Water Properties
Facts and Figures About Water

Water is unique in that it is the only natural substance that is found in all three physical states—liquid, solid, and gas—at the temperatures normally found on Earth.

Water freezes at 32° Fahrenheit (F) and boils at 212°F (at sea level, but 186.4° at 14,000 feet). Water is unusual in that the solid form, ice, is less dense than the liquid form, which is why ice floats.

Water is called the "universal solvent" because it dissolves more substances than any other liquid. This means that wherever water goes, either through the ground or through our bodies, it takes along valuable chemicals, minerals, and nutrients.

Pure water has a neutral pH of 7, which is neither acidic (<7) nor basic (>7).

The water molecule is highly cohesive—it is very sticky. Water is the most cohesive among the non-metallic liquids.

Pure water, which you won't ever find in the natural environment, does not conduct electricity. Water becomes a conductor once it starts dissolving substances around it.

Water has a high heat index—it absorbs a lot of heat before it begins to get hot. This is why water is valuable to industries and in your car's radiator as a coolant. The high heat index of water also helps regulate the rate at which air changes temperature, which is why the temperature change between seasons is gradual rather than sudden, especially near the oceans.

Water has a very high surface tension. In other words, water is sticky and elastic, and tends to clump together in drops rather than spread out in a thin film, like rubbing alcohol. Surface tension is responsible for capillary action, which allows water (and its dissolved substances) to move through the roots of plants and through the tiny blood vessels in our bodies.

The density of water means that sound moves through it long distances (ask a whale!). In sea water at 30°C, sound has a velocity of 1,545 meters per second (about 3,500 miles per hour).

Some of water's physical properties:

- Weight: 62.416 pounds/cubic foot at 32°F; 1,000 kilograms/cubic meter
- Weight: 61.998 pounds/cubic foot at 100°F; 993 kilograms/cubic meter
- Weight: 8.33 pounds/gallon; 1 kilogram/liter
- Density: 1 gram/cubic centimeter (cc) at 39.2°F, 0.95865 gram/cc at 212°F

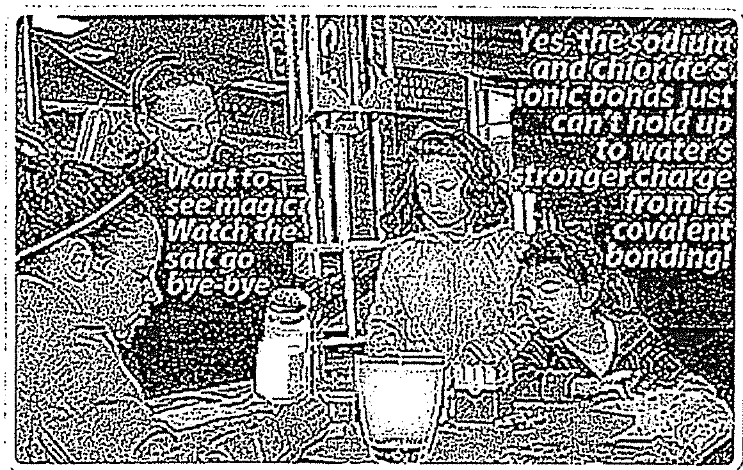
Some water volume comparisons:

- 1 gallon = 4 quarts = 8 pints = 128 fluid ounces = 3.7854 liters
- 1 liter = 0.2642 gallons = 1.0568 quart
- 1 million gallons = 3.069 acre-feet = 133,685.64 cubic feet

Flow rates:

- 1 cubic foot/second (cfs) = 449 gallons/minute = 0.646 million gallons/day = 1.98 acre-feet/day

Water, the Universal Solvent



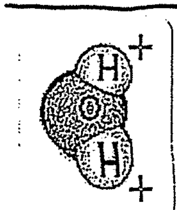
Water is called the "universal solvent" because it is capable of dissolving more substances than any other liquid. This is important to every living thing on earth. It means that wherever water goes, either through the air, the ground, or through our bodies, it takes along valuable chemicals, minerals, and nutrients.

It is water's chemical composition and physical attributes that make it such an excellent solvent. Water molecules have a polar arrangement of oxygen and hydrogen atoms—one side (hydrogen) has a positive electrical charge and the other side (oxygen) had a negative charge. This allows the water molecule to become attracted to many other different types of molecules. Water can become so heavily attracted to a different compound, like salt (NaCl), that it can disrupt the attractive forces that hold the sodium and chloride in the salt compound together and, thus, dissolves it.

Our kidneys and water make a great pair

Our own kidneys and water's solvent properties make a great pair in keeping us alive and healthy. The kidneys are responsible for filtering out substances that enter our bodies from the foods and drinks we consume. But, the kidneys have got to get rid of these substances after they accumulate them. That is where water helps out; being such a great solvent, water washing through the kidneys dissolves these substances and sends them on the way out of our bodies.

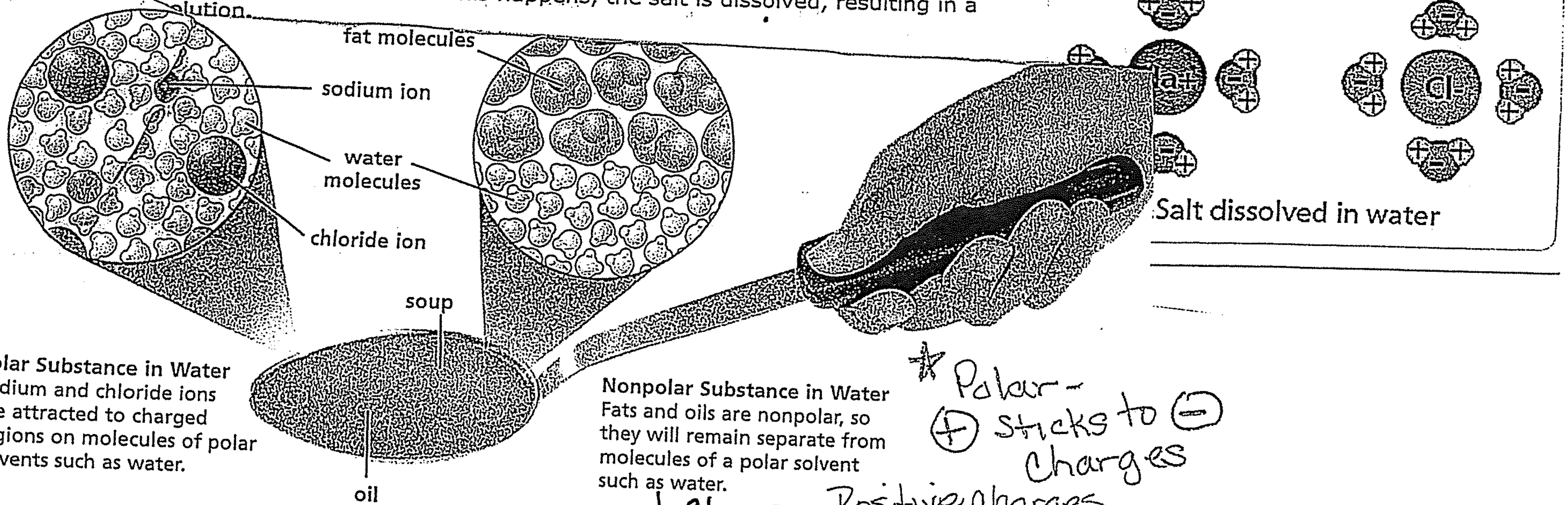
Why salt dissolves in water



At the molecular level, salt dissolves in water due to electrical charges and due to the fact that both water and salt compounds are polar, with positive and negative charges on opposite sides in the molecule. The bonds in salt compounds are called ionic because they both have an electrical charge—the chloride ion is negatively charged and the sodium ion is positively charged. Likewise, a water molecule is ionic in nature, but the bond is called covalent, with two hydrogen atoms both situating themselves with their positive charge on one side of the oxygen atom, which has a negative charge. When salt is mixed with water, the salt dissolves because the covalent bonds of water are stronger than the ionic bonds in the salt molecules.

The positively-charged side of the water molecules are attracted to the negatively-charged chloride ions and the negatively-charged side of the water molecules are attracted to the positively-charged sodium ions. Essentially, a tug-of-war ensues with the water molecules winning the match. Water molecules pull the sodium and chloride ions apart, breaking the ionic bond that held them together. After the salt

...mpounds are pulled apart, the sodium and chloride atoms are surrounded by water ...s as this diagram shows. Once this happens, the salt is dissolved, resulting in a ...olution.



Polar Substance in Water
Sodium and chloride ions are attracted to charged regions on molecules of polar solvents such as water.

Nonpolar Substance in Water
Fats and oils are nonpolar, so they will remain separate from molecules of a polar solvent such as water.

* Polar -
+ sticks to -
Charges

No Charge

Positive charges stick to Negative Charges

Because water is polar and oil is nonpolar, their molecules are not attracted to each other. The molecules of a polar solvent like water are attracted to other polar molecules, such as those of sugar. This explains why sugar has such a high solubility in water. Ionic compounds, such as sodium chloride, are also highly soluble in water. Because water molecules are polar, they interact with the sodium and chloride ions. In general, polar solvents dissolve polar solutes, and nonpolar solvents dissolve nonpolar solutes. This concept is often expressed as "Like dissolves like."

OR Salt

Sugar and Salt

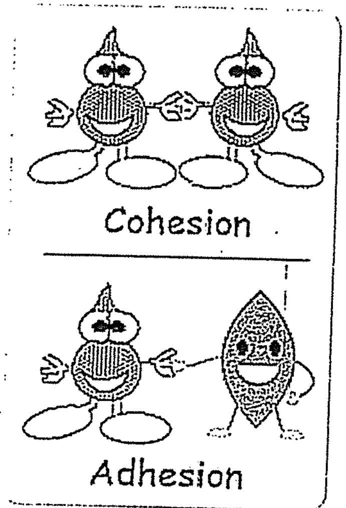
Salt

Charged solvents = Charged solutes

Salt

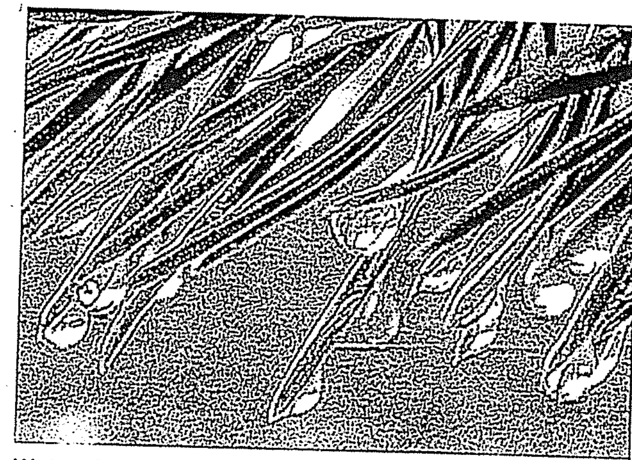
So many substances dissolve in water that it is sometimes called the universal solvent. Water is considered to be essential for life because it can carry just about anything the body needs to take in or needs to get rid of.

Adhesion and Cohesion of Water



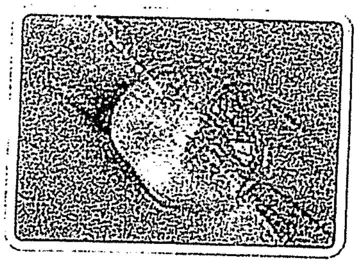
I used to wake up in a cold sweat in the middle of the night because I could not get the concepts of water adhesion and cohesion clear in my mind. If you have that problem, too, then do yourself a favor and read on to learn about these important properties of water.

Cohesion: Water is attracted to water
Adhesion: Water is attracted to other substances


Water drops on pine needles, showing the effects of gravity, adhesion, and cohesion on water.
Credit: J Schmidt; National Park Service.
View full size

Adhesion and cohesion are water properties that affect every water molecule on earth and also the interaction of water molecules with molecules of other substances. Essentially, cohesion and adhesion are the "stickiness" that water molecules have for each other and for other substances. You can see this in the picture to the right. The water drop is composed of water molecules that like to stick together, an example of the property of cohesion. The water drop is stuck to the end of the pine needles, which is an example of the property of adhesion. Notice I also threw in the all-important property of gravity, which is causing the water drops to roll along the pine needle, attempting to fall downwards. It is lucky for the drops that adhesion is holding them, at least for now, to the pine needle.

Cohesion makes a water drop a drop



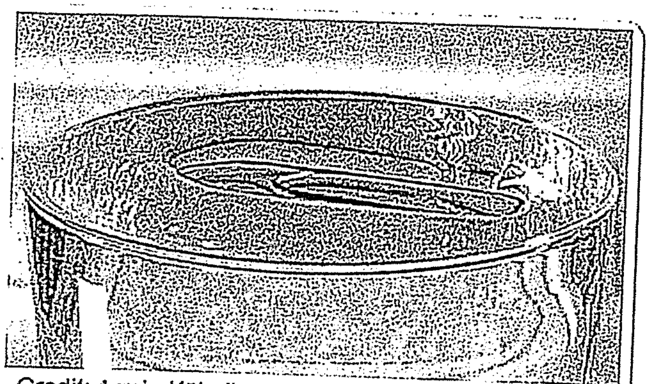
It is easy to see that the drop seems to have a "skin" holding it into a sort of flattened sphere (although there is nothing flat about a water drop in outer space.). It turns out that this surface tension is the result of the tendency of water molecules to attract one another. The natural form of a water drop occurs in the "lowest energy state", the state where the atoms in the molecule are using the least amount of energy. For water, this state happens when a water molecule is surrounded on all sides by other water molecules, which creates a sphere or ball (perfectly round if it was in outer space). On Earth, the effect of gravity flattens this ideal sphere into the drop shape we see. Although you may have heard of a "skin" where water meets the air, this is not really an accurate description, as there is nothing other than water in the drop.

Why is water sticky?

Water is highly cohesive—it is the highest of the non-metallic liquids. Water is sticky and clumps together into drops because of its cohesive properties, but chemistry and electricity are involved at a more detailed level to make this possible. More precisely, the positive and negative charges of the hydrogen and oxygen atoms that make up water molecules makes them attracted to each other. If you've played with bar magnets you will know that the positive (+) side of one magnet will repel the other positive side, while a negative (-) side of one magnet will attract the positive side of the other magnet. Positive charges attract negative charges.

In a water molecule, the two hydrogen atoms align themselves along one side of the oxygen atom, with the result being that the oxygen side has a slight negative charge and the side with the hydrogen atoms has a slight positive charge. Thus when the positive side on one water molecule comes near the negative side of another water molecule, they attract each other and form a bond. This "bipolar" nature of water molecules gives water its cohesive nature, and thus, its stickiness and clumpability (maybe "dropability" is a better term?).

Surface Tension and Water



Credit: Armin Kübelbeck

Floating paper clip made of steel with copper plating. The high surface tension helps the paper clip - with much higher density - float on the water. Credit: Armin Kübelbeck.

The cohesive forces between liquid molecules are responsible for the phenomenon known as surface tension. The molecules at the surface of a glass of water do not have other water molecules on all sides of them and consequently they cohere more strongly to those directly associated with them (in this case, next to and below them, but not above). It is not really true that a "skin" forms on the water surface; the stronger cohesion between the water molecules as opposed to the attraction of the water molecules to the air makes it more difficult to move an object through the surface than to move it when it is completely submersed. (Source: GSU).

Surface tension

The property of the surface of a liquid that allows it to resist an external force, due to the cohesive nature of its molecules.

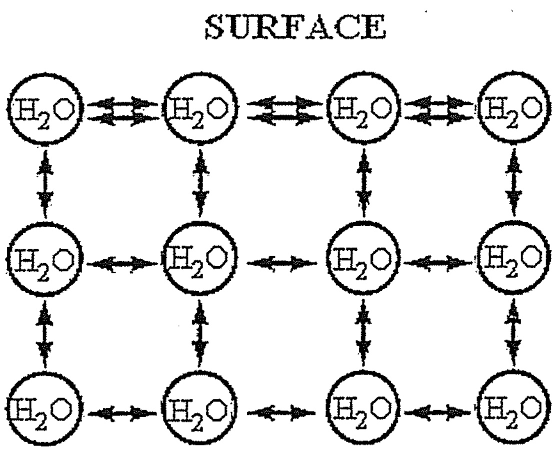
Cohesion and Surface Tension

The cohesive forces between molecules in a liquid are shared with all neighboring molecules. Those on the surface have no neighboring molecules above and, thus, exhibit stronger attractive forces upon their nearest neighbors on and below the surface. Surface tension could be defined as the property of the surface of a liquid that allows it to resist an external force, due to the cohesive nature of the water molecules.

Surface tension at a molecular level

Water molecules want to cling to each other. At the surface, however, there are fewer water molecules to cling to since there is air above (thus, no water molecules). This results in a stronger bond between those molecules that actually do come in contact with one another, and a layer of strongly bonded water (see diagram). This surface layer (held together by surface tension) creates a considerable barrier between the atmosphere and the water. In fact, other than mercury, water has the greatest surface tension of any liquid. (Source: Lakes of Missouri)

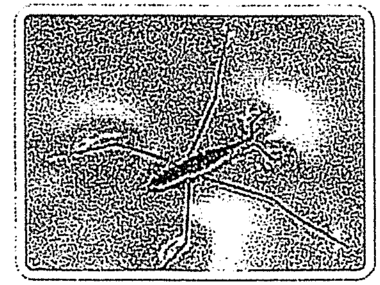
Within a body of a liquid, a molecule will not experience a net force because the forces by the neighboring molecules all cancel out (diagram). However for a molecule on the surface of the liquid, there will be a net inward force since there will be no attractive force acting from above. This inward net force causes the molecules on the surface to contract and to resist being stretched or broken. Thus the surface is under tension, which is probably where the name "surface tension" came from. (Source: Woodrow Wilson Foundation).



Surface tension—molecules at the surface form stronger bonds

Due to the surface tension, small objects will "float" on the surface of a fluid, as long as the object cannot break through and separate the top layer of water molecules. When an object is on the surface of the fluid, the surface under tension will behave like an elastic membrane.

Examples of surface tension



Walking on water: Small insects such as the water strider can walk on water because their weight is not enough to penetrate the surface.

Floating a needle: A carefully placed small needle can be made to float on the surface of water even though it is several times as dense as water. If the surface is agitated to break up the surface tension, then needle will quickly sink.

Don't touch the tent!: Common tent materials are somewhat rainproof in that the surface tension of water will bridge the pores in the finely woven material. But if you touch the tent material with your finger, you break the surface tension and the rain will drip through.

Clinical test for jaundice: Normal urine has a surface tension of about 66 dynes/centimeter but if bile is present (a test for jaundice), it drops to about 55. In the Hay test, powdered sulfur is sprinkled on the urine surface. It will float on normal urine, but will sink if the surface tension is lowered by the bile.

Surface tension disinfectants: Disinfectants are usually solutions of low surface tension. This allow them to spread out on the cell walls of bacteria and disrupt them.

Soaps and detergents: These help the cleaning of clothes by lowering the surface tension of the water so that it more readily soaks into pores and soiled areas.

Washing with cold water: The major reason for using hot water for washing is that its surface tension is lower and it is a better wetting agent. But if the detergent lowers the surface tension, the heating may be unneccessary.

Why bubbles are round: The surface tension of water provides the necessary wall tension for the formation of bubbles with water. The tendency to minimize that wall tension pulls the bubbles into spherical shapes.

Surface Tension and Droplets: Surface tension is responsible for the shape of liquid droplets. Although easily deformed, droplets of water tend to be pulled into a spherical shape by the cohesive forces of the surface layer.

Source: GSU

U.S. Department of the Interior | U.S. Geological Survey
URL: http://water.usgs.gov/edu/surface-tension.html
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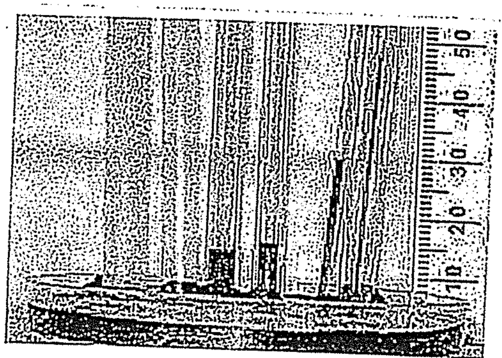
Capillary action

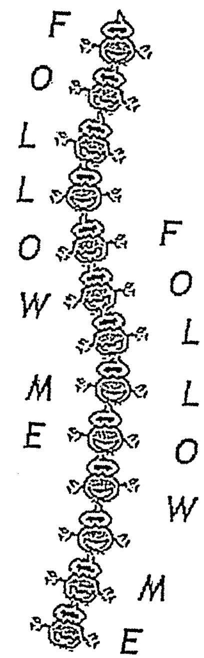
Even if you've never heard of capillary action, it is still important in your life. Capillary action is important for moving water (and all of the things that are dissolved in it) around. It is defined as the movement of water within the spaces of a porous material due to the forces of adhesion, cohesion, and surface tension.



Capillary action seen as water climbs to different levels in glass tubes of different diameters. Credit: Dr. Clay Robinson, PhD, West Texas A&M University.

Capillary action occurs because water is sticky, thanks to the forces of cohesion (water molecules like to stay close together) and adhesion (water molecules are attracted and stick to other substances). Adhesion of water to the walls of a vessel will cause an upward force on the liquid at the edges and result in a meniscus which turns upward. The surface tension acts to hold the surface intact. Capillary action occurs when the adhesion to the walls is stronger than the cohesive forces between the liquid molecules. The height to which capillary action will take water in a uniform circular tube (picture to left) is limited by surface tension and, of course, gravity.

Not only does water tend to stick together in a drop, it sticks to glass, cloth, organic tissues, soil, and, luckily, to the fibers in a paper towel. Dip a paper towel into a glass of water and the water will "climb" onto the paper towel. In fact, it will keep going up the towel until the pull of gravity is too much for it to overcome.



Capillary action is all around us every day

- When you spill your glass of BubblyBerryPowerGo (which is, of course, mostly water) on the kitchen table you rush to get a paper towel to wipe it up. First, you can thank surface tension, which keeps the liquid in a nice puddle on the table, instead of a thin film of sugary goo that spreads out onto the floor. When you put the paper towel onto your mess the liquid adheres itself to the paper fibers and the liquid moves to the spaces between and inside of the fibers. Obviously, Mona Lisa is a fan of capillary action.
- Plants and trees couldn't thrive without capillary action. Plants put down roots into the soil which are capable of carrying water from the soil up into the plant. Water, which contains dissolved nutrients, gets inside the roots and starts climbing up the plant tissue. As water molecule #1 starts climbing, it pulls along water molecule #2, which, of course, is dragging water molecule #3, and so on.