AP Chemistry Unit 6 Problem Sets: IMFs, Liquids, and Solids

Problem Set 1: Intermolecular Forces

1

The following equations describe water boiling vs. water decomposing:

$H_2O\ (l) \Rightarrow H_2O\ (g)$

$2H_2O\ (l) \Rightarrow 2H_2\ (g) + O_2\ (g)$

a)What types of bonds must be broken in each case?

b)Given that water boils at 100°C but decomposes at 3000°C, what does this say about the relative strength of the bonds involved in each case? Explain.

2

Explain why water evaporates at room temperature, even though its boiling point is 100°C.

3

4. Is it possible for the dispersion forces in a particular substance to be stronger than the hydrogen bonding forces in another substance? Explain your answer.

4

35. Identify the most important types of interparticle forces present in the solids of each of the following substances.

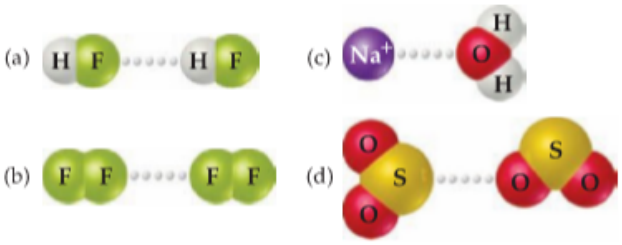
a. Ar
b. HCl
c. HF
d. $CaCl_2$
e. CH_4
f. CO
g. $NaNO_3$

5

11.15 Describe the intermolecular forces that must be overcome to convert each of the following from a liquid or solid to a gas: (a) I_2, (b) CH_3CH_2OH, (c) H_2Se.

6

11.2 **(a)** What kind of intermolecular attractive force is shown in each of the following cases? **(b)** Predict which two interactions are stronger than the other two. [Section 11.2]



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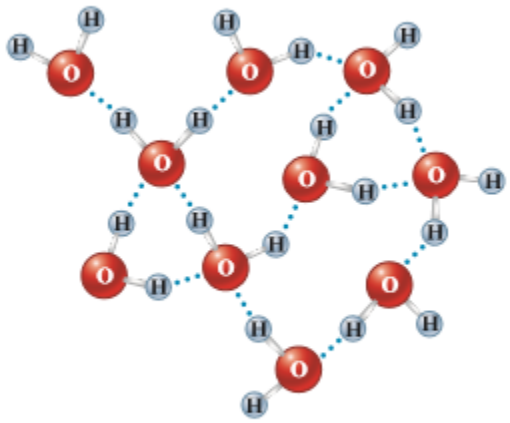
13. In the diagram below, which lines represent the hydrogen bonding?



a. the dotted lines between the hydrogen atoms of one water molecule and the oxygen atoms of a different water molecule

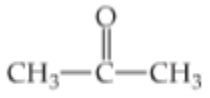
b. the solid lines between a hydrogen atom and oxygen atom in the same water molecule

c. Both the solid lines and dotted lines represent hydrogen bonding.

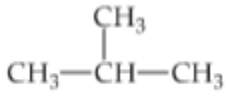
d. There are no hydrogen bonds represented in the diagram.

8

11.16 What type of intermolecular force accounts for the following differences in each case? **(a)** CH_3OH boils at 65 °C, CH_3SH boils at 6 °C. **(b)** Xe is liquid at atmospheric pressure and 120 K, whereas Ar is a gas. **(c)** Kr, atomic weight 84, boils at 120.9 K, whereas Cl_2, molecular weight about 71, boils at 238 K. **(d)** Acetone boils at 56 °C, whereas 2-methylpropane boils at −12 °C.



Acetone



2-Methylpropane

9

11.17 **(a)** What is meant by the term *polarizability*? **(b)** Which of the following atoms would you expect to be most polarizable: N, P, As, Sb? Explain. **(c)** Put the following molecules in order of increasing polarizability: $GeCl_4$, CH_4, $SiCl_4$, SiH_4, and $GeBr_4$. **(d)** Predict the order of boiling points of the substances in part (c).

10

11.18 True or false:

(a) The more polarizable the molecules, the stronger the dispersion forces between them.

(b) The boiling points of the noble gases decrease as you go down the column in the periodic table.

(c) In general, the smaller the molecule, the stronger the dispersion forces.

(d) All other factors being the same, dispersion forces between molecules increase with the number of electrons in the molecules.

11

37. Predict which substance in each of the following pairs would have the greater intermolecular forces.

a. CO_2 or OCS

b. SeO_2 or SO_2

c. $CH_3CH_2CH_2NH_2$ or $H_2NCH_2CH_2NH_2$

d. CH_3CH_3 or H_2CO

e. CH_3OH or H_2CO

12

11.23 **(a)** What atoms must a molecule contain to participate in hydrogen bonding with other molecules of the same kind? **(b)** Which of the following molecules can form hydrogen bonds with other molecules of the same kind: CH_3F, CH_3NH_2, CH_3OH, CH_3Br?

13

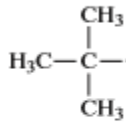
11.24 Rationalize the difference in boiling points between the members of the following pairs of substances: **(a)** HF (20 °C) and HCl (−85 °C), **(b)** $CHCl_3$ (61 °C) and $CHBr_3$ (150 °C), **(c)** Br_2 (59 °C) and ICl (97 °C).

14

39. Rationalize the difference in boiling points for each of the following pairs of substances:

a. *n*-pentane $CH_3CH_2CH_2CH_2CH_3$ 36.2°C

neopentane



9.5°C

b. HF 20°C
HCl −85°C

c. HCl −85°C
LiCl 1360°C

d. *n*-pentane $CH_3CH_2CH_2CH_2CH_3$ 36.2°C
n-hexane $CH_3CH_2CH_2CH_2CH_2CH_3$ 69°C

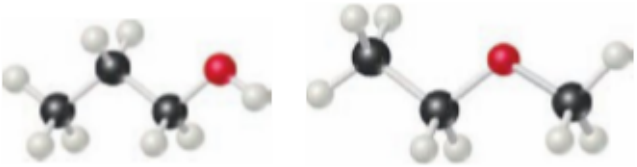
15

11.21 Butane and 2-methylpropane, whose space-filling models are shown, are both nonpolar and have the same molecular formula, yet butane has the higher boiling point (−0.5 °C compared to −11.7 °C). Explain.

(a) Butane (b) 2-Methylpropane

16

11.5 The following molecules have the same molecular formula (C_3H_8O), yet they have different normal boiling points, as shown. Rationalize the difference in boiling points.



(a) Propanol
97.2 °C

(b) Ethyl methyl ether
10.8 °C

Problem Set 2: Liquids and their Properties

1

17. Use the kinetic molecular theory to explain why a liquid gets cooler as it evaporates from an insulated container.

2

21. How does each of the following affect the rate of evaporation of a liquid in an open dish?

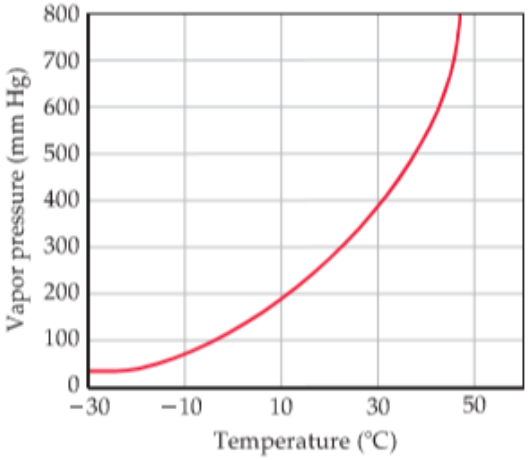
a. intermolecular forces

b. temperature

c. surface area

3

11.4 Using the following graph of CS_2 data, determine **(a)** the approximate vapor pressure of CS_2 at 30 °C, **(b)** the temperature at which the vapor pressure equals 300 torr, **(c)** the normal boiling point of CS_2.



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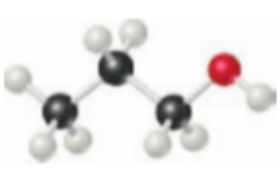
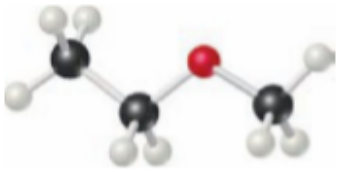
11.5 The following molecules have the same molecular formula (C_3H_8O), yet they have different normal boiling points, as shown. Rationalize the difference in boiling points. [Sections 11.2 and 11.5]



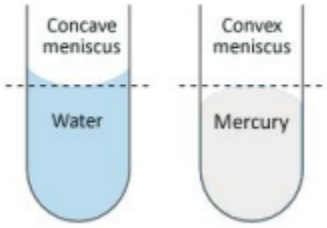
(a) Propanol
97.2 °C



(b) Ethyl methyl ether
10.8 °C

5

The shape of the meniscus of water in a glass tube is different from that in mercury in a glass tube. Why?



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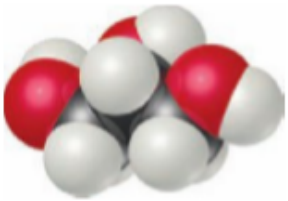
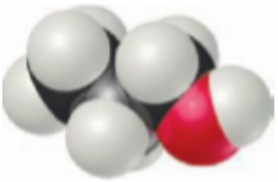
11.3 The molecular models of glycerol and 1-propanol are given here.



(a) Glycerol



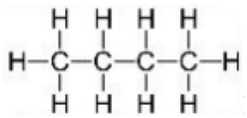
(b) 1-propanol

Do you expect the viscosity of glycerol to be larger or smaller than that of 1-propanol? Explain.

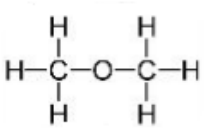
7

List all intermolecular forces present in each liquid, and use them to predict the following:

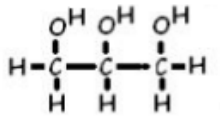
a.



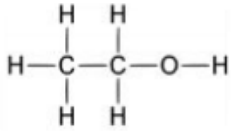
b.



c.



d.



Which substance should have the highest…

i) viscosity ii) boiling point iii)vapor pressure

8

42. In each of the following groups of substances, pick the one that has the given property. Justify each answer.

a. highest boiling point: CCl_4, CF_4, CBr_4

b. lowest freezing point: LiF, F_2, HCl

c. smallest vapor pressure at 25°C: CH_3OCH_3, CH_3CH_2OH, $CH_3CH_2CH_3$

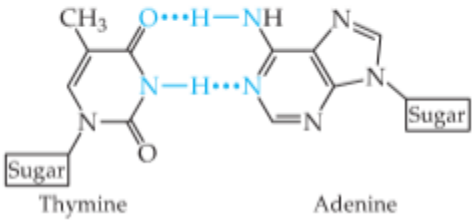
d. greatest viscosity: H_2S, HF, H_2O_2

e. greatest heat of vaporization: H_2CO, CH_3CH_3, CH_4

f. smallest enthalpy of fusion: I_2, CsBr, CaO

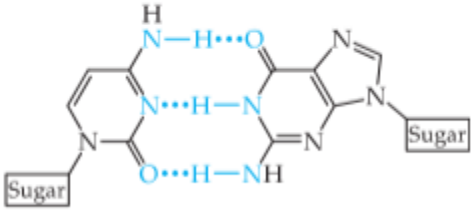
9

11.84 The DNA double helix (Figure 25.40) at the atomic level looks like a twisted ladder, where the "rungs" of the ladder consist of molecules that are hydrogen-bonded together. Sugar and phosphate groups make up the sides of the ladder. Shown are the structures of the adenine-thymine (AT) "base pair" and the guanine-cytosine (GC) base pair:



Thymine Adenine

You can see that AT base pairs are held together by two hydrogen bonds, and the GC base pairs are held together by three hydrogen bonds. Which base pair is more stable to heating?



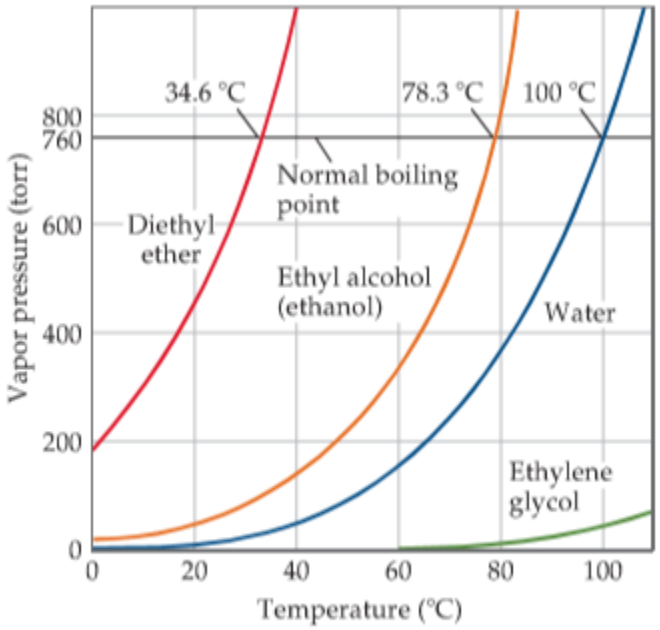
Cytosine Guanine

10

11.85 Ethylene glycol [$CH_2(OH)CH_2(OH)$] is the major component of antifreeze. It is a slightly viscous liquid, not very volatile at room temperature, with a boiling point of 198 °C. Pentane (C_5H_{12}), which has about the same molecular weight, is a nonviscous liquid that is highly volatile at room temperature and whose boiling point is 36.1 °C. Explain the differences in the physical properties of the two substances.

11

11.49 Using the vapor-pressure curves in Figure 11.24, **(a)** estimate the boiling point of ethanol at an external pressure of 200 torr; **(b)** estimate the external pressure at which ethanol will boil at 60 °C; **(c)** estimate the boiling point of diethyl ether at 400 torr; **(d)** estimate the external pressure at which diethyl ether will boil at 40 °C.



▲ Figure 11.24 **Vapor pressure for four common liquids as a function of temperature.** The temperature at which the vapor pressure is 760 torr is the normal boiling point of each liquid.

Problem Set 3: Solids – Types and Properties

1

11.71 What kinds of attractive forces exist between particles in **(a)** molecular crystals, **(b)** covalent-network crystals, **(c)** ionic crystals, **(d)** metallic crystals?

2

11.74 Which type (or types) of crystalline solid is characterized by each of the following: **(a)** high mobility of electrons throughout the solid; **(b)** softness, relatively low melting point; **(c)** high melting point and poor electrical conductivity; **(d)** network of covalent bonds; **(e)** charged particles throughout the solid.

3

11.75 A white substance melts with some decomposition at 730 °C. As a solid, it does not conduct electricity, but it dissolves in water to form a conducting solution. Which type of solid (Table 11.7) might the substance be?

4

11.76 You are given a white substance that sublimes at 3000 °C; the solid is a nonconductor of electricity and is insoluble in water. Which type of solid (Table 11.7) might this substance be?

5

11.72 Indicate the type of crystal (molecular, metallic, covalent-network, or ionic) each of the following would form upon solidification: **(a)** $CaCO_3$, **(b)** Pt, **(c)** ZrO_2 (melting point, 2677 °C), **(d)** table sugar ($C_{12}H_{22}O_{11}$), **(e)** benzene, **(f)** I_2.

6

11.78 For each of the following pairs of substances, predict which will have the higher melting point, and indicate why: **(a)** HF, HCl; **(b)** C (graphite), CH_4; **(c)** KCl, Cl_2; **(d)** LiF, MgF_2.

7

63. Explain how doping silicon with either phosphorus or gallium increases the electrical conductivity over that of pure silicon.

Specify the type of doping involved (n or p) in each case.

8

82. What type of solid will each of the following substances form?

a. diamond
b. PH_3
c. H_2
d. Mg
e. KCl
f. quartz
g. NH_4NO_3
h. SF_2
i. Ar
j. Cu
k. $C_6H_{12}O_6$

9

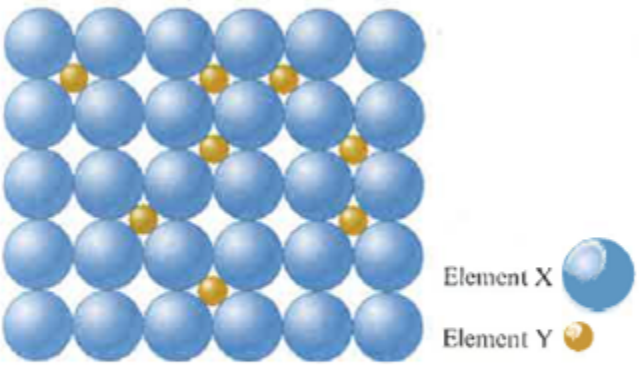
Consider the following data concerning four different substances. SiO_2 B_2H_6 W CsI

Compound	Conducts Electricity as a Solid	Other Properties	Type of Solid
	no	gas at 25°C	
	no	high mp	
	no	aqueous solution conducts electricity	
	yes	high mp	

a) Place each substance formula in the correct box.
b) Label the type of solid in each cased based on the properties (ionic, metallic, molecular, network covalent)

10

An example of an alloy is shown in the diagram below. Compared with the pure metal X, how would you expect the properties of the alloy to vary?



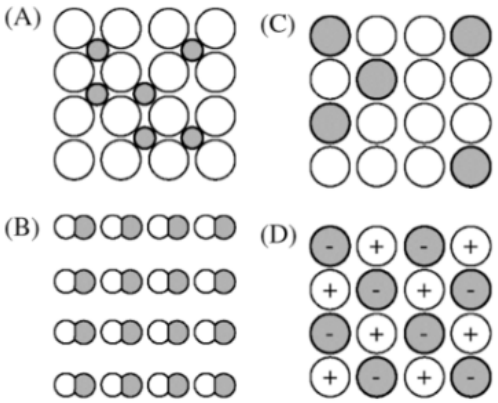
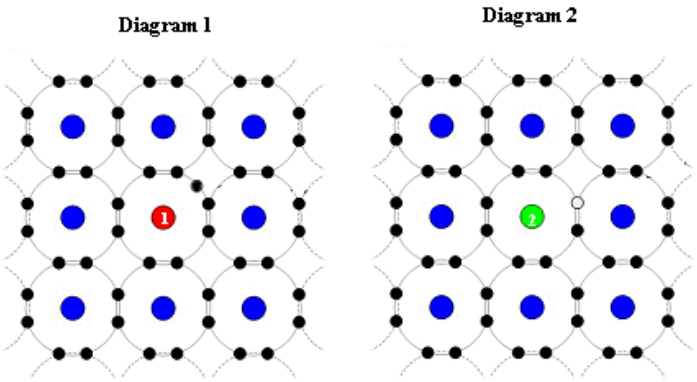
(A) The alloy has higher malleability and higher density.

(B) The alloy has lower malleability and lower density.

(C) The alloy has higher malleability and lower density

(D) The alloy has lower malleability and higher density.

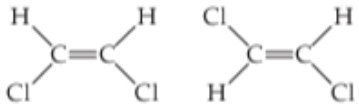
Explain your choice.

11	12
Label each type of solid based on its structure.  	The diagrams below show two different doped samples of silicon. a) Label each as other n-doped or p-doped and explain how you know. b) The doping agents (1-left, 2-right) used were boron and phosphorus. Explain which was used in each case and how you know. 

Problem Set 4: Additional Exercises

1

11.81 Two isomers of the planar compound 1,2-dichloroethylene are shown here, along with their melting and boiling points.



cis isomer trans isomer

	cis isomer	trans isomer
Melting point (°C)	−80.5	−49.8
Boiling point (°C)	60.3	47.5

(a) Which of the two isomers will have the stronger dipole–dipole forces? Is this prediction borne out by the data presented here? **(b)** Based on the data presented here, which isomer packs more efficiently in the solid phase?

2

A certain compound contains only C, H, and N. Combustion of 0.125 g of this compound produces 0.172 g of H_2O and 0.279 g of CO_2.

a. Calculate the number of moles of CO_2 and H_2O.

b. Find the mass percentages of C, H, and N and the empirical formula of this compound.

c. Assume the empirical formula is also the molecular formula. Draw structural formulas for the four different isomers that are possible for a compound with this formula.

d. The four compounds have boiling points that range from 3 °C to 48 °C. Identify the isomers that you would expect to exhibit the lowest and highest boiling points. Explain your reasoning in terms of the intermolecular forces involved.

3

4