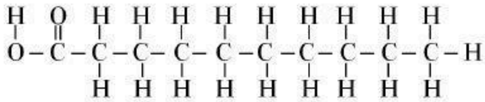
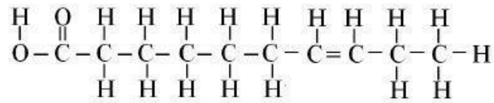
Intermolecular Forces and Properties
3.2 Properties of Solids
Worksheet Key

1) Which of the following structures is most likely to be a solid at room temperature? Justify your answer in terms of intermolecular interactions.

a.

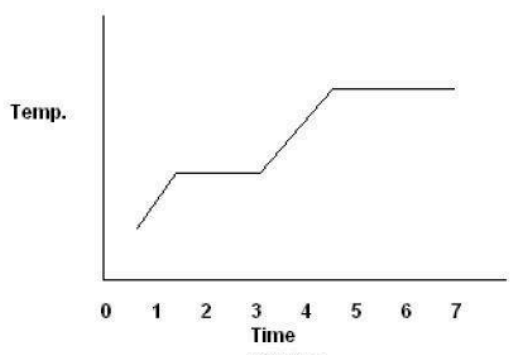


b.



Both structures are approximately the same size and have about the same number of electrons. (Structure b. has two fewer electrons than structure a., but structure b. has a pi-bond with increases polarizability.) Both structures can form H-bonds at the end with the –OH group. The London dispersion forces will, however, be stronger in structure a. due to its shape. Thus, structure a. is more likely to be a solid at room temperature.
Structure a. is saturated. This means that the carbon chain has a linear structure overall. Because of this linear structure the molecules stack up well, so there are many points of contact between neighboring molecules; which means that it has more locations where London dispersion forces can be established.
Structure b. is unsaturated, as it has a double bond between two carbons in the carbon chain. This causes the overall structure to bend at that point. Because of this kink, the molecules do not stack up very well, so there are fewer points of contact between neighboring molecules; which means that it has fewer locations where London dispersion forces can be established.

2) 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.

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.

3) Explain why the standard enthalpy of vaporization, ΔH_{vap}, values for each set of compounds below are not the same.

a. CH_4 and H_2O

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.

b. PH_3 and NH_3

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.

c. C_2H_6 and C_3H_8

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.

d. BH_3 and OF_2

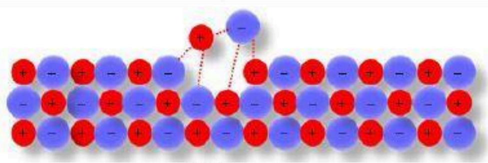
BH_3 has London dispersion forces. OF_2 has London dispersion and dipole-dipole forces. Because the intermolecular forces of attraction in these two substances are different, their enthalpies of vaporization will also be different.

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

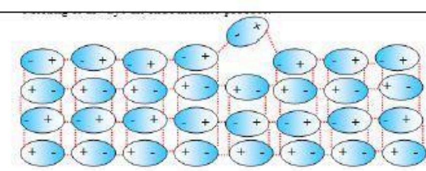
A liquid boils when its vapor pressure equals the atmospheric pressure. Vapor pressure depends on the temperature of the specific liquid. When the temperature of the liquid decreases, the vapor pressure also decreases. Atmospheric pressure decreases as elevation increases. Thus, at higher elevations,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

5) 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



HBr

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.

6) What are the main factors that account for the extreme hardness of diamond?

Diamond is a network solid, meaning that each diamond is one massive molecule held together with covalent bonds. All carbons are bound together with sp^3 hybrid orbitals. This means that there is a tetrahedral geometry around each carbon atom, which is a very strong configuration.

7) Which substance in each set has the highest melting point? Justify your answer using chemical principles.

a. KCl or SiO_2

KCl has ionic bonds. SiO_2 is a network solid held together with covalent bonds. Network solids are stronger than ionic bonds, thus, SiO_2 will have a higher melting temperature.

b. NH_3 or $C_{diamond}$

NH_3 has H-bonds and London dispersion forces. Diamond is a network solid held together with covalent bonds. Covalent bonds are stronger than intermolecular forces; thus, $C_{diamond}$ will have a higher melting temperature.