Water and the Fitness of the Environment  
Chapter 3

Water
• Two __________ atom joined to one __________ atom, each by a single  
  __________ bond  
  - Oxygen: slight __________ charge  
  - Hydrogen: slight __________ charge  
  - __________ molecule

Importance of Water
• Required for __________  __________  
  - Aquatic  
  - Terrestrial  
• Unique qualities associated with __________ nature of water  
• Each molecule can bond with _____ neighbors  
• Results in __________  __________

Emergent Properties of Water
• __________ behavior  
• __________ changes in __________  
• __________ when it __________  
• __________  __________  
  – Not really “universal solvent”
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Cohesion
- Attraction for _________ – water molecules held together by _______ bonds
- When _________
  - Hydrogen bonds fragile and _________
  - But constantly forming new bonds
  - _________ are _________ to neighbors at any one time
  - Highly structured
- Allows _________ of water _________ gravity
  - Water reaches tops of tall trees
  - Evaporation results in pull of water column up xylem vessels in plants
- _________ (attraction to other) makes it cling to walls of vessel

Surface Tension
- Measure of force necessary to stretch or break the surface of a liquid
- Water has greater _________ _________ than most other liquids
  - Hydrogen bonds among surface water molecules resist stretching or breaking the surface
  - Water behaves as if covered by invisible film
  - Some animals can stand, walk, or run on water
    without breaking the surface

Definitions Related to Resistance to Changes in Temperature
- Kinetic energy – energy of _________
- Heat – total kinetic energy due to molecular motion in a body of matter
- Calorie (cal) – amount of heat it takes to raise the temperature of _________ gram of water by _________ degree Celsius
- Kilocalorie (kcal or Cal) – amount of heat required to raise the temperature of one _________ of water by one degree Celsius
- Temperature
  - Heat intensity due to _________ kinetic energy of molecules in a body of matter
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Celsius Scale

• Some temperatures and conversions

  - Water boils: _______ ° C = 212° F
  - Water freezes: ______ ° C = 32° F
  - Human body temp: ______ ° C = 98.6° F
  - Room temp: ______ ° C = 72° F

Resistance to Changes in Temperature

• Resistance to changes is due to specific heat

• Specific Heat
  - The amount of heat that must be absorbed or lost for ___ ___ of substance to change its temperature by ___ ° ___
    - Water: 1 cal/g/°C
    - Ethanol: 0.6/g/°C
    - Iron: 0.1/g/°C

• Water has very _________ specific heat

Resistance to Changes in Temperature

• Water _____________ (buffers) changes in temperature
  - Hydrogen bonds absorb heat \( \rightarrow \) break \( \rightarrow \) then molecules move faster \( \rightarrow \) temperature rises
  - Temperature falls \( \rightarrow \) H bonds form \( \rightarrow \) heat emitted

• Gives us stable ocean temps

• Produces “Lake effect”
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Cooling

- Evaporative cooling
  - Fastest, most ____________ molecules ____________ (evaporate)
  - Leave behind less active molecules
  - Moderates temperature in lakes and ponds
  - Prevents terrestrial organisms from overheating
    - Leaves of plants
    - Skin of humans and animals

Freezing

- Freezing – water most dense at ____ °C
- ____________ upon freezing
  - less dense
    - Ice floats
  - As temp approaches 0°C
    → H-bonds ____________ in place in crystals
    → holds molecules apart
  - As temp rises above 0°C,
    H-bonds ____________ → crystals collapse
    → molecules move → liquid

Ice Floats: Floating ice insulates deep lakes from freezing solid

Water as a Solvent

- ____________
  - Liquid that is completely homogenous mixture of two or more substances

- ____________
  - Substance dissolved

- ____________ solution
  - Solution where water is the solvent
  - Versatile, but not “universal”
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Aqueous Solutions

- ______ shell – sphere of water surrounding each ion or molecule of solute

- Water especially good at forming ______-bonds w/ polar molecules and ions
  - Water + NaCl $\rightarrow$ aqueous solution of Na$^+$ and Cl$^-$

- Even large molecules may be soluble if they have polar or ionic regions

Water Love – Water Fear

- ___________ (hydro = water; philios = loving)
  - Any substance with an affinity for water
  - Even molecules too big to dissolve e.g. cellulose
  - Just need ________ covalent bonds or ionic bonds
    - e.g. Cotton (mostly cellulose)

- ___________ (phobos = fearing)
  - Any substance without affinity for water
  - Non-ionic or non-polar molecules repel water
  - Vegetable oil (carbon-hydrogen bonds non-polar)
  - Cell ____________ highly hydrophobic

Biological Solutes

- Most chemical reactions in living organisms occur in ___________

- ____________ is solvent in biological systems

- What is solute, and what ____________ is it?

- Not practical to weigh molecules of solute

- Determine molecular weight (weight of molecule in daltons)

- Re-express it in grams – more practical
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Determining Concentration

- Molecular Weight
  - Sum of weights of all of the atoms in a molecule (expressed in daltons)

- Mole
  - Numerical value of molecular weight, upscaled and re-expressed in grams

- Molecular weight of sucrose = 342 daltons
  - 1 mole sucrose = 342 grams

- Molarity
  - Number of moles of __________ per __________ of solution

E.g. Molarity of Sucrose

- Molecular Formula: \( C_{12}H_{22}O_{11} \)
- \( C = 12 \) daltons \( \times \) 12 = 144 daltons
- \( H = 1 \) dalton \( \times \) 22 = 22 daltons
- \( O = 16 \) daltons \( \times \) 11 = 176 daltons
- Molecular weight: 342 daltons
- A mole of sucrose is equal to 342 g
- 1 Molar solution = 342g in 1 L

Molarity of Ribulose

- What is the molecular weight of Ribulose \( C_5H_{10}O_5 \)?
  - __________ ? __________ daltons

- How much ribulose would be required to make a 2 molar solution in one liter of water?
  - __________ ? __________ grams

Ionization of Water

- \( H_2O \overset{\rightleftharpoons}{ } H^+ \) and \( OH^- \)
- Reaction is reversible
- \( H_2O + H_2O \overset{\rightleftharpoons}{ } H_3O^+ \) and \( OH^- \) (Hydronium ion and hydroxide ion)
- At equilibrium most water is not ionized
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Balance of Ions

• Neutral: \([H^+] = [OH^-]\)
  - Concentrations are ___________

• Acidic: \([H^+] > [OH^-]\)
  - Concentrations of ___________ ions is higher

• Basic: \([H^+] < [OH^-]\)
  - Concentration of ___________ ions is higher

Acids and Bases

• Acid
  - A substance that ___________ the relative \([H^+]\) of a solution (or decrease \(OH^-\))

• Base
  - A substance that ___________ the relative \([H^+]\) of a solution (or increases \(OH^-\))

pH Scale

• Measures degree of acidity from 0 to ______
  - \(pH = - \log[H^+]\)

• \(pH 7\) is a ___________ solution

• \(pH < 7\) is an ___________ solution

• \(pH > 7\) is a ___________ solution

pH Scale

• Scale is logarithmic (base 10)
  - So a slight change in pH is a big change in actual \(H^+\) concentration
  - Each pH unit represents a _______-fold difference

• How much greater is the \([H^+]\) in pH 4 than pH 7?
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pH of Living Organisms

• Biological fluids usually are between _____ - _____
• Stomach acid is approx 1.5
• Human blood approx 7.4
• Slight changes can be very harmful

________________________

• __________ a sudden change in pH
• Combination of H⁺ donor and H⁺ acceptor forms of weak acids and bases
• Work by accepting H⁺ ions from solutions when they are in excess, and by donating H⁺ ions when they have been depleted
• Results in ___________ ________ of body fluids
  (e.g. blood)