# CHEM 1212

## Promo Packet (Intermolecular Forces)

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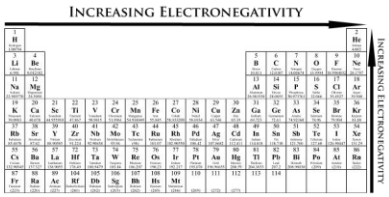
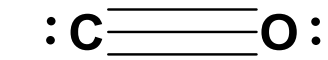
**Covalent Compounds**: Compounds in which the atoms participating in chemical bonds share the electrons which make up the bond. Covalent compounds can be either polar or non-polar.
**How Polarity Arises**: To understand how polarity arises, we must recall the concept of electronegativity and dipoles from General Chemistry 1.

I. **Electronegativity**: Corresponds to the tendency of an atom to hold its electrons tightly around its nucleus.
   a. The difference in electronegativity between two atoms making a ***covalent bond*** will determine whether the electrons composing the bond will be shared equally or not.

II. **The Trend of Electronegativity**: How we know whether one atom is more electronegative than another atom.
   a. As you move from left to right of the periodic chart, electronegativity increases.
   b. As you move from the bottom to the top of the periodic chart electronegativity increases.




III. **Polar Bonds and Dipoles Moments**: When there is a separation of charge between two atoms participating in a ***covalent bond***, the separation of charge is known as a dipole moment. Whenever a bond has a dipole moment, the bond is considered to be a polar bond.
   a. When will a bond between two atoms contain a dipole moment (uneven distribution of charge)?
      i. When two atoms of significant differences in electronegativity are covalently bound together, they share the electrons that make up the covalent bond in a non-equivalent manner.
      ii. When atoms which are bound together share the electrons making their bonds in a non-equivalent manner, at any given time, more electron density, from the bond, will reside on the more electronegative atom as opposed to the less electronegative atom.
      iii. When more electron density resides on the more electronegative atom in a covalent bond, the more electronegative atom will have a partial negative charge, while the less electronegative atom (electropositive atom) will carry a partial positive charge.




IV. **Polar Molecules**: Polar molecules arise when the sum of the individual dipoles within a molecule do not completely cancel each other out. ( You can't simply look one bond, you have to look at the molecule as a whole)
   a. The existence of polarity within a molecule is based on both the individual dipoles that exist between atoms, within a molecule, as well as the ***geometry*** of the molecule.

**Remember the past!**

| Regions of Electron Density | Hybridization | Lone Pairs of $e^-$ | Electronic Geometry | Molecular Geometry |
|---|---|---|---|---|
| **2** | **sp** | **0** | **Linear** | **Linear** |
| **3** | **$sp^2$** | **0** | **Trigonal Planar** | **Trigonal Planar** |
| | | **1** | | **Bent** |
| **4** | **$sp^3$** | **0** | **Tetrahedral** | **Tetrahedaral** |
| | | **1** | | **Trigonal Pyramidal** |
| | | **2** | | **Bent** |
| **5** | **$sp^3d$** | **0** | **Trigonal Bipyramidal** | **Trigonal Bipyramidal** |
| | | **1** | | **Seasaw** |
| | | **2** | | **T-Shaped** |
| | | **3** | | **Linear** |
| **6** | **$sp^3d^2$** | **0** | **Octahedral** | **Octahedral** |
| | | **1** | | **Square Pyramidal** |
| | | **2** | | **Square Planar** |

| Molecular Geometry | Polar? | Molecular geometry | Polar? |
|---|---|---|---|
| Linear | Not always | Seesaw | **Always** |
| Bent | **Always** | T-Shaped | **Always** |
| Trigonal Planar | Not always | Octahedral | Not always |
| Tetrahedral | Not always | Square Pyramidal | **Always** |
| Trigonal pyramidal | **Always** | Square Planar | Not always |
| Trigonal Bipyramidal | Not always | | |

**Example**: Consider the compounds below, which of these compounds are polar?

$SF_4$ $CCl_4$ $XeCl_4$

**Ionic Compounds**: Compounds in which two or more atoms which are chemically bound together have permanent and opposite charges. I.e., the atomic components of the compound are ions.

I. The atoms bearing the opposing charges are chemically bound together through the electrostatic attraction of their opposing positive and negative charges.

II. The electrostatic force that attracts two atoms of opposing charge is known as the ***ion-ion interaction***.

III. Ionic compounds are ***typically*** compounds which have a metal (which is positively charged) and non-metal (which is negatively charged) bound together. (The exception is where you have a positively charged non-metallic compound such as $NH_4^+$ acting as a cation)

IV. Additionally, all strong acids are considered ionic compounds. (ex hydrogen halides except HF)

**Intermolecular Forces:** Intermolecular forces correspond to the attractive forces between individual molecules. Intermolecular forces affect chemistry, as they are directly related to physical properties of compounds (melting point, boiling point, enthalpy of vaporization, enthalpy of fusion and solubility).

## Ion-ion interactions (the strongest intermolecular force):

**I.** Atoms bearing like charges have a tendency to repel each other, whereas atoms bearing opposite charges have a tendency to attract each other.

**II.** The strength of the attraction between two atoms bearing opposite charges is given by Coulomb's law.

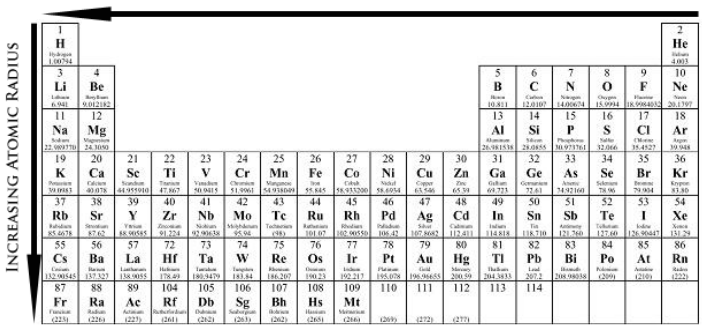
Coulomb's Law: $$Force\ (attractive\ force\ between\ atoms\ in\ an\ ionic\ bond) \propto \frac{q_1 q_2}{d^2}$$

q = charge on each atom in the compound

d = distance between the atomic nuclei

**III.** Increasing the charge of the ions participating in an ion-ion interaction will increase the strength of the ion-ion interaction. Mathematically, as the numerator of the equation increases, the attractive force between the ions increases.

***IV.*** Decreasing the distance between the atomic nuclei of the ions will increase the strength of the ion-ion interaction. Mathematically, as the denominator of the equation decreases, the attractive force between the ions increases. ***Note the periodic trends associated with atomic radius.***




**V.** Ion-ion interactions have an effect on the boiling point, melting point, heat of fusion, heat of vaporization and vapor pressure.

| Effect of Greater Ion-Ion Interactions (Greater Coulomb Force) | |
|---|---|
| | |
| **Melting Point** | **↑ Increase** |
| **Boiling Point** | **↑ Increase** |
| **Heat of Fusion** | **↑ Increase** |
| **Heat of Vaporization** | **↑ Increase** |
| **Vapor Pressure** | **↓ Decrease** |

**Example**: Rank the following according to increasing Coulomb force.

KCl $CaCl_2$ $RaBr_2$

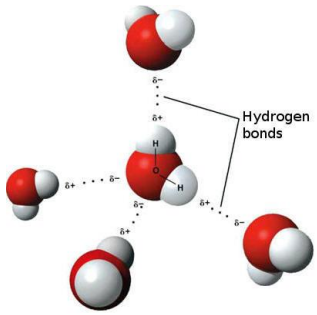
_____

**Example**: Which of the following compounds has the lowest melting point?

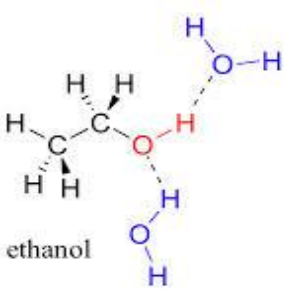
a. LiF b. $K_2S$ c. CaS d. $SrCl_2$

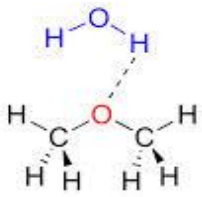
**<u>Hydrogen Bonding</u>**: Is the third strongest intermolecular force and corresponds to the attractive force between a ***hydrogen*** bound to one of three electronegative elements: ***oxygen, nitrogen, or fluorine***. There are two types of hydrogen bonding to look out for.

I. **Hydrogen Bonding between Molecules of the Same Kind:** In order for a pure substance to display Hydrogen bonding, the compound must have an X-H bond where X is ***nitrogen, oxygen, or Fluorine***.




II. **Hydrogen Bonding between Molecules of a Different Kind:** Any molecule which has an X-H bond (where X is O, N, or F) can participate in hydrogen bonding with other molecules that have X-H bonds. Additionally, compounds which have an X-H bond (where X is O, N, or F) can also participate in hydrogen bonding with any compound that has an N, O, or F, regardless of whether it is bound to a Hydrogen.


ethanol


dimethylether

**Example**: Which of the following molecules can form strong hydrogen bonds with other molecules of the same kind?

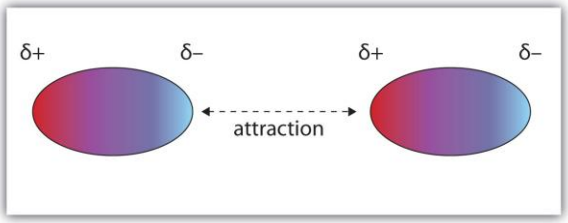
a. $C_6H_5COOH$
b. $C_6H_5OH$
c. HBr

**Example**: Which of the following molecules can form strong hydrogen bonds with water?

a. $C_6H_5CH_2F$
b. $C_6H_5NH_2$
c. $C_6H_5CH_2Br$

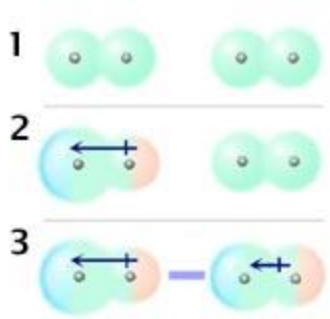
**Van der Waal Forces:** the general term describing the relatively weak attractions between different molecules - as opposed to the attractions involved within the chemical bonds of a single molecule. These forces are weaker than ion-ion, ion-dipole, and Hydrogen bonding interactions. There are two types of Van der Waal Forces that we will discuss.

**Dipole-Dipole Forces:** In dipole-dipole interactions, the positive end of one polar molecule and the negative end of another polar molecule are drawn together. All molecules which can participate in hydrogen bonding automatically have dipole-dipole interactions. Non-polar compounds can't have dipole-dipole interactions.




**Induced-Dipole-Induced Dipole Forces (Dispersion Forces)**: The dispersion force is the weakest intermolecular force. The dispersion force is a temporary attractive force that results when the electrons in two adjacent atoms occupy positions that make the atoms form ***temporary dipoles***. This force is sometimes called an induced dipole-induced dipole attraction. Dispersion forces are the attractive forces that cause nonpolar substances to condense to liquids and to freeze into solids when the temperature is lowered sufficiently.




I. **Molecular Mass and Dispersion Forces**: As the molecular weight of compounds with the same Intermolecular Forces (IMFs) increase, the dispersion forces between molecules possessing the same type IMFs will increase. Consequently, increases in the molecular weight of a substance can have an effect on the physical properties of the substance. Increases in molecular weight of compound with the same IMFs will result in an:
   a. Increase in heat of vaporization
   b. Decrease in vapor pressure

# IMF Summary

| Strength Rank | Intermolecular Force | Compound Requirement |
|---|---|---|
| 1 | Ion-Ion Forces | Ionic Bonds |
| 2 | Ion-Dipole | Need Ion and Polar Molecule |
| 3 | Hydrogen Bonding | H must be bound to F, N, or O |
| 4 | Dipole-Dipole Forces | Two or more Polar Compounds |
| 5 | London Dispersion Forces (induced-dipole) | Any Compound |

Identify all possible types of intermolecular forces that can form between particles of each substance**.**
**Methodology:** ***1.) Determine if the compound is ionic, 2.) Determine if the compound is polar. 3) Determine if there could be Hydrogen bonding, 4.) All compounds have dispersion forces.***

$XeF_2$

$CHCl_3$

He

$CH_3NH_2$