IMF – Intermolecular Forces Worksheet

Indicate the **strongest** IMF holding together **thousands of molecules** of the following. Then indicate what type of bonding is holding the atoms together in **one molecule** of the following. NOTE – if the molecule is an ionic compound, then there is no IMF, the ions are all held together by ionic bonds.

		IMF			Bonding		
		London forces	Dipole-dipole forces	Hydrogen Bonding Forces	Ionic Bonds	Polar Covalent Bonds	Nonpolar Covalent Bonds
1.	NH_3						
2.	K_2S						
3.	HCl						
4.	F_2						
5.	PCl_3						
6.	NaCl						
7.	SO_2						
8.	CO_2						
9.	I_2						
10.	CH_4						
11.	CH_3Cl						
12.	HF						
13.	H_2O						
14.	NO						
15.	H_2						
16.	CaO						
17.	O_2						
18.	CH_3OH						
19.	CO						
20.	N_2						

Answer the following questions with dipole dipole forces, H bonding forces, London forces, ion dipole forces, ionic bond, polar covalent bond, or nonpolar covalent bond.

1. What holds molecules of water together?
2. What hold the O and H atoms together in a molecule of water?
3. What holds Na^+ and Cl^- ions together in salt?
4. What holds NaCl(aq) together in salt water?
5. What holds the two F atoms together in diatomic fluorine?
6. What holds molecules of fluorine together?
7. What holds KBr(aq) together?
8. What holds the C and H atoms together in methane, CH_4?
9. What hold methane molecules with each other?
10. What holds the C and O atoms together in carbon monoxide?
11. What holds five molecules of carbon monoxide together?

Now let us compare two liquids and their properties. Consider benzene, C_6H_6, and phenol, C_6H_5OH:

1. Which has the stronger IMF?
2. Which has the lower vapor pressure?
3. Which has the higher boiling point?
4. Which has the lower viscosity?
5. Which has the higher surface tension?
6. Which one can H bond?
7. Which one has only London dispersion forces?

IMF – Intermolecular Forces Key

Indicate the **strongest** IMF holding together **several molecules** of the following. Then indicate what type of bonding is holding the atoms together in **one molecule** of the following. NOTE – if the molecule is an ionic compound, then there is no IMF, the ions are all held together by ionic bonds.

		IMF			Bonding		
		London forces	Dipole-dipole forces	Hydrogen Bonding Forces	Ionic Bonds	Polar Covalent Bonds	Nonpolar Covalent Bonds
1.	NH_3			X		X	
2.	K_2S				X		
3.	HCl		X			X	
4.	F_2	X					X
5.	PCl_3		X			X	
6.	NaCl				X		
7.	SO_2		X			X	
8.	CO_2	X					X
9.	I_2	X					X
10.	CH_4	X					X
11.	CH_3Cl		X			X (C-Cl)	X (C-H)
12.	HF			X		X	
13.	H_2O			X		X	
14.	NO		X			X	
15.	H_2	X					X
16.	CaO				X		
17.	O_2	X					X
18.	CH_3OH			X		X (O-H)	X (C-H)
19.	CO		X			X	
20.	N_2	X					X

Answer the following questions with dipole dipole forces, H bonding forces, London forces, ion dipole forces, ionic bond, polar covalent bond, or nonpolar covalent bond.

1. What holds molecules of water together? **H bonding force**
2. What hold the O and H atoms together in a molecule of water? **Polar cov bonds**
3. What holds Na^+ and Cl^- ions together in salt? **Ionic bonds**
4. What holds NaCl(aq) together in salt water? **Ion dipole force**
5. What holds the two F atoms together in diatomic fluorine? **Nonpolar cov bond**
6. What holds molecules of fluorine together? **London force**
7. What holds KBr(aq) together? **Ion dipole force**
8. What holds the C and H atoms together in methane, CH_4? **Nonpolar cov bond**
9. What hold methane molecules with each other? **London force**
10. What holds the C and O atoms together in carbon monoxide? **Polar cov bond**
11. What holds five molecules of carbon monoxide together? **Dipole dipole force**

Now let us compare two liquids and their properties. Consider benzene, C_6H_6, and phenol, C_6H_5OH:

1. Which has the stronger IMF? **phenol**
2. Which has the lower vapor pressure? **phenol**
3. Which has the higher boiling point? **phenol**
4. Which has the lower viscosity? **benzene**
5. Which has the higher surface tension? **phenol**
6. Which one can H bond? **phenol**
7. Which one has only London dispersion forces? **benzene**

Types of Intermolecular Forces

W 317

What is the strongest intermolecular force present for each of the following molecules?

1) hydrogen (H_2)_____

2) carbon monoxide (CO) _____

3) silicon tetrafluoride (SiF_4)_____

4) nitrogen tribromide (NBr_3) _____

5) water (H_2O)_____

6) acetone (CH_2O) _____

7) methane (CH_4) _____

8) benzene (C_6H_6)_____

9) ammonia (NH_3) _____

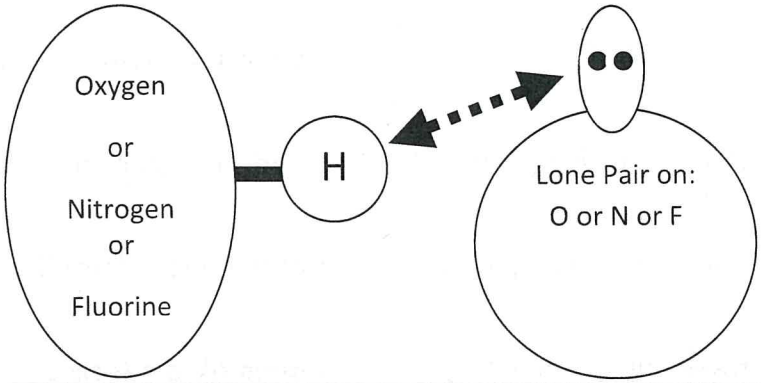
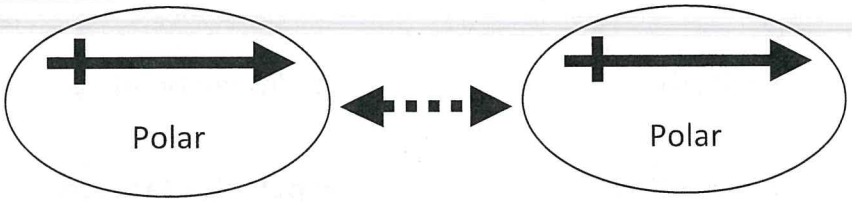
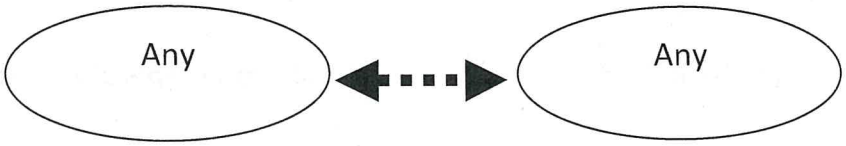
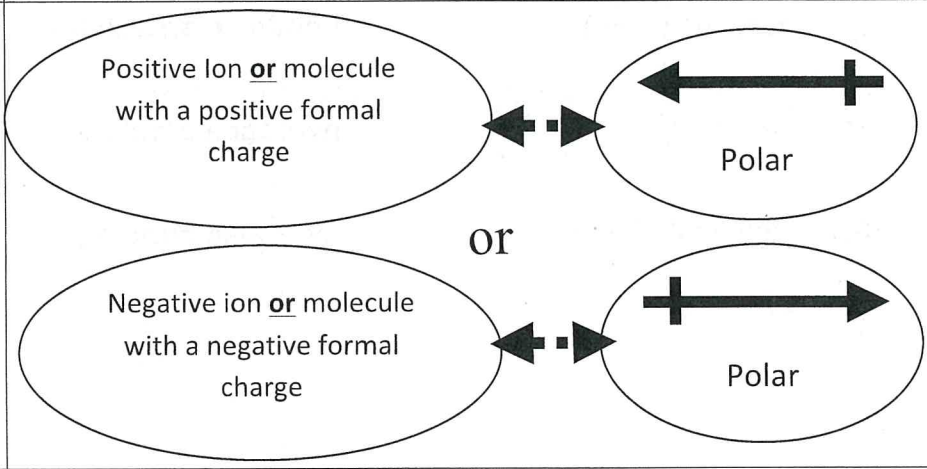
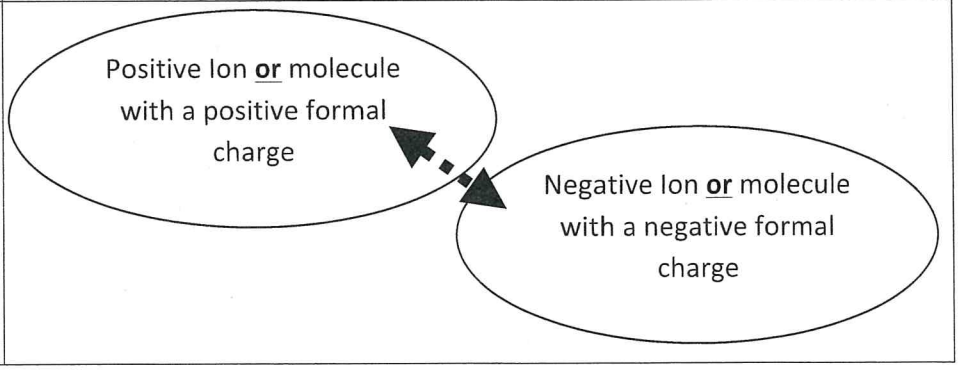
10) methanol (CH_3OH) _____

What is the strongest intermolecular force present for each of the following molecules?

1)	hydrogen (H_2)	**London dispersion forces**
2)	carbon monoxide (CO)	dipole-dipole forces
3)	silicon tetrafluoride (SiF_4)	**London dispersion forces**
4)	nitrogen tribromide (NBr_3)	**dipole-dipole forces**
5)	water (H_2O)	**hydrogen bonding**
6)	acetone (CH_2O)	**dipole-dipole forces**
7)	methane (CH_4)	**London dispersion forces**
8)	benzene (C_6H_6)	**London dispersion forces**
9)	ammonia (NH_3)	**hydrogen bonding**
10)	methanol (CH_3OH)	**hydrogen bonding**

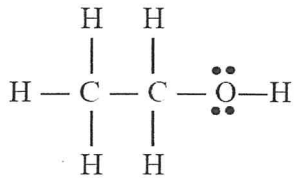
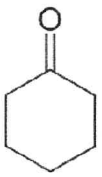
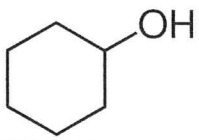
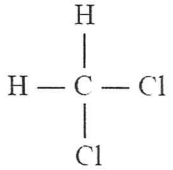
Intermolecular Forces Summary, Worksheet, and Key

Summary of Non-Covalent Interactions:

Attractive Force	Interaction Between:
Hydrogen Bonding (intermolecular)	
Dipole-Dipole (intermolecular)	
London Forces (intermolecular)	
Ion-Dipole	
Salt Bridge	

Problems:

1) Name the dominant (strongest) intermolecular force in the following pairs:

Compound	Dominant Force (Strongest Possible Force)
Methane and Methane (CH_4)	
Ethanol and Ethanol 	
Water and Water	
NH_3 and NH_3	
Cyclohexanone and Cyclohexanone 	
Cyclohexanol and Cyclohexanol 	
HCl and HCl	
CO_2 and CO_2	
CCl_4 and CCl_4	
CH_2Cl_2 and CH_2Cl_2 	

2) If the pairs of substances listed below were mixed together, list the non-covalent interaction(s) that are involved.

Choices:

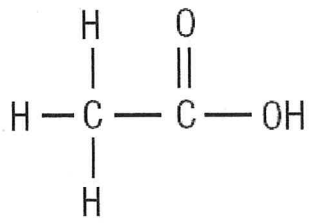
(A) Hydrogen Bonding

(B) Dipole-Dipole

(C) London Forces (induced dipole)

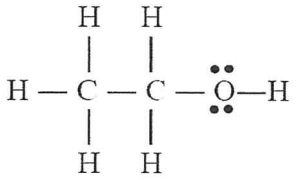
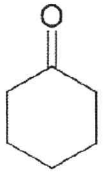
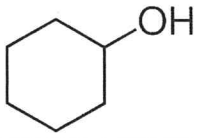
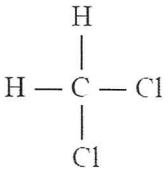
(D) Ion-Dipole

(E) Salt Bridges (ionic forces)

Compound Pairs	List of Non-covalent Interactions
NH_3 and H_2O	
Mg^{2+} and H_2O	
Cl_2 and H_2	
Acetic acid and H_2O  Acetic Acid	
SO_2 and H_2O	
SO_2 and H_2S	
ethane (CH_3CH_3) and methane (CH_4)	

Key

1) Name the dominant (strongest) intermolecular force in the following pairs:

Compound	Dominant Force
Methane and Methane	London Forces
Ethanol and Ethanol 	Hydrogen Bonding
Water and Water	Hydrogen Bonding
NH_3 and NH_3	Hydrogen Bonding
Cyclohexanone and Cyclohexanone 	Dipole-Dipole
Cyclohexanol and Cyclohexanol 	Hydrogen Bonding
HCl and HCl	Dipole-Dipole
CO_2 and CO_2	London Forces
CCl_4 and CCl_4	London Forces
CH_2Cl_2 and CH_2Cl_2 	Dipole-Dipole

2) If the pairs of substances listed below were mixed together, list the intermolecular force(s) that are involved.

Choices:

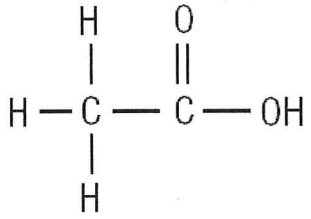
(A) Hydrogen Bonding

(B) Standard Dipole-Dipole

(C) London Forces (induced dipole)

(D) Ion-Dipole

(E) Salt Bridges (ionic forces)

Compound Pairs	List of Intermolecular Forces
NH_3 and H_2O	A, B, C
Mg^{2+} and H_2O	D
Cl_2 and H_2	C
Acetate ion and H_2O  Acetic Acid	A,B,C
SO_2 and H_2O	A,B,C
SO_2 and H_2S	B,C
ethane (CH_3CH_3) and methane (CH_4)	C

Name_____ **per**_____

Chemistry II Practice: "Intermolecular Forces"

1. Describe the three types of intermolecular forces. Include in your explanation how they work on the submicroscopic level.

2. Explain the difference between a chemical bond and an intermolecular force. Compare the relative amounts of energy involved in the forming and breaking of these forces.

3. What is the difference between a temporary and a permanent dipole? Give an example of each.

4. Explain, in terms of intermolecular forces, why water has an unusually high boiling point.

If the statement is true, write "true". If it is false, change the underlined word to make it true.

_____ **5.** Intermolecular forces determine, <u>metallic</u> properties such as the boiling point of a substance.

_____ **6.** Intermolecular forces are forces of attraction between <u>atoms</u>.

_____ **7.** Chemical bonds are the forces between <u>molecules</u>.

_____ **8.** Covalent bonds result from electrons being shared between atoms in a <u>molecule</u>.

_____ **9.** <u>Intermolecular</u> forces result from the electron interactions between neighboring molecules.

_____ **10.** When the electron cloud around a molecule is not distributed symmetrically, a molecule is <u>polar</u>.

_____ **11.** Chemical bonds include ionic bonds and <u>hydrogen bonds</u>.

_____ **12.** Intermolecular forces include dispersion forces, dipole interactions and <u>helium-bond</u> forces.

Complete each of the sentences with the appropriate word or words.

13. The stronger the intermolecular forces in a liquid, the _____ boiling point.

14. The state (solid, liquid or gas) of a substance at room temperature depends on _____.

15. Water molecules in an ice cube are held together by _____ forces or more specifically _____.

On the line at the left, write the letter of the term that matches each description below. Each choice may be used more than once. More than one choice may be used as an answer.

a. dispersion **b.** dipole-dipole **c.** hydrogen bonding

_____ **16.** the force between SO_2 molecules. **hint:** draw the 3D Lewis Diagram

_____ **17.** The force that accounts for HF being a liquid, while H_2 and F_2 are gases at room temperature.

_____ **18.** The force that results from temporary, induced dipoles.

_____ **19.** The only intermolecular force that exists in noble gases.

_____ **20.** The attractive force between dipole molecules.

_____ **21.** The force that arises because of the large difference in electronegativity between N and H in an ammonia (NH_3) molecule.

22. Which of the following statements could be used to explain why water has an unusually high boiling point? Check all of the statements that could be used to justify your explanation.

_____ **a.** Water molecules have very strong intermolecular forces.

_____ **b.** Oxygen is much more electronegative than hydrogen.

_____ **c.** A water molecule has a bent molecular geometry.

_____ **d.** Water does not contain metallic bonds.

_____ **e.** Oxygen atoms are smaller than hydrogen atoms.

23. Give a macroscopic observation besides water's high boiling point that suggests that the intermolecular forces in water are very strong compared to other liquids.

Name Key per

Chemistry II Practice: "Intermolecular Forces"

1. Describe the three types of intermolecular forces. Include in your explanation how they work on the submicroscopic level.

Dipole Interactions are the attraction between the + and - ends of dipoles.
Dispersion forces are attractions between molecules that become temporary dipoles
Hydrogen Bonds are attractions between hydrogen atoms and lone pairs on adjacent molecules.

2. Explain the difference between a chemical bond and an intermolecular force. Compare the relative amounts of energy involved in the forming and breaking of these forces.

A chemical bond is formed between atoms within a molecule and intermolecular forces are bonds between molecules. Chemical bonds are generally stronger than intermolecular forces and much greater amounts of energy are involved in their formation

3. What is the difference between a temporary and a permanent dipole? Give an example of each.

A temporary dipole occurs when electrons are denser on one end of a molecule. All molecules can become temporary dipoles.
A permanent dipole is a molecule which has a negatively and positively charged end resulting from polar bonds.

4. Explain, in terms of intermolecular forces, why water has an unusually high boiling point.

water molecules have very high intermolecular forces resulting from hydrogen bonding, which is the strongest intermolecular force.

If the statement is true, write "true". If it is false, change the underlined word to make it true.

Physical — **5.** Intermolecular forces determine, metallic properties such as the boiling point of a substance.

molecules — **6.** Intermolecular forces are forces of attraction between atoms.

True — **7.** Chemical bonds are the forces between molecules.

True — **8.** Covalent bonds result from electrons being shared between atoms in a molecule.

True — **9.** Intermolecular forces result from the electron interactions between neighboring molecules.

True — **10.** When the electron cloud around a molecule is not distributed symmetrically, a molecule is polar.

Covalent bonds — **11.** Chemical bonds include ionic bonds and hydrogen bonds.

hydrogen bond — **12.** Intermolecular forces include dispersion forces, dipole interactions and helium-bond forces.

Complete each of the sentences with the appropriate word or words.

13. The stronger the intermolecular forces in a liquid, the higher the boiling point.

14. The state (solid, liquid or gas) of a substance at room temperature depends on the strength of intermolecular forces.

15. Water molecules in an ice cube are held together by dipole-dipole forces or more specifically hydrogen bonding.

On the line at the left, write the letter of the term that matches each description below. Each choice may be used more than once.

a. dispersion **b.** dipole-dipole **c.** hydrogen bonding

a, **16.** the force between SO_2 molecules. **hint:** draw the 3D Lewis Diagram

C, **17.** The force that accounts for HF being a liquid, while H_2 and F_2 are gases at room temperature.

a. **18.** The force that results from temporary, induced dipoles.

a. **19.** The only intermolecular force that exists in noble gases.

b. **20.** The attractive force between dipole molecules.

C. **21.** The force that arises because of the large difference in electronegativity between N and H in an ammonia (NH_3) molecule.

22. Which of the following statements could be used to explain why water has an unusually high boiling point? Check all of the statements that could be used to justify your explanation.

X **a.** Water molecules have very strong intermolecular forces.

X **b.** Oxygen is much more electronegative than hydrogen.

X **c.** A water molecule has a bent molecular geometry.

d. Water does not contain metallic bonds.

e. Oxygen atoms are smaller than hydrogen atoms.

23. Give a macroscopic observation besides water's high boiling point that suggests that the intermolecular forces in water are very strong compared to other liquids.

When drops of water are carefully placed on a penny, the water stays on the penny rather than flowing off of it, showing that there must be some cohesion between the water particles.