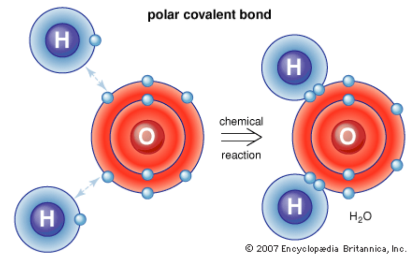
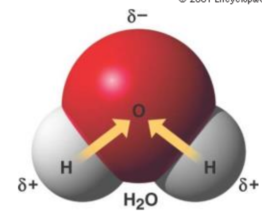
Name: ____ Date: ___________________________ Period: _____

Unit 2 Part 2 Notes – Properties of Water

AP Biology, 2018-2019

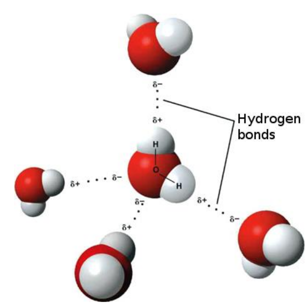




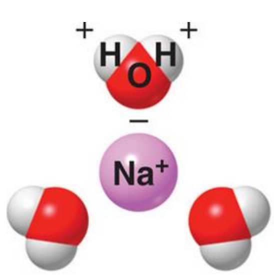
A. Why do we study water in AP Biology?

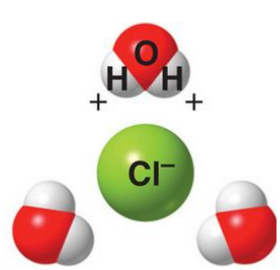
1. Water makes up 50-95% of the weight of any living thing.
2. The unique, live-sustaining properties of water result from its **polarity**. The bonds between oxygen and hydrogen within the water molecule are covalent, but they are considered **polar covalent** because the electrons are not shared equally between the two atoms. Oxygen exerts a greater pull on the shared electrons. As a result, oxygen has a partial negative charge within the water molecule, and hydrogen has a partial positive charge.
3. Oxygen holds shared electrons more tightly than hydrogen because it is more **electronegative** than hydrogen. Remember from Part 1 of the notes that **electronegativity** is the tendency of an atom to attract electrons to itself and that Flourine, Oxygen and Nitrogen have a high electronegativity.
4. Polar molecules tend to attract to one another. Polar molecules repel **non-polar** (uncharged / neutral) molecules.
5. Based on how they interact with water, other molecules receive special terms:
   a. **Hydrophilic** molecules = this means, "water loving" and refers to polar molecules that dissolve in water (ex: sugars, DNA, proteins)
   b. **Hydrophobic** molecules = this means "water fearing" and refers to nonpolar molecules that tend to cluster in water (ex: fats - remember, oil and water do not mix! An additional example is that the interactions between water and phospholipid molecules, a type of fat, enable cell membranes to form)

B. How does water's polarity enable hydrogen bonding and water's ability to act as a solvent?



1. As a result of their polarity, water molecules are able to form **hydrogen bonds** with one another. The negative oxygen end of one water molecule attracts to the positive hydrogen end of another water molecule because "opposites attract."
2. Hydrogen bonds can form between any polar molecules in which the hydrogen of one molecule is attracted to a highly electronegative atom (which gives it a slightly negative charge within a polar molecule) such as nitrogen, oxygen, or fluorine. You can remember the definition of hydrogen bonding as **H—NOF**.
3. Each water molecule can form a maximum of four hydrogen bonds with four other water molecules
4. A single hydrogen bond is weaker than a single covalent or ionic bond but when many of these bonds are present, they have the ability to create a very stable structure. This can be seen in the double helix shape of DNA that is caused by many hydrogen bonds along the "rungs" of the DNA ladder.
5. Water is known as the **universal solvent** because it can dissolve other polar or ionic (fully charged) substances to make a solution. The substance that dissolves (ex: NaCl, table salt) is known as the solute.
6. When water dissolves salt (NaCl), Na+ and Cl- split apart. The negative oxygen ends of water molecules surround the Na+ (because opposites attract) and the positive hydrogen ends of water molecules surround the Cl-. Once the Na+ and Cl- are isolated from each other and are no longer able to form the compound NaCl, we say that the salt has dissolved in the water.



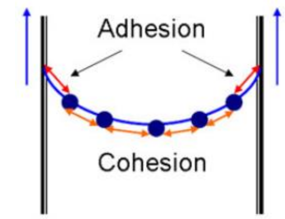


C. How does water's ability to form hydrogen bonds cause other unique properties?

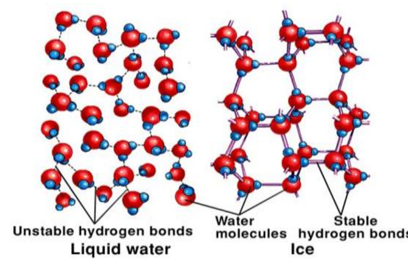
1. Due to hydrogen bonding between water molecules, they display **cohesion** (molecules sticking to identical molecules)
   a. Cohesion makes water act as if it has an invisible skin and causes **surface tension** (how difficult it is to break the surface of water)
   b. Examples of Cohesion and Surface Tension: Water droplets bead up, water strider insects can "walk on water" by spreading their weight and using the surface tension of the water.

2. Due to water's polarity and its ability to form hydrogen bonds, water molecules display **adhesion** (molecules sticking to other types of molecules) with other polar or charged substances
   a. Examples of Adhesion: water forms a meniscus (dip) in a graduated cylinder because the water molecules closest to the sides of the tube are attracted to the glass and are pulled up

3. Cohesion and Adhesion of water molecules causes **capillary action**, the ability of water to move through a <u>narrow</u> passageway.
   a. Adhesion occurs between the water molecules and the sides of the passageway / tube. This pulls the water molecules closest to the sides of the tube up.
   b. Cohesion occurs between the water molecules closest to the sides of the tube and the water molecules towards the center of the tube that do not have contact with the sides of the tube. This pulls the water molecules towards the center of the tube up as well.
   c. In addition, there is **a transpirational-pull cohesion tension**, which also aides in water movement up a tree. This results from a process known as transpiration where a molecule of water is lost from the leaf which causes another molecule to be drawn up through the roots

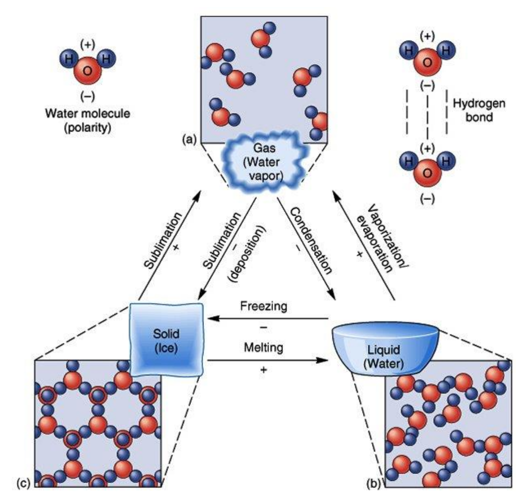


4. As water cools and freezes to form ice, the movement of water molecules slows down, which allows more hydrogen bonds to form (and *stay formed*) between water molecules and pushes them farther apart. This makes **ice less dense than liquid water**. Since ice floats on the surface of a lake or pond, it insulates the water in the pond and prevents it from being exposed to the cold air. This protects organisms in aquatic ecosystems over the winter.
   a. This property of water allows for **spring overturn**. In the spring, the ice melts, becomes denser and sinks to the bottom of the lake, causing the water to circulate throughout the lake. Oxygen from the surface is returned to the depths and nutrients released by the activities of bottom-dwelling bacteria during winter are carried to the upper layers.
   b. This property of water is also the reason why frost can make roads bumpy in the winter time. Water enters the cracks in the roads and has a larger volume when frozen, thus causing bumps in the road.



5. Specific heat is the amount of energy it takes to raise or lower 1 gram of a substance 1˚C. Because hydrogen bonds must be broken to raise the temperature of water and create more movement / kinetic energy between the water molecules, water has a very **high specific heat**. Relative to most other materials, the temperature of water changes less when a given amount of heat is lost or absorbed.
   a. *Note:* ***Heat capacity*** *is a more general term for specific heat and refers to the amount of energy required to change the temperature of a substance by a particular amount.*
   b. Example: When you go to the beach in the summer time and although it is hot outside, the water temperature is still very cold. This is because it takes a lot of energy to warm up the temperature of the water. Further, the ability to resist changes in temperature allows for a table environmental temperature for aquatic organisms.

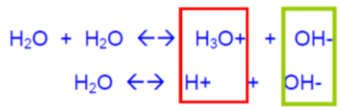
6. Due to its high specific heat, water also has a **high heat of vaporization**, the energy required to change liquid water to a gas (water vapor).
   a. *Note: Vaporization, or the transformation of a substance from a liquid to a gas, is also known as evaporation.*
   b. Evaporation of water produces a cooling effect, so some organisms sweat / pant to cool off. This process is known as **evaporative cooling.** This happens because evaporating water requires the absorption of a relatively great amount of heat, so the evaporation of sweat (mostly water) cools the body surface.



D. What is the pH of water?

1. The **pH scale** measures how acidic or basic a substance is. It runs from 0-14 and measures the hydrogen ion (H+) concentration of a substance. For example: a substance with a pH of 3 has 1.0 x 10^{-3} (.001) moles per liter of hydrogen ions in a solution. A substance is considered neutral at pH 7.
2. Each difference in one pH unit represents a 10X difference in the H+ concentration (ex: pH 2 has 1000 times more H+ ions than a pH 5)
3. An **acid** is a substance that has a high amount of H+ ions and a low amount of OH- ions [H+] > [OH-] and their numerical value on the pH scale is less than 7
   a. *Note: OH- is the hydroxide ion.*
   b. A **base** (alkaline) is a substance that has a high amount of OH- ions and a low amount of H+ ions ions [H+] < [OH-] and their numerical value on the pH scale is greater than 7
   c. There are two equations used to compare pH and H+ and OH- concentrations. Note: Brackets around an ion—ex: [H+]—signify the concentration of that ion.

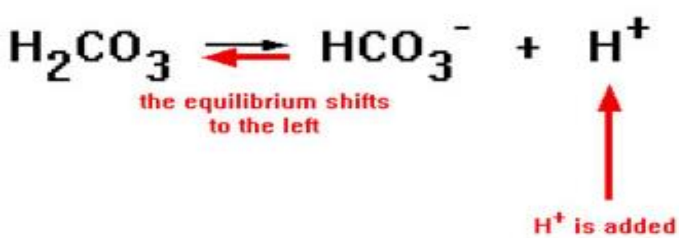
Equation	Example
pH = $-\log_{10}$[H+]	if [H+] = 1 x 10^{-7}, then pH = 7
[H+] x [OH-] = 10^{-14}	if [H+] = 1 x 10^{-9}, then [OH-] = 10^{-5}



4. Water molecules occasionally **dissociate** (come apart and form charged ions). When this occurs, one water molecule dissociates into equal numbers of H+ and OH-, or two water molecules will dissociate into H_3O+ (hydronium ion) and OH-
5. Only 1 of every 554,000,000 water molecules dissociates in pure water at 25 degrees Celsius.
6. In pure water, [H+] = [OH-] = 1.0 x 10^{-7} M, which means pH = 7 (neutral)

E. How do our bodies maintain constant pH levels?

1. One example of a mechanism for maintaining acid-base balance in the blood involves the **carbonic acid-bicarbonate buffer system.**
2. **Buffers** are weak acids or bases that act by combining reversibly with H+. They can donate H+ to solutions when concentrations fall and remove H+ from solutions when concentrations increase. In other words, a buffer woks by either absorbing excess hydrogen ions or donating hydrogen ions when there are too few. Because they minimize changes in the concentrations of H+ and OH-, they counteract major changes in pH. Buffer systems are one way that the body attempts to maintain homeostasis (stable internal conditions).
3. The carbonic acid-bicarbonate buffer system maintains blood pH between 7.38 and 7.42. The system involves the use of HCO_3^- (bicarbonate, a weak base and H+ acceptor) and H_2CO_3 (carbonic acid, a weak acid and H+ donor) to minimize changes in blood pH.



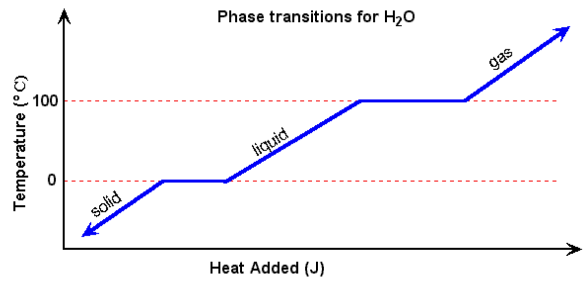
4. If the H+ concentration in the blood begins to fall (that is, if pH rises), the reaction "shifts" to the right and more carbonic acid dissociates, creating more H+ and lowering the pH.
5. If the H+ concentration in the blood begins to rise (that is, if pH falls), the reaction "shifts" to the left and bicarbonate combines with excess H+ to form carbonic acid. This removes the excess H+ and raises the pH.
6. This system is of vital importance to our body. If your blood pH alters even slightly out of range, the change in pH can cause the proteins in your blood (hemoglobin) to change shape and be rendered ineffective. If blood cannot properly transport oxygen throughout your body, serious consequences can occur including death.

F. Video on pH and Buffers – short quiz on this next class.

1. Watch the 6 minute video on pH and buffers and add any notes that would be beneficial to your annotations: http://www.bozemanscience.com/ap-chem-069-ph/?rq=buffers or https://goo.gl/55DxpP
2. There will be a short 5 question quiz next class to see if you actually watched this video.

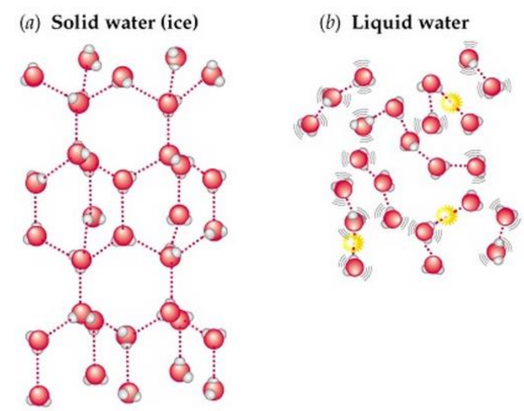
Notes Questions

1. Explain why the temperature of water changes very little as it changes phase from solid to liquid and liquid to gas. Use the term “high specific heat / heat capacity” in your response.



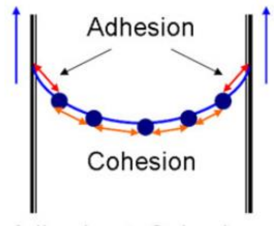
2. Explain why a water strider insect can walk on the surface of a lake or pond. Use the terms hydrogen bonding, cohesion, and surface tension in your response.

3. Explain why ice floats on liquid water. Use the term “hydrogen bonds” in your response. Use the image to the right to help you answer the question.



4. Describe the difference between a hydrophobic and hydrophilic substance. Use the terms “polar” and “nonpolar” in your response.

5. Define capillary action and explain how adhesion and cohesion cause capillary action.



6. Explain why water is a polar molecule and explain how water's polarity contributes to its ability to form hydrogen bonds with other water molecules.

7. If water molecules surround a solute particle with their oxygen ends all pointing to the solute particle, what can you conclude about the charge of the solute particle? Is it positive, negative, or neutral, and how do you know? Draw what this would look like to help you answer your question (use the first page of notes if needed).

8. Acid precipitation has lowered the pH of a particular lake to 4.0. What is the hydrogen ion concentration of the lake?

9. How does the concentration of hydrogen atoms in a solution with a pH of 2 compare with the concentration of hydrogen atoms in a solution with a pH of 5?

Ex: "The concentration of hydrogen atoms is 10 times lower in a solution with a pH of 2 than a pH of 1."

Self-Quiz: questions from Campbell's Biology**.** Use this resource as you see fit.

1. Many mammals control their body temperature by sweating. Which property of water is most directly responsible for the ability of sweat to lower body temperature?
    a. water's change in density when it condenses
    b. water's ability to dissolve molecules in the air
    c. the release of heat by the formation of hydrogen bonds
    d. the absorption of heat by the breaking of hydrogen bonds

2. The bonds that are broken when water vaporizes are
    a. ionic bonds.
    b. bonds between water molecules.
    c. bonds between atoms within individual water molecules.
    d. polar covalent bonds.

3. Which of the following is an example of a hydrophobic material?
    a. paper b. table salt c. wax d. sugar