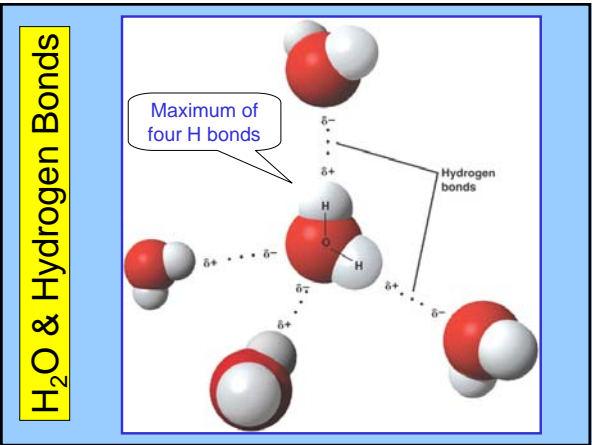
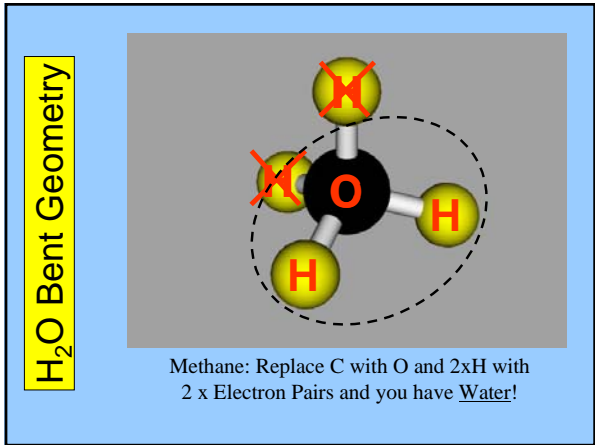
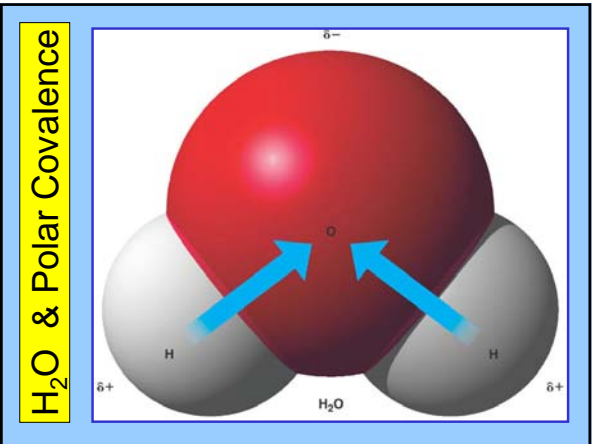


Chapter 3: Water and the Fitness of the Environment



- H₂O Properties from H Bonds**
- Water molecules adhere to other molecules (adhesion)
 - Liquid water effects hydrophobic exclusion
 - Liquid water has high specific heat
 - Liquid water has high heat of vaporization
 - Water molecules adhere to each other (cohesion)
 - Water is a liquid rather than gas at room temperature
 - Ice floats
 - Liquid water is a powerful polar solvent

- Hydrophilic/Hydrophobic**
- Hydrophilic = Water Loving
 - These are things that like to dissolve in or be wet by water
 - Typically these things have polar bonds or full charges
 - Hydrophobic = Water Hating
 - Things that do not like to dissolve in or be wet by water
 - Typically these things lack polar bonds or full charges
 - For example, hydrocarbons are hydrophobic, e.g., oils

Adhesion—Hydration Shells

Liquid water operates as a solvent on many substances that are electrically charged or polar.

Sodium ion Chloride ion

Solid NaCl

Water molecule Hydrogen bond

When completely dissolved, the ions of NaCl are uniformly distributed throughout the solvent.

A solution of Na⁺ and Cl⁻

Shown are water molecules adhering to various ions (adhesion), forming hydration shells around them

Adhesion—Capillary Action

MENISCUS

Symbol used to show surface of water in contact with air.

WATER

Water rising in a small glass tube by capillary action.

Shown are water molecules adhering to the walls of the tube (adhesion)

Cohesion

“Cohesion” refers to the high potential for water molecules to hydrogen bond to each other

Hydrophobic Exclusion

non-polar molecules [2-D squiggles] displace more water molecules dissolved [26 = 13 + 13] than “banded together” [16].

Hydrophobic Exclusion

Water molecules prefer to interact with molecules they can form hydrogen bonds with, such as each other; the result is a clumping of non-polar molecules away from water

non-polar molecules [2-D squiggles] displace more water molecules dissolved [26 = 13 + 13] than “banded together” [16].

Hydrophobic Exclusion

Hydrophobic Exclusion

Ice

No hydrogen bonds between water and ice

In water, each and liquid water, each water molecule can attract two neighbors for hydrogen bonds

Hydrophobic Exclusion

Extracellular fluid

Carbohydrate

Integral protein

Peripheral protein

Flowers of cholesterol

Cytoplasm

Hydrophobic Excl. of Globular Protein

(a) (b) (c)

Hydrophobic Interior Hides from Water

Hydrophilic Exterior "Embraces" Water

H₂O High Specific Heat

- Temperature is a measure of molecular movement
- To move around more, water molecules must break H bonds
- Breaking H bonds requires energy (water wants to H bond)
- So, much heat that could raise temps instead breaks H bonds
- Now for the less intuitive part...
- If water is to move around, then less than H bonds are formed
- Water wants to form H bonds: bond formation releases energy
- So, as you take heat away from water, water compensates by releasing heat!
- Due to H bonds, water resists heating & cooling—technically, we describe this as water having a high specific heat

High Heat Vaporization

Water resists evaporating (i.e., vaporizing) because hydrogen bonds must be broken in order for water to transition from the liquid to the gas state

Vapor

Liquid

Evaporative Cooling

Faster (hotter) molecules leave the liquid-phase first, lowering the temperature of the remaining liquid—you (via your sweat and skin) and engineers take advantage of this by using water evaporation to cool things

How it works

evaporation

Wet T-Shirts

http://www.adobear.com/coolers/evap_cooling.htm


Water Adheres to Water

Water doesn't H bond with air, so preferentially sticks to itself at air-water interfaces

Water Adheres to Water

To optimize the exchange of oxygen and carbon dioxide between the body and the environment, the lung is divided into alveoli, or small air sacs, that maximize the area over which gas is in close contact with capillary blood. A thin layer of water coats each of the alveoli and protects the living tissue underneath. This creates an extensive air-water interface within the lung cavity, and the surface tension of the water tends to collapse the lungs. Surface tension accounts for approximately two-thirds of the contractile force within the lungs. The effect of surface tension is greater for structures with tighter curvature, and consequently alveoli that lack surfactant tend to collapse at the end of exhalation. The subsequent tearing open of the alveoli upon inhalation damages the epithelium of the distal airways, resulting in impaired lungs that exchange gas poorly.

Surface Tension



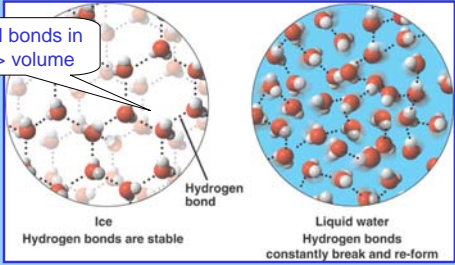
Surface tension is an emergent property of water that results from the tendency of water molecules to stick to each other (by hydrogen bonding) better than they adhere to air molecules

H₂O Liquid at Room Temp

Formula	Mol. Weight	Phys. State
CO ₂	44	Gas
O ₂	32	Gas
CO	28	Gas
N ₂	28	Gas
H ₂ O	18	Liquid
CH ₄	16	Gas
H ₂	2	Gas

Water is a liquid at room temperature not because of its mass because of hydrogen bonding (cohesion)

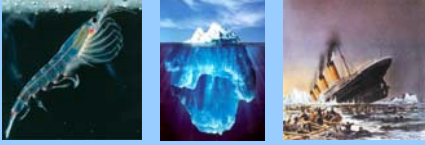
Ice Floats



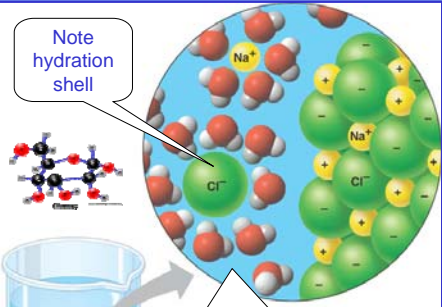
More H bonds in ice => volume

Ice
Hydrogen bonds are stable

Liquid water
Hydrogen bonds constantly break and re-form




Powerful Polar Solvent



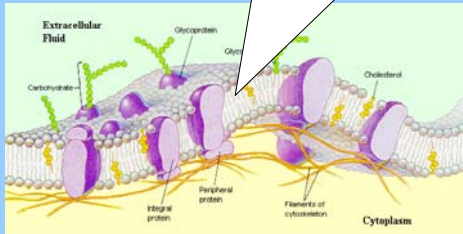
Note hydration shell

Also Effective with Molecules containing only partial charges, e.g., sugars and alcohols



Crucial to Life

The most important property of water to the existence of life has to do with the ability of water to dissolve some substances and exclude others



Solution Lore

- Water dissolves substances to which it can readily hydrogen bond (or is otherwise attracted to typically because the substance contains full or partial charges)
- Solute = a substance that dissolves in another substance
- Solvent = the substance the solute dissolves in
- Solution = a solvent in which solutes are dissolved
- Aqueous solution = a solution in which water is the solvent

pH & Chemical Equilibria

pH Scale

- 0 Battery acid
- 1 Digestive (stomach) juice, lemon juice
- 2 Vinegar, beer, wine, cola
- 3 Tomato juice
- 4 Black coffee
- 5 Rainwater
- 6 Urine
- 7 Pure water
- 8 Human blood
- 9 Seawater
- 10 Milk of magnesia
- 11 Household ammonia
- 12 Household bleach
- 13 Oven cleaner
- 14

Hydronium ion (H₃O⁺) Hydroxide ion (OH⁻)

pH Buffering

Carbonic-Acid-Bicarbonate Buffering (e.g., of blood)

$$\text{H}_3\text{O}^+(\text{aq}) + \text{HCO}_3^-(\text{aq}) \xrightleftharpoons{K_1} \text{H}_2\text{CO}_3(\text{aq}) + \text{H}_2\text{O}(\text{l}) \xrightleftharpoons{K_2} 2 \text{H}_2\text{O}(\text{l}) + \text{CO}_2(\text{g})$$

acid-base reaction

not an acid-base reaction

>pH = less H₃O⁺ ≈ H⁺

pK
[H₂CO₃] = [HCO₃⁻]

base added →

% buffer in the form of HCO₃⁻

Normal blood pH →

% buffer in the form of H₂CO₃ and CO₂

You'll learn much more about this in Chemistry

