is the significance of water transitioning to and from a liquid?*
What is the significance of ice being less dense than liquid-water?

Water is effective as a heat bank, because it absorbs or releases a relatively large amount of heat with only a slight change in temperature. This means that water has a high ***specific heat***. ***Specific heat*** is the amount of heat required to raise the temperature of one gram of a substance by 1 degree Celsius. To raise the temperature of water — increase the kinetic energy of water molecules — many hydrogen bonds must be broken. Water absorbs a substantial amount of heat while its temperature rises only slightly. Water can also give off a great deal of heat with only a slight decrease in temperature when the bonds are reformed at lower temperatures.

Q. How Does Salt Dissolve in Water?

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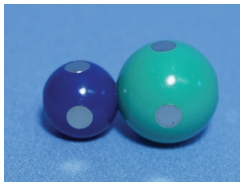
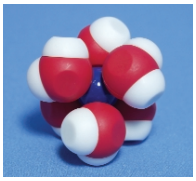
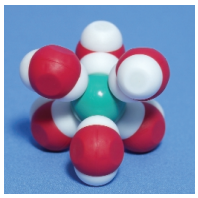
A. Sodium ions and chloride ions are held together tightly by electrostatic forces,forming crystalline salt — an ordered crystal. When salt is added to water, sodium and chloride ions interact with water. Positive hydrogen forms an electrostatic interaction with the chloride ions (green), and negative oxygen forms an electrostatic interaction with sodium ions. When enough water molecules surround the sodium-chloride crystal, the ions are pulled apart and salt is dissolved.





Use the Water Kit© to show how water can dissolve salt, by forming a "shell" of water molecules around the negatively charged chloride ion with their hydrogens atoms directed toward the chloride. The magnets in the hydrogen atoms will snap onto the chloride's magnets. Form another "shell" around the sodium, with the oxygen atoms directed toward the sodium and the magnets in the oxygen will snap onto sodium's magnets.



* The Water Kit© activity can demonstrate the principle behind hydration, but it can't simulate the true chemical reaction. For example to approximate a physiological salt solution (~0.1M), the ratio of water molecules to ions should be roughly 600 water molecules for every sodium chloride ion pair, since the concentration of water is 55.6M.

Q. Why Will Oily Substances Not Dissolve in Water?

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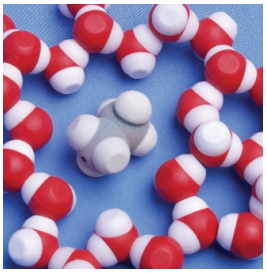
A.

Many chemical compounds are made of carbon atoms covalently bonded to hydrogens. Oily substances are made of carbon-hydrogen bonds and are non-polar. In a carbon-hydrogen bond the electrons are equally shared between the carbon and the hydrogen, and the bond is not charged (also called non-polar). As a result, carbon-hydrogen bonds don't have charges to form hydrogen bonds with water, so water and oil don't hydrate (mix). If you shake the molecules, you will see tiny droplets as the water tries to create open spaces to for non-polar oils or various organic solvents.



Use the Water Kit© to show the lack of hydrogen bonds with ethane — a simple two carbon molecule — and how a water "cage" forms around ethane.

Q. Sugar Has Many Carbons, Why Does It Dissolve In Water?

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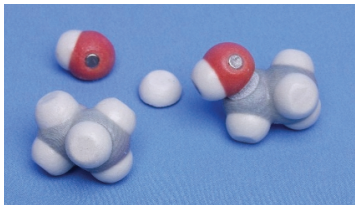
A.

Although sugar is made of many carbon and hydrogen atoms, it also has several ***hydroxyl (OH) groups***. These ***OH groups*** act in a similar way to water. The groups are polar with a negative oxygen and positive hydrogen. As a result, ***OH groups*** in sugar form hydrogen bonds with water and dissolve in the same way as salt dissolves.



Use the Water Kit© to show how ethanol dissolves in water. While not a sugar, ethanol illustrates how the presence of a hydroxyl group enables hydrogen bonding — ***hydration***. *Note: the rest of the ethanol molecule is non-polar.*

Q. Why Does Water Form Droplets On An Apple?

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A.

In its liquid form, water molecules are pulled in all directions by hydrogen bonds. However, at the surface of liquid-water — ***water-air interface*** — the water molecules are pulled in only 2 ways — to the side and toward the interior. As a result, the molecules exposed to the air tighten. This ***surface tension*** is the amount of energy required to stretch or increase the surface of a liquid by a unit area. Water has very high ***surface tension*** compared to other liquids due to its hydrogen bonding.

Since there is no significant attraction between polar water molecules and the non-polar wax molecules on an apple or freshly waxed car, a drop of water assumes the shape of a small round bead because a sphere minimizes the surface area of a liquid.

Use the Water Kit© to simulate ***surface tension*** and explore what ***surface tension*** means.

Q. How Does Water “Go Up” Plants?

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A. ***Capillary action***, the spontaneous rising of water in a tube-like structure — whether a glass tube or a plant vessel — is possible due to cohesion and surface tension. Water sticks to the tube wall through a process called ***adhesion***. ***Adhesion*** is an attraction between unlike molecules, such as between water and a glass surface. ***Surface tension*** tightens the water molecules, thus pulling them up the tube. In a capillary tube, the height to which water rises is determined by a balance between the adhesive force and the weight of the water in the tube. In a plant, water reaches the leaves through microscopic vessels that extend upward from the roots. Water that evaporates from a leaf is replaced by water molecules from the vessels, with the hydrogen bonds literally pulling water up aided by the ***adhesion*** of the water to the surface of the vessel walls.

Use the Water Kit© to explore adhesion by forming a vertical chain of water molecules. You can simulate adhesion on a metal tube and demonstrate evaporation with either a metal, glass or clear plastic tube.


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Caution: This product should be kept out of the reach of children under the age of 3, because the molecules or their pieces may present a choking hazard to small children. The Water Kit is a science education product, not a toy. It is not intended for children under 8 years old.
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