Name ________________ **Honors Chemistry** **___/___/___**

Covalent Compounds & Intermolecular Forces

A **covalent compound** is a compound in which the outer energy level (valence) electrons are shared by two or more atoms. Covalent bonds form between non-metals. Covalent bonds can consists of one pair of shared electrons (a single bond), two pairs of shared electrons (a double bond) or three pairs of shared electrons (a triple bond). In bond length, longest to shortest: single > double > triple. In bond strength, strongest to weakest: triple > double > single. Intermediate bonds observed in resonance structures fill in accordingly in terms of length and strength.

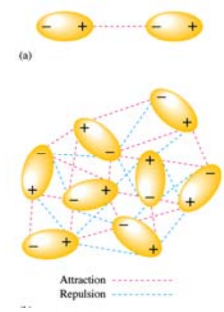
Comparing Ionic and Covalent Compounds

Ionic Compounds	Covalent Compounds
Composed of a metal and a non-metal	Composed of two non-metals
Atoms gain or lose electrons to form a compound	Atoms share electrons in a compound
Atoms are arranged into a rigid crystal structure	Atoms form distinct molecules
Have high melting and boiling points	Have low melting and boiling points
Conduct electricity when dissolved in water	Do not conduct electricity when dissolved in water
Chemical formulas are called formula units	Chemical formulas are called molecular formulas
Highly soluble in water	High to low solubility in water
Solid at room temperature	Can be solid, liquid or gas at room temperature

Intermolecular Forces

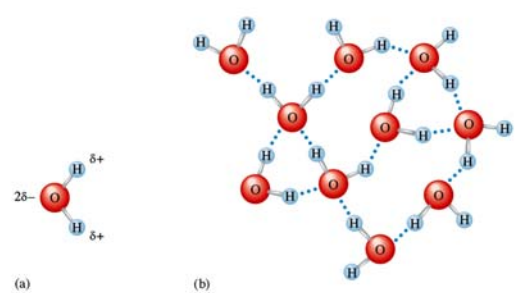
- The solid and liquid states of matter are referred to as the **condensed states of matter**.
- **Intramolecular** forces exist **between atoms** (**covalent bonds**).
- **Intermolecular** forces exist **between molecules** (dipole-dipole forces, hydrogen bonds and London forces)
- When a substance **changes state** the molecules remain intact. The changes in state are due to changes in the **intermolecular forces** between the molecules rather than in those within the molecules (intramolecular forces).

Dipole-Dipole Forces



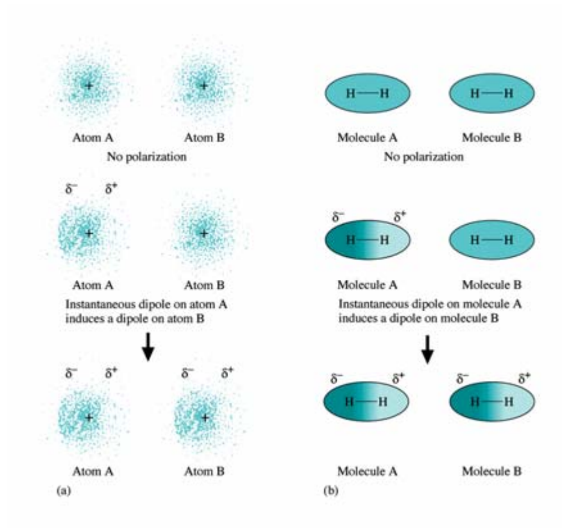
- **Molecules with polar bonds** often behave in an electric field as if they had a center of positive charge and a center of negative charge. They exhibit a **dipole moment**.
- **Molecules with dipole moments** can attract each other electrostatically by lining up so that the positive and negative ends are close to each other. This is called a **dipole-dipole attraction**.
- **Dipole-dipole** forces are typically only about **1% as strong as covalent or ionic bonds** and they rapidly become weaker as the distance between the dipoles increases.

Hydrogen Bonding



- Particularly strong **dipole-dipole interactions** are seen in molecules in which **hydrogen is bound to a highly electronegative atom, such as nitrogen, oxygen or fluorine**.
- **Two factors** account for the strength of these interactions: the great **polarity of the bond** and **the close approach of the dipoles**, allowed by the very small size of the hydrogen atom. Because dipole-dipole attractions of this type are so unusually strong, they are called **hydrogen bonding**. Below, note the hydrogen bonding that occurs between water molecules.
- Hydrogen bonding is responsible for many of water's interesting properties such as: why it appears to crawl up the sides of a glass, why ice is less dense than water, why water and ammonia have relatively high boiling points despite their low molecular masses, how capillary action works, etc.

London Dispersion Forces



- London dispersion forces are thought to be caused by the movement of electrons. **As the number of electrons increases, the London dispersion force increases**. London dispersion forces explain why fluorine and chlorine are gases, bromine is a liquid and iodine is a solid. London dispersion forces are the weakest of all intermolecular attractions and occur between 2 or more non-polar molecules.
- Even molecules without dipole moments must exert forces on each other. We know this because even the noble gases exist in solid and liquid states under certain conditions.
- The forces that exist between noble gas atoms and non-polar molecules are called **London dispersion forces**.
- As the electrons move about the nucleus, a momentary nonsymmetrical electron distribution can develop that produces a temporary dipolar arrangement of charge. The formation of this temporary dipole can, in turn, affect the electron distribution of a neighboring atom. The instantaneous dipole that occurs accidentally in a given atom can then induce a similar dipole in a neighboring atom as seen in the diagram to the right.
- For these reactions to produce a solid, the motions of the atoms must be greatly slowed down. This explains why noble gases have such low freezing points.
- Freezing point increases going down a group. The principle cause for this trend is that as the atomic number increases, the number of electrons increases, and there is an increased chance of the occurrence of momentary dipole interactions. This phenomenon is described using the term **polarizability** which indicates the ease at which the electron "cloud" of an atom can be distorted to give a dipolar distribution.
- The importance of London dispersion forces increases greatly as the number of electrons in an atom increases.

Homework:

1. Identify each of the following as being a property of **ionic compounds** or **covalent compounds**.

 a. ______________________________ Have high melting and boiling points

 b. ______________________________ High to low solubility in water

 c. ______________________________ Chemical formulas are called molecular formulas

 d. ______________________________ Atoms are arranged into a rigid crystal structure

 e. ______________________________ Have low melting and boiling points

 f. ______________________________ Conduct electricity when dissolved in water

 g. ______________________________ Atoms share electrons in a compound

 h. ______________________________ Atoms form distinct molecules

 i. ______________________________ Solid at room temperature

 j. ______________________________ Composed of two non-metals

 k. ______________________________ Highly soluble in water

 l. ______________________________ Composed of a metal and a non-metal

 m. ______________________________ Atoms gain or lose electrons to form a compound

 n. ______________________________ Do not conduct electricity when dissolved in water

 o. ______________________________ Can be solid, liquid or gas at room temperature

 p. ______________________________ Chemical formulas are called formula units

2. Identify if each of the following bonds exists **between atoms (intramolecular)** or **between molecules (intermolecular)**.

a. ________________________ ionic bond

b. ________________________ hydrogen bonds

c. ________________________ London dispersion force

d. ________________________ non-polar covalent bond

e. ________________________ polar covalent bond

f. ________________________ dipole interactions

3. Put the following bonds in order from **strongest to weakest** bond strength and **longest to shortest** bond length: single bond, double bond, triple bond.

Strength	Length
a. ______________________________	a. ______________________________
b. ______________________________	b. ______________________________
c. ______________________________	c. ______________________________

4. Put the following **intramolecular** bonds in order of strength from strongest to weakest: ionic bond, non-polar covalent bond, and polar covalent bond.

Bond Strength

a. ______________________________

b. ______________________________

c. ______________________________

5 Put the following **intermolecular** forces in order of strength from strongest to weakest: London dispersion forces, dipole interactions, hydrogen bonds.

Bond Strength

a. ______________________________

b. ______________________________

c. ______________________________

6. Identify if the following properties are being properties of London dispersion forces, dipole interactions or hydrogen bonds.

a. ______________________________ Attractive forces that occur when a hydrogen atom is covalently bonded to a highly electronegative atom.

b. ______________________________ Interactions occur when polar molecules are attracted to one another.

c. ______________________________ This intermolecular force explains why F_2 is a gas and I_2 is a solid at room temperature.

d. ______________________________ This is the weakest of all intermolecular forces.

e. ______________________________ Forces that are caused by the movement of electrons.

f. ______________________________ This is the strongest of all intermolecular forces.

g. ______________________________ This intermolecular force is similar to the attraction in ionic compounds.

7. Choose the best answer for each of the following.

a. __________ Which of the following compounds cannot have a resonance structure?
a. sulfur trioxide   b. sulfur dioxide   c. arsenic trifluoride   d. carbonate ion

b. __________ Which of the following types of attractions is the strongest?
a. London dispersion forces   b. dipole interactions   c. hydrogen bonds   d. covalent bonds

c. __________ Which of the following bonds is the shortest?
a. single bond   b. double bond   c. triple bond   d. all bonds are the same length

d. __________ Which of the following intermolecular forces explains why fluorine is a gas, but iodine is a solid?
a. dipole interactions   b. London dispersion forces   c. hydrogen bonds   d. none of the above

e. __________ The SF_5^- ion has a square pyramidal structure. The hybridization of the s orbitals in sulfur is:
a. dsp^3 b. sp   c. d^2sp^3 d. sp^3 e. sp^2

f. __________ Which of the following elements does not follow the octet rule?
a. carbon   b. nitrogen   c. iodine   d. hydrogen   e. fluorine

g. __________ Which of the following is a non-polar covalent bond?
a. $C \equiv N$ b. N- H   c. C – O   d. H – Se   e. F - Cl

h. __________ Which of the following is NOT an intermolecular force?
a. dipole interaction   b. London dispersion forces   c. hydrogen bond   d. covalent bond

i. __________ Which of the following can have a triple bond?
a. diatomic oxygen   b. dihydrogen monoxide   c. carbon dioxide   d. ammonia

j. __________ Which of the following molecules has polar bonds but is a non-polar molecule?
a. carbon tetrahydride   b. ammonia   c. carbon tetrachloride   d. dihydrogen monoxide

k. __________ CCl_4, CO_2, PCl_3, PCl_5, SF_6 Which of the following does not describe any of the molecules above?
a. Linear   b. Octahedral   c. Square planar   d. Tetrahedral   e. Trigonal pyramidal

l. __________ Molecules that have planar configurations include which of the following?
I. BCl_3 II. $CHCl_3$ III. NCl_3
a. I only   b. III only   c. I and II only   d. II and III only   e. I, II, and III

m. __________ The electron-dot structure (Lewis structure) for which of the following molecules would have two unshared pairs of electrons on the central atom?
a. H_2S b. NH_3 c. CH_4 d. HCN   e. CO_2

n. __________ The $SbCl_5$ molecule has trigonal bipyramid structure. Therefore, the hybridization of Sb orbitals should be:
a. sp^2 b. sp^3 c. dsp^2 d. dsp^3 e. d^2sp^3

o. __________ Which of the following compounds is ionic and contains both sigma and pi covalent bonds?
a. $Fe(OH)_3$ b. HClO   c. H_2S d. NO_2 e. NaCN

p. __________ Which of the following bonds is expected to be most polar?
a. C-Si   b. C-N   c. O-C   d. S-C   e. H-C

q. __________ For which of the following may we draw both polar and nonpolar Lewis structures?
a. $CHCl_3$ b. NH_3 c. BF_3 d. SF_2Cl_4 e. PCl_5