Heat and Energy Transfer
Energy of Phase Change

Temperature

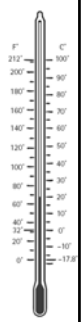
- Measure of hotness
- Celsius
  - ➢ 0^o freezing point of pure water at standard pressure
  - ➢ 100^o boiling point at standard pressure
- Fahrenheit
  - ➢ 0^o was lowest attained
  - ➢ 32 was his age when he performed experiments
  - ➢ 212 is boiling point in those increments

Temperature

- **Convert with equations**
  - ➢ Order of operations
    - Parentheses first
    - Then multiply or divide
    - Add or subtract last
- **Or use adjacent scales such as p. 142 of *Conceptual Physical Science* textbook**

$$C = \frac{5}{9}(F - 32)$$

$$F = \frac{9}{5}C + 32$$



Temperature

- Kelvin same size as degree Celsius
- 'Absolute Zero' is 0 K
  - ➢ (notice no degree symbol on K)
- 0^o C = 273 K
- Molecular motion ceases at absolute zero

Heat

- Calorie
  - – Amount of heat required to raise the temperature of 1 gram of pure water 1^o C
  - – Food 'Calories' are kilocalories
- Joule ~ ¼ of calorie
  - – 1 cal. = 4.184 J

Laws of Thermodynamics

1. Heat added = increase in thermal energy + external work done by the system
2. Heat never spontaneously flows from a cold substance to a hot substance
3. No system can reach absolute zero

Entropy

- Natural increase of randomness in system
- Energy spreads to disorder in the system
- Does not spontaneously reform gasoline from carbon dioxide and water

Specific Heat Capacity

- Quantity of heat needed to change the temperature of given amount of a substance 1º C
- Water—very high specific heat capacity
  - Maritime areas more mild temperature than continental areas
  - Takes 1/8 calorie to raise temperature of iron 1º C

Heat Expansion

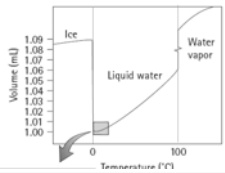
- Random motion causes substance to be bigger
- Liquids usually have greater heat expansion than solids
- Thermostats use different expansion of different type of metals

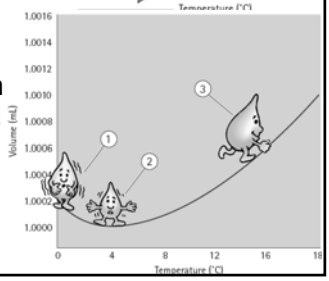
www.alaskarails.org/terminology/questions.html

http://demo.physics.uiuc.edu/LectDemo/scripts/demo_descript.idc?DemoID=40

Water Expansion

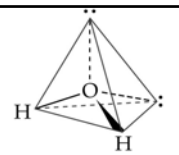
- Unusual response to cooling
- Contracts until reaching 4º C
- Expands slightly upon further cooling to 0º C
- Expands 9% upon freezing





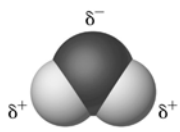
Water Molecule

- Bent
- Polar



(a)

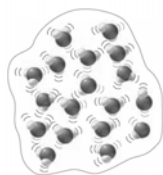
(b)



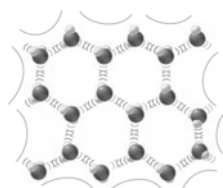
(c)

Water Expansion

- Molecule shape fit together closer in liquid
- Open structured crystal due to hydrogen bonding of polar molecules upon freezing

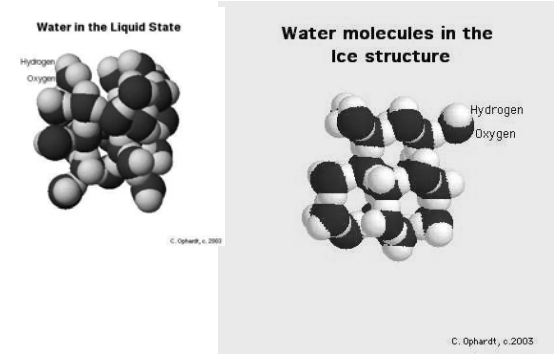


Liquid water
(dense)



Ice
(less dense)

Water Expansion



http://www.elmhurst.edu/~chm/vchembook/122densityice.html

Heat Transfer: conduction

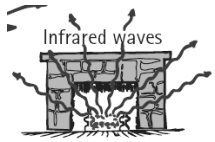
- Tile is a better conductor of heat than the wood floor

Heat Transfer: convection

- Currents from heater shown by shadows

Heat Transfer: radiation

- Does not need material to transfer radiant energy
- Dark bodies absorb it better than light-colored ones



Radiant Energy

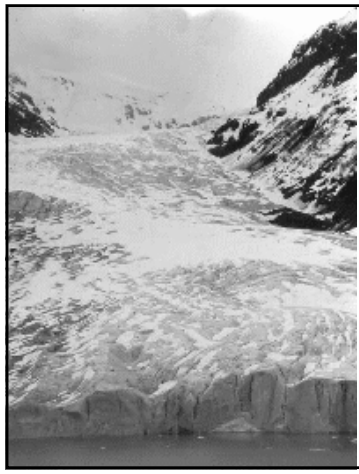
- All objects emit thermal energy
  - Visible light above ~500°C
  - Re-emit absorbed radiation at wavelength according to temperature
- Good absorbers are good emitters
- Poor absorbers are poor emitters

Heat Transfer

- Conduction
  - Direct molecule interaction
  - Transferring energy to next molecule
- Convection
  - Movement of fluid: liquid or gas
- Radiation
  - Through open space
  - Electromagnetic radiation

Phases of Matter

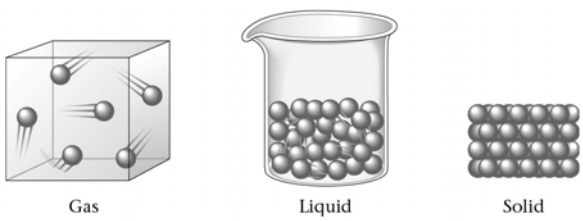
- Solid
- Liquid
- Gaseous or vapor
- Plasma



Three phases of water

http://www.cdli.ca/CITE/glaciers.htm

Gas, Solid and Liquid

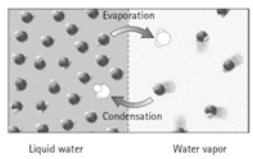


Zumdahl, Zumdahl, DeCoste, World of Chemistry 2002, page 441

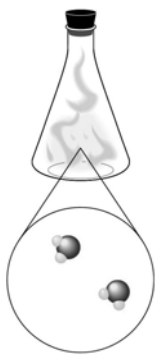
http://www.unit5.org/christjs/Matter%20and%20Energy/Unit%202%20PP_files/frame.htm

Evaporation

- Kinetic energy of molecules great enough to escape surface
- Energy is taken from liquid—cools it
- Gaseous phase or vapor phase

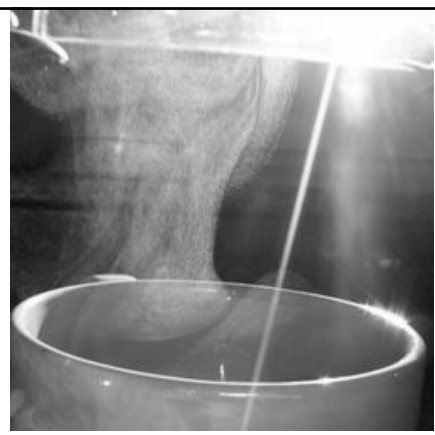


Gas
Steam



$H_2O(g)$ Steam

http://www.unit5.org/christjs/Matter%20and%20Energy/Unit%202%20PP_files/frame.htm



http://en.wikipedia.org/wiki/Water_vapor

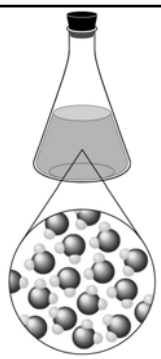
Evaporation or Not

http://www.geology.sdsu.edu/classes/geol351/01watercycle/watercyclefigs.htm

Condensation

- Opposite of evaporation
- Kinetic energy of molecules running into surface of liquid and joining it
- Heats environment

Liquid Water



$H_2O_{(l)}$ Water

http://www.unit5.org/christjs/Matter%20and%20Energy/Unit%202%20PP_files/frame.htm

Condensation on Glass

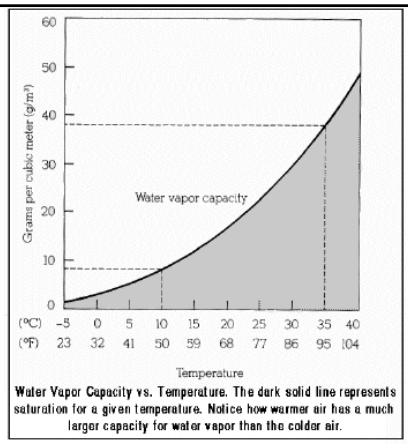
http://www.geology.sdsu.edu/classes/geol351/01watercycle/watercyclefigs.htm

Atmosphere

- Evaporation
  - Energy goes into air
  - Cools remaining water
- Condensation
  - Energy goes from air to surface
  - Warms local environment

Atmosphere

- Warm air has greater capacity for holding water in the vapor phase
- Saturation = at capacity
- Relative Humidity—percent of water contained compared to saturated amount at that temperature

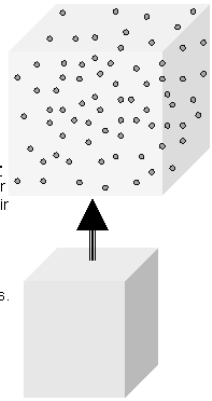


Water Vapor Capacity vs. Temperature. The dark solid line represents saturation for a given temperature. Notice how warmer air has a much larger capacity for water vapor than the colder air.

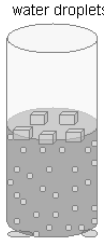
http://www.wdtv.com/weather/images/Weather_Review/humidity.htm

http://observe.arc.nasa.gov/nasa/earth/hydrocycle/graphics/condensation.jpg

Condensation due to the expansion of air
Some of the water vapor in a rising air parcel turns into liquid water droplets as the air parcel expands and cools.



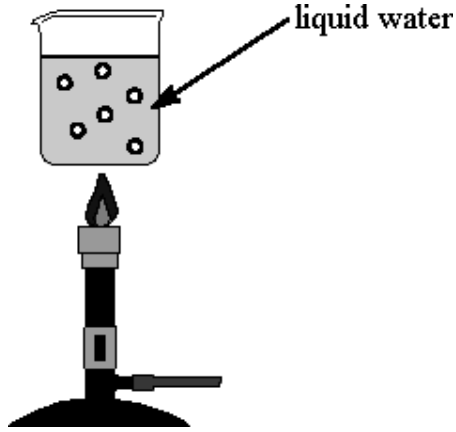
Condensation due direct cooling of air
Some of the water vapor in air next to a cold surface turns into liquid water droplets.



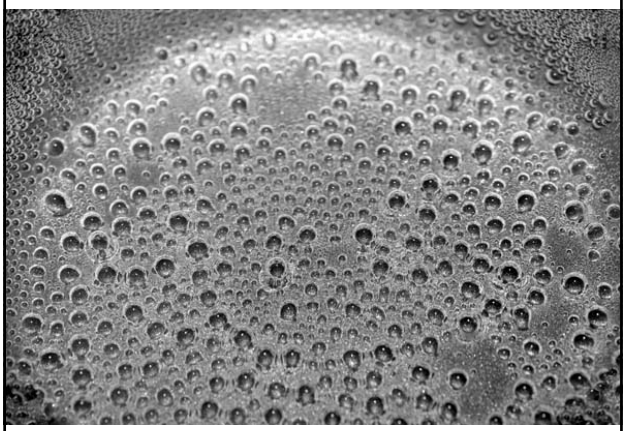
http://weatherstreet.com/weatherquestions/What_is_condensation.htm

http://www.anythingmarine.co.uk/anything/met.htm

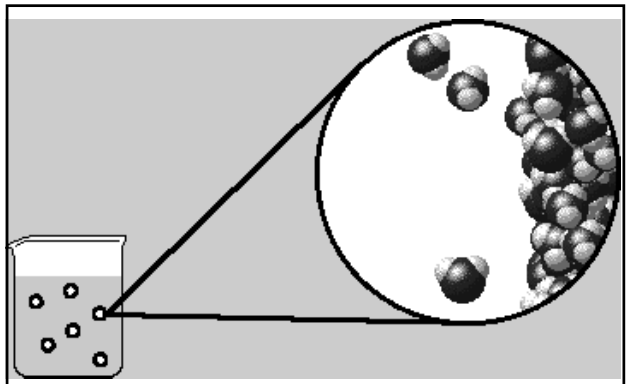
http://www.victoriaweather.ca/clouds.php?image=fog



http://www.chem.purdue.edu/gchelp/liquids/boil2.html

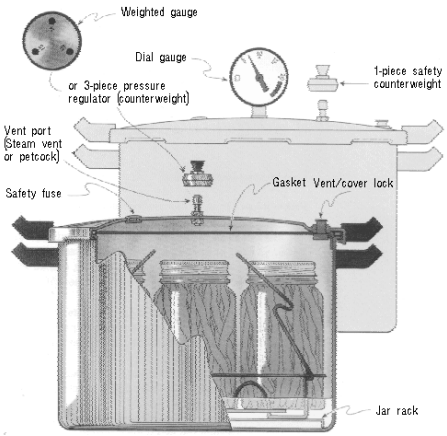


http://www.deepseaimages.com/dsilibrary/showphoto.php?photo=2912&password=&sort=1&size=medium&cat=853&page=1

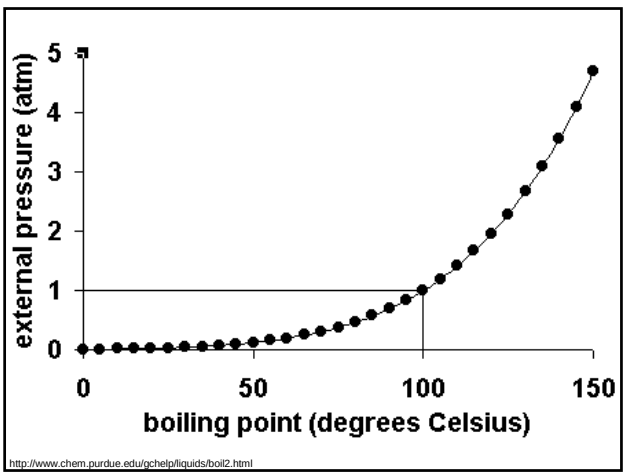


http://www.chem.purdue.edu/gchelp/liquids/boil2.html

http://www.goodmans.net/get_item_ma-6qt_maitres-806212-6-qt-cooker.htm



http://hgic.clemson.edu/factsheets/HGIC3020.htm



http://www.chem.purdue.edu/gchelp/liquids/boil2.html

Boiling at less than 100 ^{o} C

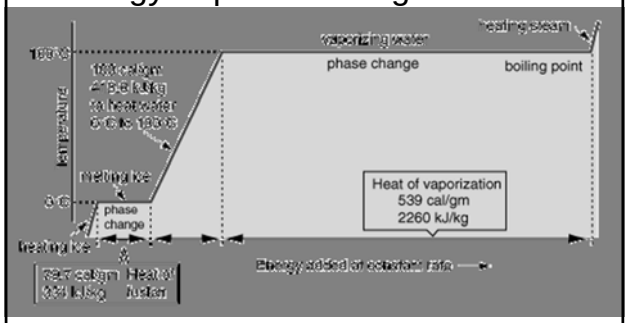
- Pour in hot water
- Reduce Pressure with syringe

http://www.micrecol.de/air2.html

Energy of Water Phase Change

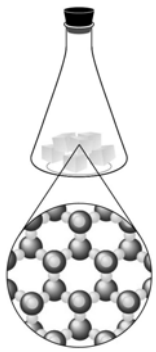
- Calorie:
  energy to change 1 g water 1 K or 1 ^{o}C
- Also need energy to change to different state of matter
- Energy of vaporization/condensation
  - ➢540 calories per gram of water = 2256 J/g
- Energy of melting/freezing
  - ➢80 calories per gram= 334 J/g

Energy of phase change for water



http://hyperphysics.phy-astr.gsu.edu/hbase/thermo/phase.html

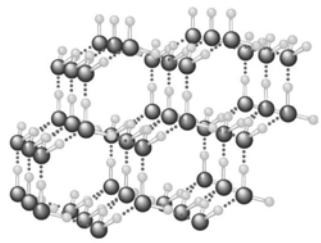
Solid Ice



$H_2O(s)$ Ice

http://www.unit5.org/christjs/Matter%20and%20Energy/Unit%202%20PP_files/frame.htm

Molecular Structure of Ice



Ice

Zumdahl, Zumdahl, DeCoste, World of Chemistry 2002, page 455

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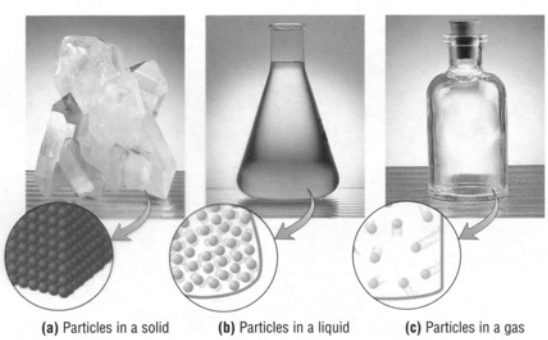
Solid, Liquid, Gas



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