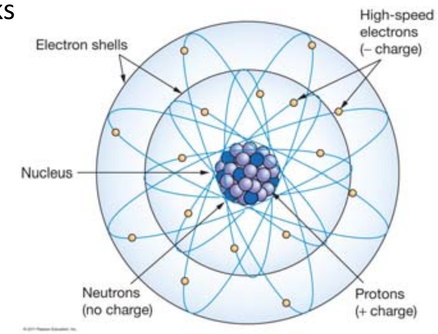
CHAPTER 5
Water and Seawater

- Water has many unique thermal and dissolving properties.
- Seawater is mostly water molecules but has dissolved substances.
- Ocean is layered by salinity and density differences.

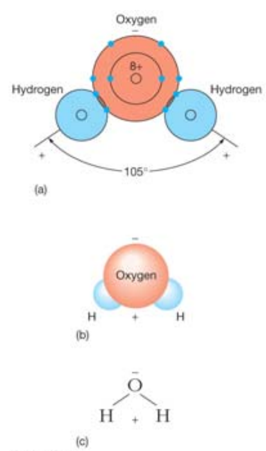
Atomic Structure

- Atoms – building blocks of all matter
- Subatomic particles
  - Protons
  - Neutrons
  - Electrons
- Number of protons distinguishes chemical elements



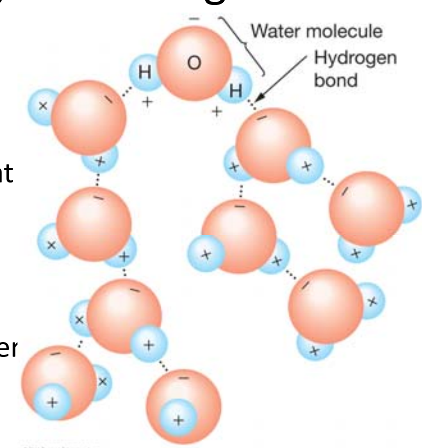
Water molecule

- Strong covalent bonds between one hydrogen (H) and two oxygen (O) atoms
- Both H atoms on same side of O atom
- Dipolar



Hydrogen Bonding

- Polarity means small negative charge at O end
- Small positive charge at H end
- Attraction between positive and negative ends of water molecules to each other or other ions

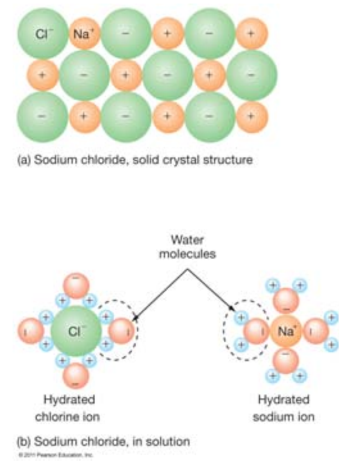


Hydrogen Bonding

- Hydrogen bonds are weaker than covalent bonds but still strong enough to result in
  - High water surface tension
  - High solubility of chemical compounds in water
  - Unusual thermal properties of water
  - Unusual density of water

Water as Solvent

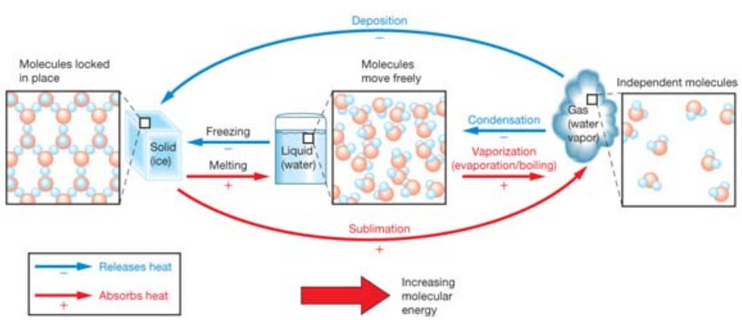
- Water molecules stick to other polar molecules.
- Electrostatic attraction produces ionic bond.
- Water can dissolve almost anything.
- Hydration



Water's Thermal Properties

- Water is solid, liquid, and gas at Earth's surface.
- Water influences Earth's heat budget.

Water's Three States of Matter



Heat

- Energy of moving molecules
- Calorie is the amount of heat needed to raise the temperature of 1 gram of water by 1°C.
- Temperature is a measurement of average kinetic energy.

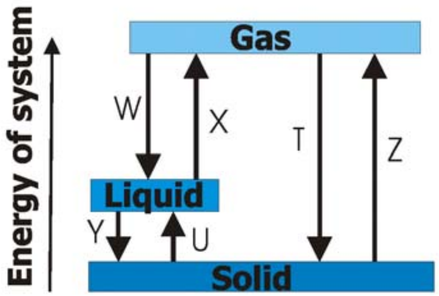
Freezing and Boiling Points

- Freezing point = melting point: 0°C (32°F)
- Boiling point = condensation point: 100°C (212°F)
- Freezing and boiling points of water unusually high

Latent Heat of Vaporization = 600 calories / 1g

Latent Heat of Condensation = 600 calories / 1g

Latent Heat of Fusion= 80 calories / 1g

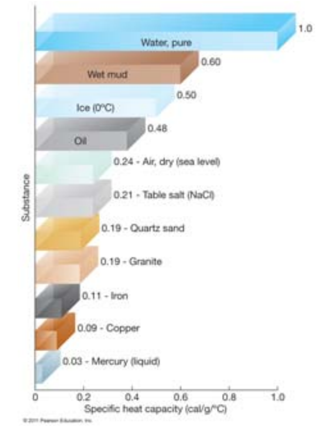


How much energy to sublimate?

http://www2.chemistry.msu.edu/courses/cem152/snl_cem152_SS12/pracprob/practiceexam1.html

Water's Heat Capacity and Specific Heat

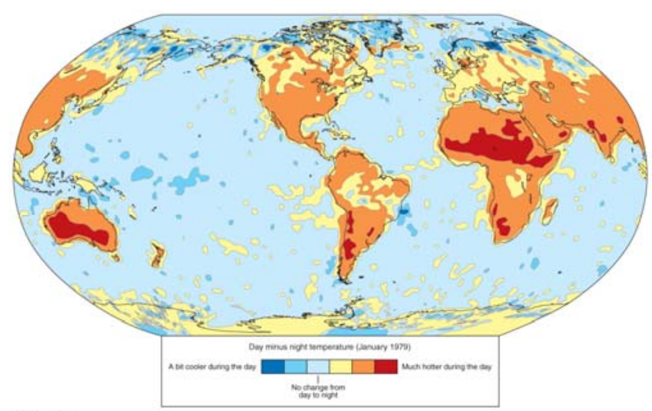
- Heat Capacity – amount of heat required to raise the temperature of 1 gram of any substance by 1°C
- Water has a high heat capacity – can take in or lose much heat without changing temperature
- Specific Heat – heat capacity per unit mass



Global Thermostatic Effects

- Moderate temperature on Earth's surface
  - Equatorial oceans do not boil
  - Polar oceans do not freeze solid
- Marine effect
  - Oceans moderate temperature changes from day to night and during different seasons
- Continental effect
  - Land areas have greater range of temperatures from day to night and during different seasons

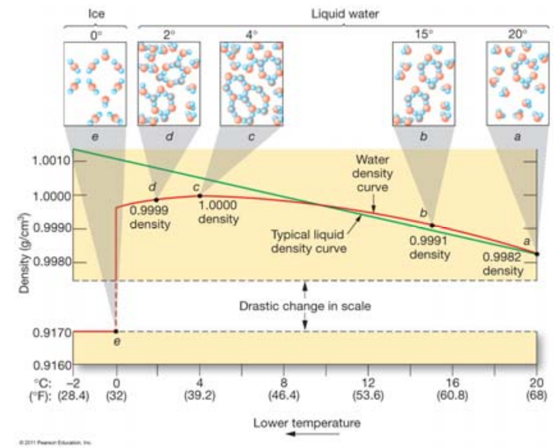
Day/Night Temperature Differences



Water Density

- Density of water increases as temperature decreases.
  - Thermal contraction
- From 4°C to 0°C the density of water decreases as temperature decreases.
- Ice is less dense than water.
  - Changes in molecular packing
  - Water expands as it freezes.

Water Density and Temperature



Water Density

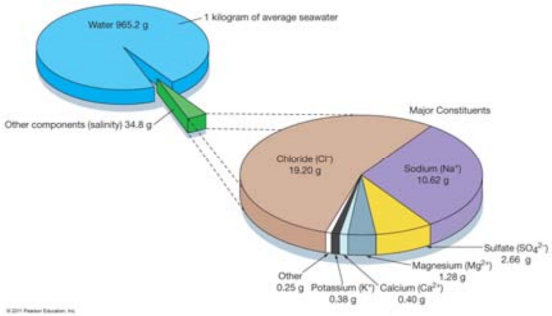
- Increasing pressure or adding dissolved substances decreases the maximum density temperature.
- Dissolved solids also reduce the freezing point of water.
  - Most seawater never freezes.

Salinity

- Total amount of dissolved solids in water including dissolved gases
  - Excludes dissolved organics
- Ratio of mass of dissolved substances to mass of water sample

Salinity

- Expressed in parts per thousand (ppt)
- Typical ocean salinity is 35 ppt ($^{o}/_{oo}$)



Determining Salinity

- Evaporation
- Chemical analysis–*titration*
  - Principle of constant proportions
  - Major dissolved constituents in same proportion regardless of total salinity
  - Measure amount of halogens (Cl, Br, I, F) (chlorinity)
  - Salinity = 1.80655 * Chlorinity *(ppt)*
- Refractometer (today)
- Hydrometer (today)
- Electrical conductivity
  - Salinometer

Salinity Variations

- Open-ocean salinity is 33–38 $^{o}/_{oo}$
  - 1‰ = 10^{-3}= $^{1}/_{1000}$ = 0.001 = 0.1%
  - 1% = $^{1}/_{100}$ = 10‰
- In coastal areas salinity varies more widely.
  - An influx of freshwater lowers salinity or creates brackish conditions.
  - A greater rate of evaporation raises salinity or creates hypersaline conditions.
  - Salinity may vary with seasons (dry/rain).

Processes Affecting Salinity

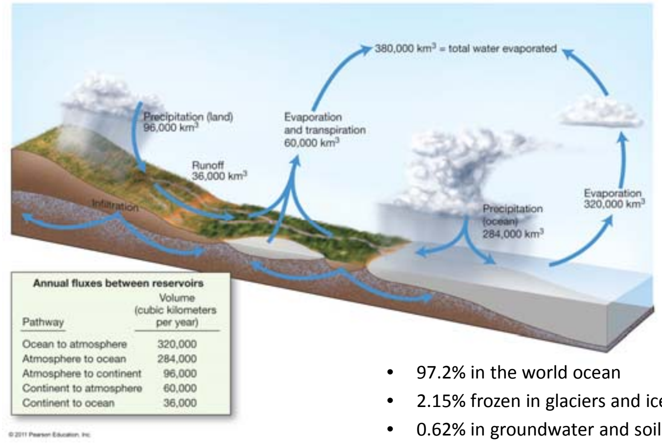
- Decreasing salinity – adding fresh water to ocean
  - Runoff, melting icebergs, melting sea ice
  - Precipitation
- Increasing salinity – removing water from ocean
  - Sea ice formation
  - Evaporation

Processes Affecting Salinity

TABLE 5.3 PROCESSES AFFECTING SEAWATER SALINITY

Process	How accomplished	Adds or removes	Effect on salt in seawater	Effect on H_2O in seawater	Salinity increase or decrease?	Source of freshwater from the sea?
Precipitation	Rain, sleet, hail, or snow falls directly on the ocean	Adds very fresh water	None	More H_2O	Decrease	N/A
Runoff	Streams carry water to the ocean	Adds mostly fresh water	Negligible addition of salt	More H_2O	Decrease	N/A
Icebergs melting	Glacial ice calves into the ocean and melts	Adds very fresh water	None	More H_2O	Decrease	Yes, icebergs from Antarctic have been towed to South America
Sea ice melting	Sea ice melts in the ocean	Adds mostly fresh water and some salt	Adds a small amount of salt	More H_2O	Decrease	Yes, sea ice can be melted and is better than drinking seawater
Sea ice forming	Seawater freezes in cold ocean areas	Removes mostly fresh water	30% of salts in seawater are retained in ice	Less H_2O	Increase	Yes, through multiple freezings, called *freeze separation*
Evaporation	Seawater evaporates in hot climates	Removes very pure water	None (essentially all salts are left behind)	Less H_2O	Increase	Yes, through evaporation of seawater and condensation of water vapor, called *distillation*

Earth's Hydrologic Cycle

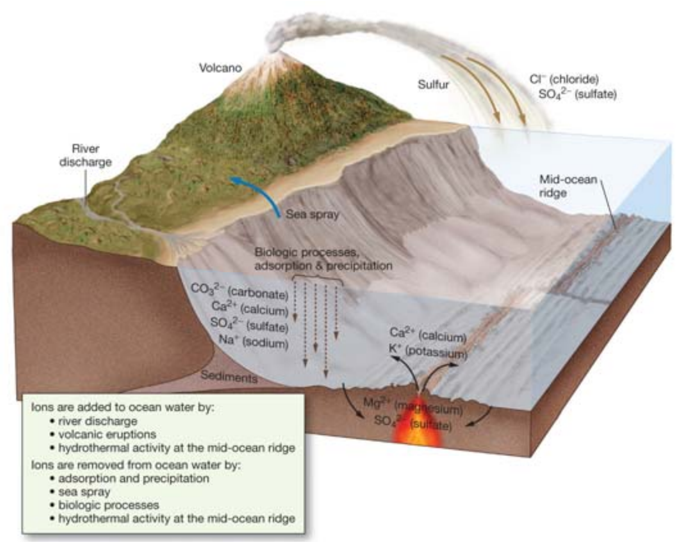


- 97.2% in the world ocean
- 2.15% frozen in glaciers and ice caps
- 0.62% in groundwater and soil moisture
- 0.02% in streams and lakes
- 0.001% as water vapor in the atmosphere

Residence Time

- Average length of time a substance remains dissolved in seawater
- Ions with long residence time are in high concentration in seawater.
- Ions with short residence time are in low concentration in seawater.
- Steady state condition

Processes that Add/Subtract Dissolved Substances

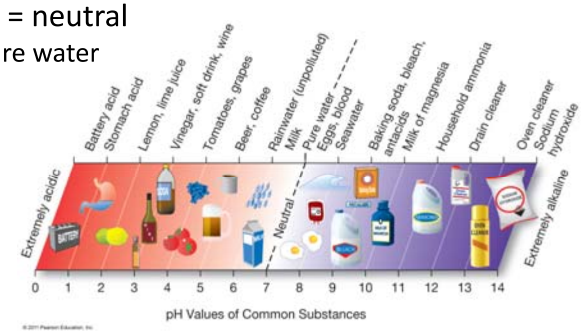


Acidity and Alkalinity

- Acid releases a hydrogen ion (H+) when dissolved in water.
- Alkaline (or base) releases a hydroxide ion (OH-) in water.

pH Scale

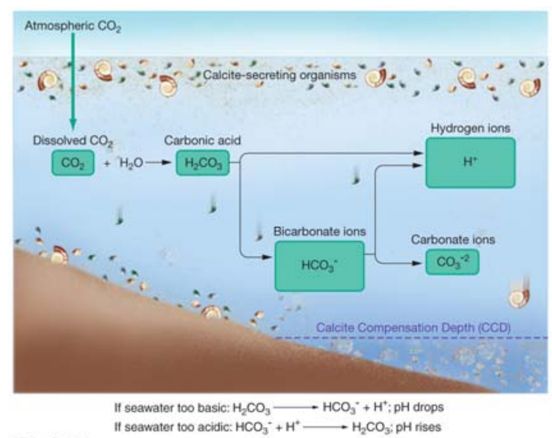
- Measures hydrogen ion concentration
  - Low pH value, acid
  - High pH value, alkaline (basic)
  - pH 7 = neutral
    - Pure water



Carbonate Buffering System

- Ocean pH averages 8.1 and ranges from 8.0 to 8.3.
- Buffering keeps the ocean from becoming too acidic or too basic.
- Precipitation or dissolution of calcium carbonate, $CaCO_3$, buffers ocean pH.
- Oceans can absorb CO_2 from the atmosphere without much change in pH.

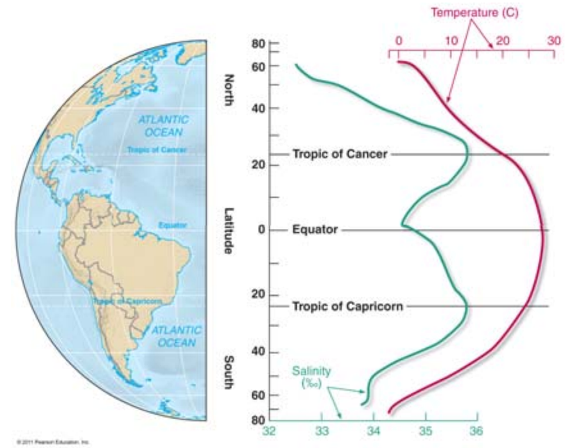
Carbonate Buffering System



Surface Salinity Variation

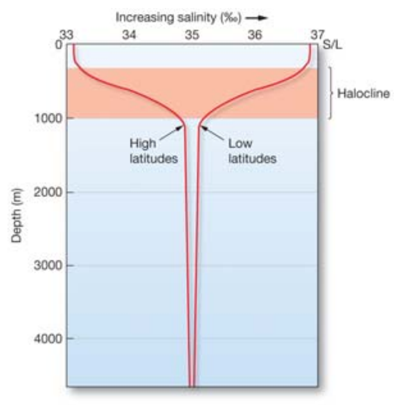
- High latitudes
  - Low salinity
  - Abundant sea ice melting, precipitation, and runoff
- Low latitudes near equator
  - Low salinity
  - High precipitation and runoff
- Mid latitudes
  - High salinity
  - Warm, dry, descending air increases evaporation

Surface Salinity Variation by Latitude



Salinity Variation with Depth

- Low latitudes – salinity decreases with depth
- High latitudes – salinity increases with depth
- Deep ocean salinity fairly consistent globally
- Halocline – separates ocean layers of different salinity

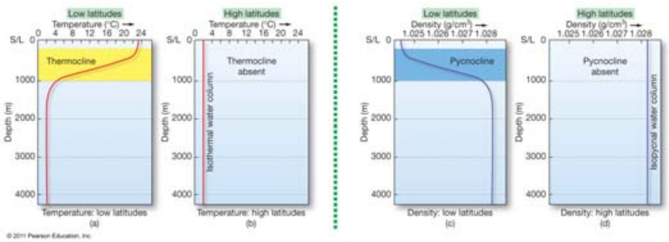


Seawater Density

- Density increases with decreasing temperature (due to thermal expansion)
  - Greatest influence on density
- Density increases with increasing salinity (due to the addition of dissolved material)
- Density increases with increasing pressure (due to the compressive effects of pressure)
  - Does not affect surface waters

Temperature and Density Variation With Depth

- Pycnocline – abrupt change of density with depth
- Thermocline – abrupt change of temperature with depth



Layered Ocean

Three distinct water masses based on density:

- Mixed surface layer – above thermocline
- Upper water – thermocline and pycnocline
- Deep water – below thermocline to ocean floor
- High latitude oceans – thermocline and pycnocline rarely develop
  - Isothermal
  - Isopycnal