

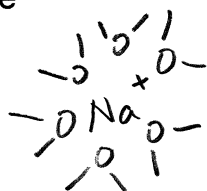
Secret Code \_\_\_\_\_

**KEY**

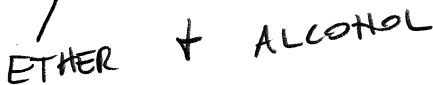
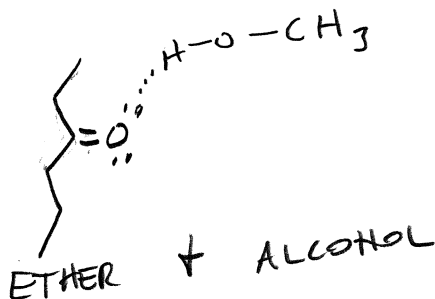
There are 100 points. The exam will be graded on a percentage basis.  
Closed book, closed Internet, closed notes, closed cell phone, closed neighbor!  
**CLARIFICATIONS ARE ALLOWED BUT NO OTHER QUESTIONS!**  
I'll be in every 30 minutes or so. If you need me come to my lab or office.

1. (10 pts) Give an example of each of the following types of intermolecular interactions, and provide a chemical sketch for each. Your examples may be either between chemicals of the same type or different types. Use actual chemical formulas or structures to show these interactions.

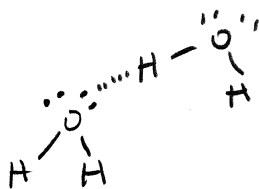
Ion-dipole



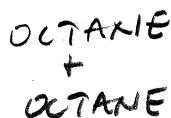
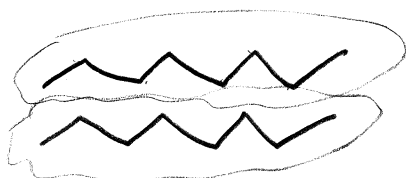
Dipole-dipole



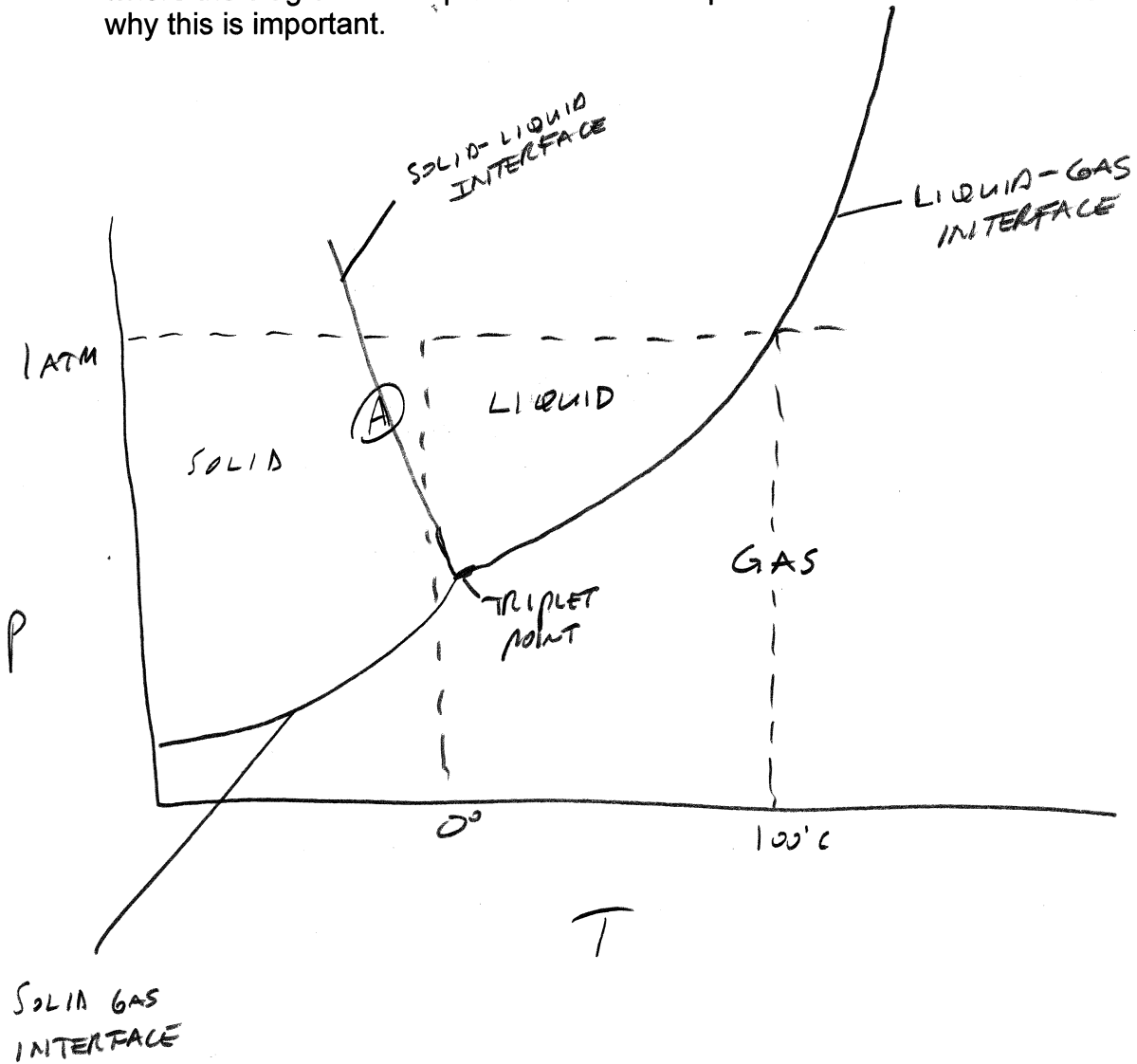
Hydrogen bonding



van der Waals (dispersion)



2. (10 pts) Draw a phase diagram for H<sub>2</sub>O noting all of the important reference points (actual numbers) of temperature and pressure on your plot. Show where the diagram is unique for water and explain in one or two sentences why this is important.



- THE LINE AT POINT A IS UNIQUE. FOR A GIVEN T, AS MORE PRESSURE IS APPLIED, THE CRYSTAL LATTICE COLLAPSES TRANSFORMING A LESS DENSE SOLID TO A MORE DENSE LIQUID.
- ALSO LARGE RANGE OF TEMPS WHERE H<sub>2</sub>O IS LIQUID

3. (10 pts) 40.0 kJ of heat are added to an insulated vessel containing a mixture of 100.0 g liquid water and 100.0 g ice at 0.00° C. The enthalpy of fusion of ice is 6.02 kJ/mol, and the specific heat capacity of liquid water is 4.18 J/g·K. Calculate the final temperature of the equilibrated system.

40.0 kJ HEAT

DOES ALL OF THE ICE MELT? IF SO, HOW MUCH HEAT IS REQUIRED?

$$q_{\text{MELT ICE}} = (100.0 \text{ g}) \left( \frac{\text{mol}}{18.0 \text{ g}} \right) \frac{6.02 \text{ kJ}}{\text{mol}} = 33.4 \text{ kJ NEEDED + WE HAVE 40.0}$$

THE HEAT LEFT OVER TO HEAT THE WATER (NOTE: NOW 200g)

$$40.0 \text{ kJ} - 33.4 \text{ kJ} = 6.56 \text{ kJ}$$

$$q = \delta \cdot \text{sp. ht.} \cdot (T_F - T_I)$$

$$\frac{1000 \text{ J}}{\text{kJ}} \cdot 6.56 \text{ kJ} = (200.0 \text{ g}) (4.18 \text{ J/g}\cdot\text{K}) (T_F - 0)$$

$$T_F = 7.84^\circ \text{C}$$

4. (10 pts) Name the *dominant* intermolecular force involved in the following (you need two names, one for each chemical):

dissolving NaCl in water ION - DIPOLE

dissolving O<sub>2</sub> in water INDUCED DIPOLE - DIPOLE

dissolving CH<sub>3</sub>OH in water HYDROGEN BONDING

dissolving CH<sub>3</sub>OH in CH<sub>2</sub>Cl<sub>2</sub> DIPOLE - DIPOLE

dissolving CH<sub>3</sub>OCH<sub>3</sub> in water DIPOLE - DIPOLE

dissolving CCl<sub>4</sub> in benzene (C<sub>6</sub>H<sub>6</sub>) INDUCED DIPOLE - INDUCED DIPOLE

5. 10 pts) Calculate the molarity, molality, and mole fraction of methanol ( $\text{CH}_3\text{OH}$ ) in a solution composed of 26.5 g  $\text{CH}_3\text{OH}$  and 244 g water. (Assume that the density of the solution is 0.975 g/mL)

MOLARITY = MOLES / L OF SOLUTION

$$26.5 \text{ g } \text{CH}_3\text{OH} + 244 \text{ g } \text{H}_2\text{O} = 270.5 \text{ g SOLN}$$

$$(270.5 \text{ g SOLN}) / (0.975 \text{ g/mL SOLN}) = 277.4 \text{ mL}$$

$$\text{MOLES} = \frac{26.5 \text{ g } \text{CH}_3\text{OH}}{32.04 \text{ g/mol}} = 0.827 \text{ MOL}$$

$$M = \frac{0.827 \text{ mol}}{0.2774 \text{ L}} = \boxed{2.98 \text{ M}}$$

MOLALITY =  $m$  = MOLES / kg SOLVENT

$$\text{MOLES } \text{CH}_3\text{OH} = 0.827 \text{ (FROM ABOVE)}$$

$$0.244 \text{ kg } \text{H}_2\text{O}$$

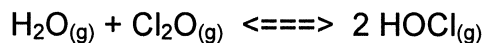
$$m = 0.827 \text{ MOLES} / 0.244 \text{ kg} = \boxed{3.39 \text{ M}}$$

MOLE FRACTION = MOLES  $\text{CH}_3\text{OH}$  / TOTAL MOLES

$$\text{MOLES } \text{H}_2\text{O} = 244 \text{ g} / 18.02 \text{ g/mol} = 13.54 \text{ MOLES}$$

$$X_{\text{CH}_3\text{OH}} = \frac{0.827 \text{ CH}_3\text{OH}}{0.827 \text{ CH}_3\text{OH} + 13.5 \text{ H}_2\text{O}} = \boxed{0.0576 X_{\text{CH}_3\text{OH}}}$$

6. (10 pts) At 298 K, the equilibrium constant ( $K_c$ ) for the following reaction is 0.090.



1.00 mol of HOCl is placed in a 2.00 L reaction flask and the reaction progresses. Calculate the concentration (in M) of all three species at equilibrium. Show as much of your work as possible but you may use your calculator to solve functions as necessary!

	$\text{H}_2\text{O}$	$\text{Cl}_2\text{O}$	$2\text{HOCl}$
I	0	0	0.500 M
C	+x	+x	-2x
E	x	x	0.500 - 2x

$$K_c = \frac{[\text{HOCl}]^2}{[\text{H}_2\text{O}][\text{Cl}_2\text{O}]} = 0.090$$

$$\frac{(0.5 - 2x)^2}{x^2} = 0.090$$

$$0.25 - 2x + 3.91x^2 = 0$$

w/ QUAD. FORMULA  $x = 0.2174 \text{ M}$

$$[\text{HOCl}] = 0.500 - 2x = 0.065 \text{ M}$$

$$[\text{H}_2\text{O}] = x = 0.217 \text{ M}$$

$$[\text{Cl}_2\text{O}] = x = 0.217 \text{ M}$$

$$\begin{array}{r} .500 \\ -.44 \\ \hline \end{array}$$

7. (5 pts) We have discussed the "constant" nature of equilibrium constants. What is the easiest way to manipulate (change) the numerical value of the constant?

CHANGE THE TEMPERATURE

8. (5 pts) Name as many ways as possible to produce more products for the generic reaction shown below.



$\uparrow [ ]$  OF A                       $\uparrow$  PRESSURE

$\uparrow [ ]$  OF B                       $\downarrow$  VOLUME

$\uparrow T$

ADD CATALYST

REMOVE C

9. (10 pts) An equimolar aqueous solution of calcium carbonate and potassium nitrate is made up and it is found that the freezing point of the solution is  $-5.82^\circ\text{C}$ . What are the molal concentrations of each dissolved salt, as calcium carbonate and potassium nitrate? The freezing point depression ( $K_f$ ) for water is  $1.86^\circ\text{C/m}$ .

$$\Delta T = (1.86^\circ\text{C/m}) m$$

$$-5.82^\circ\text{C} = (1.86^\circ\text{C/m}) x$$

$$x = 3.13^\circ\text{C} = m \text{ FOR ALL PARTICLES}$$

$\text{CaCO}_3 = 2 \text{ PARTICLES}$

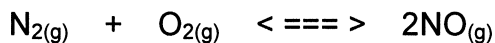
$\text{KNO}_3 = 2 \text{ PARTICLES}$

TOTAL

4 PARTICLES  
FOR 2 COMPOUNDS

$$\text{So } \frac{3.13 m}{2} = 1.56 m \text{ CaCO}_3 + \text{KNO}_3$$

10. (10 pts) Our atmosphere is composed of primarily diatomic nitrogen and oxygen, which coexist at 25°C without reacting to any significant extent. However, at high temperatures the two gases can react to form nitrogen monoxide according to the following reaction



- Calculate the  $\Delta G^\circ$  for this reaction at 25°C, the ambient temperature. Is the reaction spontaneous?
- Calculate  $K_p$  for this reaction, obviously at equilibrium.

Things that might be useful:  $\Delta G^\circ$  for  $\text{NO}(\text{g}) = 87.6 \text{ kJ/mol}$ ,  $R = 8.314 \text{ J/mol}\cdot\text{K}$ , and yes you should know the  $\Delta G^\circ$  for  $\text{N}_2$  and  $\text{O}_2$ .

$$a) \Delta G^\circ = \sum \Delta G^\circ_{\text{F}} \text{ PRODUCTS} - \sum \Delta G^\circ_{\text{F}} \text{ REACTANTS}$$

$$\Delta G^\circ_{\text{f}} \text{ NO} = 87.6 \frac{\text{kJ}}{\text{mol}}$$

$$\text{N}_2 = 0$$

$$\text{O}_2 = 0$$

$$\Delta G^\circ_{\text{f}} = \left( 2 * 87.6 \frac{\text{kJ}}{\text{mol}} \right) - 0 = \boxed{175.2 \text{ kJ}}$$

$$b) \Delta G^\circ_{\text{RXN}} = \Delta G^\circ + RT \ln K_c$$

$$\text{AT EQUIL } \Delta G^\circ_{\text{RXN}} \equiv 0$$

$$0 = \Delta G^\circ + RT \ln K$$

$$\Delta G^\circ_{\text{RXN}} = -RT \ln K$$

$$\left( \frac{1000 \text{ J}}{\text{kJ}} \right) 175.2 \text{ kJ} = \left( 8.314 \frac{\text{J}}{\text{mol}\cdot\text{K}} \right) (298 \text{ K}) \ln K_c$$

$$K_c = 1.95 \times 10^{-31}$$

$$K_c = K_p \text{ SINCE } \Delta n = 0$$

11. (2 pts each)

- a) Name a way to expand the temperature range of a liquid, both on the top and lower end of the temperature scale.

ADD/DISSOLVE A SOLUTE

- b) In general does the solubility of an inorganic salt increase or decrease with temperature?      ↑

Why? THEY ARE ENDOTHERMIC RXNS

- c) In general does the solubility of a non-reactive gas increase or decrease with temperature?      ↓

Why? ↑ IN KE OF MOLECULES ↓ INTERMOLECULAR INTERACTIONS / ATTRACTIONS

- d) What are the two most interesting qualities and characteristics of super critical fluids?

THEY HAVE THE DISSOLVING POWERS OF LIQUIDS  
↓ THE PENETRATION POWERS OF GASES