Mr. Bracken
AP Chemistry

Name ___________________________
Period _____

Intermolecular Forces Notes #1

States of Matter:
A **gas** expands to fill its container, has neither a fixed volume nor shape, and is easily compressible.
A **liquid** has a fixed volume, flows to assume the shape of its container and is only slightly compressible.
A **solid** has a fixed volume, maintains a definite shape, and is more difficult to compress than a liquid.

In a gas, we visualize speedy, energetic, widely spaced atoms or molecules undergoing frequent collisions but never coming to rest or clumping together.

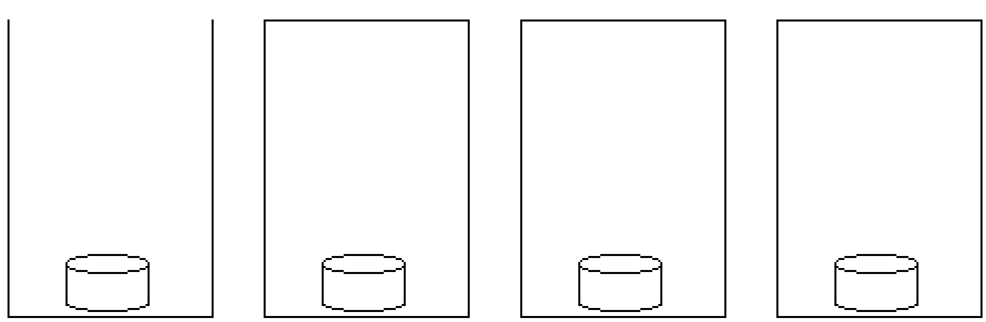
In a liquid, atoms or molecules are close together, and intermolecular forces are strong enough to hold them in a fixed volume but not in a definite shape.

In a solid, the structural particles (atoms, ions, or molecules) are in direct contact, and the intermolecular forces hold them into a fixed volume and definite shape.

Phase Change Terms	Process
Melting	solid $\rightarrow$ liquid
Freezing	liquid $\rightarrow$ solid
Vaporization	liquid $\rightarrow$ gas
Condensation	gas $\rightarrow$ liquid
Sublimation	solid $\rightarrow$ gas
Deposition	gas $\rightarrow$ solid

Vapor Pressure of Liquids:
The partial pressure exerted by the vapor when it is in dynamic equilibrium with the liquid at a constant temperature. (Equilibrium here means Vaporization Rate = Condensation Rate)

Vapor pressures of liquids increase as the temperature increases. (Higher temp = Higher Vapor Pressure)



Open System

Equilibrium Achieved
Vaporization Rate = Condensation Rate

Boiling Point:
Basic definition: Temperature at which a liquid becomes a gas. However, it's more complicated.

The boiling point of a liquid is the temperature at which its vapor pressure becomes equal to the atmospheric pressure. Water does not always boil at 100°C.

The **normal boiling point** is defined as the boiling point at 1 atmosphere of pressure. (sea level)

The observed boiling point of water in Denver is 95°C. (P_{atm} in Denver = 0.83 atm)

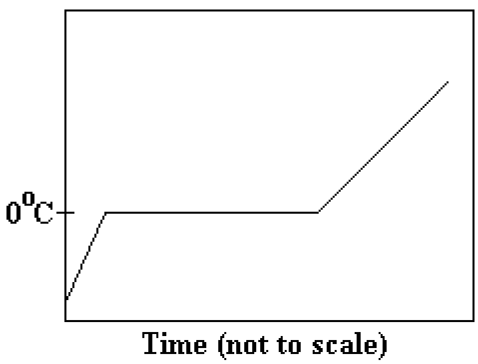
Food cooking times are affected by this:

Makes sense because "boiling" in water means approximately 100°C here in Central Ohio, but "boiling" in Denver means 95°C. Cooking times would be even longer on Mount Everest!

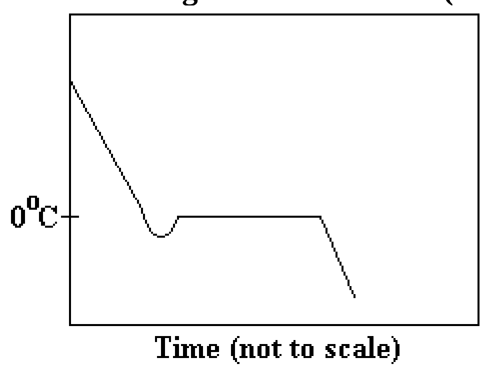
Inside a pressure cooker, the internal pressure is much higher. Therefore, the liquid water boils at a much higher temperature. One would certainly expect the potatoes to cook faster at 110°C than at only 100°C.

Do NOT simply say that pressure cookers cook food faster by holding in the heat better.

Heating Curve for Water



Cooling Curve for Water (with supercooling)



Sublimation:
The direct conversion of solid molecules to gaseous molecules (no liquid state observed)

Examples: Dry Ice (CO_2), mothballs, and solid-stick room deodorizers

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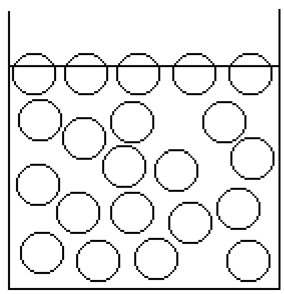
Intermolecular Forces Notes #2

Properties of Liquids:

Viscosity: Resistance of a liquid to flow. Dependent on temperature. At higher temps, molecules have more kinetic energy and are able to overcome attractive intermolecular forces.

Surface Tension:
Explains why water "beads up" on a waxy surface.
Water has a very high surface tension because of hydrogen bonding between the water molecules.

Water molecules on the surface experience a net inward attraction through hydrogen bonding with the other water molecules. Surface molecules pack closely together, liquid acts as if it had a skin.



Cohesive Forces:
Intermolecular forces that bind similar molecules to one another, such as hydrogen bonding in water.

Adhesive Forces:
Intermolecular forces that bind a substance to a surface.

Cohesive vs. Adhesive Forces: "Which dominates?"
We are familiar with the fact that water forms a meniscus inside a glass graduated cylinder. This can be attributed to the fact that the adhesive forces between the glass and the water are greater than the cohesive forces between the water molecules.

Liquid mercury has such strong cohesive forces that it forms a "dome" at the top surface. The cohesive forces keep the mercury together rather than being attracted to the walls of a test tube or graduated cylinder.

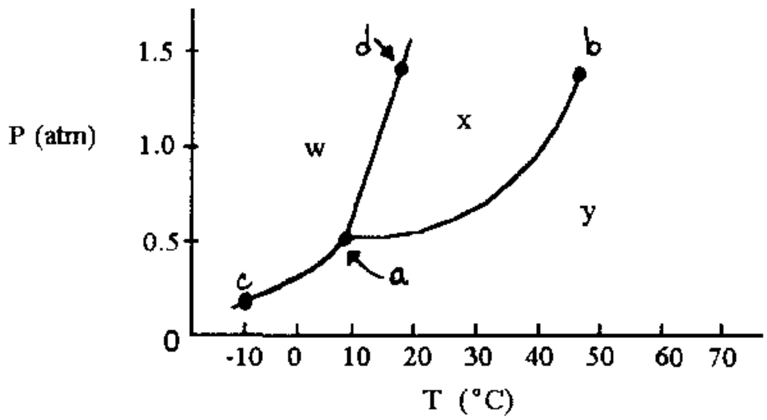
Interpretation of Phase Diagrams:

Critical Temperature:
The highest temperature at which a distinct liquid phase can form.

Critical Pressure:
The pressure required for liquefaction at the critical temperature.

General Shape for a Phase Diagram (Pressure vs. Temp)

Temperature



1. The phase diagram of a substance is given above. This substance is a _____ at 25^{o}C and 1.0 atm.
   (a) gas
   (b) crystal
   (c) liquid
   (d) supercritical fluid
   (e) solid

2. In the phase diagram shown above, the area labeled ______ indicates the gas phase for the substance.
   (a) w
   (b) x
   (c) y
   (d) a
   (e) a & y

3. In the phase diagram above, the area labeled ______ indicates the solid phase for the substance.
   (a) w
   (b) x
   (c) y
   (d) a
   (e) a & y

4. The normal boiling point of a substance in the phase diagram shown above is ______ ^{o}C.
   (a) 10
   (b) 20
   (c) 30
   (d) 40
   (e) 50

5. On the phase diagram above, the segment ________ corresponds to the conditions of temperature and pressure under which the solid and the gas of the substance are in equilibrium.
   (a) ab
   (b) ac
   (c) cd
   (d) bc
   (e) ad

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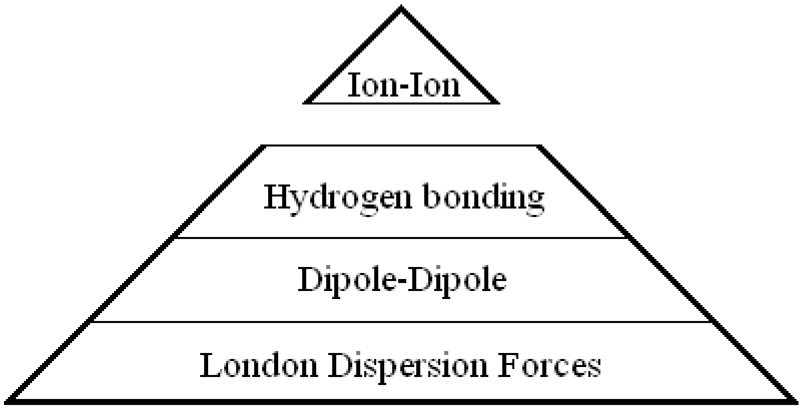
Intermolecular Forces Notes #3



I. Types of Intermolecular Forces

A. **Ion-Ion**: Ionic compounds (metal ion/nonmetal ion) ***STRONGEST***

B. **Hydrogen Bonding**: Compounds with H directly bonded to F, O, or N ***STRONG***

C. **Dipole-Dipole**: polar compounds ***Medium***

D. **London Dispersion Forces**: All compounds exhibit these. ***Quite Weak***

Most important with nonpolar compounds because nonpolar molecules do not exhibit any other intermolecular forces.

Compounds with the greater formula weights have the stronger London Dispersion Forces.

C_4H_{10} vs. $C_{10}H_{22}$ more London Dispersion Forces since it has a greater formula weight

II. Effect of Intermolecular Forces on Physical Properties:

A. Strongest intermolecular forces = highest boiling point, highest melting point, and highest heat of vaporization.

Example: Which has the higher melting point? **NaCl** *or* **CCl_4**

B. Compounds with the highest vapor pressure exhibit the weakest intermolecular forces.

Example: Explain why octane C_8H_{18} has a higher vapor pressure than candle wax $C_{25}H_{52}$

III. Comparing Ionic Compounds vs. Ionic Compounds

A. If two compounds are both ionic, the compound containing the ions with the ***greater charge*** has the ***greater intermolecular forces***.

Example: Both KCl and CaF_2 are ionic compounds. However, the melting points are very different. Which compound would be expected to have the higher melting point?

B. If ions have the same charge, the **smaller diameter ions** have **greater intermolecular forces**.

Example: Which has a higher melting point? *NaCl* or *KCl*

Example: Arrange these from lowest to highest melting point: NaCl, CO_2, Ne, $CaCl_2$, H_2O, H_2S

________ < ________ < ________ < ________ < ________ < ________

lowest MP *highest MP*

Answer: We must consider each compound's intermolecular forces

NaCl ______________________________ $CaCl_2$ ______________________________

CO_2 ______________________________ H_2O ______________________________

Ne ______________________________ H_2S ______________________________