AP Biology Student Interactive Learning Guide

North Salem University

MISSION: *Engage students to continuously learn, question, define and solve problems through critical and creative thinking.*

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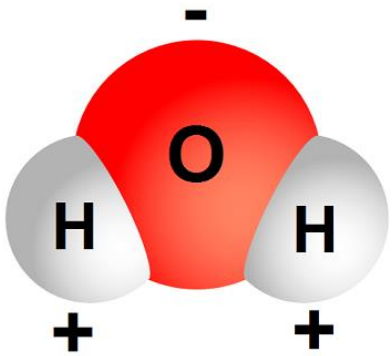
*Water is so common that it is easy to overlook the fact that it is an exceptional substance with many extraordinary qualities. The abundance of water on our planet is the major reason life on Earth is possible. The main objective of this chapter is to develop a conceptual understanding of how water contributes to the fitness of Earth for Life. We will be going through this chapter VERY quickly as much of the information contained in it is considered "**prior knowledge**." The questions and activities that follow in this Interactive Learning Guide should help you focus on the most important points in the chapter.*

If you have any problems – feel free to drop me an email.

Chapter 3: *Water*



Chapter 3: Water

OBJECTIVES:

Effects of Water's Polarity

___1. Describe how water contributes to the fitness of the environment to support life.
___2. Describe the structure and geometry of a water molecule, and explain what properties emerge as a result of this structure.
___3. Explain the relationship between the polar nature of water and its ability to form hydrogen bonds.
___4. List four characteristics of water that are emergent properties resulting from hydrogen bonding.
___5. Describe the biological significance of the cohesiveness of water.
___6. Explain how water's high specific heat, high heat of vaporization, and expansion upon freezing affect both aquatic and terrestrial ecosystems.
___7. Distinguish among a solute, a solvent, and a solution.
___8. Explain how the polarity of the water molecule makes it a versatile solvent.
___9. Distinguish between hydrophilic and hydrophobic substances.

Dissociation of Water Molecules

___10. Write the equation for the dissociation and re-formation of water.
___11. Explain the basis for the pH scale.
___12. Explain how acids and bases directly or indirectly affect the hydrogen ion concentration of a solution.
___13. Using the bicarbonate buffer system in blood as an example, explain how buffers work.
___14. Describe the causes of acid precipitation and explain how it harms the environment.

KEY TERMS:

acid precipitation	adhesion	aqueous solution	buffer
calorie (cal)	Celsius scale	cohesion	evaporative cooling
heat of vaporization	heat	hydration shell	hydrogen ion
hydrophilic	hydrophobic	hydroxide ion	kinetic energy
molarity	mole (mol)	molecular weight	pH
polar molecule	solute	solution	solvent
specific heat	surface tension	temperature	

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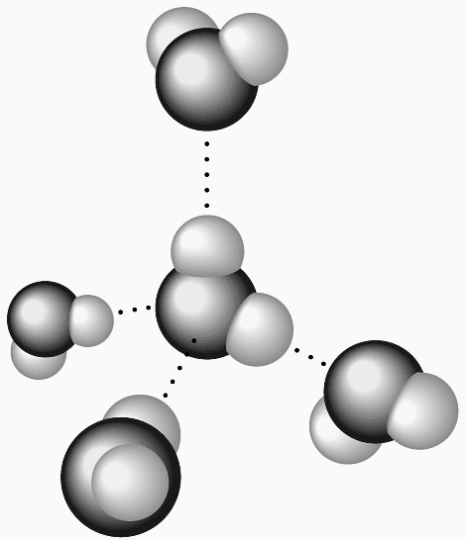
WORD ROOTS:

kilo- = a thousand (kilocalorie: a thousand calories)
hydro- = water; -philos = loving; -phobos = fearing (hydrophilic: having an affinity for water; hydrophobic: having an aversion to water)

Guided Reading: Chapter 3

1. Study the water molecules at the right. On the central molecule, label oxygen (O) and hydrogen (H).



2. Why is water considered a polar molecule?

3. Now, add **+** and **–** signs to indicate the charged regions of *each* molecule. Then label the hydrogen bonds. Explain *hydrogen bonding*. How many hydrogen bonds can a single water molecule form?

4. For each of the below listed properties of water – briefly define the property and then explain how water's polar nature and polar covalent bonds contribute to the water special property. Include an example of how this property is important to life on planet Earth.

Property	Example
Cohesion –	
Adhesion -	
Surface Tension -	
High Specific Heat -	
Evaporative Cooling -	

5. Ice floats! So what? Consider what would happen if ponds and other bodies of water accumulated ice at the bottom. Describe why this property of water is important?

6. Define the following terms:

a. **Solute** -

b. **Solvent** -

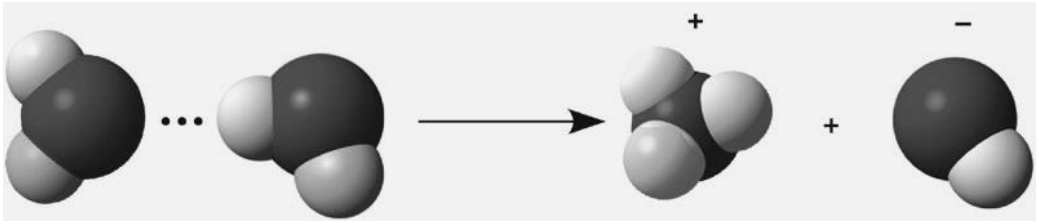
c. **Aqueous solution** -

d. **Hydrophilic** -

e. **Hydrophobic** -

f. **Molarity** -

7. Label the diagram below to demonstrate the dissociation of the water molecule and then relate this diagram to pH.



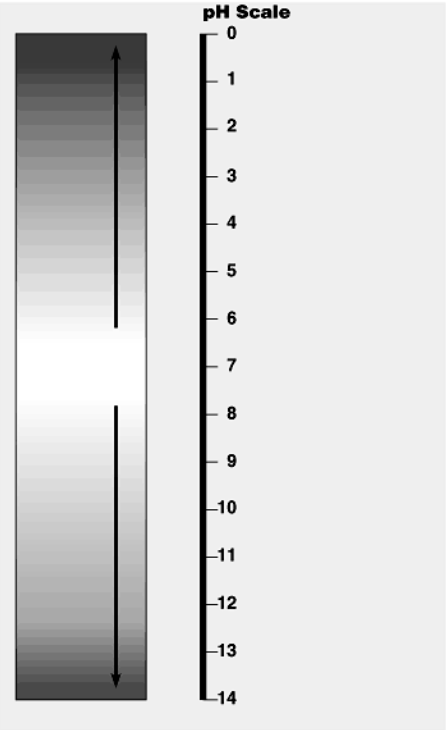
8. Water, which is neutral with a pH of 7, has an equal number of H+ and OH– ions. In light of the previous statement, define the terms **acid** and **base**.

a. **Acid** -

b. **Base** -

9. Why are "apparently" small changes in pH so important in biology?

10. On the pH chart below, label *neutral, acid, base*. Indicate the locations of pure water, human blood, urine, gastric juice, and bleach.



11. Because the pH scale is logarithmic, each numerical change represents a 10X change in ion concentration.

a. So, how many times more acidic is a pH of 3 compared to a pH of 5?

b. How many times more basic is a pH of 12 compared to a pH of 8?

c. Explain difference between a pH of 8 and a pH of 12 in terms of H+ concentration.

12. What is a buffer?

13. Exercise will result in the production of CO_2, which will acidify the blood. Explain the buffering system that minimizes blood pH changes.

14. Acid precipitation is increasing. What is it and why is it important to living organisms? *(Be sure to explain its sources.)*

15. Discuss how CO_2 emissions can affect forest ecosystems.

Summary of Key Concepts: Chapter 3

The Effects of Water's Polarity

- The polarity of water molecules results in hydrogen bonding **(pp. 41-42, FIGURE 3.1)** A hydrogen bond forms when the oxygen of one water molecule is electrically attracted to the hydrogen of a nearby molecule. Hydrogen bonding between water molecules is the basis for water's unusual properties.
- Organisms depend on the cohesion of water molecules (p. 42) Hydrogen bonding makes water molecules stick to each other, and this cohesion helps pull water upward in the microscopic vessels of plants. Hydrogen bonding is also responsible for water's surface tension.
- Water moderates temperatures on Earth (pp. 42-44) Hydrogen bonding gives water a high specific heat. Heat is absorbed when hydrogen bonds break and is released when hydrogen bonds form, helping minimize temperature fluctuations to within limits that permit life. Evaporative cooling is based on water's high heat of vaporization. Water molecules must have a relatively high kinetic energy to break hydrogen bonds. The evaporative loss of these energetic water molecules cools a surface.
- Oceans and lakes don't freeze solid because ice floats **(pp. 44-45, FIGURE 3.6)** Ice is less dense than liquid water because its more organized hydrogen bonding causes expansion into a crystal formation. Floating ice allows life to exist under the frozen surfaces of lakes and polar seas.
- Water is the solvent of life **(pp. 45-47, FIGURE 3.7)** Water is an unusually versatile solvent because its polar molecules are attracted to charged and polar substances. When ions or polar substances are surrounded by water molecules, they dissolve and are called solutes. Hydrophilic substances have an affinity for water. Hydrophobic substances do not; they seem to repel water. Biologists usually use molarity, the number of moles of solute per liter of solution, as a measure of solute concentration in solutions. A mole is the number of grams of a substance equal to its molecular weight.

The Dissociation of Water Molecules

- Organisms are sensitive to changes in pH **(pp. 47-49, FIGURE 3.9)** Water can dissociate into H^+ and OH^-. The concentration of H^+ is expressed as pH, where pH = -log $[H^+]$. Acids donate additional H^+ in aqueous solutions; bases donate OH^- or accept H^+. In a neutral solution, $[H^+] = [OH^-] = 10^{-7}$, and pH = 7. In an acidic solution, $[H^+]$ is greater than $[OH^-]$, and the pH is less than 7. In a basic solution, $[H^+]$ is less than $[OH^-]$, and the pH is greater than 7. Buffers in biological fluids resist changes in pH. A buffer consists of an acid-base pair that combines reversibly with hydrogen ions.
- Acid precipitation threatens the fitness of the environment (pp. 49-50) Acid precipitation is rain, snow, or fog with a pH below 5.6. It often results from a reaction in the air between water vapor and sulfur oxides and nitrogen oxides produced by the combustion of fossil fuels.

Chapter 3 - Review Questions

___1) A hydrogen atom has one electron. How many covalent bonds can hydrogen form?
A) one covalent bond
B) two covalent bonds
C) four covalent bonds
D) no covalent bonds

___2) Which of the following statements regarding the oxygen atom of a water molecule is true?
A) Oxygen is more positively charged than the hydrogen atoms.
B) Oxygen attracts electrons less strongly than the hydrogen atoms.
C) Oxygen is more electronegative than the hydrogen atoms.
D) Oxygen is attracted to the negatively charged atoms of other molecules.

___3) In a water molecule, hydrogen and oxygen are held together by a(n) _____ bond.
A) double covalent
B) nonpolar covalent
C) hydrogen
D) polar covalent

___4) The hydrogen atoms of a water molecule are bonded to the oxygen atom by _____ bonds, whereas neighboring water molecules are held together by _____ bonds.
A) hydrogen . . . polar covalent
B) polar covalent . . . hydrogen
C) ionic . . . covalent
D) polar covalent . . . ionic

___5) _____ are weak bonds that are not strong enough to hold atoms together to form molecules but are strong enough to form bonds within and around large molecules.
A) ionic bonds
B) covalent bonds
C) polar covalent bonds
D) hydrogen bonds

___6) Water molecules stick to other water molecules because -
A) water molecules are neutral, and neutral molecules are attracted to each other.
B) hydrogen bonds form between the hydrogen atoms of one water molecule and the oxygen atoms of other water molecules.
C) covalent bonds form between the hydrogen atoms of one water molecule and the oxygen atoms of other water molecules.
D) the oxygen atoms of adjacent water molecules are attracted to one another.

___7) The tendency of water molecules to stick together is referred to as -
A) adhesion.
B) polarity.
C) cohesion.
D) transpiration.

___8) Water's surface tension and heat storage capacity is accounted for by its -
A) orbitals.
B) hydrogen bonds.
C) mass.
D) size.

___9) The temperature of evaporation is much higher for water than for alcohol. Without knowing more about the chemistry of alcohol, which of the following is the most logical chemical explanation for this phenomenon?
A) Ionic bonds form between alcohol molecules. These are the weakest type of bond and are easier to break than the hydrogen bonds between water molecules.
B) Alcohol has a higher surface tension than water. This means that alcohol molecules can easily break away from other alcohol molecules and evaporate at a lower temperature.
C) Alcohol molecules are more cohesive than water molecules. This means that as alcohol molecules evaporate, they pull other alcohol molecules into the air along with them.
D) Fewer hydrogen bonds form between alcohol molecules. As a result, less heat is needed for alcohol molecules to break away from solution and enter the air.

____10) As ice melts, -
A) hydrogen bonds are broken.
B) water molecules become less tightly packed.
C) the water becomes less dense.
D) heat is released.

___11) Which of the following statements about water is false?
A) Ice is more dense than liquid water.
B) Water naturally exists in all three physical states on Earth.
C) Floating ice on a pond insulates the liquid water below, slowing its rate of freezing.
D) If ice sank, the oceans would eventually freeze solid.

___12) You've made a hot drink by dissolving a teaspoon of instant coffee and a teaspoon of sugar in a cup of hot water. Which of the following statements is true?
A) You've just prepared an aqueous solution.
B) The water is the solute portion of the drink.
C) The instant coffee and sugar are solvents.
D) The instant coffee and sugar dissolve because they have no charged regions to repel the partial positive and partial negative regions of the water molecules.

___13) Which of the following is dependent on the ability of water molecules to form hydrogen bonds with other molecules besides water?
A) the evaporative cooling of skin surfaces
B) the milder temperatures of coastal regions compared to inland areas
C) the ability of certain insects to walk on the surface of water
D) the universality of water as a solvent

___14) A solution with a pH of 7 is -
A) strongly acidic.
B) weakly acidic.
C) neutral.
D) weakly basic.

___15) Compared to a solution of pH 3, a solution of pH 1 is -
A) 100 times more acidic.
B) 10 times more acidic.
C) 10 times more basic.
D) 100 times more basic.

___16) Which of the following statements about pH is true?
A) The pH scale is a measure of oxygen ion concentration.
B) A single unit change on the pH scale is equivalent to a 1% change in hydrogen ion concentration.
C) An increase in hydrogen ion concentration means a decrease in pH scale units.
D) Basic pH levels are less than 7.

___17) Household ammonia has a pH of 12; household bleach has a pH of 13. Which of the following statements about them is true?
A) Both of these substances are strong acids.
B) The ammonia has 10 times as many OH^- ions as the bleach.
C) The ammonia has 10 times as many H^+ ions as the bleach.
D) A solution that could buffer the bleach and ammonia would remove excess OH^- ions.

___18) A buffer -
A) is an acid that is used to offset overly basic conditions in the body.
B) is a base that is used to offset overly acidic conditions in the body.
C) donates H^+ ions when conditions become too basic and accepts H^+ ions when conditions become too acidic.
D) donates OH^- ions when conditions become too basic and accepts OH^- ions when conditions become too acidic.

___19) Which of the following would be considered an effective way to decrease the production of acid precipitation?
A) Drive more full-size SUVs.
B) Build more coal-generated electricity power plants.
C) Discourage the use of alternative energy resources such as solar, wind, and geothermal energy.
D) Whenever possible, walk or ride a bicycle instead of driving a car.

___20) Which of the following hypotheses would be supported if liquid water were found on Mars and contained evidence of bacteria-like organisms?
A) Life must evolve in the presence of oxygen.
B) The chemical evolution of life is possible.
C) Life on Earth must have originated on Mars.
D) Life is guided by intelligent design.