Chapter 3: Water and Life

3.1 Explain how hydrogen bonding results from polar covalent bonds.

3.2 Identify four properties of water that are important for life and describe how they result from hydrogen bonding.

3.3 Differentiate between an acid and a base; define pH and describe how it affects the processes of life.

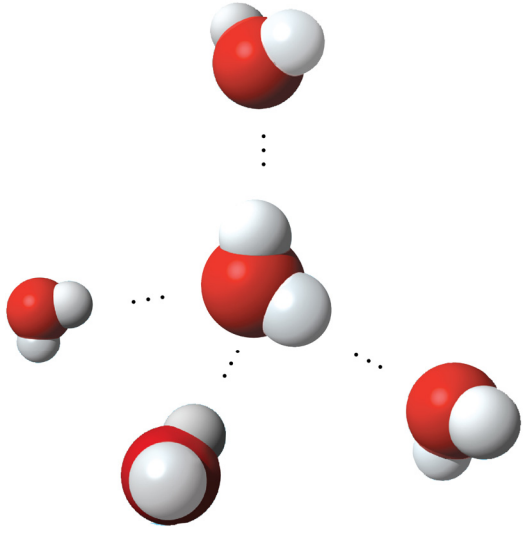
Living systems depend on properties of water that result from its polarity and hydrogen bonding. As you work through this chapter, you will come to understand how these properties impact life processes. Be sure you understand the concept of determining pH as well as its biological significance.

Study Tip: Figure 3.1 in your text gets at the core of why water is such a remarkable compound. Read and study the entire figure, and then use the information to help you answer the questions that follow.

Concept 3.1 Polar covalent bonds in water molecules result in hydrogen bonding

LO 3.1: Explain how hydrogen bonding results from polar covalent bonds.

1. Study the water molecules below. On the central molecule, label oxygen (O) and hydrogen (H). Now, add + and − signs to indicate the charged regions of *each* molecule. Then, indicate the hydrogen bonds.



2. Water is considered a polar molecule. What does this mean?

3. Explain *hydrogen bonding*. How many hydrogen bonds can a single water molecule form?

Concept 3.2 Four emergent properties of water contribute to Earth's suitability for life

LO 3.2: Identify four properties of water that are important for life and describe how they result from hydrogen bonding.

Hydrogen bonding accounts for the unique properties of water. Let's look at several of these properties.

4. Distinguish between *cohesion* and *adhesion*.

5. Which property explains the ability of a water strider to walk on water?

6. Which property is demonstrated when paper towels absorb a water spill?

7. The calorie is a unit of heat. Define *calorie*.

8. Water has high *specific heat*. What does this mean? How does water's specific heat compare to alcohol's specific heat?

9. Explain how hydrogen bonding contributes to water's high specific heat.

10. Summarize how water's high specific heat contributes to the moderation of temperature. How is this property important to life?

11. Define *evaporation*. What is *heat of vaporization*? Explain at least three effects of this property on living organisms.

12. 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.

13. Now, explain *why* ice floats. Why is 4°C the critical temperature?

14. Review and define these terms:

solvent

solution

solute

aqueous solution

15. Consider coffee to which you have added sugar. Which of these is the solvent? Which is the solute?

16. Explain why water is such a fine solvent.

17. Distinguish between *hydrophobic* and *hydrophilic substances*. Give an example of each.

18. You already know that some materials, such as olive oil, will not dissolve in water. In fact, oil will float on top of water. Explain this property in terms of hydrogen bonding.

19. Now, let's do a little work that will enable you to prepare solutions. Read the section on solute concentrations carefully and show your calculations here for preparing a 1-molar (1-*M*) solution of sucrose. Steps to help you do this follow. The first step is done for you. Fill in the steps below.

Steps to Prepare a Solution

a. Write the molecular formula.

$(C_{12}H_{22}O_{11})$

b. Use the periodic table (Appendix B in the textbook) to calculate the atomic mass of each element. Multiply by the number of atoms of the element. (For example, oxygen has a mass of 16. Therefore, oxygen has a total mass of 16 × 11 = 176 grams.)

c. Add the masses of each element in the molecule.

d. Add water to the total molar mass you determined and bring the solution to a volume of 1 L. This makes a liter of a 1-*M* solution.

20. Can you prepare 1 L of a 0.5-*M* solution of *glucose*? Show your work here. You can check the answer at the end of this chapter.

21. Define *molarity.*

Concept 3.3 Acidic and basic conditions affect living organisms

LO 3.3: Differentiate between an acid and a base; define pH and describe how it affects the processes of life.

22. What two ions form when water dissociates?

(You should have answered "hydronium (H_3O^+) and hydroxide ions (OH^-)" in the preceding question. However, by convention, we will represent the hydronium ion as H^+.)

23. Draw and label the chemical reaction that occurs when water dissociates.

24. What is the concentration of H^+ and OH^- in pure water at 25°C?

25. Water has a pH of 7. pH is defined as the negative log of the hydrogen ion concentration $[H^+]$. Explain why water is assigned a pH of 7.

26. To go a step further, the product of H^+ and OH^- concentrations is constant at 10^{-14}.

$$[H^+][OH^-] = 10^{-14}$$

Water, which is neutral with a pH of 7, has an equal number of H^+ and OH^- ions. Now, define

acid

base

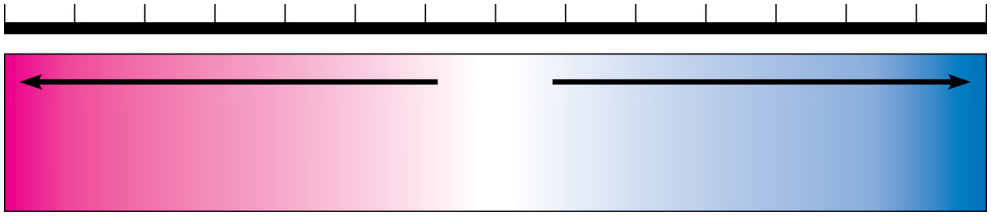
27. Because the pH scale is logarithmic, each numerical change represents a 10× change in ion concentration.

    a. 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 the difference between a pH of 8 and a pH of 12 in terms of H^+ concentration.

28. On the pH scale, label pH 1–14. Label *neutral*, *acid*, and *base*. Indicate the locations of pure water, urine, gastric juice, and bleach.



29. Even a slight change in pH can be harmful! How do *buffers* moderate pH change?

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

31. Using Figure 3.12 in the text as a starting point, discuss how CO_2 emissions affect marine life and ecosystems.

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Now you should be ready to test your knowledge. Place your answers here:

1. ____ 2. ____ 3. ____ 4. ____ 5. ____

Answer to Question 20: The formula for glucose is $C_6H_{12}O_6$ which gives a molar mass of 180 g. A 0.5*M* solution would require 90 g of glucose, adding water to bring the total volume to 1 L.