AP Chemistry – Intermolecular Forces (IMF)

What are IMFs? They are forces between molecules that hold them together

➔ IMFs are caused by DIPOLES (unequal distribution of electrons within molecules) or POLARITY and can be permanent or temporarily induced dipoles

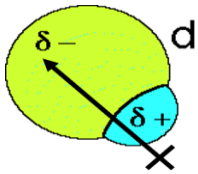
Properties affected by IMF: Boiling point (BP)
Melting point (MP)
Vapor pressure (VP)

Generally Speaking:
Strongest IMF: Hydrogen Bonding
Weakest IMF: Induced dipoles
*** Be careful there are exceptions to this***

Dipole – Dipole IMF

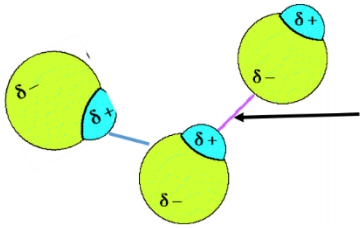
Occur between polar molecules (both have dipoles)

➔ Polar molecules have large ΔEn (greater than 0.4)
➔ Polarity = have partial pos. and partial neg. within molecule



dipole

Dipole indicated by arrow with positive (+) end. Tip of arrow always points toward negative side of molecule

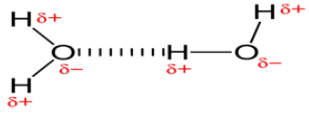


IMF – (between molecules!) positive end of molecules attracted to negative end of adjacent molecules. ALL molecules within sample/solution will align this way!

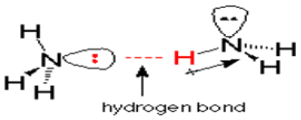
Hydrogen Bonding

THIS IS NOT A BOND, IT IS A TYPE OF DIPOLE-DIPOLE IMF!

Occurs when hydrogen bonded directly to N, O, F
(b/c these bonds are polar and create permanent dipoles!)
➔ Most common example is water (H_2O)



H-bonding b/w H-O



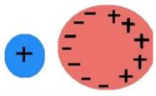
H-bonding b/w H-N

(H-F) not shown but you get the idea!

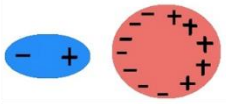
Trick alert: the hydrogen has to be directly bonded to N, O, F for H-bonding to occur. Just the presence of these 4 atoms does not create H-bonding

Induced Dipoles (these are temporarily forced dipoles)

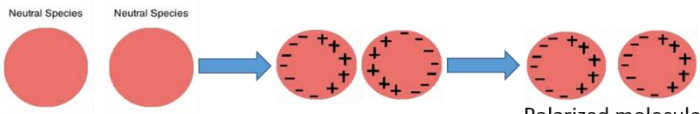
** Occur from e^-/e^- repulsion when nonpolar molecules get "too close" to each other
** the more electrons present the larger the induced dipole (big molecules can have large induced dipoles b/c of # of electrons)



Ion – Induced Dipole
Ion induces dipole in neighboring neutral molecule



Dipole – Induced Dipole
Polarity induces dipole in neighboring neutral molecule



Neutral molecules get "too close"

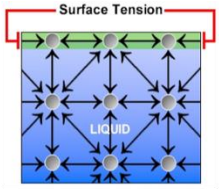
e/e repulsion

Polarized molecules rearrange so positive and negative align

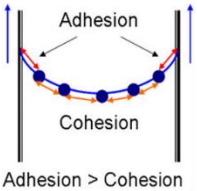
Induced Dipole – Induced Dipole
(a.k.a. London Dispersion Forces)

The Liquid State

The following properties of liquids are determined by IMFs (generally the greater the IMFs the greater the property)



Surface Tension (ST)
- Resistance to increase in surface area
- Stronger IMF have higher ST
- Occurs b/c molecules at surface attracted to each other as well as others in solution



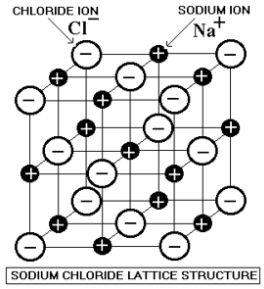
Adhesion > Cohesion

Capillary Action
- Adhesion: attraction of molecules to side of container
- Cohesion: attraction of molecules to each other
- If adhesion > cohesion the molecules will naturally travel up the side of the container and pull others up

Viscosity
- Liquids resistance to "flow"
- Generally strong IMF mean higher viscosity
- Molecular complexity also affects Viscosity b/c longer/bigger/more complex molecules get tangled together

Ionic Solids

* Held together by strong electrostatic forces (coulombs law!) that exists between oppositely charged ions
* The larger the charges of the ions the stronger the IMF

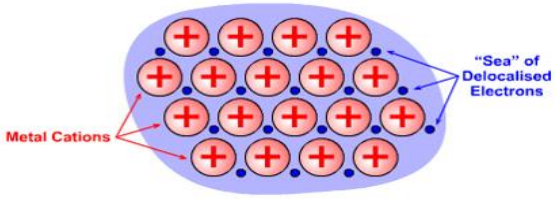


Coulombs Law: $F = \frac{q_1 q_2}{r^2}$

The bigger the q's…
the bigger the F!

Metallic Solids

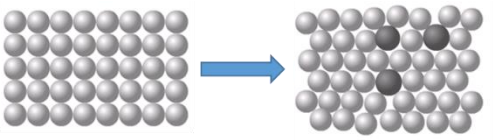
Valence electrons are released, creating an "electron sea" to which the positive metal ions are attracted (the attraction is non-directional)



Mobility of the electrons and positive ions account for metals malleability, ductility, thermal conductivity, and electrical conductivity

Metal Alloys

Metal alloys are mixtures of metal (or other atoms) that change the properties of the pure metal. There are 2 types:



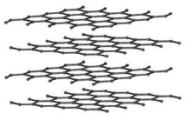
Substitutional Alloy

Different metals mixed together "disturbs" the 3-D arrangement and therefore changes properties (b/c metals have different atomic radii, ENC, that changes interactions)

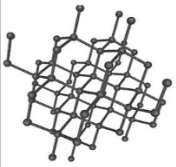
Interstitial Alloy

Made when interstices (holes b/w metal ions) are filled by small atoms
Carbon is the most commonly used "filler" atom
The more holes that are "filled" the more the property of the metal is changed

Covalent Network Solids



Network solid –
Atoms bonded in linear sheets
IMFs between sheets hold them together
Common example: graphite
Can conduct electricity, slippery



Network solid –
Atoms are all bonded together
Each atom is bonded to 4 others (tetrahedral)
Common example: diamond
Not conductive, very brittle

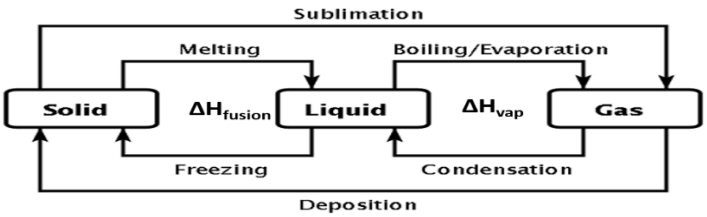
It's the molecular arrangement that determines the properties!
Network solids are generally silicon or carbon based

Molecular Solids

Non-polar	Polar	Hydrogen-bonded
Soft	Soft	Hard
Insulator of electricity	Insulator of electricity	Insulator of electricity
Very low melting point	Low melting point	Low melting point
Intermolecular forces - Despersion or London forces	Intermolecular forces - Dipole - dipole interaction	Intermolecular forces - Hydrogen bonding
Example - Ar, CCl_4, H_2, CO_2	Example - HCl, SO_2	Example - H_2O (ice)

Characteristic of molecular solids –
As molecular weight/complexity increase the IMFs are stronger which will effect BP, MP, VP

State Changes



Boiling point – to boil IMF between molecules must be overcome so molecule can "escape" gas phase

Freezing point – molecules must be slowed down to a point where IMFs are stronger than KE forces

Vapor pressure – some molecules have enough energy to naturally escape (Boltzmann distribution) from IMFs and enter gas phase

Summary of IMF Effects

IMF = strong intermolecular forces
IMF = weak intermolecular forces

IMF	**BP**	**FP**	**H_{vap}**	**H_{fus}**	VP
IMF	BP	FP	H_{vap}	H_{fus}	**VP**

Summary:

Strong IMFs lead to high BP, FP and large H_{vap}, H_{fus} low VP

Weak IMFs lead to low BP, FP and smaller H_{vap}, H_{fus} high VP