

Chapter 3: Water and the Fitness of the Environment

1. Study the water molecules at the right. On the central molecule, label oxygen and hydrogen. ✍

2. What is a polar molecule? Why is water considered polar?

Since oxygen is more electronegative than hydrogen, the electrons of the covalent bonds between them are more strongly attracted to oxygen's than hydrogen's nucleus. This unequal distribution of electrons makes water a polar molecule, meaning that the two ends of the molecule have opposite charges.

3. Add + and – signs to indicate the charged regions of each molecule. Indicate the hydrogen bonds. ✍

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

Hydrogen bonds occur when H bonds with F, O, or N and the partially positive H of one molecule is attracted to the partially negative F, O, or N of a nearby molecule. A single water molecule can form four hydrogen bonds.

5. Distinguish between cohesion and adhesion.

Cohesion is the attraction water molecules have towards each other due to hydrogen bonding; adhesion is their attraction to molecules of another substance.

6. What is demonstrated when you see beads of water on a waxed car hood?

The beads have not stretched or broken because of water's high surface tension.

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

The point at which the surface of the water interacts with air is an ordered molecular arrangement, causing the water to behave as though coated with an invisible film. This is attributable to water's high surface tension.

8. The calorie is a unit of heat.

A calorie is the amount of heat needed to raise the temperature of 1g of water by 1°C and also the amount of heat released by 1g of water when it cools by 1°C. One calorie is equal to 4.184J.

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

A substance's specific heat is the amount of heat that must be absorbed or lost for 1g of that substance to change its temperature by 1°C. Water's specific heat is 1 cal/g/°C, unusually high compared to other substances. Ethyl alcohol, found in alcoholic beverages, only requires 0.6 calories to raise 1g by 1°C.

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

Heat must be absorbed in order to break hydrogen bonds, and heat is released when hydrogen bonds form. Specific heat indicates how well a substance resists changing its temperature when it absorbs or releases heat. Due to its molecular structure, water resists temperature change, and absorbs or loses a relatively large quantity of heat for each degree of change.

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

Large bodies of water can absorb a tremendous amount of heat from the sun while only warming up by a few degrees, while gradually cooling water can warm the air when sunlight is scarce. Thus, in controlling the range of temperature fluctuations through water's high specific heat, bodies of water allow for milder climates on nearby land and stable ocean temperatures, conditions which favor the sustenance of life.

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

Evaporation is a substance's transformation from a liquid to a gaseous state. Heat of vaporization is the quantity of heat a liquid must absorb for 1g of it to evaporate. Relative to other liquids, water has a relatively high heat of vaporization due

to its high specific heat. This helps moderate Earth's climate, accounts for the severity of steam burns, and allows for efficient perspiration and transpiration.

13. Consider what would happen if bodies of water accumulated ice at the bottom. Describe why this property of water is important.

If ice would sink, life in water would not have been able to evolve as we know it because bodies of water on Earth would freeze entirely, rather than the surface layer of floating ice providing an insulating cover, which is essential for the survival of marine life.

14. Explain why ice floats. Why is 4°C the critical temperature in this story?

While other materials contract when they solidify, water expands. Thus, its solid form is less dense than its liquid form, allowing ice to float on water. However, at temperatures above 4°C, water behaves like other liquids, expanding as it warms and contracting as it cools.

15. Define the terms solvent, solution, and solute.

A solution is a liquid consisting of a completely homogeneous mixture of two or more substances. A solvent is the dissolving agent of a solution, and the dissolving substance is the solute.

16. Consider coffee to which you have added sugar. Which is the solvent? The solute?

Sugar is the solute as it dissolves in the coffee solvent.

17. Explain why water is such a fine solvent.

Water is an exceedingly versatile solvent because its polar charge allows it to dissolve other polar compounds easily by dissociating ionic compounds into their positive and negative elements.

18. Define hydrophobic and hydrophilic.

Hydrophobic substances are repelled by water; hydrophilic substances are attracted to water.

19. 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.

Substances that are nonionic and nonpolar cannot form hydrogen bonds and thus do not easily dissociate in water.

20. Show the calculations for preparing 1L of a 1-molar sucrose solution. ✎

21. Show the calculations for preparing 1L of a 0.5-molar glucose solution. ✎

22. Define molarity.

Molarity measures a solute's concentration in a solution in M: moles of solute per liters of solution.

23. What two ions form when water dissociates?

The dissociation of water forms hydronium and hydroxide ions.

24. What is the concentration of each ion in pure water at 25°C?

$10^{-7} M$

25. Water has a pH of 7. pH is defined as the negative log of the hydrogen ion concentration. How is water assigned a pH of 7?

Pure water is neutral with a pH of 7 and has an equal amount of H^+ and OH^- ions.

26. The product of H^+ and OH^- concentrations is constant at 10^{-14} . Define acid and base.

An acid is a substance that increases the hydrogen ion concentration of a solution. A base reduces the hydrogen ion concentration, some directly by accepting hydrogen ions.

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

A pH of 3 is 10^2 times more acidic than a pH of 5. A pH of 12 is 10^4 times more basic than a pH of 8, meaning that pH 8 has 10,000 times more H^+ ions than pH 12.

28. On the pH chart, label pH 1-14. Label neutral, acid, 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?

Buffers are substances that minimize changes in the concentrations of H^+ and OH^- in a solution by accepting hydrogen ions from the solution when they are in excess and donating hydrogen ions to the solution when they have been depleted, thus allowing for a relatively constant pH in biological fluids despite the addition of acids or bases. Most buffers contain a weak acid and its corresponding base, which combine reversibly with hydrogen ions.

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

Carbonic acid, formed when CO_2 reacts with water in blood plasma, dissociates to yield a bicarbonate ion and a hydrogen ion. The carbonic acid–bicarbonate buffering system consists of an acid and a base in equilibrium with each other. As carbonic acid acts as an acidic H^+ donor and the bicarbonate ion acts as a basic H^+ acceptor, the reaction shifts towards the products in response to a rise in pH and towards the reactant in response to a drop in pH, thus maintaining a relatively stable pH range.

31. Acid precipitation is increasing. Explain its sources.

Unlike regular precipitation, which has an average pH of 5.6, acid precipitation has a pH lower than 5.2, which is caused by pollutants issuing from man-made electric power plants.

32. Discuss how CO_2 emissions affect marine life and ecosystems.

About half the CO_2 emitted stays in atmosphere, acting like a reflective blanket over the planet that traps heat by preventing it from escaping into outer space. While photosynthesizing organisms absorb some of the gas, approximately 30% is taken up by the oceans, and excessive CO_2 uptake might damage the fragile marine ecosystem. For instance, exorbitant levels of CO_2 lead to excessive bicarbonate ion levels, necessarily involving a reduction in carbonate ion levels, which has a negative impact on calcification, the process that allows for the formation of coral reefs, an environment crucial for the sustenance of many diverse marine organisms. One study predicted that the expected doubling of CO_2 emissions by 2065 could lead to a 40% decrease in coral reef calcification. Chemical imbalances in ocean water can also have a tremendous influence on weather systems.