Sections 11.1 – 11.3
Properties of Liquids

Bill Vining
SUNY Oneonta

Properties of Liquids

In these sections…

REVIEW

a. Phases of Matter
b. Phase Changes
on molecular scale

see experimentally

c. Properties of Liquids:
  1. Enthalpy of Vaporization – how much energy it takes
  2. Boiling Point
  3. Relating Vapor Pressure, Boiling Point and Enthalpy of Vaporization
  relate
  4. Surface Tension, Viscosity and Capillary Action

1st: properties of liquids seen experimentally
2nd: how controlled by molecular structure
vp = how much pressure gas from vaporization of liquid causes

Phases of Matter on the Bulk Scale

Solids + liquids have similar densities, > than gas

Densities of H_2O:

$H_2O(g)$	0.000804 g/cm^3	low
$H_2O(\ell)$	0.9999 g/cm^3	similar, high
$H_2O(s)$	0.9150 g/cm^3	

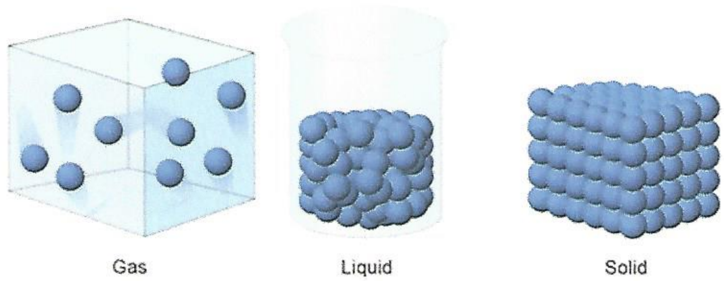
Table 11.1.1: Properties of Solids, Liquids, and Gases

Physical State	IMFs between Particles	Compressibility	Shape and Volume	Ability to Flow
Gas	Generally weak	High	Takes on shape and volume of container	High
Liquid	Generally intermediate	Very low	Takes on shape of container; volume limited by surface area	Moderate
Solid	Generally strong	Almost none	Maintains own shape and volume	Almost none

→ rigid

reason for differences see $\boxed{\text{SIMULATION}}$

Phases of Matter on the Molecular Scale



- All have molecules in motion.
- Gases and Liquids have molecules that can move freely. – fluid
- Liquid and Solids have molecules in close proximity.
- Only Solids have molecules that cannot change positions with one another. – rigid

Solids and Liquids have molecules held near one another by Intermolecular Forces (IMFs)

solid - molecules can jiggle, but not move past each other

↑ heat

liquid - molecules still attracted, but can flow pas

↑ heat

gas - kinetic energy causes molecules to not be able to stay together; independent entit

Properties of liquids

ex: Neon - solid → liquid @ low temp (~30K)
liquid → gas @ not much higher (~34K)

ex: oxygen - solid @ 69K, but melts + boils at much higher

why do some molecules melt, boil at higher temps?

ex: water - @ 150K, liquid or solid. doesn't have enough energy b/c forces between molecules much stronger

Phase Changes on the Bulk Scale

Table 11.1.2: Phase Changes - one phase changes to another

Phase Change	Physical Process	Energy Change
— Fusion (melting)	solid → liquid	Energy is absorbed.
— Vaporization	liquid → gas	Energy is absorbed.
— Sublimation	solid → gas	Energy is absorbed.
— Freezing	liquid → solid	Energy is released.
— Condensation	gas → liquid	Energy is released.
— Deposition	gas → solid	Energy is released.

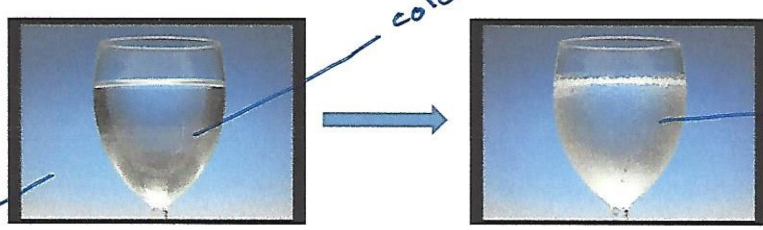
$\left.\begin{array}{l}\text{Fusion (melting)}\\ \text{Vaporization}\\ \text{Sublimation}\end{array}\right\}$ requires energy

$\left.\begin{array}{l}\text{Freezing}\\ \text{Condensation}\\ \text{Deposition}\end{array}\right\}$ releases energy

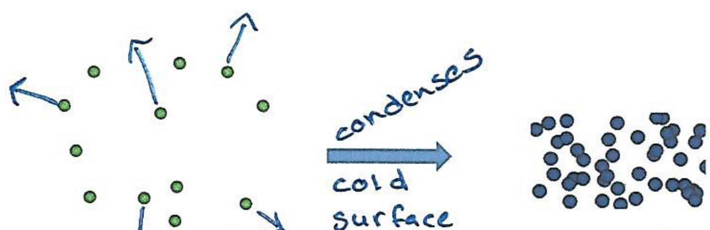
Phase Changes on the Molecular Scale

cold liquid

warm, humid air



glass gets wet



condenses

cold surface

H_2O gas

liquid (molecules have stronger attraction)

molecular scale:

ex: on warm, humid day - glass of cold liquid gets wet. WHY?

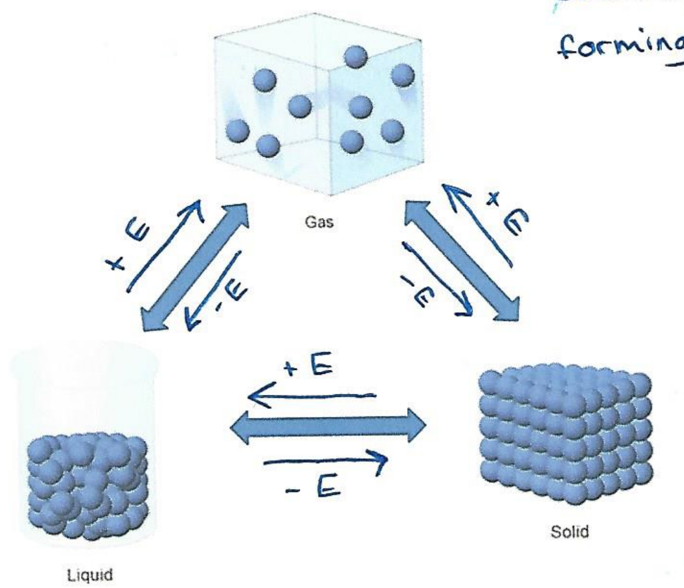
- H_2O molecules in air in gas phase condense on cold surface
- stronger attraction, becomes liquid

b/c: warm - molecules have enough energy to breake intermolecular forces

cold - not enough energy, so molecules stick together

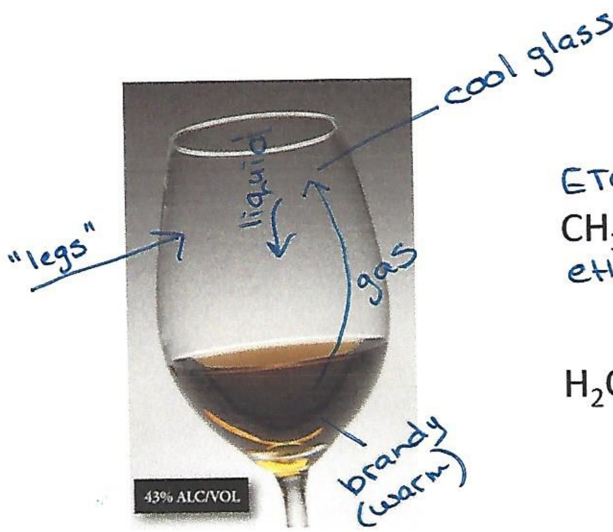
Phase Changes on the Molecular Scale

breaking bonds requires energy
forming bonds releases energy



E= energy

Different Liquids have Different Properties



ETOH
CH_3CH_2OH
ethanol

H_2O

In this case: ethanol has higher vapor pressure

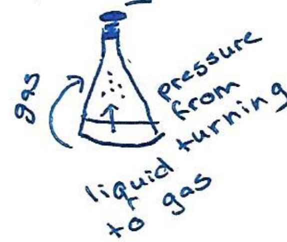
"legs" - warm ethanol evaporates from water; when it hits cool glass, it condenses
ethanol has weaker IMFs (intermolecular forces) than the water, + greater VP;
it changes into gaseous state better (ethanol is more VOLATILE)

Properties of Liquids

ΔH_{vap}

Enthalpy of Vaporization: Energy required to vaporize a liquid. - most directly relates to IMF - energy required to separate molecules in liquid & make it a gas. direct measure of strength of interactions between molecules

Vapor Pressure: The gas pressure of a vapor
(a vapor is a gas that comes from a liquid vaporizing.) → function of IMF strength. vapor that comes from liquid evaporating



Boiling Point: Temperature at which vapor pressure reaches external atmospheric pressure.

Surface Tension: The tendency of a liquid surface to resist change.
keep its surface at a minimum surface area

Viscosity: The resistance of a liquid to flowing.
→ how thick

Enthalpy of Vaporization

Also called heat of vaporization, ΔH_{vap}.

Energy required to vaporize a liquid to form a gas.

$$\underbrace{1 \text{ mol } H_2O(l)}_{\text{liquid}} \xrightarrow{+E} \underbrace{1 \text{ mol } H_2O(g)}_{\text{gas}} \quad \Delta H = 40.7 \text{ kJ}$$

amt of energy H_2O takes

So,

$\Delta H_{vap}(H_2O) = 40.7$ kJ/mol
→ "enthalpy of vaporization of water"

always positive = endothermic
(it always takes energy to vaporize liquid)

mole of liquid, heat it up (+E) & get mole of gas
enthalpy of vaporization = how much energy that takes
the bigger the *, the more strongly the molecules are held together

Enthalpy of Vaporization: Trends

examples

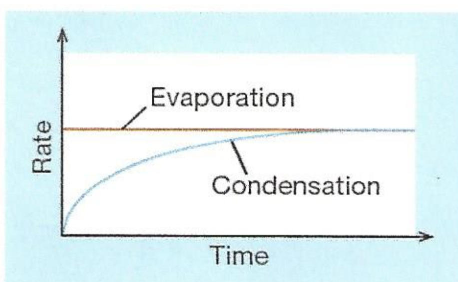
Table 11.1.3 Enthalpy of Vaporization for Some Common Substances

Compound	Enthalpy of Vaporization (kJ/mol)
Helium, He	0.0828 - low (lowest of anything known)
Argon, Ar	6.43
Methane, CH_4	8.17
Ethane, CH_3CH_3	14.7
Methanol, CH_3OH	35.4
Water, H_2O	40.7 - high (one of the highest for liquids)
Benzene, C_6H_6	34.1

Stronger IMFs lead to larger enthalpy of vaporization.

the stronger the IMF the larger the enthalpy of vaporization

Vapor Pressure



The pressure exerted by a vapor in equilibrium with the liquid from which it vaporizes.

Vapor pressure represents a "dynamic equilibrium." - no change in # of molecules in gas phase, but not same molecules

closed container:

on molecular scale: (1) (2) (3)

(1) some molecules escape into gas phase; makes pressure
(2) over time, some gas hits surface, + goes back to liquid phase
(3) $l \to g$, $g \to l$ } when rates are equal = equilibrium

see $\boxed{\text{SIMULATION}}$