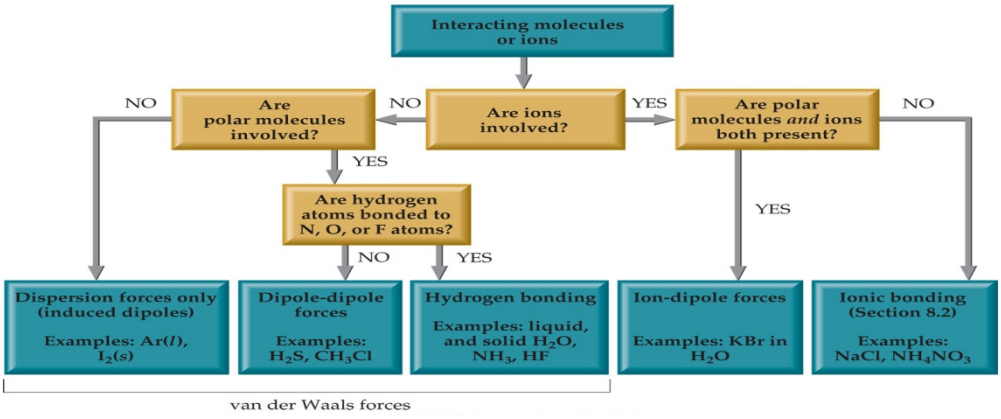
Ch.11-Intermolecular Forces, Liquids, and Solids

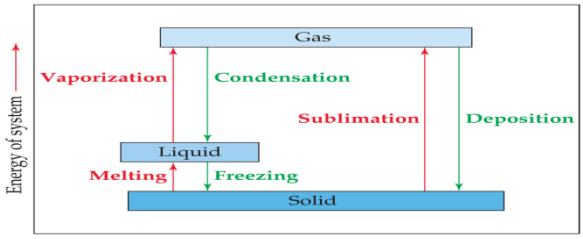
- Intra vs. Inter Molecular forces.
  - Intra molecular forces are strong interactions **within** molecules
  - Inter molecular forces are weak interactions **between** molecules
- Gas, Liquids, Solids
- The state a substance is in at a particular temperature and pressure depends on two antagonistic entities:
  - The kinetic energy of the particles
  - The strength of the attractions between the particles
- Gasses
  - assumes the shape and volume of its container
  - compressible
  - flows easily (particles can move past one another)
- Liquids
  - assumes the shape of the part of the container which it occupies
  - not easily compressible
  - flows easily
- Solids
  - retains a fixed volume and shape
  - not easily compressible
  - rigid - particles cannot move/slide past one another
- Inter molecular forces
- Ion-Dipole Forces
  - Ion-Dipole Forces exist between an ion and the partial charge on the end of a polar molecule
  - The magnitude of the attraction increases as either the charge of the ion or the magnitude of the dipole moment increases
- Dipole-Dipole Forces (generally weaker than Ion-Dipole forces)
  - Exists between neutral polar molecules
  - Strength increases with increasing polarity
- London Dispersion Forces
  - London forces are exhibited by nonpolar molecules because of the correlated movements of the electrons in interacting molecules. This is frequently described as formation of "instantaneous dipoles" that attract each other
  - More polarizable molecules end to have stronger London Dispersion forces. LDF tend to increase in strength with increasing molecular weight
  - Dispersion forces operate between all molecules.
    - TIP: When molecules differ widely in weight, dispersion forces tend to be the dominant force acting on them.
- Hydrogen Bonding (Generally the strongest inter molecular force)
  - Is a special type of intermolecular attraction that exists between the hydrogen atom in a polar bond (particularly H-F, H-O, or H-N) and an unshared electron pair on a nearby small electronegative ion or atom (usually an F, O, or N atom on another molecule)



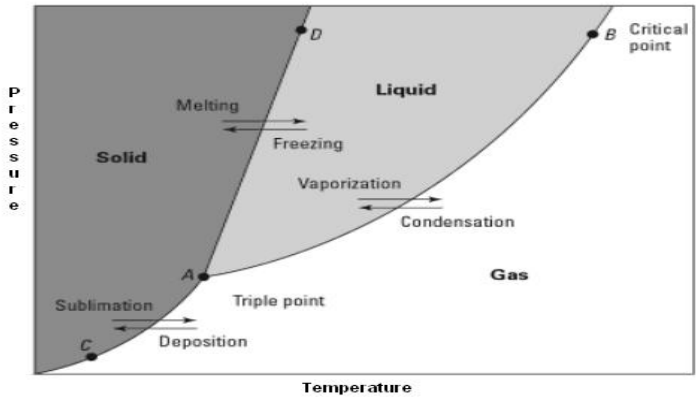
- PRACTICE: List the following substances in order of increasing normal boiling point:
  - HBr, HCl, HF, HI.
- ANSWER: In order of increasing boiling point: HCl, HBr, HI, HF.
- The trend is determined by strength of dispersion force which is related to the number of electrons, except for HF, which exhibits hydrogen bonding sufficiently strong to more than compensate for the smaller number of electrons in the HF molecule. This results in a boiling point higher than even the most electron rich hydrogen halide, HI.

- TIP: Hydrogen Bonding is almost always the strongest intermolecular force. Ion Dipole is generally next, then Dipole-Dipole, then London Dispersion (but London forces can sometimes be very strong). Ionic bonding, however, is stronger than all of those.

- Liquid Properties
- Viscosity
  - measure of a fluid's resistance to flow
  - strong intermolecular forces ⇒ higher viscosity
  - molecules "stick" together so flow is reduced
- Surface Tension
  - Surface tension results from the net inward force experienced by the molecules on the surface of a liquid.
- Phase Changes



- Vapor Pressure
  - At any temperature, some molecules in a liquid have enough energy to escape.
  - As the temperature rises, the fraction of molecules that have enough energy to escape increases
  - As more molecules escape the liquid, the pressure they exert increases
  - The liquid and vapor reach a state of dynamic equilibrium: liquid molecules evaporate and vapor molecules condense at the same rate
  - The boiling point of a liquid is the temperature at which its vapor pressure equals atmospheric pressure.
  - The normal boiling point is the temperature at which its vapor pressure is 760 torr.
- Phase Diagrams



- Phase diagrams display the state of a substance at various pressures and temperatures and the places where equilibrium exist between phases.
- The AB line is the liquid-vapor interface. It starts at the triple point (A), the point at which all three states are in equilibrium. It ends at the critical point (B); above this critical temperature and critical pressure the liquid and vapor are indistinguishable from each other. Each point along this line is the boiling point of the substance at that pressure.
- The AD line is the interface between liquid and solid. The melting point at each pressure can be found along this line.
- Below A the substance cannot exist in the liquid state.
- Along the AC line the solid and gas phases are in equilibrium; the sublimation point at each pressure is along this line.