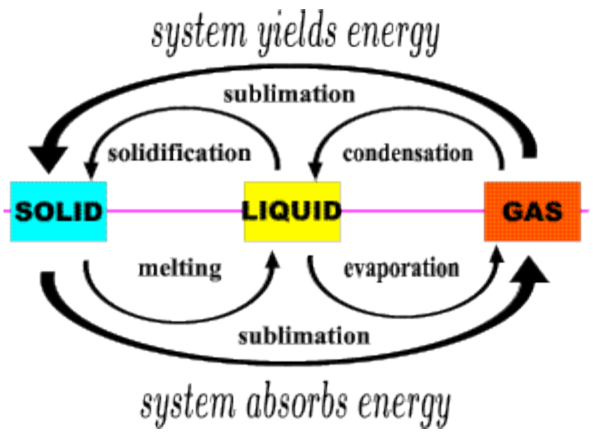
Liquids and Intermolecular Forces

<u>Topics</u>
Changes of State
Energy Changes
Attractive Forces (dipole-dipole, induced dipole, hydrogen bonding)
Liquid State
Liquid-Vapor Equilibrium (equilibrium, vapor pressure, boiling pt.)
Liquid-Solid Equilibrium (Freezing pt.)
Solid-Vapor Equilibrium (Vapor Pressure of Solid)
Phase Diagrams

<u>Changes of State:</u>



(http://yesican.yorku.ca/home/h3.html)

gas -- (condensation) → liquid -- (freezing, solidification) → solid -- (sublimation) → gas

gas ←(vaporization, evaporation) -- liquid ←(melting) -- solid ←(deposition) --gas

Physical changes there are: NO atoms exchanged and NO new bonds

With chemical changes there are atoms exchanged and new bonds

At 1 atm the normal melting pt. for water is 0^oC
At 1 atm the normal boiling pt. for water is 100^oC

Energy is equal in both directions (just have opposite sign)

Solid --> (endothermic) --> Liquid (note: endothermic means it takes in heat)
Solid <-- (exothermic) <-- Liquid (note: exothermic means gives off heat)

Independent of path
Solid → Liquid
Solid → Liquid → Gas

Body uses sweating (evaporation of water)

<u>Energy Changes</u>

Heat Capacity
When Heat added to a substance the temperature increases
 except at phase change (melt, evaporate) and then energy is all going to change phase

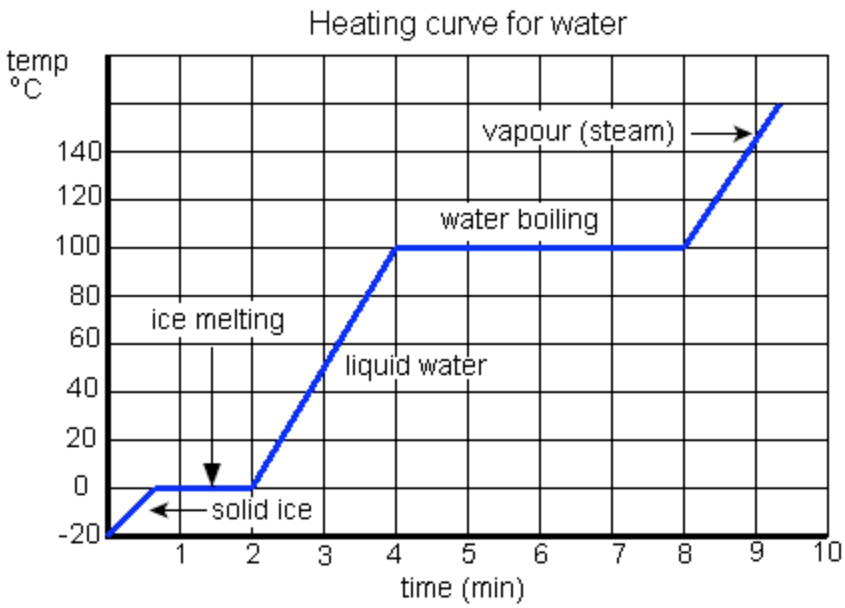
Heat needed to raise temperature by $1^{o}C$ is called the heat capacity
More substance the higher the heat capacity
Can have heat capacity per mole or per gram

Heat capacity of ice 2 J/ (g ^{o}C) = 36 J/(mol ^{o}C)

		For Water
molar Heat of Fusion (melting) put heat in	solid → liquid	+6.01 kJ
molar Heat of Solidification takes heat out	liquid → solid	- 6.01 kJ
molar Heat of Vaporization puts heat in	liquid → gas	+40.7 kJ

Example:
Bromine 0.5 mol from $-7^{o}C$ to $59^{o}C$

Melt (10.5 kJ/mol)(.5 mol) = 5.25
Heat (0.76 kJ/mol oC)(66oC)(.5 mol) = 2.51 ($q = h\ m\ \Delta T$)
Vaporize (30.0 kJ/mol)(.5 mol) = 15.00/ 22.76 kJ ($q = C\ \Delta T$)

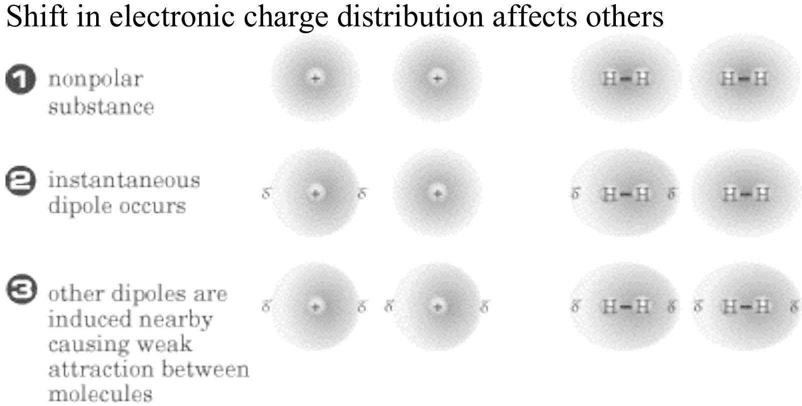


(http://www.saskschools.ca/curr_content/physics20/heat/latent_heat.htm)

Attractive Forces between Molecules

Instantaneous induced dipole --> Van der Waals Interaction
London forces (dispersion forces)

Shift in electronic charge distribution affects others



(http://www.sparknotes.com/testprep/books/sat2/chemistry/chapter5section1.rhtml)

Large molecules have larger electron clouds so more attraction

Methane CH_4 gas
Pentane C_5H_{12} liquid
Candle Wax $C_{18}H_{38}$ solid

He < Ne < Ar < Kr

Dipole-dipole

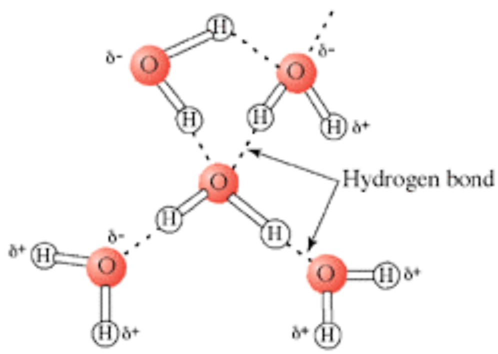
Polar molecules have higher melting and boiling points than expected for size

Compound	Dipole	Melting Pt.	Boiling Pt.
HI	.38	222	238
HBr	.78	185	206

Less dipole then higher melting point because of London (dispersion) forces

Hydrogen Bonding

Compound	Boiling Pt.
H_2O	100
H_2S	-60
CO_2	-79



(http://www.wiley.com/legacy/college/boyer/0470003790/reviews/pH/ph_water.htm)

Attraction between positive hydrogen and lone pair such as an O, F, N (strong electronegativity)

Association between several water molecules causes the boiling and melting point to be very high

NH_3 and HF also hydrogen bond but H_2O is most effective

The larger the size of the molecule then the greater the London Forces therefore the higher the boiling point
Exception: Hydrogen Bonding

Liquid State
Molecules close together so attraction holds together

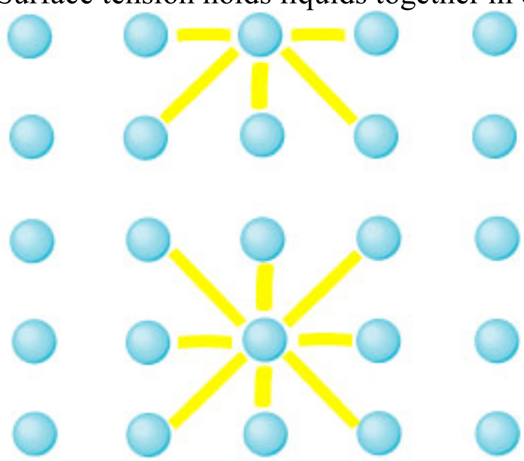
Pressure increase will only change volume slightly

Increase in temperature will increase volume
The molecular motion increases as a result (ex: thermometer)

Diffusion in liquids much slower than in air because a lot more collision occurs

Viscocity → is measure of attraction of liquid molecules

Surface tension holds liquids together in droplets or container



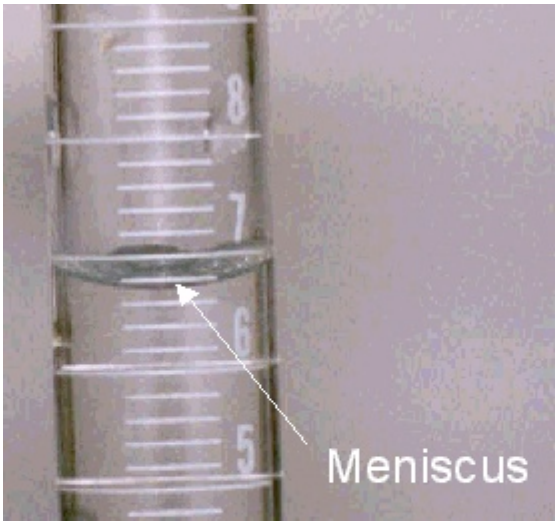
(http://media.nasaexplores.com/lessons/03-048/images/)

H_2O Surface Tension

Mercury Surface Tension

(http://www.chem.purdue.edu/gchelp/liquids/tension.html)

Cohesive force → liquid to liquid (ex: water to water)
Adhesive force → liquid to solid (ex: water to the test tube)



(http://faculty.clintoncc.suny.edu/faculty/Michael.Gregory/files/Bio%20101/Bio%20101%20Lectures/Chemistry/chemistr.htm)

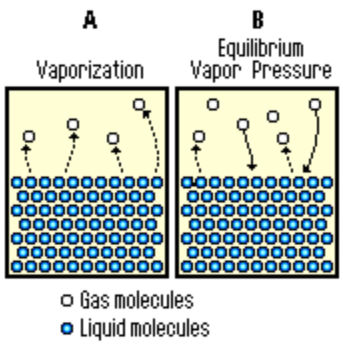
Effects of Temperature and Pressure

Low temperature and high pressure form liquid
Above critical temperature gas cannot be liquefied no matter how high the pressure

At equilibrium in a closed container some molecules will become vapor and some will become liquid

Vapor pressure → is pressure of gas of substance at equilibrium

Figure 1. Liquid Vaporization



(http://www.epa.gov/eogapti1/module4/vaporpres/vaporpres.htm)

Volatile → evaporating readily at a normal temperature

Stronger interaction between molecules then the lower the vapor pressure

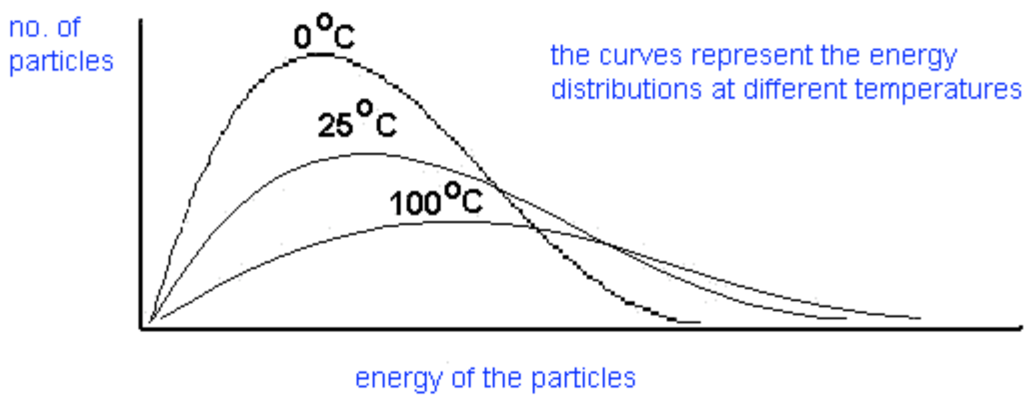
Relative humidity → **(pressure of water vapor/ vapor pressure of water) x 100**
Note: In a closed container

Superheating→ if bubbles don't form sudden bump
Use boiling chips as a surface for bubbles

<u>Liquid Vapor Equilibrium</u>

Evaporation is the change from liquid to gas

Kinetic energy of liquid is the Maxwell Boltzmann curve
Higher energy molecules leave first
Temperature drops because remaining molecules have lower average kinetic energy



(http://ibchem.com/IB/ibc/equilibrium/equ_htm/8.1.htm)

Have to put more energy to keep liquid boiling

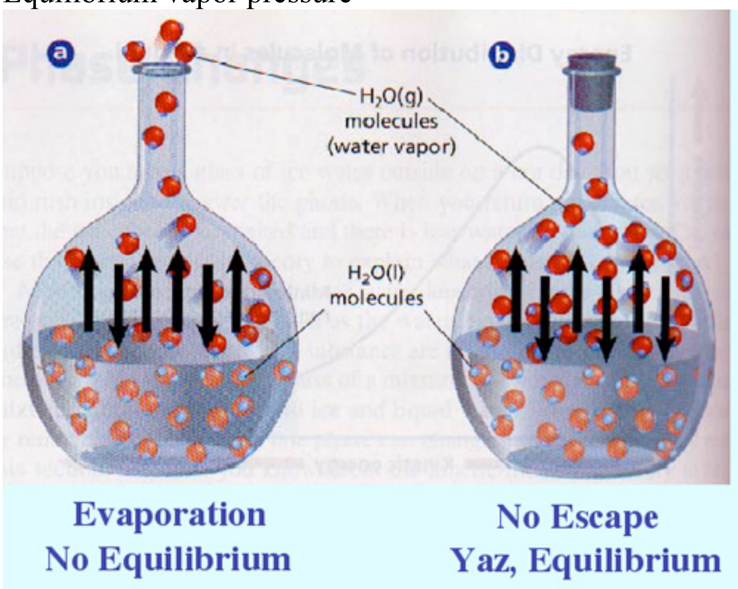
Vapor Pressure

Closed container equilibrium is reached

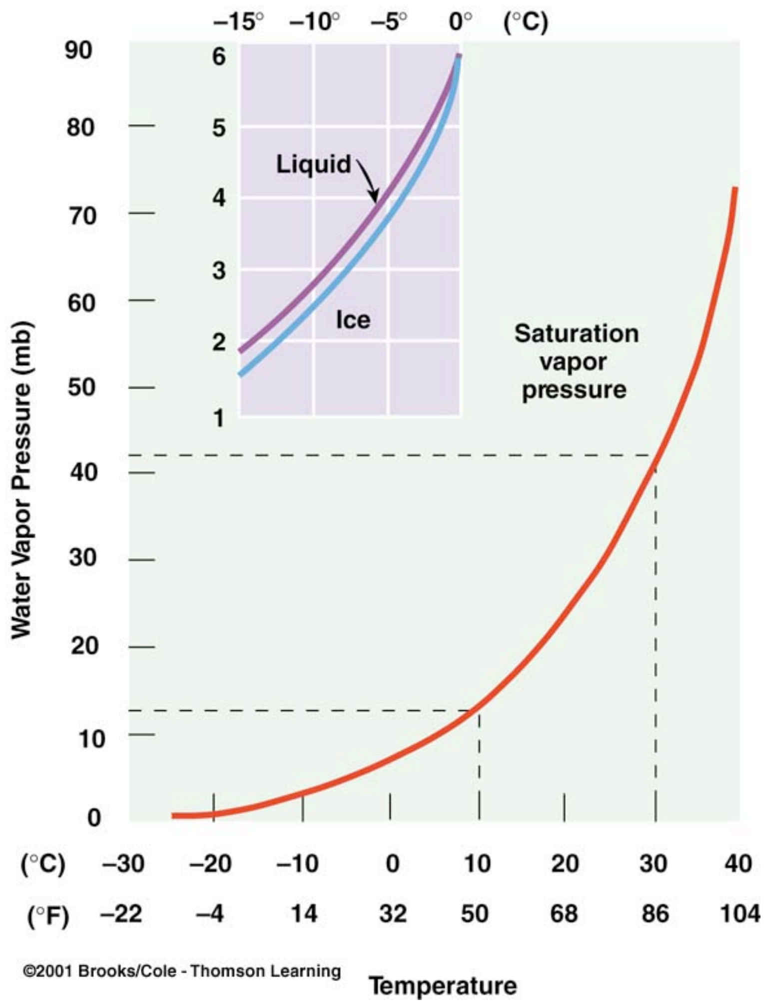
H_2O (l) <----> H_2O (g) dynamic equilibrium

Both vaporization and condensation are occurring

Equilibrium vapor pressure



(http://cougar.slvhs.slv.k12.ca.us/~pboomer/physicslectures/heat/vapor.html)



(http://clem.mscd.edu/~wagnerri/Intro/dewclouds.htm)

Equilibrium vapor pressure

Normal atm	Boiling pt (°C)	Point
1.000	100	
.836	95.1	
.695	90.1	10,000 ft
.0121	10	

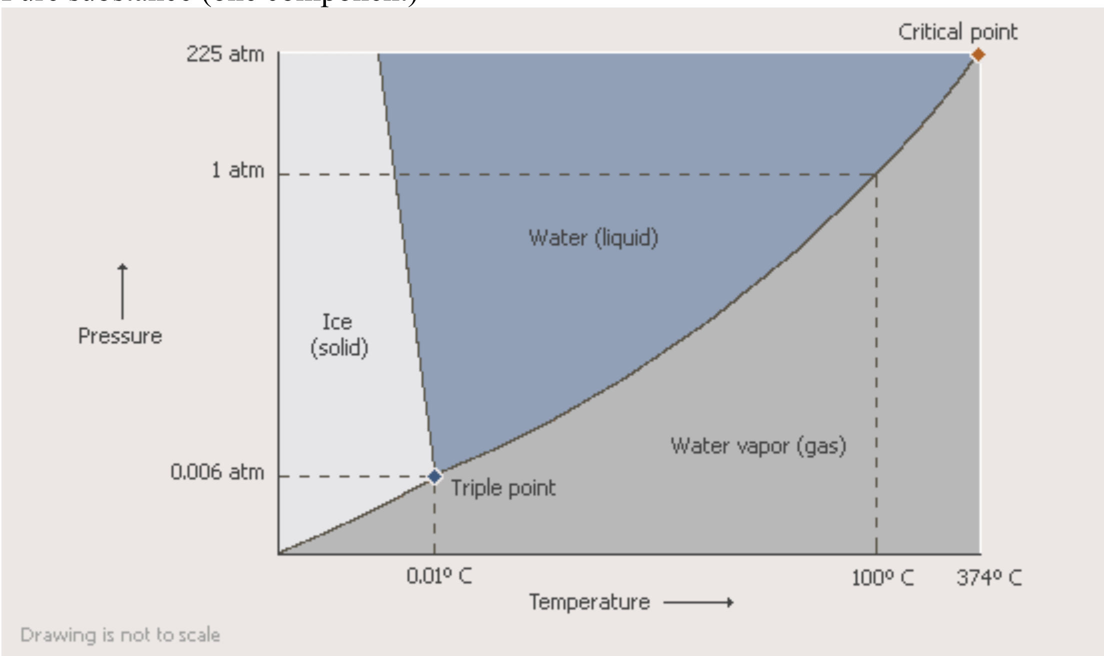
Liquid Solid Equilibrium (Freezing Pt.)

Lower temperature the kinetic energy is low enough so intermolecular attractions hold crystal lattice

Normal freezing pt. liquid <----> solid equilibrium at 1 atm of water
Liquid --> solid molar enthalpy of crystallization = -6.02 kJ/mol (exothermic)
Solid --> liquid molar enthalpy of fusion = 6.02 kJ/mol (endothermic)

Vapor Pressure of a Solid
Equilibrium between solid and vapor may be very low at ordinary temperature

Phase Diagrams
Temperature and Pressure regions where phases exist
Pure substance (one component)



(http://encarta.msn.com/media_461541579/Phase_Diagram_for_Water.html)

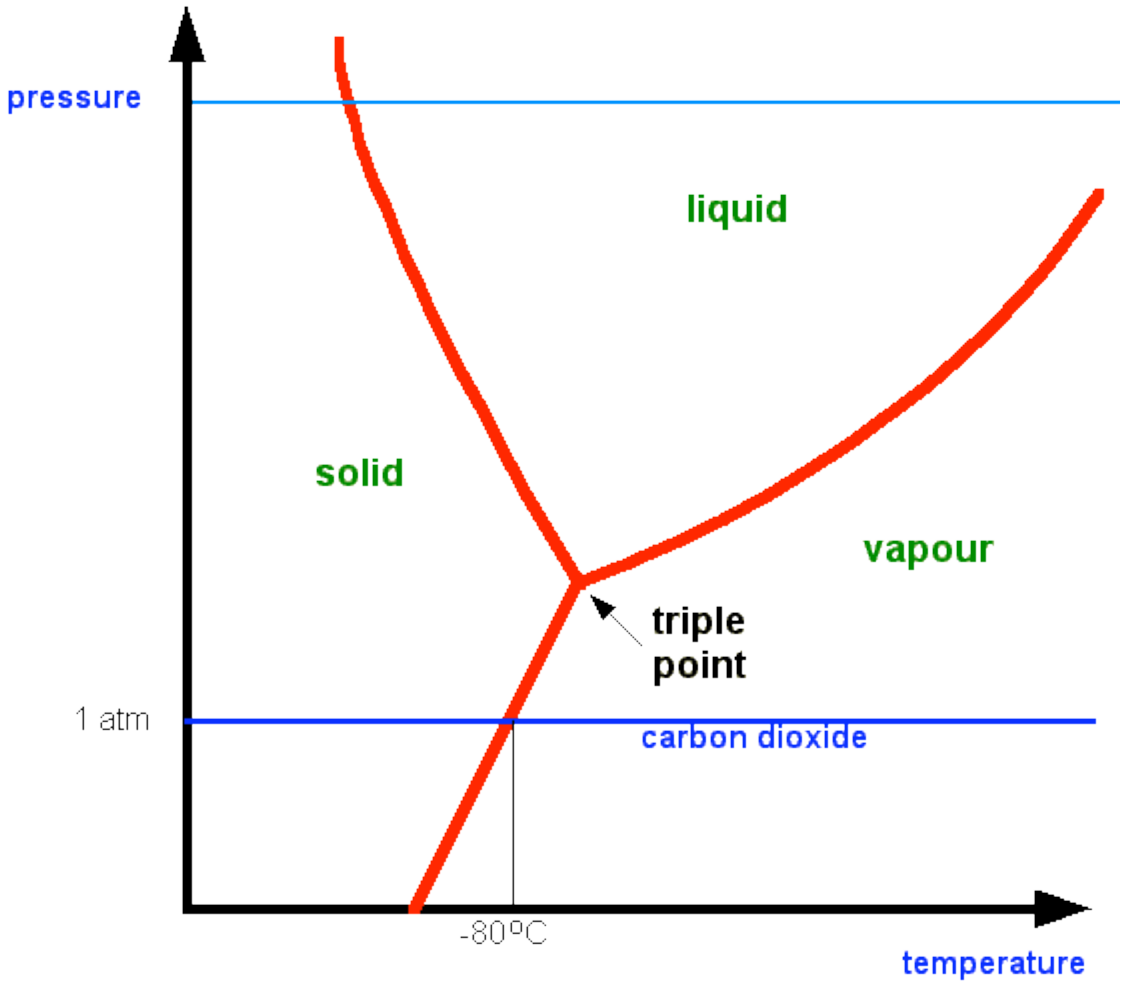
At the critical point above this temperature gas cannot be liquified

Triple point is where solid, liquid and gas exist together

One phase
Two phases on line
Three phases on triple point

Water liquid more dense than solid (this is an exception from normal liquids)

Exert pressure solid goes to liquid (ice skate on H_2O)



(http://www.colorado.edu/che/CLASSES/3320f/pages/liquification.html)

Topics below covered in “Solids”

Properties and Types of Solids

Crystal Structure of Metals