Lecture 24
Intermolecular Forces II
Worksheet Key

1) Explain why the standard enthalpy of vaporization, ΔH_{vap}, values for each set of compounds below are not the same. CH_4 - LDF
   a. CH_4 and H_2O H_2O - LDF, H-Bonding

CH_4 has only London dispersion forces. H_2O has London dispersion and H-bonds. Because the intermolecular forces of attraction in these two substances are different, their enthalpies of vaporization will also be different. LO 2.16, LO 5.6

   b. PH_3 and NH_3 PH_3 - LDF, Dipole-Dipole NH_3 - LDF, H-Bonding

PH_4 has London dispersion forces and dipole-dipole forces. NH_3 has London dispersion and H-bonds. Because the intermolecular forces of attraction in these two substances are different, their enthalpies of vaporization will also be different. LO 2.16, LO 5.6

   c. C_2H_6 and C_3H_8 C_2H_6 - LDF C_3H_8 - LDF

Both C_2H_6 and C_3H_8 only experience London dispersion forces. Because C_3H_8 is larger and has more electrons, it is more polarizable and thus has larger dispersion forces. Because the intermolecular forces of attraction in these two substances are different, their enthalpies of vaporization will also be different. LO 2.16, LO 5.6

   d. BH_3 and OF_2 BH_3 - LDF OF_2 - LDF, Dipole-Dipole

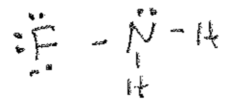
BH_3 has London dispersion forces. OF_2 has London dispersion and dipole-dipole forces. Because the intermolecular forces of attraction in these two substances are different, their enthalpies of vaporization will also be different. LO 2.16, LO 5.6

2) Classify each of the following processes as a physical change, a chemical change, or both. Justify your answer by identifying the types of intermolecular or intramolecular forces that are involved in each of the following processes and describing what happens to those forces while the processes are occurring.
   a. $CO_2(s) \rightarrow CO_2(g)$ - Physical Change - LDF

Physical change. London dispersion forces in solid carbon dioxide are overcome, generating individual CO_2 molecules. LO 5.10

   b. $CO_2(g) \rightarrow C(s) + O_2(g)$ - covalent bonds broken chemical change

Chemical change. Covalent bonds in the CO_2 molecule are broken. LO 5.10



c. $NH_2F(l) \rightarrow NH_2F(g)$ Physical Change → LDF, H-Bond in Liquid

Physical change. London dispersion forces and H-bonds in liquid NH_2F are overcome, generating individual gaseous NH_2F molecules. LO 5.10

d. $NaCl\ (s) \rightarrow Na^+(aq) + Cl^-(aq)$ physical change or Chemical Change ion-dipole IMF Breaking Ionic Bonds

Dissolving an ionic compound in water can be classified as a physical change and a chemical change. Ionic bonds are broken (chemical change) and ion-dipole intermolecular forces between water and the ions are formed (physical change). LO 5.10

e. $NH_2F(l) \rightarrow \frac{1}{2} N_2(g) + H_2(g) + \frac{1}{2} F_2(g)$ – chemical Change covalent bonds broken and New ones formed

Chemical change. Covalent bonds in the NH_2F molecule are broken and new covalent bonds are formed. LO 5.10

f. $H_2O(s) \rightarrow H_2O(l)$ – Physical Change → LDF, H-bonds

Physical change. London dispersion and H-bonds in solid water are stretched to produce liquid water. LO 5.10

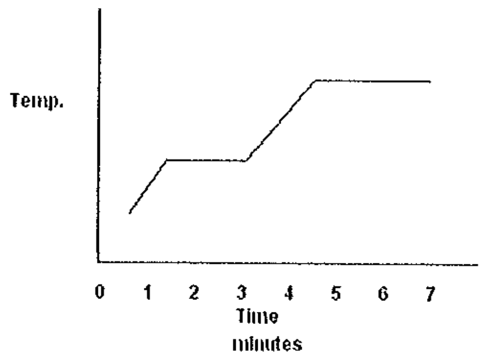
3) Explain why the temperature of a liquid remains constant while it is being boiled, although heat continues to be absorbed. Describe what happens to the heat that is absorbed. The heat absorbed by the liquid is used to break IMF of attraction allowing the formation of gas.

Temperature increases as the average kinetic energy of the molecules in a system increases. As the temperature does not increase during the boiling process, the average kinetic energy of the water molecules does not increase.
The heat that is absorbed by the liquid is used to break intermolecular forces of attraction, allowing units to separate from one another to become independent gaseous molecules.

4) Explain why the boiling point of water decreases as elevation increases.

A liquid boils when its vapor pressure equals the atmospheric pressure. Vapor pressure depends on the temperature of the specific liquid. When the temperature of the liquid decreases, the vapor pressure also decreases. Atmospheric pressure decreases as elevation increases. Thus, at higher elevations, liquid will boil at lower temperatures.

5) The following graph shows the plot of temperature versus time as heat is added to a pure substance.



a. During what period of time was the substance at its normal freezing point?

~1.3 to 3.1 minutes

b. Over what period of time was the substance boiling?

~5 to 7 minutes

c. What is happening to the substance between the 1 and 1.5 minute marks?

The substance remains in a solid phase; however, the average kinetic energy of the particles increases steadily as heat is added to the system.

d. What is happening to the substance between the 2 and 3 minute marks?

The intermolecular forces of attraction are weakening. The substance is changing from the solid state to the liquid state. The average kinetic energy of the particles remains the same. LO 5.6, LO 2.16

e. What is happening to the substance between the 3.5 and 4.5 minute marks?

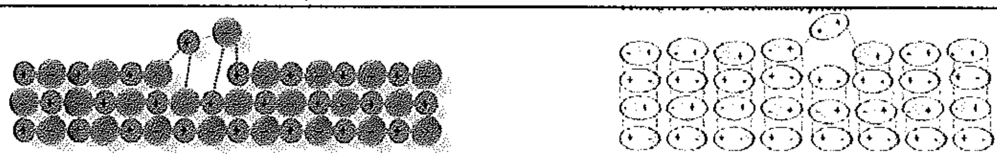
The substance remains in the liquid state. The average kinetic energy of the particles increase steadily.

f. What is happening to the substance between the 5 and 7 minute marks?

The intermolecular forces of attraction between particles are breaking. The substance is changing from the liquid state to the gaseous state. The average kinetic energy of the particles remains the same. LO 5.6, LO 2.16

6) At -92°C, a pure sample of HBr has a higher vapor pressure than a pure sample of KBr.

   a. Create visual representations that show the interactions between the particles in both samples during vaporization.

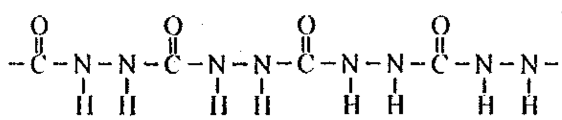


KBr — Ionic Bonds - Very Strong | HBr — Dipole-Dipole | LO 2.23, LO 2.19

   b. Explain why the vapor pressure of HBr is higher than the vapor pressure of KBr at -92°C.

KBr is held together by ionic bonds, which are very strong; and HBr is held together by dipole-dipole interactions, which are much weaker. Because the forces or attraction between particles in HBr are weaker, molecules or HBr can enter the gas phase more easily. LO 2.24, LO 2.19, LO 2.16

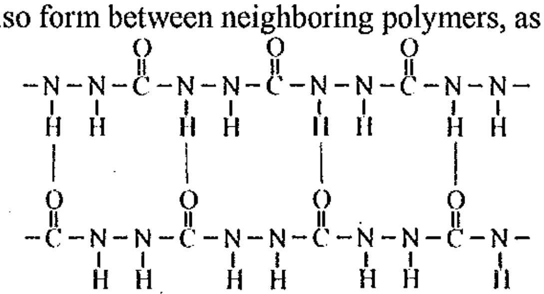
7) Nylon is made up of long synthetic polymers that interact with one another. The Lewis structure for a section of a nylon polymer is shown below. Explain why nylon is such a strong material in terms of the interactions between adjacent polymers. Use a diagram to help with your explanation.



- LDF
- Highly Polarizable
- Polymers linear - Stack up well
- Form H-Bonds

Nylon molecules are long chains that form strong London dispersion forces of attraction for one. They are large chainlike structures with many atoms and electrons. This makes them highly polarisable. Because the overall shape of the individual molecules is somewhat linear, the polymers stack up well and have many contact points, which increases the strength of London dispersion forces.

Hydrogen bonds can also form between neighboring polymers, as shown below.

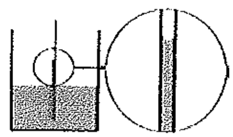


LO 5.11

10) Is the surface tension of water greater than, equal to, or less than that of methane, CH_4, at 15.0°C? Justify your answer. water : H-Bonds, LDF
Methane: LDF

The surface tension of water is greater than that of methane when both liquids are at the same temperature. Water has stronger intermolecular attractions as it can form H-bonds and weak London dispersion forces, whereas methane can only form weak London dispersion forces. Surface tension increases as the strength of intermolecular forces increases. LO 2.3, LO 2.16

11) If a glass tube with a small diameter is placed in water, water rises up the tube. Explain why this happens. Use a diagram to assist with your explanation.



The adhesive forces between water molecules and the glass are stronger than the cohesive forces between the water molecules. The adhesive forces pull the water up the walls of the glass tube, and this works to increase the surface area of the liquid. Surface tension, which is caused by cohesive forces, works to reduce the surface area by pulling the liquid up the tube. LO 2.3, LO 2.16