Water and the Fitness of the Environment

Chapter 3

- Objectives
  - List and explain the four properties of water that emerge as a result of its ability to form hydrogen bonds
  - Distinguish between the following sets of terms: hydrophobic and hydrophilic substances; a solute, a solvent, and a solution
  - Define acid, base, and pH
  - Explain how buffers work

2

- Overview: The Molecule That Supports All of Life
  - Water is the biological medium here on Earth
  - All living organisms require water more than any other substance
- Three-quarters of the Earth's surface is submerged in water
  - The abundance of water is the main reason the Earth is habitable

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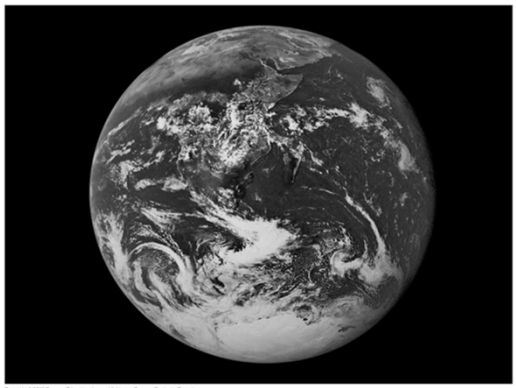

Properties of Water

- Forms hydrogen bonds
  - results in all the other properties of water discussed here

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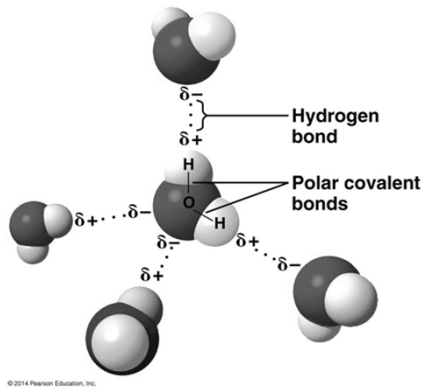
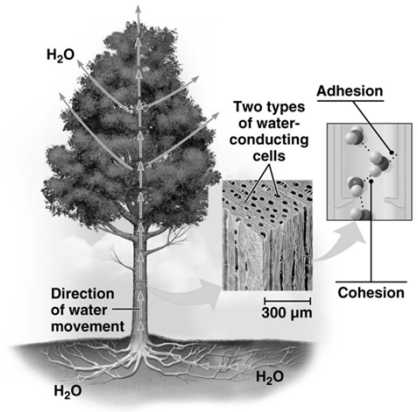


6

Cohesion and Adhesion

- Cohesion
  - water molecules attracted to each other
    - allows trees to transport water to heights greater than 100 m against gravity
- Adhesion
  - water molecules attracted to charged surfaces
    - capillary action due to attraction between water molecules and charged surface of capillary tube

7



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- Surface tension is a measure of how hard it is to break the surface of a liquid
  - cohesion of water molecules at the air-water interface gives water high surface tension

9

10

Heat and Temperature

- Kinetic energy is the energy of motion
- Heat is a measure of the total amount of kinetic energy due to molecular motion
- Temperature measures the intensity of heat

11

Water's High Specific Heat

- The specific heat of a substance is the amount of heat that must be absorbed or lost for 1 gram of that substance to change its temperature by 1ºC
- Water has a high specific heat, which allows it to minimize temperature fluctuations to within limits that permit life
  - heat is absorbed when hydrogen bonds break
  - heat is released when hydrogen bonds form

12

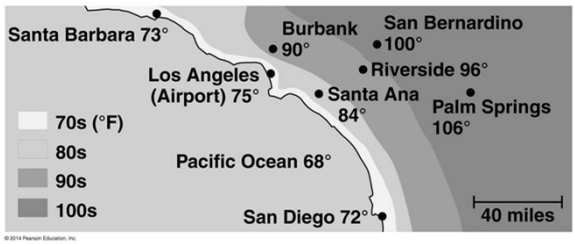
- Specific heat is often measured in calories
  - a calorie (cal) is the amount of heat required to raise the temperature of 1 g of water by 1°C
    - the "calories" on food packages are actually kilocalories (kcal), where 1 kcal = 1,000 cal
  - the joule (J) is another unit of energy where 1 J = 0.239 cal, or 1 cal = 4.184 J

13

Moderation of Temperature

- Water moderates air temperature by absorbing heat from air that is warmer and releasing the stored heat to air that is cooler

14



15

Evaporative Cooling

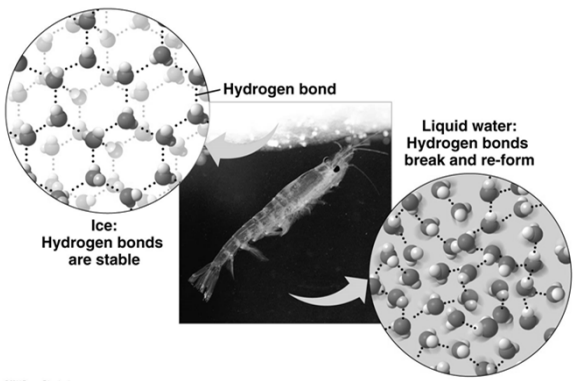
- Evaporation is the transformation of a substance from a liquid to a gas
  - the heat of vaporization is the quantity of heat a liquid must absorb for 1 gram of it to be converted from a liquid to a gas
- Evaporative cooling is due to water's high heat of vaporization
  - allows water to cool a surface

16

Insulation of Bodies of Water by Floating Ice

- Solid water is less dense than liquid water
  - water molecules in ice are held farther apart by hydrogen bonds than in water
    - approximately 10% less molecules per unit volume in ice than in water
  - floating ice forms an insulating barrier over bodies of water
    - prevents oceans and lakes from freezing solid

17

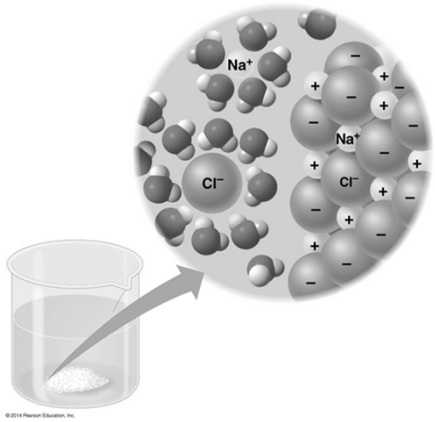


18

The Solvent of Life

- Polar nature of water makes it a good solvent for polar molecules and ionic compounds
  - substances with high affinity for water are hydrophilic
  - substances that are non-ionic and non-polar do not interact with water and are hydrophobic

19



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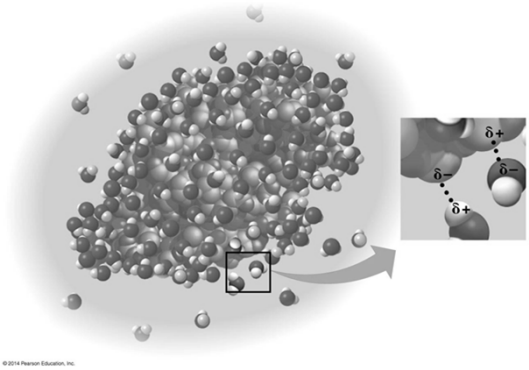
- Water can also interact with large molecules such as proteins
  - Large biological molecules frequently have numerous polar groups on the surface that interact with water

21



22

Solute Concentration in Aqueous Solutions

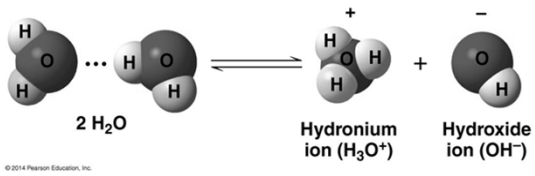
- Since most biochemical reactions occur in water it is important to learn to calculate the concentration of solutes in an aqueous solution
  - A mole represents an exact number of molecules of a substance in a given mass
  - molarity is the number of moles of solute per liter of solution

23

Dissociation of Water

- Water molecules occasionally dissociate to form a hydronium ion (H_3O^+) and a hydroxide ion (OH^-)
  - can be represented by the following equation: $2H_2O \leftrightarrow H_3O^+ + OH^-$
- At equilibrium one in 554 million water molecules dissociated
  - equals a concentration of 10^{-7} M H^+ and OH^-, respectively, in pure water at 25°C
    - the dissociation constant is the product of the ions released in solution at equilibrium
      - for water, $K_w = [H^+][OH^-] = 10^{-7} \times 10^{-7} = 10^{-14}$

24



25

Acids, Bases and Salts

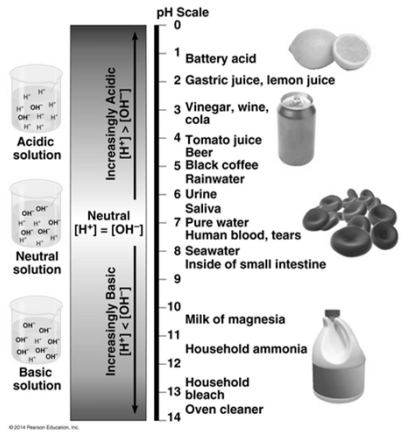
- Acid-releases H^+ in solution
- Base-releases OH^- in solution
- pH scale measures H^+ concentration in solution
  - the pH of a solution is defined by the negative logarithm of H^+ concentration, written as

    $pH = -\log [H^+]$
  - scale runs from 0 (acid) to 7 (neutral) to 14 (base)

26

- The pH of a solution is determined by the relative concentration of hydrogen ions
  - low pH=high H^+ concentration
  - high pH=low H^+ concentration

27



28

Salts

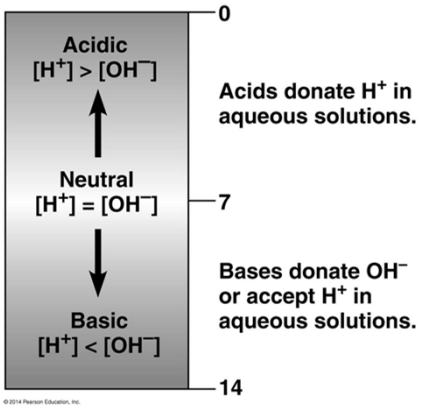
- Salts formed when an acid reacts with a base
  - example:
  - $NaOH + HCl \rightarrow NaCl + H_2O$

29

Buffers

- The internal pH of most living cells must remain close to pH 7
- Buffers-combine with, or release, H^+ to prevent large pH changes
  - consist of an acid-base pair that reversibly combines with hydrogen ions
    - bicarbonate ion (HCO_3^-) is the buffer in blood
      - formed when CO_2 dissolves in water

30

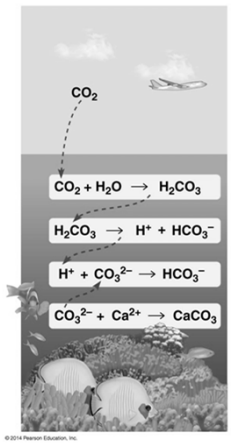


31

The Threat of Acid Precipitation

- Acid precipitation refers to rain, snow, or fog with a pH lower than pH 5.6
  - caused primarily by the mixing of different pollutants with water in the air
- About 25% of human-generated CO_2 is absorbed by the oceans
  - CO_2 dissolved in sea water forms carbonic acid; this process is called ocean acidification

32



33

- As seawater acidifies, H^+ ions combine with carbonate ions to produce bicarbonate
  - Carbonate is required for calcification (production of calcium carbonate) by many marine organism, including reef-building corals

34