Forces, Vapor P, Phases__________ Z Ch 16.1-2, 10-11, Petrucci

"[There were] only two fundamental forces to account for all natural phenomena. One was Love, the other was Hate. The first brought things together while the second caused them to part."
Empedocles ~ 450 BC

Exam II (M, Oct 25) – everything from last exam through next week – Ch 5, 13, 16, 17

midterm grades R Oct 21

labs and late lab reports

H_Exp 8 – in-person lab has lab partners

16.10 Vapor Pressure and Changes of State
16.11 Phase Diagrams

LAB PARTNERS

Types of Forces

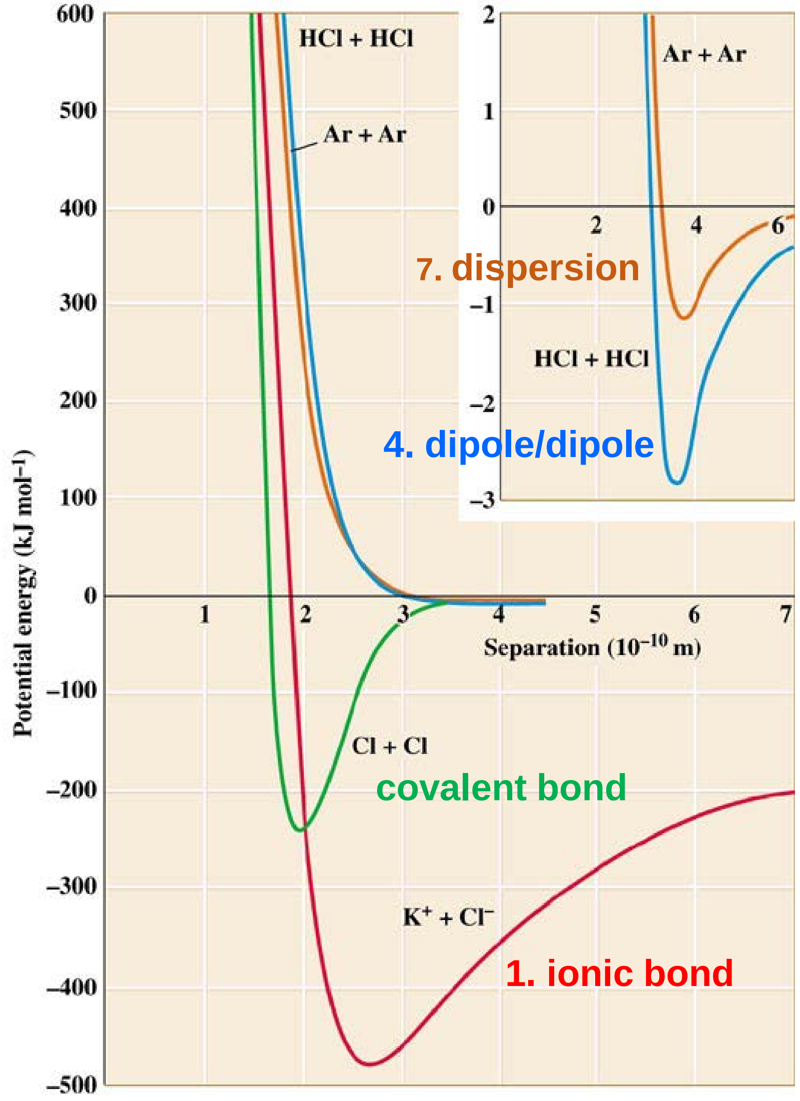
in decreasing strength
- intramolecular (bonding)
  1. ion/ion
  2. covalent
  3. metallic
- intermolecular (nonbonding)

**table of forces,
all ways of combining ion,
dipole, induced dipole in pairs**

van der Waals

force	example	energy
1. **ion/ion**	KF(*s*)	1/r
2. ion/dipole	NaCl(*aq*)	$1/r^2$
3. hydrogen bond (strong dipole/dipole)	H_2O(*l*)	$1/r^2$
4. **dipole/dipole**	HCl(*g*)	$1/r^3$
5. ion/induced dipole	He/Li^+	$1/r^4$
6. dipole/induced dipole	H_2O(*l*) / O_2(*g*)	$1/r^6$
7. **induced dipole/ induced dipole** (dispersion, London)	Ne(*g*)	$1/r^6$

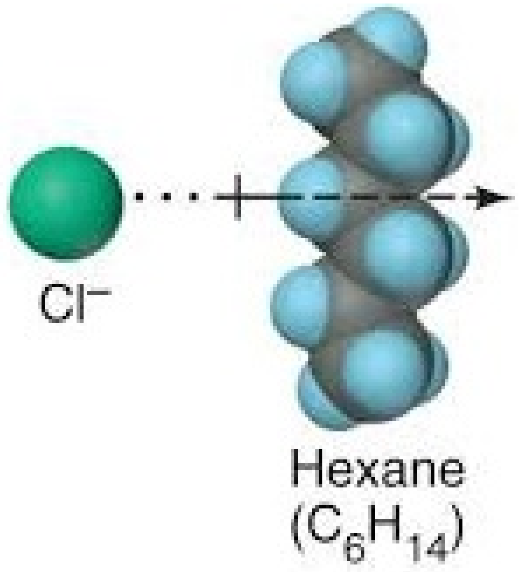
FIG I – Potential energy of pairs of atoms, ions, and molecules



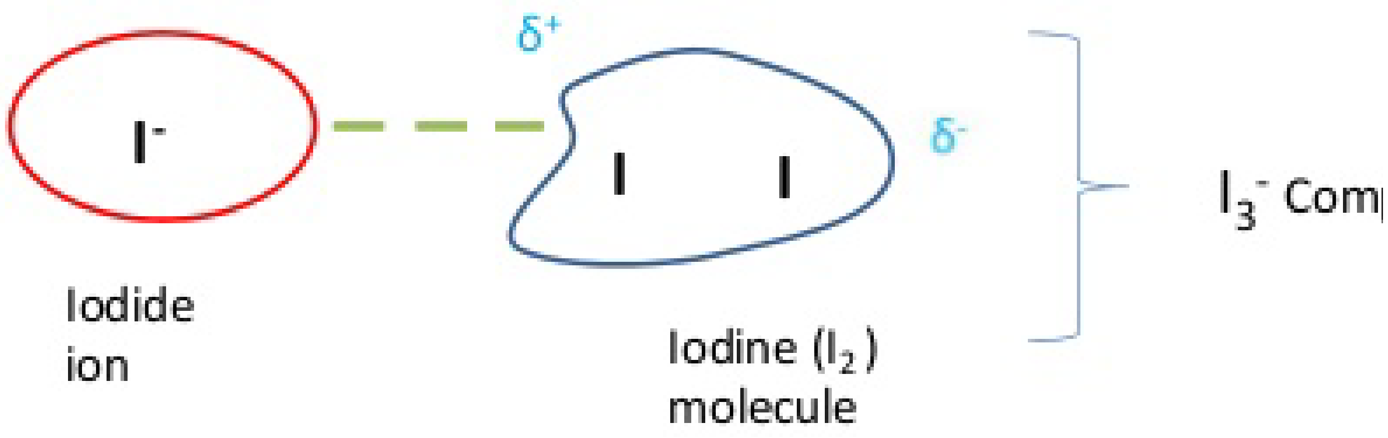
Ion / Induced Dipole

IMF that exists between a full charge on one species and the electron cloud of a nonpolar species which becomes polarized.

$Li^+ \cdots He$ $Li^+ \cdots Ne$ $Li^+ \cdots Ar$



electron cloud is polarized



Dipole / Induced Dipole

An IMF for a polar compound interacting with a nonpolar species. The dipole of the polar compound distorts the electron cloud of the nonpolar species, inducing a dipole moment in it.

solubility of gases in water (N_2, O_2)

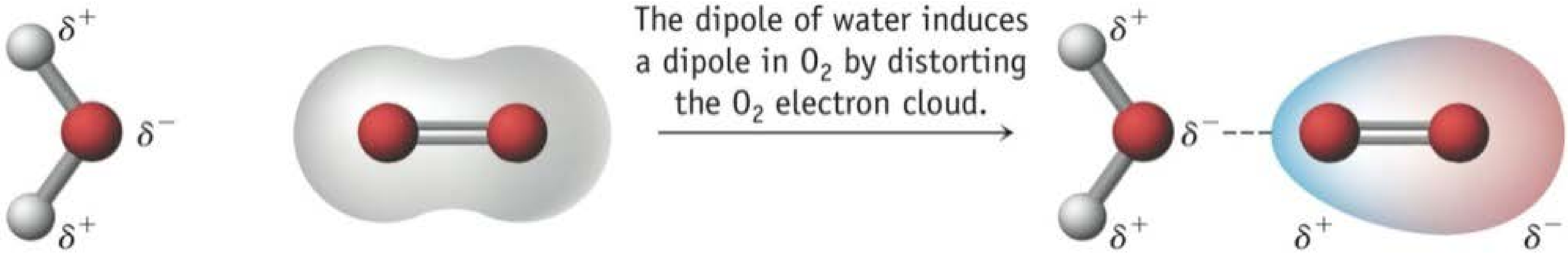
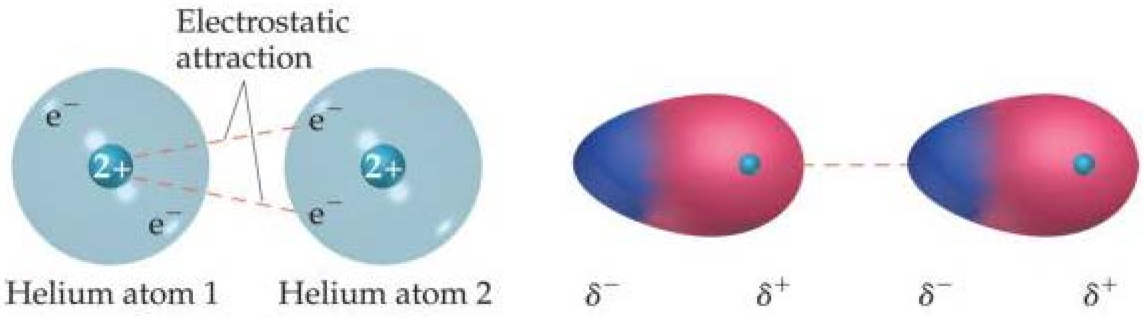


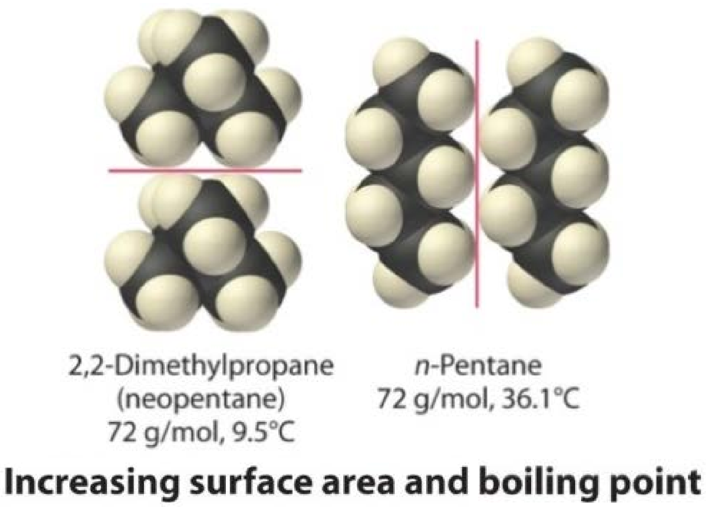
FIG IV – Water dipole inducing a dipole on O_2

Induced Dipole / Induced Dipole

very short ranged

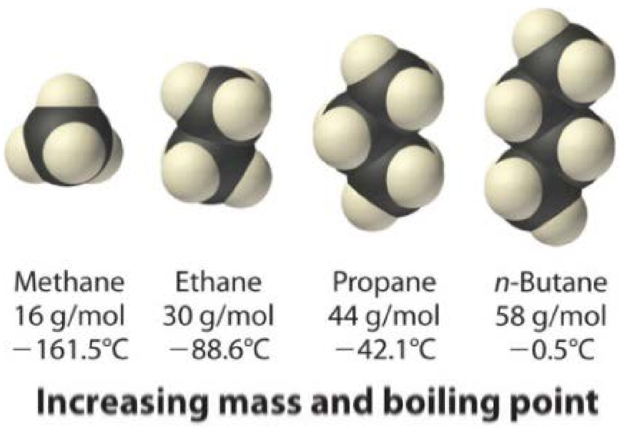
IMF (London dispersion forces) that exist between nonpolar entities due to attractions between opposite charges which originate in the formation of instantaneous dipole moments induced by the polarization of valence electrons. Occurs for anything that has electrons.





Effect of Dispersion on Boiling, Freezing Point

halogen	bp (°C)	inert gas	bp (°C)	fp (°C)
F_2	-188.1	He	-268.6	-269.7
Cl_2	-34.6	Ne	-245.9	-248.6
Br_2	58.8	Ar	-185.7	-189.4
I_2	184.4	Kr	-152.3	-157.3
		Xe	-107.1	-111.9
		Rn	-61.8	



Comparison of van der Waals Forces

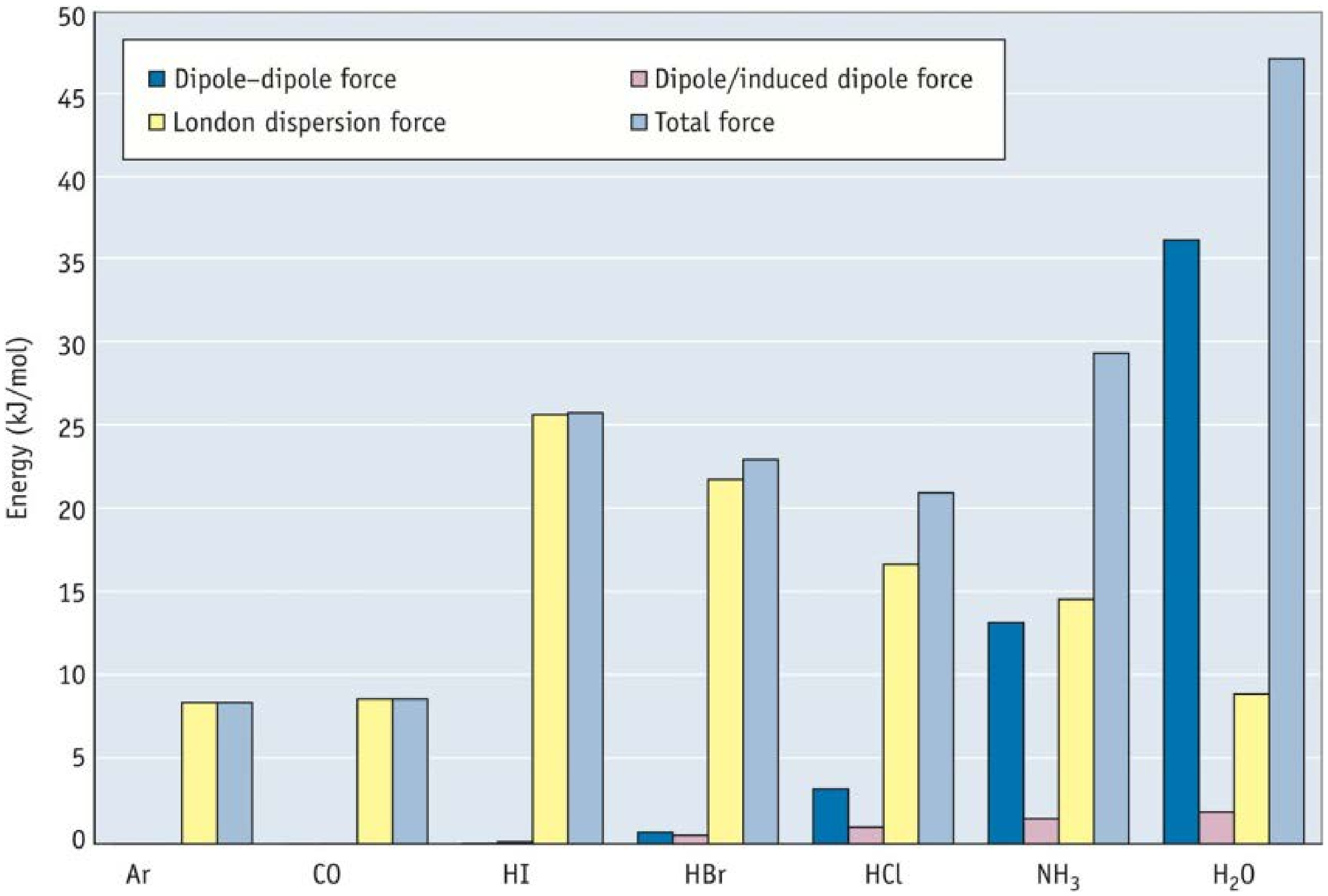


FIG VI – van der Waals forces in some molecules

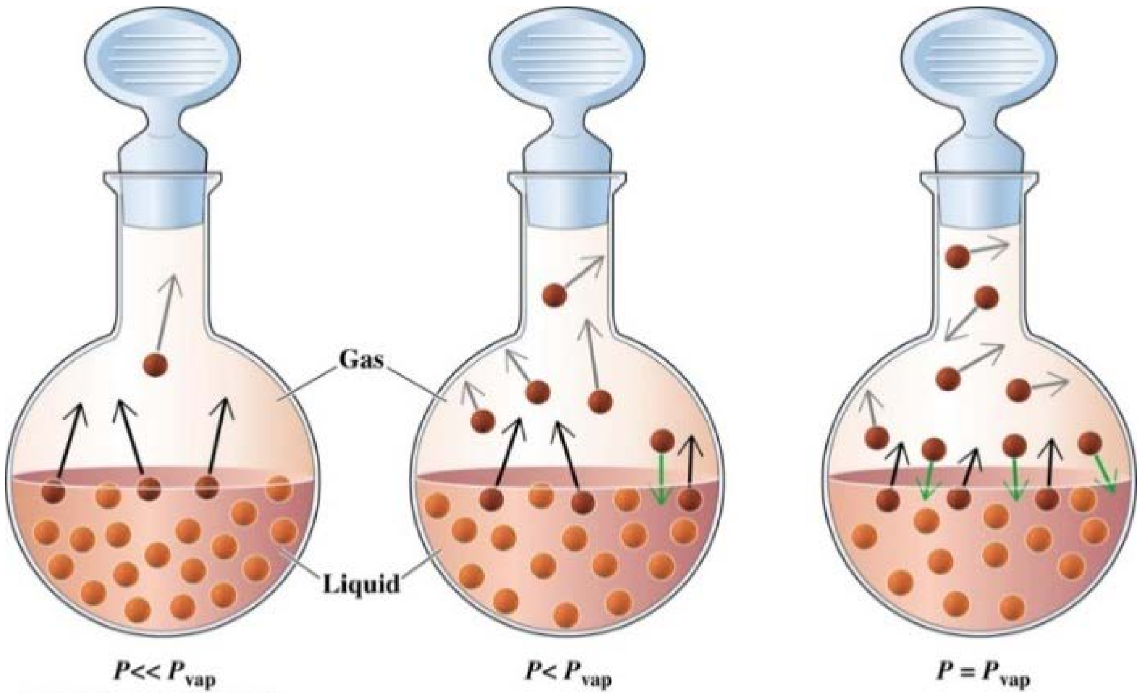
Yellow is Dispersion

Aside from small, highly polar molecules such as H_2O, dispersion energies are the largest contribution to intermolecular bonding between uncharged molecules.

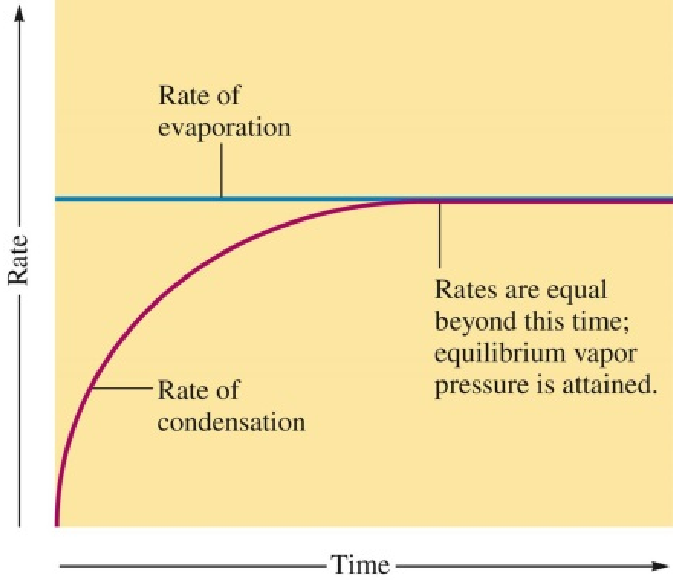
Changes of State and Phase Equilibria

vapor pressure

liquid in equilibrium with its vapor
determined by IMF's
vapor not an ideal gas!
P(*T*)



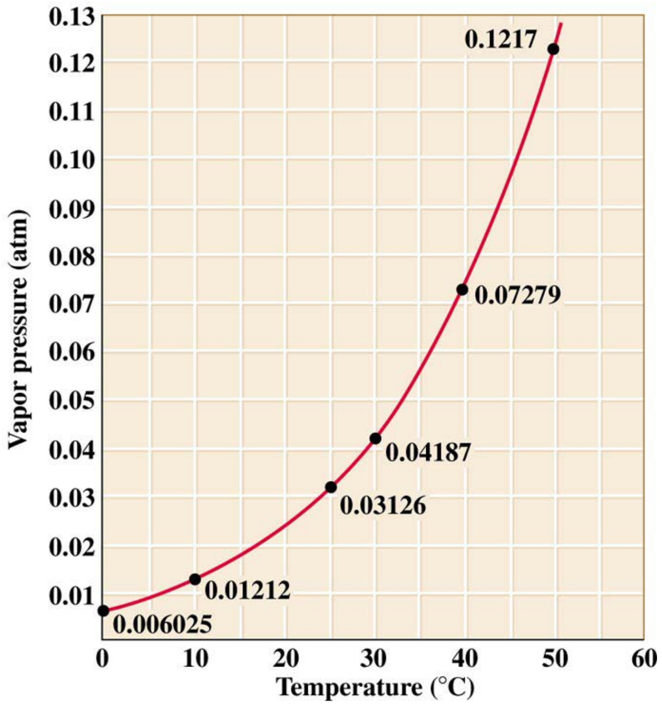
Rates of condensation and evaporation for a liquid sealed in a closed container. Evaporation rate remains constant, condensation rate increases as number of molecules in the vapor phase increases, until the two rates are equal; equilibrium vapor pressure attained.



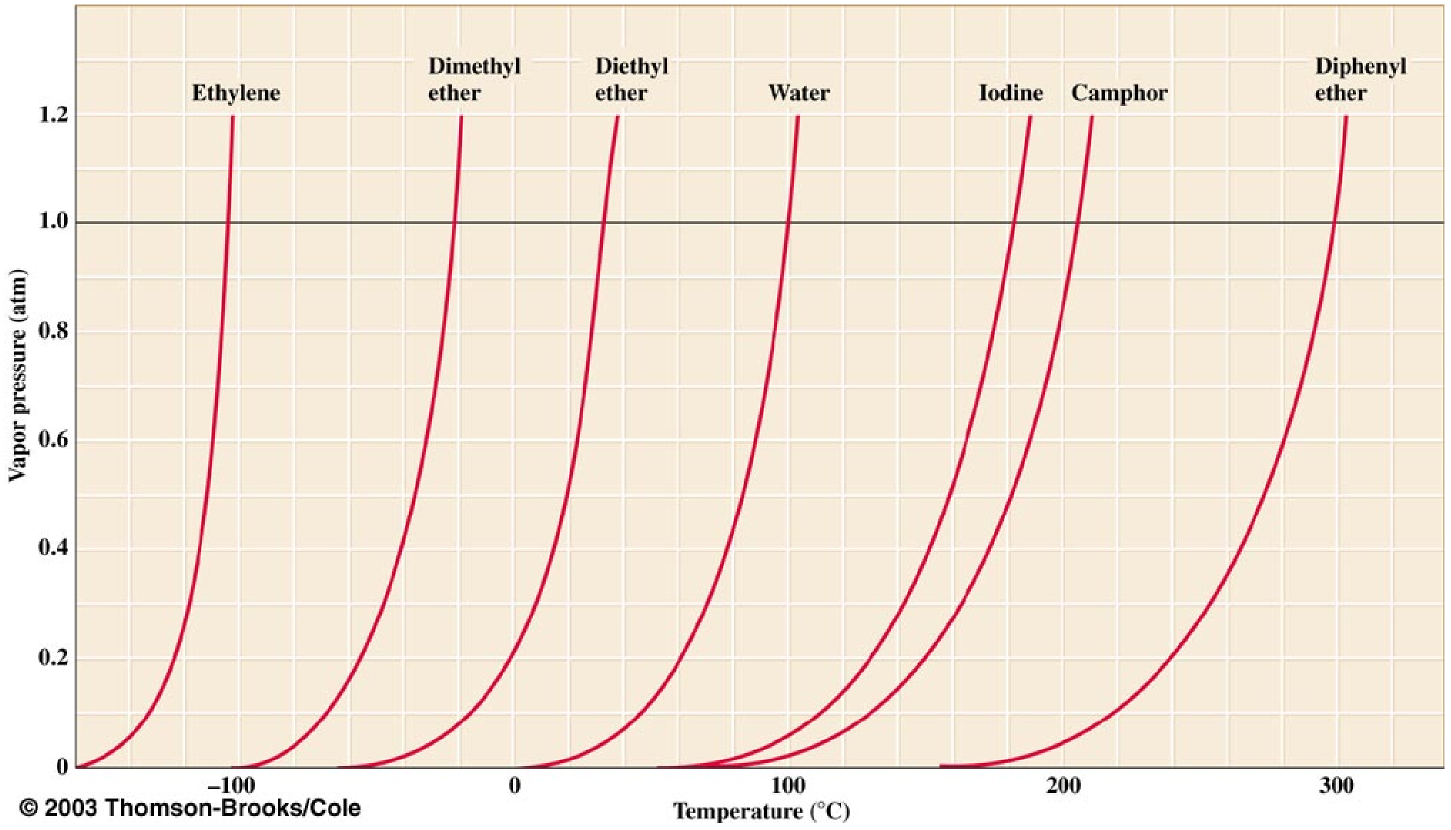
Vapor Pressure

Vapor pressure is only a function of temperature.

FIG VII – Vapor pressure of water as a function of temperature



$CH_2{=}CH_2$ CH_3OCH_3 $CH_3CH_2OCH_2CH_3$ I_2



Vapor Pressure

A Maxwell Boltzmann distribution also exists for liquids. If the velocities follow a Maxwell Boltzmann distribution then since kinetic energy = ½ mu^2, the kinetic energy also does.

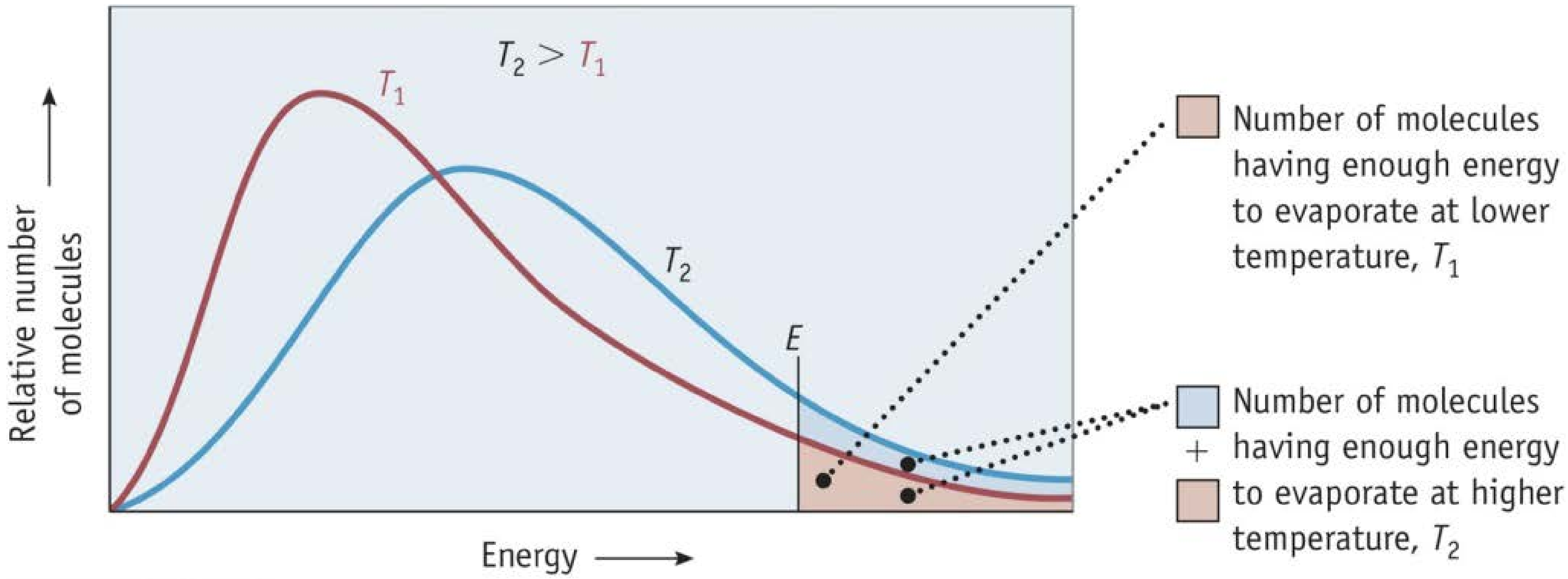


FIG VIII – Distribution of kinetic energies in a liquid

Phase Transitions

induced by a change in temperature or pressure

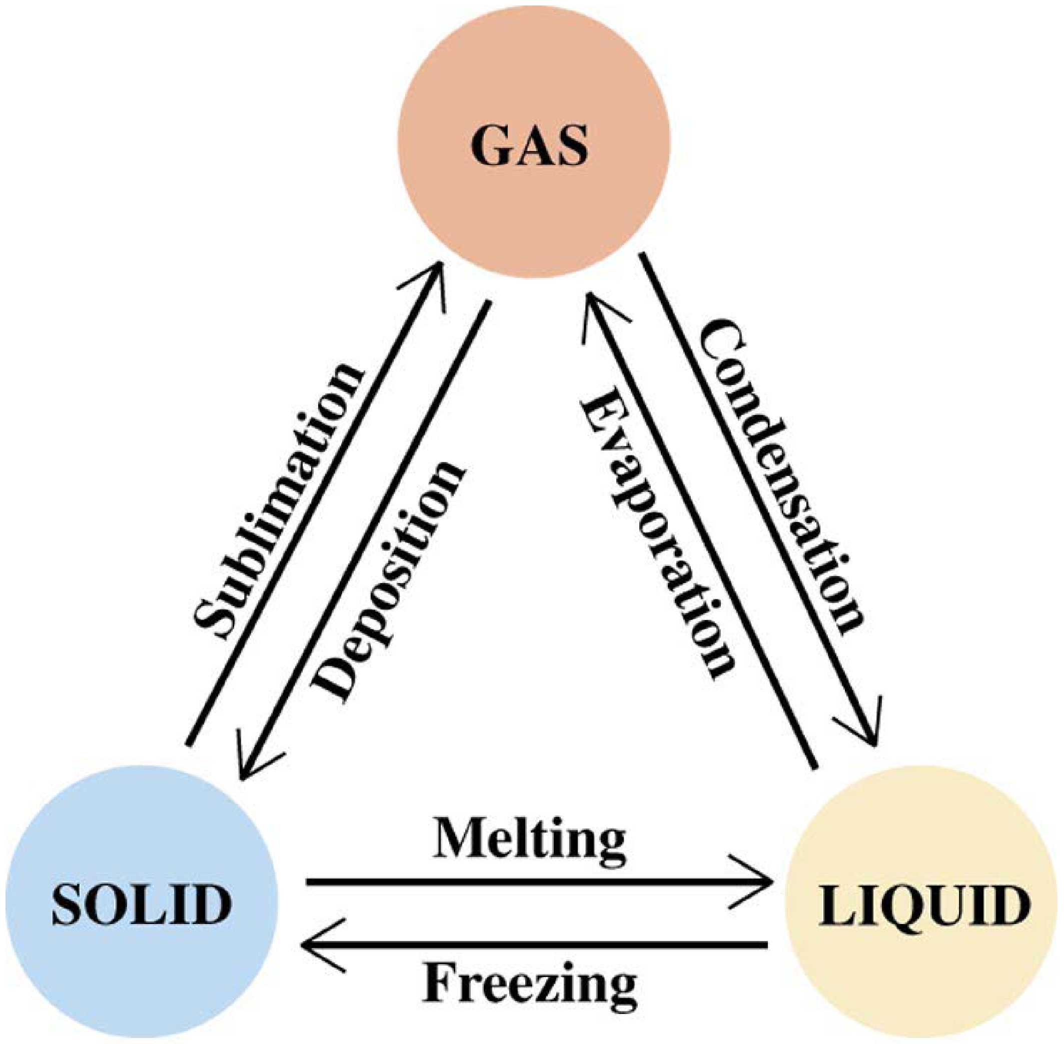
boiling point
  normal boiling point

melting point
  normal melting point

sublimation point
  normal sublimation point

melting ≡ fusion

normal => *P* = 1 atm



Simple Phase Diagram

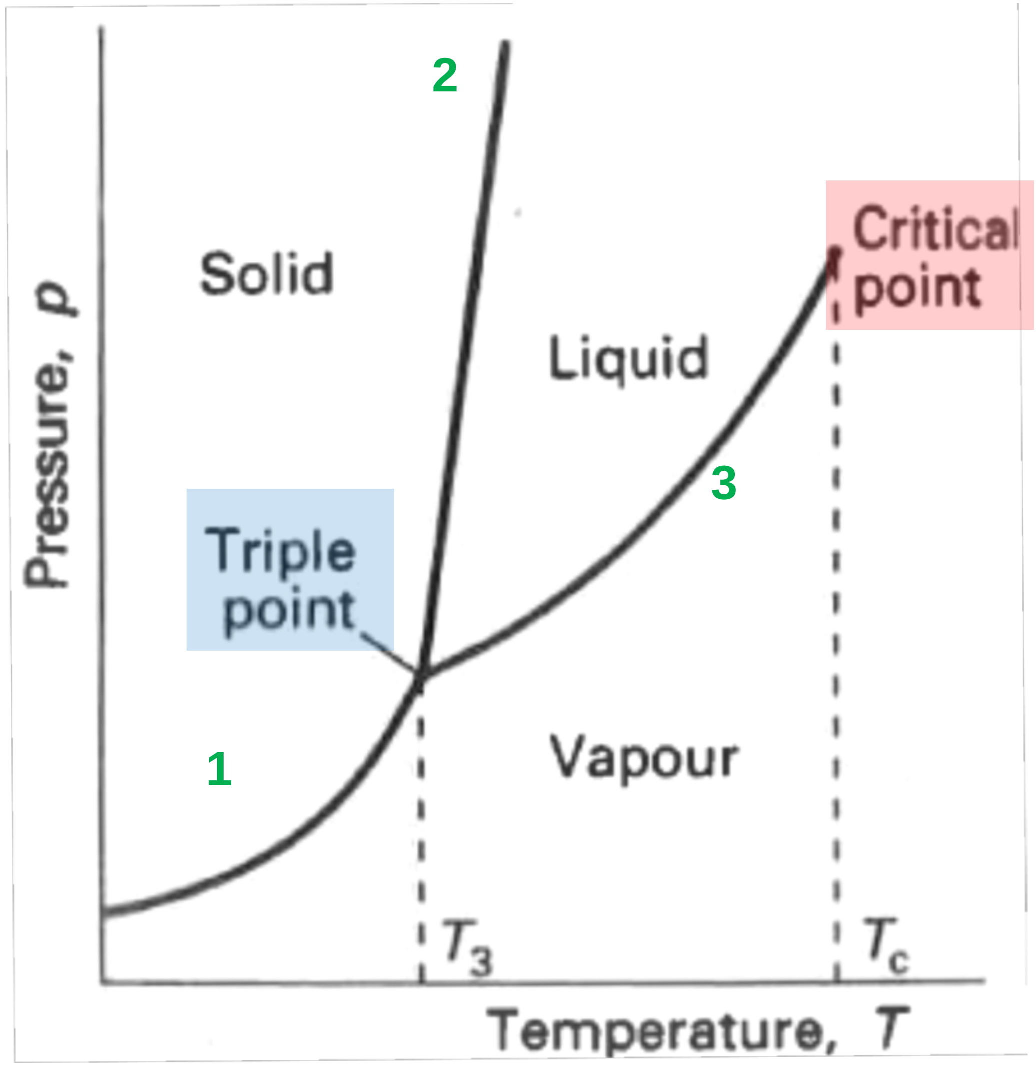
phase diagrams *P*(*T*)

shows *P*,*T* behavior of all solid, liquid, gas phases

1) solid <=> gas
2) solid <=> liquid
3) liquid <=> gas

triple point – single value of P, T where three phases coexist in equilibrium

critical point – value of P, T beyond which a gas cannot be condensed into a liquid



Comparing Phase Diagrams

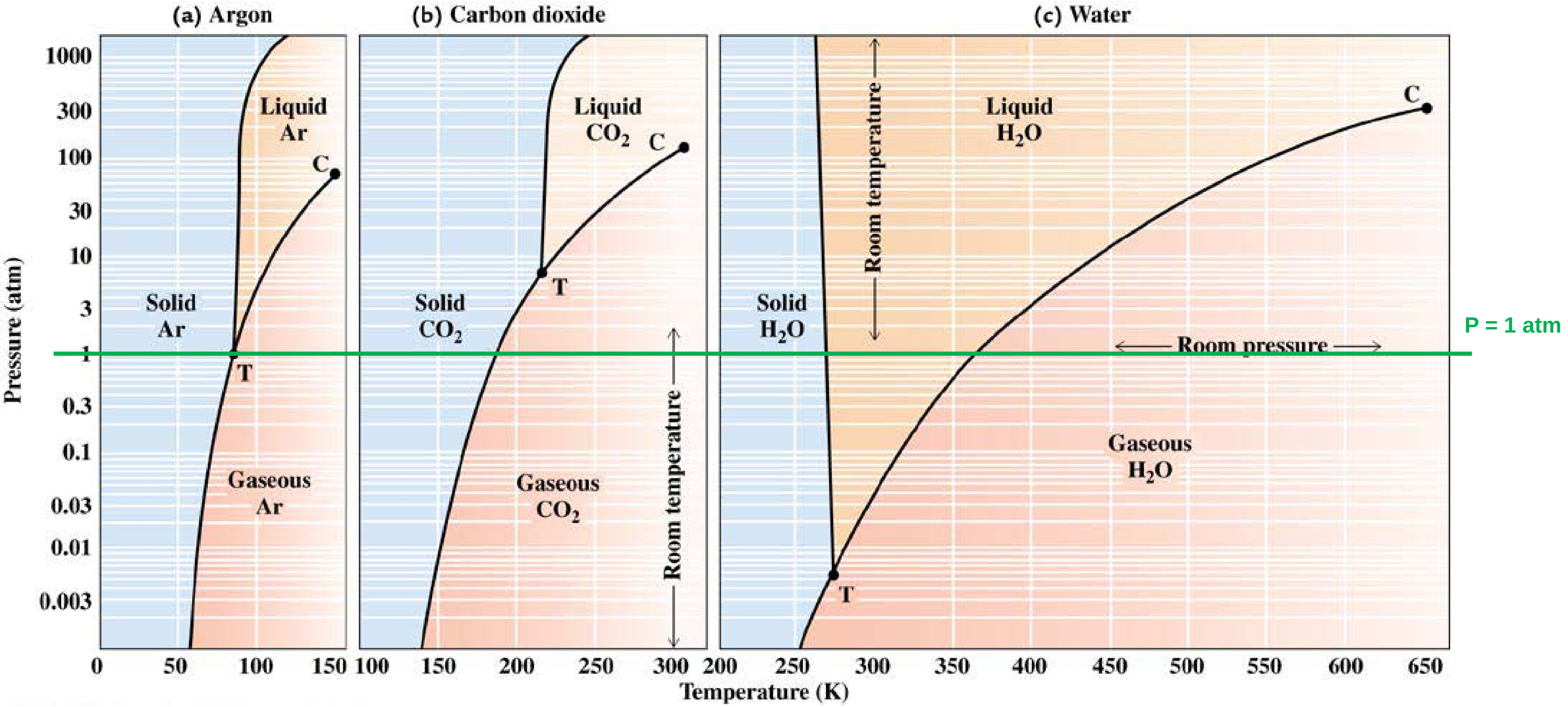


FIG X. Phase diagrams of Ar, CO_2, and water Note: *y*-axis (pressure) is logarithmic

Comparing Phase Diagrams

EX. 2 Consult the phase diagram on the right.

a) What is the phase at room temperature and 1 atm pressure?

b) What is the phase at -114^{o}C and 0.75 atm?

c) If the vapor pressure of a liquid sample is 380 mm Hg, what is the temperature of the liquid phase?

d) What is the vapor pressure of the solid at -122^{o}C?

e) Which is the denser phase, solid or liquid? Explain.