Reading Notes
Intermolecular Forces

Name Key
Period _____ Date _____

**Introduction:** Substances exist in three states of matter: solids, liquids and gases. We know that molecules are... (a) far apart in gases; (b) close together, yet moving in liquids; and (c) held together in orderly structures in solids. At this point, you might be wondering:

– Why do molecules stick together in liquids and solids?
– Why does it take a lot of heat (energy) to change some liquids into gases, while other liquids change into gases at very cold temperatures (low energy)?

Read the attached article and answer the following questions as you go to understand the forces of attraction between molecules in liquids and solids. These forces of attraction hold molecules together in liquids and solids and these forces must be broken when liquids and solids are turned into gases.

**Read the excerpt** (p. 442-444) taken from *The World of Chemistry* text book written by Zumdahl. In the reading, you will learn about these attractive forces between molecules called intermolecular forces. Answer the following questions as you read.

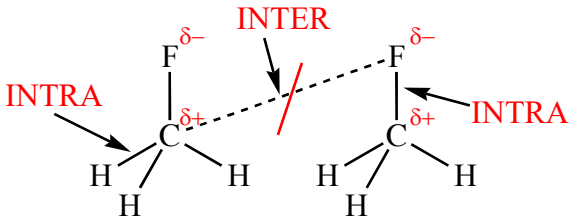
**Part A: Intermolecular forces vs. Intramolecular forces**

1) Intermolecular forces are the forces of attraction that occur between molecules.

2) Intramolecular forces *(or covalent bonds)* are forces that occur within molecules.

3) **(Intermolecular, ~~Intramolecular~~)** forces must be broken when a substance changes from a liquid to a gas.
HINT: molecules must break ~~apart~~ away from each other when they change from a liquid to a gas.

4) Look at this diagram at right. Draw in all *significant* partial charges (δ+ or δ–). Do not use dipole arrows. There are three arrows pointing to where there are forces of attraction. Label each arrow as either an INTERmolecular force or an INTRAmolecular force.

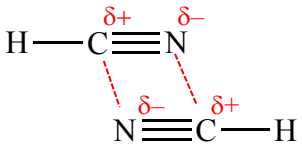



5) In the diagram above, draw a slash through the bond(s) that must be broken to change this substance from a liquid to a gas.

**Part B: Dipole-Dipole attractions** (This is one type of intermolecular force.)

6) Dipole-dipole forces occur between polar molecules. Describe why polar molecules are attracted to each other.
Dipoles contain a partially positive end and a partially negative end. The partial positive ends of a dipole on the molecules attract the partial negative ends of the dipoles on other molecules through electrostatic attraction.

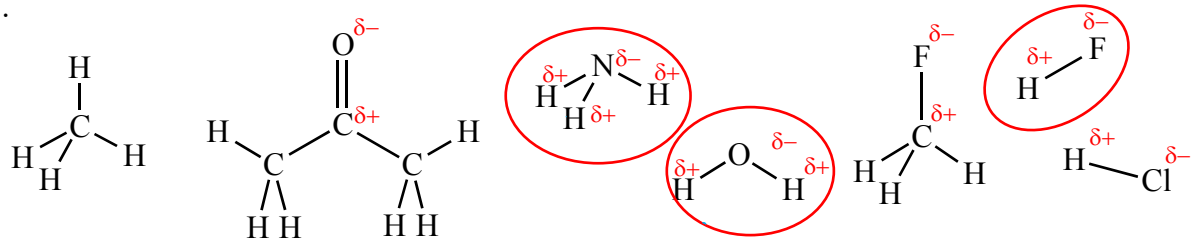
7) The two molecules drawn below are attracted to each other by dipole-dipole attractions. Put in all partial charges (again, no arrows) and draw a dotted line to show where this dipole-dipole attraction is. (See example diagram in notes.)



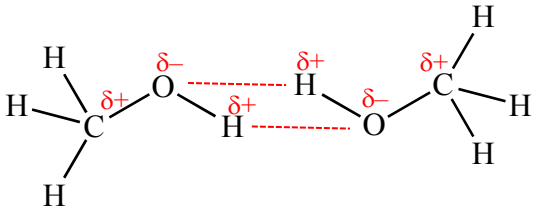

**Part C: Hydrogen Bonding** *(Another type of intermolecular force)*

Hydrogen bonding is a particularly strong dipole-dipole force. Hydrogen bonding can only occur between polar molecules which have a hydrogen covalently bonded to a highly electronegative atom. Only the three most electronegative atoms (F, O and N ) will be considered electronegative enough for hydrogen bonding.

8) Look at the molecules drawn below. Put in all significant partial charges. **Circle the molecules that can hydrogen bond.** HINT: The molecules must have a hydrogen atom covalently bonded to either a F, O, or N.



9) In the diagram at right, I have drawn two of the same molecules which are attracted to each other by hydrogen bonding. **Put in all significant partial charges and draw a dotted line or lines to show the attraction(s) between molecules**. *(The dotted lines should be the hydrogen bond.)*



10) What are the two main factors that make hydrogen bonds stronger than your typical dipole-dipole attraction?

The difference in electronegativity between H and N, O, or F is very large, giving an especially strong dipole, and the H, N, O & F atoms are very small, allowing the molecules to get very close together.

**<u>Part D:</u> Dispersion forces** (The last type of intermolecular force.)

*It makes sense that polar molecules are attracted to each other because they have partial charges. As we know, non-polar molecules and noble gas atoms do **not** have partial charges, yet they must be able to be attracted to each other because we know that they do form liquids and solids when cooled enough.*

11) How is it possible for a temporary (or instantaneous) dipole to form in a noble gas atom or a nonpolar molecule?

The electrons can become non-uniformly distributed as they move around the nucleus (nuclei).

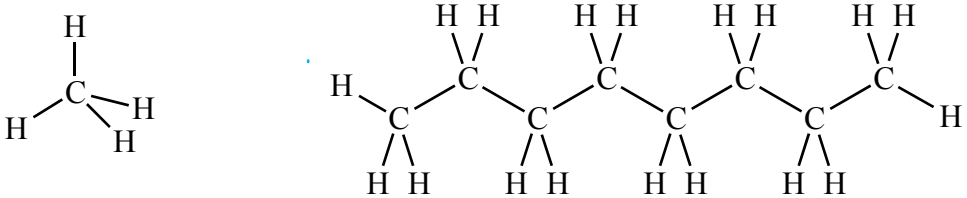
12) In your own words, explain how an *instantaneous dipole* can *induce* a similar dipole in a neighboring atom. Why does this happen?

The instantaneous dipole can attract or repel the electron cloud on a neighboring atom, causing its electron distribution to also become non-uniform. It happens because the electrons in the second atom/molecule are attracted or repelled by the partial positive or negative end of the dipole on the first atom/molecule, causing the second atom/molecule to itself form a dipole.

13) Why are dispersion attractions weaker than dipole-dipole attractions and hydrogen bonding?

Because they are short-lived and small.

14) **Thinking Critically** In a methane molecule ($CH_4$), there are 4 single covalent bonds. In an octane molecule ($C_8H_{18}$), there are 25 single covalent bonds. How does the number of bonds affect the dispersion forces in samples of methane and octane?



With more bonds, octane has more electrons to form temporary dipoles, so it is more polarizable, which means that it has greater dispersion forces than methane.