Water and Life
Chapter 3

Water naturally exists as liquid, solid, vapor

Life evolved in water
3 billion years
75% Earth’s surface

Life dependent on water
Cells: 70-95% water
How long can humans live without water?

Water, a polar molecule
Oxygen more electronegative → unequal sharing of e⁻

Polar covalent bond | opposite ends, opposite charges
H-bonding
cohesion
adhesion
surface tension
temperature
stabilization
expansion upon freezing
solvent

Neighboring H₂O molecules likely to take on this arrangement?

---

cohesion

H-bonding holds H₂O molecules together

SURFACE TENSION

---

adhesion

H-bonding enables H₂O to stick to other substances

(meniscus)

H₂O transport in plants

adhesion to cell walls helps resist gravity

cohesion helps H₂O upward pull
heat and temperature
heat | total kinetic energy
temperature | heat intensity, representing average kinetic energy
energy disrupts hydrogen bonds
heat absorbed when H-bonds break
heat released when H-bonds form

moderation of temperature
specific heat
amount of heat absorbed or lost for 1g of substance to change temperature by 1°C
high specific heat, H₂O absorbs/releases large quantities of heat with little change in temp
H₂O | effective stabilizer of temperature
H-bonding
sweat cools

calories and Calories
calorie | amount of heat energy required to raise temperature of 1g of H₂O by 1°C
Calorie (on food packages) | kilocalorie, amount of heat energy to raise temperature of 1000g of H₂O by 1°C
joule | 1 J = 0.239 cal, 1 cal = 4.184 J
specific heat of H₂O = 1 cal/g/°C
evaporative cooling

evaporation | highest energy molecules escape H-bond attractive forces in liquid (even in ice!)

heat of vaporization | heat absorbed for conversion of 1g of liquid to gas

evaporative cooling maintains temperature of organisms, bodies of water

ice

lattice at 0 °C
H-bonds stable, less dense

water: solvent of life

solution sugar water
solute sugar
solvent water
aqueous

hydration shell
hydrophilic molecules capable of H-bonding or polar | tend to dissolve in H\(_2\)O

hydrophobic molecules typically non-polar | tend to repel H\(_2\)O

like dissolves like

acids, bases, life

proton (H\(^+\)) transfer | hydrogen atom shared by two H\(_2\)O molecules can shift from one to the other

\[
H_2O + H_2O \rightleftharpoons H_3O^+ + OH^-
\]

hydronium ion hydroxide ion

at equilibrium, H\(_2\)O \(>>\) H\(^+\) and OH\(^-\)

pure H\(_2\)O only one in every 554 million molecules dissociate

acids and bases

acid \(\rightarrow\) \([H^+]\)
proton donor (e.g. HCl)

pure H\(_2\)O: \([H^+] = [OH^-]\)

base \(\rightarrow\) \([H^+]\)
proton acceptor (e.g. NaOH)

changes in concentrations drastically affect proteins and other cellular molecules

even slight change in blood pH could cause death!
human stomach can reach pH 2

acids | pH < 7
bases | pH > 7
most biological fluids | 6 < pH < 8

logarithmic scale

buffers
- most living cells, pH ~7 (7.4)
- buffers minimize changes in [H⁺] and [OH⁻] by accepting/donating H⁺
- weak acid / conjugate base pair
- accept H⁺ when excess, donate when depleted
- carbonic acid important buffer in human blood

H₂CO₃ product favored if decreased pH (excess H⁺)  \( \text{HCO}_3^- + \text{H}^+ \) products favored if increased pH (less H⁺)

H₂CO₃ \( \leftrightarrow \) HCO₃⁻ + H⁺

acidification and water quality
fossil fuel combustion
\( \uparrow \) CO₂, sulfur oxides, nitrogen oxides
\( \downarrow \) pH in oceans, lakes, rivers, soil
\( \downarrow \) deleterious to ecosystems