**Types of IMF**

*Weakest*

London dispersion forces

All molecules have LDF, it is the force of attraction between molecules resulting from a temporary uneven distribution of electron density. Non polar molecules have only London dispersion forces operating in the substance. The larger the molecule the stronger the LDF will be.

Dipole-dipole forces

Polar molecules have dipole-dipole forces because there are two oppositely charged poles created in the molecule. The oppositely charged poles are attracted to one another.

*Strongest*

Hydrogen bonding forces

Polar molecules that have hydrogen attached to an O, N, or F can form hydrogen bonds. These are the strongest of the intermolecular forces.

Figure 1

Figure 1shows the temperature of 1.00 kilograms of ice (H2O) starting at −20 °C that is heated at a constant rate of 100 Joules per second (100 J/s). After about 8.6 hours, the ice has become water vapor (still H2O!) at 120 °C. There are five distinct regions in the curve, each of which has an arrow nearby.

1. Above each arrow *write what is happening* to the H2O in that region and how it relates to IMF. (See the example for the first region.)

2. Heating a sample of water at 90 °C will cause an immediate temperature change of the water. However, heating a sample of water at 100 °C will not cause an immediate temperature change. Explain both of these observations.

3. Compare the types of intermolecular forces between water molecules in water as a solid, a liquid, and a gas. What causes the phase changes?

4. Claiming that the boiling point of water is 100 °C is not necessarily incorrect, but it is incomplete. Explain why.

5. Using your knowledge of molecular structure, identify the all of the intermolecular forces present in the following compounds. You may find it useful to draw Lewis structures to find your answer.

a) PF3 \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

b) H2CO \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

c) HF \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

d) Cl2 \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

e) CO \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

f) CH3-O-CH3 \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

g) CH2Cl2 \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

6. Explain/draw a picture how dipole-dipole forces cause molecules to be attracted to one another in water.

7. Rank the following compounds from lowest to highest boiling point: calcium carbonate, methane (CH4), methanol (CH4O), dimethyl ether (CH3OCH3).

8. What is meant by the term “vapor pressure”? What is the relationship between vapor pressure and strength of intermolecular forces? Explain.

9. For each pair of substance identify the substance that is likely to have the higher vapor pressure. Explain your reasoning.

a. CO2 or SO2

b. CH3OH or CH3-O-CH3

10. Explain why nonpolar molecules usually have much lower surface tension, vapor pressure and boiling points than polar molecules.

11. Paraffin wax C25H52 is a solid at room temperature. Draw the Lewis structure and describe why it is a solid and not a liquid or gas at room temperature.

**Phase Diagrams of Matter:** The following figure depicts the phase diagram for an unidentified substance. Phase diagrams are another way of representing the phases and phase changes that happen for a substance at various temperatures and pressures. There are many important points on the phase diagram. See how many of them you can identify correctly.



Answer each question where appropriate ***by using the letters that are adjacent to the points on the figure***.

12. Which **letter** (a-j) identifies the **gas phase**? Ans:

13. Which **letter** (a-j) identifies the **solid phase**? Ans:

14. Which **letter** (a-j) identifies the **liquid phase**? Ans:

15. Which **letter** (a-j) identifies the **triple point?** Ans:

(the point where all threephases exist together)

16. Which **letter** (a-j) identifies the **critical point**? Ans:

(the point where the substance will transition into a critical fluid)

At what **temperature** and **pressure** do all three phases coexist? T =   
 P =

17. What is the **normal melting point** (NMP) for this substance? Ans:

18. What is the **normal boiling point** (NBP) for this substance? Ans:

19. Is the **density** of the liquid at the NMP **greater** than or **less** than or **equal** to the density of the solid?

How do you know? Ans:

20. Would an increase in **pressure** at 50°C cause this substance to **melt** or to **freeze**?  
 Ans: