ES 106 Heat and Energy Transfer, Heat of Water Phase Change

/. Heat
- A. heat is the motion of the energy from one substance to the other
  1. molecules have energy of motion (internal or thermal energy), not heat
  2. Cold is not a quantity, it is the absence of heat
  3. Temperature—
     a. related to the random molecular motion of the substance
     b. proportional to the internal energy
- B. Heat transferred from substance with higher temperature to one with lower temperature, not from one with more heat energy to less heat energy
  1. As heat is transferred, molecular energy changes
     a. May not change temperature if a phase change is occurring
     b. Reflected in a change in temperature of the substance
- C. Heat is measured in joules or calories
  1. one calorie = 4.184 joules
  2. one Calorie in food is 1000 calories, really one kilocalorie

//. Specific Heat Capacity
- A. Quantity of heat to raise quantity of substance 1^{o} C
- B. calorie = heat to raise 1 gram water 1^{o} C
- C. water has a very large specific heat capacity
  1. results in water moderating temperature
  2. maritime areas more mild in temperature than continental areas
     a. temperature difference from day to night
        1) here commonly 10 to 15^{o} F
        2) east of Cascades, commonly 30-40^{o} F
     b. Gulf Stream carries heat to Europe

///. Expansion upon heat transfer
- A. Random motion of molecules increases
- B. Hit one another and drive each other further apart
- C. Different substances have different expansion rates
  1. Thermocouple is a bimetal strip that flexes with temperature change
  2. Used in thermostats to turn on and off a heating unit or cooling unit
  3. liquids commonly have expansion rates greater than solids
- D. Water has strange response to temperature change
  1. Melting ice, at 0^{o} C, contracts as the temperature increases
  2. decreases in volume to 4^{o} C, then it behaves ‘normally’
  3. smallest volume at 4^{o} C, and increases 9% as it solidifies
  4. volume decreases after it freezes, but not 9%
     a. open structured crystals have greater volume than liquid
     b. ends of polar molecules fit together closer in random motion of liquid
  5. densest water sinks to bottom of pond—4^{o} C
     a. cooling occurs at surface
     b. reaches 4^{o} C, sinks because it is denser than water at other temperatures
     c. all water becomes cooled to 4^{o} C before further cooling occurs
     d. further cooling results in increase in volume, decrease in density
     e. 0^{o} C is reached at top, and freezes from top downward

IV. Heat Transfer
- A. Conduction
  1. direct contact from molecule to molecule
  2. metals excellent conductors—free electrons
  3. poor conductors—
     a. electrons tightly held: like glass
     b. with air spaces: wool, plastic foam, snow—INSULATORS
- B. Convection
  1. movement of material from one place to another
  2. occurs in fluids, not solids
  3. heated material rises due to the expansion upon heating
- C. Radiation
  1. through empty space
  2. electromagnetic radiation
     a. visible light from about 500^{o}C
     b. all objects emit thermal energy
  3. dark bodies absorb more than light-colored ones
  4. good absorbers are good emitters, and poor are poor

V. Four common phases of matter
- A. Solid—ice
- B. Liquid—water
- C. Gaseous—steam or vapor
- D. Plasma—electrons dissociated to form independent ions

VI. Evaporation
- A. Kinetic energy of fluid
- B. Molecules bumped off surface into air
- C. Energy leaves vessel as molecules leave vessel
  1. results in lowered energy
  2. also lowers temperature

VII. Condensation
- A. Molecules in air attracted to surface
- B. Higher energy is transferred to liquid when they join it
- C. Atmospheric system
  1. warm air can hold more moisture
     a. molecules are energetic enough to not condense
     b. saturated warm air has greater mass of water than saturated cold air
     c. charts show grams water per kilogram of air capacity at temperatures (Lab 6, page 3)
  2. expansion of air creates cooling
     a. begins to condense into droplets
     b. ‘nucleation’ particles enhance this
        1) Dust
        2) Acid aerosols
        3) Ions
     c. Air close to saturation will form clouds or fog if it is cooled
        1) Moving to cooler sea-surface area
        2) Moving over cooler land surfaces

VIII. Boiling
- A. At sea-level pressure, 100^{o} C water forms bubbles within fluid
- B. Energy of molecules forces liquid water apart, because their pressure is greater than the weight of the water and atmosphere above them
- C. Pressure-cookers allow increased pressure to build in vessel—higher temperatures can be reached, reducing cooking time
- D. Higher elevations have lower boiling temperatures because the atmospheric pressure is lower—longer cooking times
- E. Boiling is a cooling process
  1. cools as the molecules leave the fluid
  2. temperature remains constant throughout the boiling process
- F. Boiling can be achieved by reduction of pressure
  1. less energy is needed to escape fluid
  2. reduces temperature of the fluid

IX. Melting and Freezing
- A. Bonds break upon heating of solid substances—kinetic energy of molecules exceeds bond strength
- B. Lowering energy in liquids results in ability of molecules to attract one another and form a cohesive bond
- C. Pure water will freeze at 0^{o} C at sea-level air pressure
  1. impurities depress the freezing temperature
  2. the ice that forms, at first, does not contain the impurity
- D. increase in pressure will also depress freezing temperature
  1. how ice skates work
  2. how glaciers slide

X. Energy of phase changes
- A. Temperature of substance does not change during phase change
- B. Energy is absorbed by
  1. solid to become liquid
  2. liquid to become vapor: heat of vaporization
- C. Energy is released by
  1. vapor to become liquid
  2. liquid to become solid: heat of fusion
- D. Water energy
  1. 1 calorie to change 1 gram water one K (same as 1^{o} C) without phase change
  2. heat of fusion
     a. absorbed to change from solid to liquid
        1) 80 calories per gram
        2) 335 joules per gram
     b. Same amount released to change from liquid to solid
  3. heat of vaporization
     a. absorbed to change from liquid to vapor
        1) 540 calories per gram
        2) 2260 joules per gram
     b. Same released when condensing from vapor to liquid