One way to write the formula for hydrogen hydroxide is HOH. You can also write this formula as H_2O. Written this way, you may recognize it as the formula for water. A molecule made of two atoms of hydrogen bonded to one atom of oxygen can be called hydrogen hydroxide, dihydrogen monoxide, hydronium hydroxide, or even hydric acid. In this course, we will use the molecule's most familiar name, water. See if you can tell which of the items shown below contains water.

Multiple Choice

Instructions

Which items below do you think contain water?

A scorpion

1. Yes
2. No

Aluminum Foil

1. Yes
2. No

Lightning

1. Yes
2. No

A human

1. Yes
2. No

A plant

1. Yes
2. No

Gold

1. Yes
2. No

3. A scorpion
4. **Answer:** A scorpion is a living organism. It not only has water but it also has the unique ability to retain this water for a large amount of time. This contributes to the scorpion's adaptation to desert living.
5. Aluminum Foil
6. **Answer:** Aluminum is an element and does not contain water.
7. Lightning
8. **Answer:** Lightning is a stream of electrical energy. Although it passes through the air which contains water molecules, it does not contain water itself.
9. A human
10. **Answer:** A large portion of the human body contains water.
11. A plant
12. **Answer:** All plants, trees, and even the soil all contain water.
13. Gold
14. **Answer:** Gold is another pure substance. It is an element that does not contain water.

What Makes Water Unique?

Video Text Version

Water appears a very simple chemical, but it has some remarkable properties, and it is unique in some ways because of its molecular structure and composition. A water molecule forms when two hydrogen atoms join one oxygen atom, forming two covalent bonds where electrons are shared. Its chemical formula is the first one everybody learns—H_2O. Often the phase is indicated with the formula. A water molecule has a bent triangular shape. Water in large volumes can appear blue, which is because of the absorption of red and infrared light. This is due to the vibration of bonds between the oxygen and hydrogen atoms. This is unique to water and demonstrates the relationship between its chemical structure and properties.

Water is a polar molecule. The pairs of electrons shared by the hydrogen atoms in a water molecule are actually more attracted to the oxygen atom with its eight protons than to the hydrogen atoms with their one each. The hydrogen end of the molecule is weakly positive and the oxygen end is weakly negative. This property of an atom within a molecule is known as electronegativity. This table shows electronegativity values for various atoms relative to fluorine. Oxygen is 3.44 while hydrogen is 2.20. The polar nature of water's molecular structure means there are strong bonds between water molecules. They are held together by hydrogen bonds. The weakly or partially positive hydrogen end of one molecule is attracted to the weakly or partially negative oxygen of another molecule and hydrogen bonds form. This structural characteristic of water explains why its surface tension is so high and how liquid water is able to spread like a film, pool into droplets, and remain in droplets on vertical surfaces like a window despite the downward pull of gravity.

A water molecule contains covalent bonds between the two hydrogen atoms and the oxygen atom. Recall that in a covalent bond the valence electrons are shared by both atoms in the bond.

Some atoms that form covalent bonds share the valence electrons equally. In the case of a water molecule, this is not true.

Look at the diagram of a water molecule. Notice that both electron pairs are closer to the oxygen atom than they are to the hydrogen atoms. The oxygen atom attracts the electrons more strongly than do the hydrogen atoms.

The valence electrons spend more time near the oxygen atom than they do near the hydrogen atoms because of this attraction.

Since electrons are negatively charged particles, the shared pairs of electrons in a water molecule give the oxygen portion of the molecule a slight, or partial, negative charge. The oxygen atom does not have a full negative charge of -1. It has a negative charge, but that negative charge is very small—a partial negative charge. Each hydrogen atom in a water molecule has a partial positive charge. The overall molecule has no total charge.

The bonds between oxygen and hydrogen in water are called polar covalent bonds. In a polar covalent bond, the electrons spend more time near one of the atoms than the other.

Polar covalent bonds most commonly form between atoms of elements that are far apart on the periodic table.

Look again at the water molecule. Notice that all of the positive partial charge is concentrated at one "side" of the molecule.

All of the positive charge is concentrated on one side of the water molecule, and the negative charge is concentrated at the other. Therefore, the water molecule is said to be a polar molecule. Each water molecule acts like a tiny, electrically charged particle.

The positive "side" of the water molecule can attract negatively charged particles. The negative "side" can attract positively charged particles.

A covalent bond in which the electrons are shared equally between the atoms is called a nonpolar covalent bond. Nonpolar covalent bonds typically form between atoms of the same element.

It is important to realize that most bonds are not completely polar or completely nonpolar. Some bonds lie somewhere in between.

The H–H bond in a molecule of hydrogen gas.

Nonpolar Polar

The H–N bond in a molecule of ammonia.

Polar Nonpolar

The O–O bond in a molecule of oxygen gas.

Polar Nonpolar

The C–Cl bond in a molecule of chloroform.

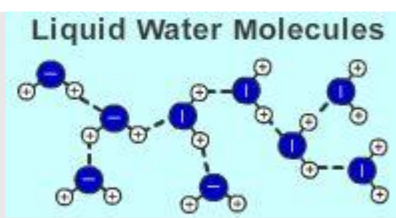
Polar Nonpolar

Blow up a balloon and rub it against your shirt or hair several times. Hold the balloon close to a thin stream of water flowing from a faucet. Make sure the balloon does not touch the water.
The water should be as thin of a stream as you can make it without it breaking into drops. When the balloon is placed near the water from the faucet, the water stream bends toward the balloon!

Why does this happen?

Rubbing the balloon with the cloth produces a negative charge on the balloon's surface. When you bring the negatively charged balloon close to the stream of water, the positively charged ends of the water molecules are attracted to the negative charges on the balloon. This attraction makes the water stream bend toward the balloon.

Water has some unusual properties compared to many other substances. Many of these properties are vital to life as we know it. Many of water's properties are the result of the partial charges on the water molecule and the hydrogen bonds that form between the positive end of one water molecule and the negative end of another water molecule.



When most liquids freeze, the molecules pack together and move closer. Water is an exception. When water molecules freeze, they actually move farther apart.

Look again at the arrangement of the water molecules in liquid water. Notice that the molecules are not bonded together in any special arrangement. Also notice that hydrogen bonds do not form between each positive and negative end of nearby molecules. Now watch what happens when water freezes.

When water freezes, the water molecules arrange themselves into rigid structures resembling six-sided figures, or hexagons. This specific arrangement requires more space than the arrangement of water molecules in liquid water. As a result, frozen water, or ice, is less dense than liquid water. That means ice will float in liquid water.

The fact that ice floats in liquid water is important to fish and all aquatic life. If ice were denser than liquid water, lakes and ponds would freeze from the bottom up. This would kill all the organisms living in the water during the winter months.

Fortunately, this does not happen. Instead, ponds freeze from the top down. The ice that forms floats on top of the water. The layer of ice at the surface of a lake or pond acts as an insulator. The ice keeps the liquid water beneath it from coming into contact with the cold air above, which helps keep the rest of the water from freezing. Underneath the layer of ice, the water remains in the liquid state. This allows the organisms in the water to survive when the weather is cold.

Water as a Solvent

Recall that one of the properties of ionic compounds is that many of them dissolve in water. When an ionic compound dissolves in water, it breaks apart into its ions. Complete the activity to see how an ionic solid, such as sodium chloride, dissolves in water.

Notice that the partial positive charge of the hydrogen atom in each water molecule is attracted to the negatively charged chloride ion, and the partial negative charge of the oxygen atom in each water molecule is attracted to the positively charged sodium ion. As more water molecules surround each ion, the solid sodium chloride is pulled apart into separate sodium ions and chloride ions. Finally, the sodium chloride no longer exists as a solid. It has completely dissolved in the water. This mixture of sodium ions and chloride ions dissolved in water is a solution.

Just as water dissolves solid sodium chloride, it can also dissolve many other solid ionic compounds. The partially charged water molecules pull apart the ions.

Water as a Solvent

The animation shows a beaker with water. Salt is added and then stirred. The view zooms in on the molecules in the beaker. The animation shows a cluster of green and gray circles. The gray circles are labeled with a “positive sign” and they represent the sodium ions (Na^+) in salt. The green circles are labeled with a “negative sign” and they represent the chlorine ions (Cl^-) in salt. As water molecules approach this cluster of salt, the negative ends of water molecules (H) are attracted to the positive sodium charges. The positive charge of oxygen (O) in each water molecule is attracted to the negative chlorine atoms. As water molecules approach this cluster of salt, the negative ends of water molecules (O) are attracted to the positive sodium charges. The positive charge of hydrogen (H) in each water molecule is attracted to the negative chlorine atoms.

This is an experiment you can do at home. What you need for this experiment: liquid soap, a cup, or a small bowl. So I've got the staple. OK, so as you can see, it is floating in the water, which is pretty amazing because the steel that it's made from has a density that is higher than water, so it should sink. Actually, the hydrogen bonds between the water molecules that are supporting [an object], we call that surface tension. And you can think of it as, when water molecules get close to one another they hold hands, and while they are holding hands they are able to support things like our staple or like the insects that walk on water. Now, if we put something like soap in there, it actually breaks the hydrogen bonds between the molecules. So think of it, if you get soap on your hands it is harder to hold hands with someone. So now let's try putting our staple into the soapy water. And notice, when I put it [the staple] in this time, the soap in the water has destroyed the surface tension and it sinks. We're using staples, but if you want a real challenge you are going to use a sewing needle. You have to get it perfectly flat and dry on the surface of the water so that it floats.

Hydrogen bonds form in water as it cools and are broken as it heats up. Read how H_2O reacts when in a liquid, solid, and vapor state. The animation observes water in a glass beaker. It measures the temperature of the water and zooms in on the arrangement of water molecules in the water.

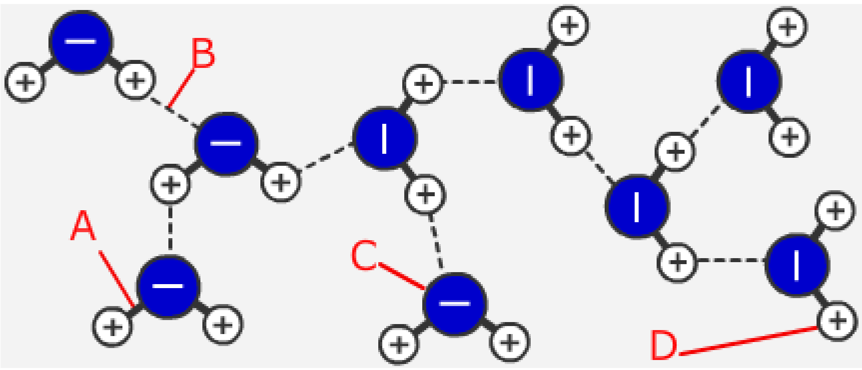
Ice: The animation shows water molecules positioned in a hexagonal shape. The temperature indicates that the water is 0 ºC (32 ºF). Notice the hydrogen bonds that form between water molecules as the water reaches a freezing temperature. As this happens, a hexagonal pattern emerges. As water freezes in the beaker, it expands and rises.

Water: The animation shows water molecules oriented so that the positive atoms of one molecule are aligned with the negative atoms of another molecule. They do not form a particular pattern. The temperature indicates that the water is between 0 ºC (32 ºF) and 100 ºC (212 ºF). Notice that in the water state, there are no hydrogen bonds between water molecules. This allows each molecule to move freely.

Water Vapor: The animation shows the hydrogen and oxygen atoms breaking apart. The temperature indicates that the water is above 100 ºC (212 ºF). If enough heat energy is added to the water, the covalent bond between the hydrogen and oxygen will be broken. This releases hydrogen and oxygen gas into the air.

What is the hydrogen bond in the diagram?

○ D ○ A ○ C ○ B



Which property of water is the result of the attraction between water molecules which results in the ability to support small objects?

- Specific heat
- Covalent bonds
- Ionic bonds
- Surface tension

Which would you expect to stay warm for the longest period of time?

- Bicycle
- Water
- Window pane
- Sand