Module 7-What are Intermolecular Forces (IMFs)?

Draw the Lewis Structures for the following compounds in their appropriate shapes. Identify all polar bonds. Put partial charges on all partially charged atoms. Then determine if the molecule is polar or nonpolar. As Polarity and Non-Polarity plays key role in determining Intermolecular structures (So make sure you draw them correct. You learned to draw Lewis structure and Polarity in Module 3).

H_2	HF	HCl
H_2O	CO_2	SCl_2
PCl_3	NH_3	CS_2
Cl_2O	CH_2O	CH_4
CH_3CH_3	CH_3Cl	CH_3Br
CH_3OH	$CH_3CH_2CH_3$	Br_2

INTERMOLECULAR FORCES

Physical Properties

Polar Molecules → Hydrogen Bonds → strong*
Polar Molecules → Dipole-Dipole Interactions → medium
Non-polar Molecules → London Forces → weak

boiling point/evaporation
melting point
solubility

The three intermolecular forces are described in your textbook.
*Hydrogen bonds are the strongest of all three intermolecular forces. But they are still weaker than ionic or covalent bonds(also known as intramolecular).

- Bonds › Intermolecular Forces.

DIPOLE-DIPOLE INTERACTIONS

Dipole-dipole interactions occur between the negative end of one polar molecule and the positive end of a neighboring molecule. The molecule and its neighbor may be molecules of the same substance or molecules of different substances.

Examples) two CH_2O molecules
two PCl_3 molecules
one PCl_3 molecule with one H_2O molecule

HYDROGEN BONDS

Hydrogen bonds are like "special" dipole-dipole interactions. They are stronger than ordinary dipole-dipole interactions. Hydrogen bonds occur between nitrogen, oxygen, or fluorine atoms in one molecule and hydrogen atoms that are bonded to nitrogen, oxygen, or fluorine atoms in the second molecule.

Examples) two NH_3 molecules
two H_2O molecules
one molecule of CH_2O and one molecule of H_2O

There are two reasons for the strength of hydrogen bonds (relative to dipole-dipole interactions):

- Nitrogen, oxygen and fluorine all have very high electronegativities. As a result, the charges on either end of the molecule or bond are higher than they are in other polar molecules and the attractive forces are greater.

  - Hydrogen has the smallest atoms; nitrogen, oxygen and fluorine all have fairly small atoms. This means that the positive charges on the hydrogen atoms and the negative charges on the nitrogen, oxygen and fluorine atoms are closer together, and the attractive forces are greater.

Note: These are NOT examples of hydrogen bonds. Why not? What are they?
two SH_2 molecules
one molecule of CH_4 and one molecule of H_2O

LONDON FORCES

London forces are usually weaker than dipole-dipole interactions because London forces are temporary forces; they are present when electrons temporarily accumulate at one end or side of any molecule. The end where the electrons accumulate has a very tiny and short-lived negative charge. The other end of the molecule has a very tiny and short-lived positive charge. This positive charge attracts electrons from a neighboring molecule so that the neighboring molecule has a negative and a positive end. Though, London dispersion forces are present in those molecules which have H-bonding or D-D interactions but since this force is weak there, so we do not indicate them there. However, non-polar molecules have only London dispersion forces.

Examples) two CH_4 molecules
two molecules of Br_2
two molecules of CCl_4

Practice 1

Draw each molecule below twice. Label the polar bonds. Label atoms with partial charges (δ+, δ-). If the two molecules can interact with a dipole-dipole force or by hydrogen bonding, draw and label a dashed line representing the intermolecular force between the two molecules. Remember that London forces can occur between any two molecules, polar or nonpolar. If London forces are the *only* forces that can exist between two molecules, indicate so.

a. hydrogen, H_2

b. hydrogen fluoride, HF

c. hydrogen chloride, HCl

Intermolecular Forces (IMFs) and Physical Properties

Although intermolecular forces are <u>much</u> weaker than covalent bonds, they do have a big effect on the

- melting temperatures
- boiling temperatures
- surface Tension
- Vapor Pressure

Stronger the intermolecular forces, higher will be the melting and boiling temperatures and Surface Tension but lower will be the vapor pressure.

of molecular substances because intermolecular forces must be overcome when molecules melt or boil, but the covalent bonds in the molecular substances remain intact.

Practice 2

Molecules must overcome intermolecular forces before they can flow (or melt) and before they can evaporate (or boil). So melting and boiling temperatures are good measures of the strength of intermolecular forces. Use the intermolecular forces that you identified for H_2, HF and HCl and the table below to explain the following:

Substance	melting temperature	boiling temperature
Hydrogen (H_2)	- 259.14 ^{0} C	-252.8 ^{0} C
hydrogen chloride	-114.8 ^{0} C	- 84.9 ^{0} C
hydrogen fluoride	-83.1 ^{0} C	+ 19.54 ^{0} C

1. Explain why hydrogen has melting and boiling temperatures which are much lower than the melting and boiling temperatures of hydrogen fluoride and hydrogen chloride.

2. Use the intermolecular forces that you identified above to explain why hydrogen chloride has lower melting and boiling temperatures than hydrogen fluoride does.

Practice 3

Which molecule has the higher boiling point? To get your answer, sketch each molecule twice and show the intermolecular forces between them.

CO_2 or SCl_2

PCl_3 or NH_3

What else affects intermolecular forces/physical properties?

If two molecules have the same intermolecular forces (i.e. CH_4 and CCl_4 are both nonpolar molecules with low boiling points since they can only form London forces), which one will have the higher boiling point?

There are three "tie-breakers":

1. Longer, skinnier molecules can form *more* London forces and therefore have higher boiling points
   [Note: Because electrons are always moving, the accumulation of electrons does not last long (and London forces do not last long.) As a result, the London dispersion forces between small molecules are quite weak. However, a temporary accumulation of electrons is much more likely to occur in long skinny molecules with lots of electrons. London dispersion forces are stronger in those molecules. In fact, for very long molecules with lots of electrons can have higher boiling points than smaller molecules that can form hydrogen bonds.]

   Example) CH_4 vs CH_3CH_3

2. Molecules with more electrons can from *stronger* London forces and therefore have higher boiling points.

   Example) Br_2 vs. Cl_2

3. Polar molecules with more electrons are more strongly polarized and will have *stronger dipole-dipole forces* and therefore will have higher boiling points.

   Example) HBr and HCl

Practice 4: Draw the following compounds. Identify the intermolecular forces that can occur between molecules of the individual compounds. Then decide which compound has higher melting and boiling temperatures.

a. methane, CH_4 and chloromethane, CH_3Cl

b. chloromethane (from above) and bromomethane, CH_3Br

c. methane (from above) and wood alcohol, CH_3OH

d. methane and propane, $CH_3CH_2CH_3$