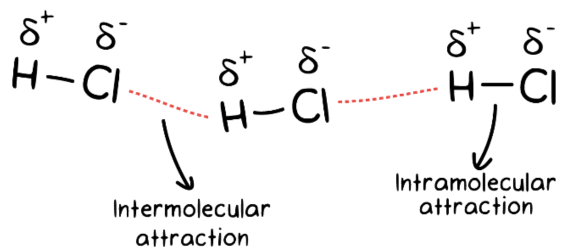
CHM 002 Workshop @ Chem Center
Topic: Intermolecular Forces Chapter 6

Introduction to Intermolecular Forces



- The term "**INTER**molecular forces" is used to describe the forces of attraction **BETWEEN** atoms, molecules, and ions when they are placed close to each other
- This is different from **INTRA**molecular forces which is another word for the **covalent bonds** inside molecules.
- When two particles experience an intermolecular force, a positive (+) charge on one particle is attracted to the negative (-) on the other particles.
- When intermolecular forces are **strong** the atoms, molecules or ions are strongly attracted to each other, and draw **closer** together. These are more likely to be found in condensed states such as liquid or solid.
- When intermolecular forces are **weak**, the atoms, molecules or ions do not have a strong attraction for each other and move far **apart**.

Q1 State the difference between intermolecular forces and intramolecular forces in terms of where they occur at the molecular level.

Q2 What is the minimum number of molecules (or atoms, ions) needed for an intermolecular force?

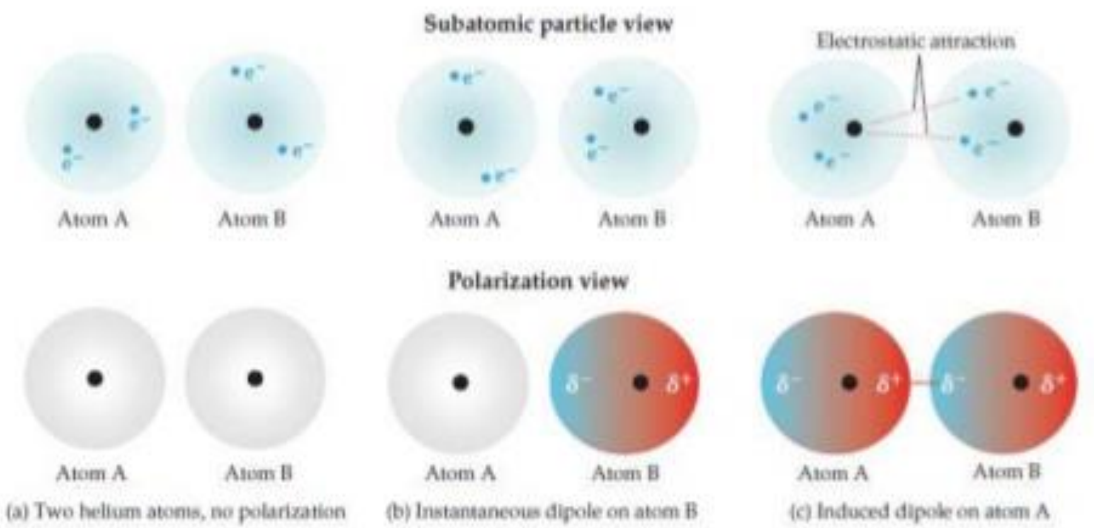
Q3 When two particles experience an intermolecular force, how are the two particles attracted to each other?

Q4 Would it be easier to separate two molecules experiencing a strong intermolecular force or a weak intermolecular force?

Types of Intermolecular Forces

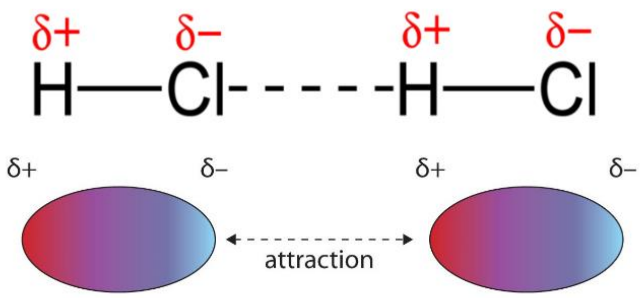
There are three types of intermolecular forces: **London dispersion forces** (LDF), **dipole-dipole interactions**, and **hydrogen bonding**. Molecules can have any mix of these three kinds of intermolecular forces, but all substances at least have LDF.

London Dispersion Forces (LDFs):



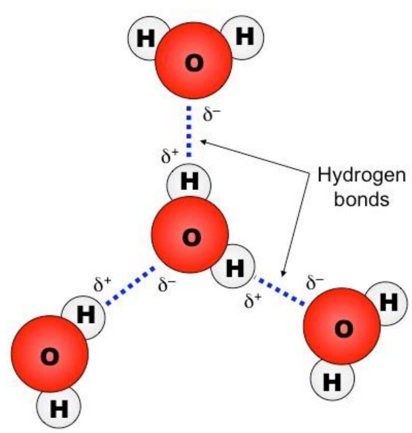
- **LDFs exist for all substances, whether composed of polar or nonpolar molecules**
- LDF arise from the formation of temporary instantaneous polarities across a molecule from the circulations of electrons.
- An instantaneous polarity in one molecule may induce an opposing polarity in an adjacent molecule, resulting in a series of attractive forces among neighboring molecules.
- Molecules with higher molecular weights have more electrons. This makes their electron clouds more deformable from nearby charges, a characteristic called **polarizability**.
- As a result, molecules with higher molecular weights have higher LDF and consequently have higher melting points, boiling points and enthalpies of vaporization.

Dipole-Dipole Interactions:



- Dipole-dipole forces exist between molecules that are **polar**-those that have a permanent dipole moment due to uneven sharing of electrons
- This uneven sharing gives one side of the molecule a **partial positive charge** (δ+) and the other side a **partially negative charge** (δ-)
- The polarities of individual molecules ten to **align by opposites**, drawing molecules together and thereby favoring a condensed phase.
- Substances with dipole-dipole attractions tend to have higher melting and boiling points compared to nonpolar molecules, which only have LDF.

Hydrogen Bonds:



- When a **hydrogen** atom is covalently bonded to **nitrogen**, **oxygen** or f**luorine** a very strong dipole is formed.
- The dipole-dipole interactions that result from these dipoles is known as **hydrogen bonding**.
- Hydrogen bonding is an **especially strong** form of dipole-dipole interaction.

Q1 Rank the intermolecular forces from strongest to weakest.

Q2 Even though the krypton atom is electrically neutral, why would it be said to have a momentary dipole?

Q3 Which substance would have greater LDFs, F_2 or I_2? Explain.

Q4 What causes the dipole in polar molecules?

Q5 What happens to the strength of intermolecular forces as polarity increases? Why?

Q6 Explain how hydrogen bonds are different from dipole-dipole interactions.

Identifying Intermolecular Forces

Intermolecular Force	
LDF	Present in mixtures of all molecules Strongest force for nonpolar molecules
Dipole-Dipole	Present mixtures of molecules with permanent dipoles
Hydrogen Bonding	Strongest dipole-dipole interaction Present in mixtures that contain molecules with H covalently bonded to N, O, or F

In the table below:

1. Draw the Lewis structure for each molecule.
2. Determine if there is a permanent dipole moment in the molecule. (Are there polar bonds? Is the molecule asymmetrical? Can you divide it into a positive side and a negative side?)
3. Identify the strongest intermolecular force

Molecule	PF_5	CS_2	BrO^{-3}
Lewis Structure			
Dipole Moment: (Yes/No)			
Intermolecular Force?			
Molecule	NH^{4+}	SCl_4	BrF_5
Lewis Structure			
Dipole Moment: (Yes/No)			
Intermolecular Force?			
Molecule	BF_3	SCl_6	PH_3
Lewis Structure			
Dipole Moment: (Yes/No)			
Intermolecular Force?			

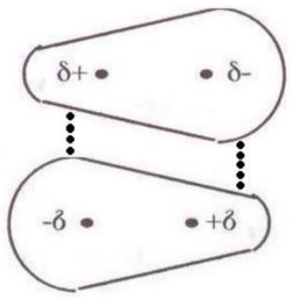
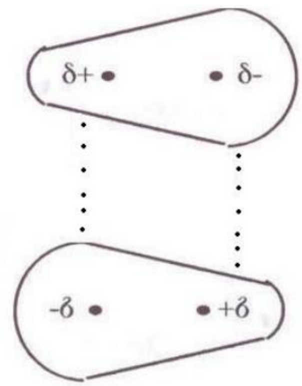
The Effect of Intermolecular Forces

Table 1: Physical Properties of non-polar Halogens

Element	F_2	Cl_2	Br_2	I_2
m.p. (°C)	-220	-101	-7.3	114
b.p. (°C)	-188	-34	58.8	184
At 25 °C	gas	gas	liquid	solid

- **Stronger** molecular forces **draw molecules closer** together resulting in a condensed phase such as liquid or solid
- In order for molecules to move from solid to liquid to gas phases they must overcome the intermolecular forces
- The stronger the intermolecular force the more energy (heat!) is required to undergo a phase change from solid to liquid to gas
- **In the table above you can see that as the LDF increase with increasing molecular weight, more energy is required to melt (solid→liquid) and boil (liquid →gas) the halogen. At room temperature the halogens with the higher intermolecular force will be found in a more condensed phase.**
- In liquids molecular attractions give rise to **viscosity**, a resistance to flow, and **surface tension**.

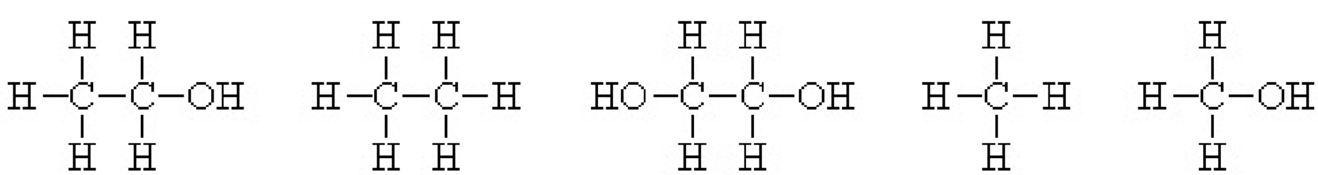
Complete the table below:

Property	Strong IMF	Weak IMF
		
Distance between molecules	SMALL	LARGE
Energy it takes to separate molecules	LARGE	SMALL
Affinity for other molecules like itself		
Volatility (ability to go from liquid to gas)		
Boiling/ melting point		
Viscosity		

Q1 Rank gas, liquid and solid in order of increasing intermolecular forces.

Q2 To go from a liquid to a gas, what must happen?

Q3 Rank from lowest to highest boiling point



Q4 Give an explanation in terms of intermolecular forces for the following differences in boiling point.

a. HFHF (20° C) and HClHCl (-85° C)

b. $CHCl_3$CHCl3 (61° C) and $CHBr_3$CHBr3 (150° C)

c. Br_2Br2 (59° C) and IClICl (97° C)