

Notes about Intermolecular Forces and Liquids

Intermolecular Forces

Intermolecular Forces – forces between the molecules in a liquid or a molecular solid

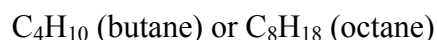
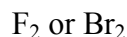
- If the intermolecular forces are low relative to the kinetic energy of the substance (which is directly related to temperature), the molecules will not be held together as a liquid and instead form a gas
- If the intermolecular forces are moderate relative to the kinetic energy, the molecules are held as a liquid
- If the IMF are high relative to the kinetic energy, the molecules are held in fixed positions as a solid
- **Higher intermolecular forces means a higher melting point and a higher boiling point**

Types of Intermolecular Forces (IMF)

Dispersion Forces

- The default IMF. Also the weakest IMF.
- Caused by fluctuations in the electron distribution within molecules
- These fluctuations in the electron distribution create an instantaneous dipole
- Strength of dispersion force increases with
 - Size of the electron cloud / size of atom
 - Molar mass

Questions: Which has the higher boiling point, and why?



Dipole-Dipole Force

- Exists for all polar molecules (permanent dipoles) – a medium strength IMF
- Positive end of one molecule is attracted to the negative end of the other
- In addition to dispersion forces (polar molecules have both)
- Molecules with dipole-dipole forces exclude those without (polar vs. nonpolar substances)

Question: Which has the higher boiling point, and why: CH_4 or CH_3Cl ?

Hydrogen Bonding

- Polar molecules with a H-F H-O or H-N bond
- A “super” dipole-dipole force – the strongest IMF
- The large electronegativity difference and small size gives strong attraction
- Still only 2% - 5% the strength of a covalent chemical bond

Question: Which has the higher boiling point, and why: CH_4 , CH_3Cl or CH_3OH ?

Phenomena in the Liquid State

Surface Tension

- Strong intermolecular forces will pull the molecules of a liquid together
- The liquid will tend to form spherical droplets, etc
- The liquid will also have a “skin” that allows some objects to float on water

Viscosity (higher viscosity means more resistance to flow, or a “thicker” liquid)

- If the molecules interact strongly, they cannot flow past one another easily
- Thus water has a higher viscosity than acetone or ethanol
- In addition, if the molecules are long chains (syrup, oil) the molecules get tangled and the viscosity is higher
- If the intermolecular forces are equal, a molecule with a higher molecular weight has a higher viscosity

Capillary Action

- The spontaneous rising of a liquid in a narrow tube
- The polar liquid is attracted to a polar surface (glass is a polar surface): these *adhesive forces* cause the liquid to creep up the glass
- The polar liquid also has *cohesive forces* that keep the liquid together (same forces that are responsible for surface tension), and these cohesive forces will cause a whole column of the liquid to be pulled up the capillary tube
- The liquid is pulled up the tube until the weight of the column of liquid balances the adhesive forces

Vapor Pressure and Changes of State

Boiling

- As you heat the liquid, you increase the kinetic energy of the molecules
- If you add enough heat, the molecules have enough kinetic energy to break free of the intermolecular forces (IMF), and they escape into a gas
- **Boiling Point:** when the vapor pressure of the liquid is equal to the pressure above it
- Also, when the thermal energy is high enough for the molecules in the interior of the liquid to break free into a gas
- As you add heat to a liquid:
 - First, temp of the liquid increases
 - then liquid is converted to gas
 - finally temp of gas increases
- Boiling point decreases with decreasing IMF

(continued on next page)

Vapor Pressure and Changes of State (Continued)

Melting, Freezing, Sublimation

- Similar to liquid-gas transitions
- Molecules in a solid held in a fixed place by IMF, adding energy allows them to slide past each other (*l*)
- As you add heat to a solid:
 - First, temp of the solid increases
 - then solid is converted to liquid
 - finally temp of liquid increases
- This is why ice water is always 0°C
- Melting point decreases with decreasing IMF
- Sublimation is similar, except it turns into a gas
- No way to predict what molecules will sublime instead of melt

Evaporation

- Molecules at the surface of the liquid experience fewer attractions to neighboring molecules, and break away more easily
- The molecules in the liquid have a distribution of energy, so even if the overall temperature is under the boiling point, some molecules still have enough kinetic energy to break free into a gas
- Rate of evaporation increases with
 - Increasing surface area
 - Increasing temperature
 - Decreasing strength of IMF
- As you heat the liquid, you increase the kinetic energy of the molecules
- Liquids that evaporate quickly are volatile, those that don't are non-volatile
- No evaporation in a closed container. Instead, the molecules will evaporate and condense at the same rate, and reach dynamic equilibrium

Condensation

- As steam cools, water molecules have less kinetic energy.
- When these molecules come near each other, the IMF overcomes the kinetic energy, and the molecules condense into a liquid.

Vapor Pressure

- The partial pressure of gas in dynamic equilibrium with its liquid (at 25°C, water's v.p. is 23.8 torr)
- Increases with
 - Increasing temperature
 - Decreasing strength of IMF
 - Independent of surface area

Questions:

- 1) Why do recipes have "high altitude directions?"
- 2) Why are organic solvents (nail polish remover, paint thinner) so stinky?
- 3) Rank the following from lowest to highest IMF:
ethanol (b.p. 78°C) water (b.p. 100°C), nitrogen (b.p. -196°C)