Special Properties of Water

Water is Special

We'll overlook the indiscretion of hydrogen bonds in light of the fact that they are partly responsible for water's unique properties. Now, everyone is special, and we're not trying to belittle any other chemical compounds by singling water out, but water really is amazing and über-important to life on Earth. By now, you're surely on the edge of your seat wondering why, so here are the top five things that make water great:

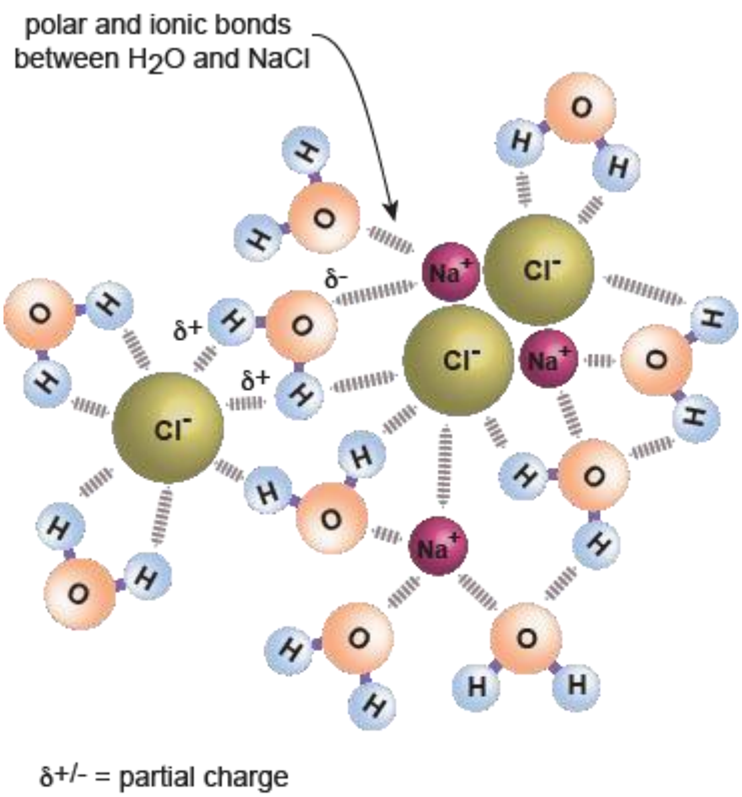
1. Water has high cohesion.

So what? We'll tell you what. Hydrogen bonds between water molecules make them stick together. But, you already knew that. The reason this is nifty is that it results in high surface tension, or the tendency for water molecules to stick together when at the boundary of a gas and a liquid (or a liquid and a solid, or even a liquid and a liquid...you get the idea), which means that it's actually pretty hard to break the surface of water compared to other liquids. Surface tension is what allows some things to float on water even if they're denser than water. Bugs, for instance. Or this guy! Look at him go!

2. Water is a great solvent.

Water is dangerously good at dissolving things. A master dissolver, if you will. Since water is a polar molecule, its positive end is attracted to negatively charged ions or the negative sides of other polar molecules, and its negative side is attracted to positively charged ions or the positive sides of other polar molecules. If you drop a salt crystal into water, the sodium ion (Na^+) will quickly be surrounded by eager water molecules with the negative sides facing the positive sodium ion; the chlorine ion (Cl^-) will be similarly surrounded by other water molecules with positive sides facing the negative chlorine ion. It’s vaguely reminiscent of the way paparazzi descend on celebrities, or the way vultures hone in on a dead carcass. Metaphors aside, the important point is that the Na^+ and Cl^- get separated from each other, or dissolve in the water. Things that dissolve in water easily are **hydrophilic** ("water-loving"), and the "dissolvability" property is called **solubility**.

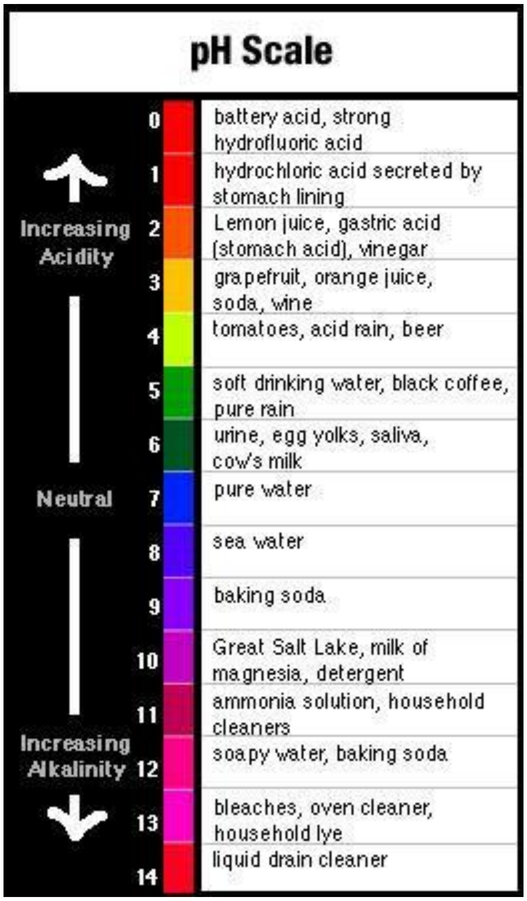
Looks like a party!



Have you ever tried to mix oil and water? No? Not much of a partier then, are you? It’s a humbling experience because everyone fails. Oil is **hydrophobic** ("water-fearing") and immediately puts a stop to all of this dissolving business. Fats, including oil, are **nonpolar molecules**. All the component atoms in nonpolar molecules are sharing electrons equally among themselves. No squabbles there. The result, though, is that there is nothing for water to be attracted to, since water, the polar snob that she is, likes either ions or other polar molecules. The take-home point is this: if a substance is not polar or charged in any way, it usually won’t dissolve in water (insoluble). You're out of luck, nonpolar molecules.

3. Water acts like a buffer.

What is a buffer? Let's start with some background info first.



To understand buffers, we need to know a thing or two about **acids** and **bases**. **Acids** are substances that release hydrogen ions (H^+) into solution. HCl, or hydrochloric acid, is a compound formed by ionic bonds. When you drop it in water, the H^+ and Cl^- come apart, because as we said before, water is polar and will attack charged ions. Cue the paparazzi and/or vulture imagery. As a result, a whole bunch of H^+ ions are released into solution, which dramatically increases the concentration of H^+. An increase in the concentration of H^+ causes an increase in acidity.

A **base**, on the other hand, is a substance that will bind to the free hydrogen ions (H^+) that might be floating around in solution. NaOH is an example of a base. Bases are also known as **alkaline**. When you drop NaOH in water, the Na^+ ions become separated from the hydroxide ions (OH^-). Even though the oxygen and hydrogen of OH^- are bound together covalently, they still count as an ion because, as a unit, they possess an extra electron, and therefore, have a net negative charge. Back to bases. You can probably guess what happens when a stray OH^- ion encounters a free H^+ ion: it's love at first sight, and the ions bind. What happens as a result? The concentration of free H^+ ions in that solution decreases, which *increases* the basicity. Bases have more OH^- ions than acids.

To summarize, acids release a bunch of H^+ ions into solution, and bases mop them up like they're Swiffer. The last thing to mention before we come back to buffers is **pH**. The pH scale goes from 1 to 14 and is the way we measure how acidic a solution is, which has to do with how many hydrogen ions are in solution. Pure water has a pH of 7, which is neutral, and has exactly the same number of H^+ ions as OH^- ions floating around in solution.

Two things to remember:

1. If there are relatively more H^+ ions, the pH goes down, increasing the acidity. More H^+, more acidic, lower pH.

2. If there are fewer H^+ ions, the pH increases, increasing the basicity. Less H^+, more basic, higher pH.

Remember that the pH scale runs from 0 to 14, and each step represents a tenfold difference. In other words, a solution with a pH of 5 is 100 times more acidic than something with a pH of 7. And a solution with a pH of 3 is 10,000 times more acidic than something with a pH of 7. To put this in perspective, soda has a pH of 3. Kind of makes you want to rethink that Big Gulp Coke, doesn't it?

OK, back to buffers. A **buffer** is a substance that helps to moderate any changes in pH that result from the addition of acids or bases. This is important because, as you'll learn later, most of the chemical processes that occur in living organisms are highly sensitive to pH, and drastic changes in pH can cause some serious trouble. Therefore, buffers are a little bit like well-meaning control freaks.

Water, as stated at the beginning of this section, can act like a buffer if there is a sudden change in pH. At any given moment, there are a few H_2O molecules that break apart and form H^+ and OH^-. Don't worry...most of the water molecules are still completely bound together. There are a few hydrogen ions here and there who effectively get tired of "sharing" an electron with the pushy, selfish oxygen atoms. They throw their little atomic arms up and shout, "Fine! The electron is all yours. I'm outta here!" Therefore, there are a few stray H^+ and corresponding OH^- ions floating around in solution.

These few dissociated water molecules are what give water its buffering ability. If we add an acid to solution, some of the free OH^- ions will bind to the newly added H^+ ions, which will moderate the decrease in pH. Similarly, if we add a whole bunch of base to the solution, some of the added base will bind to the free H^+ ions in solution, which will moderate the increase in pH.

Having said all of this, while water *can* be a buffer, it isn't a fantastic one since most of the H_2O molecules remain completely stuck together. It has a little bit of buffering capability and is helpful with small changes in pH, but it is by no means the best and certainly can't compensate for super drastic changes in pH.

4. Water resists temperature changes.

Water is stubborn. Why is water like this, and who decided being stubborn makes you special?

First, water has a high **specific heat capacity**, which is the amount of energy that it takes to raise the temperature of 1 gram of a substance by 1 °C. In other words, it takes a *lot* of energy to heat water.

Second, water has a high **heat of vaporization** (the amount of heat required to convert liquid water into gaseous water, aka steam). The high heat of vaporization of water is due to those pesky hydrogen bonds. Water molecules at the surface need to be moving really fast to break free into the air. Heating increases the movement of the molecules, but we already know it takes a lot of energy to heat water because water has a high specific heat.

If we put these two concepts together, we find that it takes a lot of energy to heat a water molecule, and we need to heat it a lot to give it the kinetic energy it needs to break the hydrogen bonds holding it to the rest of the water molecules. A double whammy if you're trying to get water to boil.

Lastly, water has a high **heat of fusion**, or the heat you need to take out of water to get it to solidify (freeze). What all this means is that water can hold a lot of heat energy before it changes temperatures and states (solid to liquid to gas). This property of water is great if you are an organism that lives in the water. Why, you might ask? A high heat of fusion means that, even if the temperature of the air changes a lot, water will shelter you from those changes and provide a pretty stable environment. Thanks, water.

5. Ice floats.

We know; you knew that. For most compounds, the solid is denser than the liquid, meaning that the solid will sink to the bottom of the container holding the liquid. Not for ice! Tricked ya! Ice is cool like that. Get it? *Cool*? Sorry. The point is that water actually becomes less dense when it freezes, which allows the solid form, or ice, to float on the liquid form, or water. This is important for organisms that live underwater. If frozen water sunk, small bodies of water would be more likely to freeze completely in the winter, which would be bad for all the organisms living there. And by bad, we mean certain death. Instead, a layer of ice effectively insulates the underlying water, allowing many aquatic organisms to survive through the winter. (from http://www.shmoop.com/biomolecules/properties-water.html)