CHAPTER 5
Water and Seawater

Chapter Overview
- Water has many unique thermal and dissolving properties.
- Seawater is mostly water molecules but has dissolved substances.
- Ocean water salinity, temperature, and density vary with depth.
-

Water on Earth
- Presence of water on Earth makes life possible.
- Organisms are mostly water.

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

Molecules
- Molecule
  - Two or more atoms held together by shared electrons
  - Smallest form of a substance

Water molecule
- Strong covalent bonds between two hydrogen (H) and one oxygen (O) atoms
- Both H atoms on same side of O atom
  - Bent molecule shape gives water its unique properties
- 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 contribute to
  - Cohesion – molecules sticking together
  - 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 – universal solvent

Water's Thermal Properties
- Water is solid, liquid, and gas at Earth's surface.

- Water influences Earth's heat budget.

14 **Water's Three States of Matter**

15 **Water Phase Changes**

16 **Heat, Temperature, and Changes of State**

- Van der Waals forces
  - Weak interactions when molecules are close together
- Energy must be added for molecules to overcome attractions.

17 **Heat and Temperature**

- Heat – transfer of both kinetic and potential energy from one object to another due to temperature differences
- Temperature – average kinetic energy of molecules in a substance
- Calorie is the amount of heat needed to raise the temperature of 1 gram of water by 1°C.
-

18 **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

19 **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

20 **Latent Heat**

- Water has high latent heats
  - Heat absorbed or released during change of state
- Water's latent heat related to its high heat capacity

21 **Latent Heat**

- Latent Heat of Melting
  - Energy needed to break intermolecular bonds that hold water molecules rigidly in place in ice crystals
  -
  -

22 **Latent Heat**

- Latent Heat of Vaporization
  - Amount of heat that must be added to a substance at its boiling point to break the intermolecular bonds and change state from liquid to vapor
  - 540 calories/gram
  - All hydrogen bonds must be broken

23 **Latent Heat**

- Latent Heat of Evaporation
  - Evaporation = conversion of liquid to gas below the boiling point
  - 585 calories/gram
  - Lower temperature of surface water not at boiling point means more hydrogen bonds to break

24 **Latent Heat**

- Latent Heat of Condensation
  - Cooled water vapor turns to liquid and releases heat to the environment
  - Identical to latent heat of vaporization
- Latent Heat of Freezing
  - Heat released when water freezes
  - Identical to latent heat of melting

25 **Global Thermostatic Effects**
- Water's properties moderate temperature on Earth's surface
  - Equatorial oceans do not boil
  - Polar oceans do not freeze solid
- Heat energy exchanged in evaporation-condensation cycle
  - Makes life possible on Earth

26 **Atmospheric Heat Transport**

27 **Global Thermostatic Effects**
- 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
-

28 **Day and Night Temperature Differences**

29 **Water Density**
- Density = mass/unit volume
- Density of water increases as temperature decreases.
  - Thermal contraction = shrinkage of most substances caused by cold temperatures
-
-

30 **Water Density**
- From 4°C to 0°C the density of water decreases as temperature decreases.
  - Unique property of water
- Ice is less dense than liquid water.
  - Changes in molecular packing
  - Water expands as it freezes.
-

31 **Water Density and Temperature**

32 **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.

33 **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

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

35 **Seawater**

36 **Determining Salinity**
- Evaporation
  - Early technique
  - Weigh water and weigh evaporated salts
  - Not accurate because some salts can evaporate with water
-

37 **Determining Salinity**
- Salinometer

- Measures water's electrical conductivity
- More dissolved substances increase conductivity

38 **Determining Salinity**
- Principle of Constant Proportions
  - Chemical analysis via titration
  - Major dissolved constituents in same proportion regardless of total salinity
  - Measure amount of halogens (Cl, Br, I, F) (chlorinity)
  - Salinity = 1.80655 * Chlorinity *(ppt)*

39 **Pure Water vs. Seawater**

40 **Salinity Variations**
- Open-ocean salinity is 33–38 $^{o}/_{o}$.
- In coastal areas salinity varies more widely.

41 **Salinity Variations**
- Brackish
  - Influx of fresh water from rivers or rain lowers salinity
- Hypersaline
  - High evaporation conditions
  - Dead Sea
- Salinity may vary with seasons (dry/rain).

42 **Earth's Water and the Hydrologic Cycle**

43 **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

44 **Processes Affecting Salinity**

45 **Earth's Hydrologic Cycle**
- Processes that affect seawater salinity
- Recycles water among ocean, atmosphere, and continents
- Water in continual motion between water reservoirs

46 **Earth's Hydrologic Cycle**

47 **Earth's Water**
- 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

48 **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 – average amounts of various elements remains constant

49 **Processes that Add/Subtract Dissolved Substances**

50 **Acidity and Alkalinity**
- Acid releases a hydrogen ion (H+) when dissolved in water.

- Alkaline (or base) releases a hydroxide ion (OH-) in water.

51 **pH Scale**
- Measures hydrogen ion concentration
  - pH value less than 7 = acid
  - pH value greater than 7 = base (alkaline)
  - pH 7 = neutral
    - Pure water
-

52 **pH Scale**

53 **Ocean pH**
- Seawater is slightly alkaline
  - Surface water average pH 8.1
- Ocean water pH decreases with depth

54 **Carbonate Buffering System**
- 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.
-

55 **Carbonate Buffering System**

56 **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
  -

57 **Surface Salinity Variation by Latitude**

58 **Aquarius Satellite View of Global Salinity, Aug.–Sept. 2011**

59 **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
-
-

60 **Seawater Density**
- Freshwater density = 1.000 g/cm^3
- Ocean surface water =1.022 to 1.030 g/cm^3
- Ocean layered according to density
-

61 **Seawater Density**
- Density increases with decreasing temperature
  - Greatest influence on density
- Density increases with increasing salinity
- Density increases with increasing pressure
  - Does not affect surface waters

62 **Temperature and Density Variations With Depth**

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

63 **Temperature and Density Variations with Depth**

64 **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
-

65 **Layered Ocean**

- High latitude oceans – thermocline and pycnocline rarely develop
  - Isothermal – no temperature variation in water column
  - Isopycnal – no density variation in water column
-

66 **Desalinization**

- Removing salt from seawater
- Human need for fresh water increasing, water supply decreasing
- Energy-intensive and expensive
- Most desalinization plants in arid regions
  - Provide less than 0.5% of human water needs

67 **Desalinization**

- Distillation
  - Most common process
  - Water boiled and condensed
  - Solar distillation in arid climates
- Electrolysis
  - Electrode-containing freshwater
  - Membrane between fresh and salt water tanks
-

68 **Desalinization**

- Reverse osmosis
  - Salt water forced through membrane into fresh water
- Freeze separation
  - Water frozen and thawed multiple times
-

69 **End of CHAPTER 5**