1. (5 pts) Of ethylene and water, which is expected to have the higher boiling point, and why?

Water has hydrogen bonds and dipole-dipole interactions and dispersion (induced dipole/induced dipole) interactions, while ethylene only has dispersion so it's less strongly attracted to each other and it's easier for molecule to escape into gas phase. See lecture notes p.6-6.

2. (5 pts) On top of a tall mountain, the boiling point of water is expected to be: problem 6-3.

(a) Above 100°C
(b) 100°C
(c) Below 100°C

3. (15 pts) Below is a phase diagram for H₂O.

(a) Identify regions I, II, and III as gas, liquid, or solid.
(b) Draw and label the critical point and the triple points on the graph.
(c) Give the temperature for which the vapor pressure is 0.1 atm. about 320 K.
4. (15 pts) Which is more effective (on a per-gram basis) for melting ice on streets. NaCl or K$_2$SO$_4$? You must show your work.

\[
\begin{align*}
100 \text{g} \text{ NaCl} & \times \frac{\text{mol}}{58.443 \text{g}} = 1.71 \text{ mol} \times (i=2) = 3.42 \text{ mol of particles} \\
\end{align*}
\]

\[\Delta T_f = -K_f \text{ molality} \times \text{ van't Hoff factor} \]

\[
\begin{align*}
100 \text{g} \text{ K}_2\text{SO}_4 & \times \frac{\text{mol}}{174.260 \text{g}} = 0.574 \text{ mol} \times (i=3) = 1.72 \text{ mol of particles} \\
\end{align*}
\]

Practice problem #2

100 g of NaCl gives more mol of particles than 100 g of K$_2$SO$_4$

\[\therefore \text{NaCl more effective (will lower freezing pt more)}\]

5. (5 pts) If the reaction N$_2$(g) + O$_2$(g) ⇌ 2 NO(g) is endothermic, then the reaction 2 NO(g) ⇌ N$_2$(g) + O$_2$(g) is

(a) endothermic
(b) exothermic
(c) neither endothermic nor exothermic
(d) not enough information to determine

6. (15 pts) Solid sodium hydrogen carbonate is added to a closed container. Once equilibrium is reached, the total pressure of the gases in equilibrium with solid sodium hydrogen carbonate at 110 °C is 1.648 atm, corresponding to

\[2 \text{NaHCO}_3(s) \rightleftharpoons \text{Na}_2\text{CO}_3(s) + \text{H}_2\text{O(g)} + \text{CO}_2(g).\]

(a) Calculate the equilibrium constant at 110 °C.

\[K = \frac{P_{\text{H}_2\text{O}}P_{\text{CO}_2}}{1}\]

\[\text{If we start from NaHCO}_3(s) \text{ only, then } P_{\text{H}_2\text{O}} = P_{\text{CO}_2}\]

\[P_{\text{CO}_2} = P_{\text{H}_2\text{O}} + P_{\text{CO}_2} = 2x\]

\[x = 1.648/2 = 0.824 \text{ atm}\]

\[K = (0.824)(0.824) = 0.6790 \text{ (no units)}\]
(b) Now suppose that CO$_2$(g) is added or removed until its partial pressure is 0.800 atm. maintaining a constant temperature of 110°C. What is the partial pressure of water vapor in the new equilibrium?

\[ K = \frac{P_{CO_2}}{P_{H_2O}} \]

\[ 0.6790 = (0.800)(P_{H_2O}) \]

\[ P_{H_2O} = \frac{0.6790}{0.800} = 0.8487 \]

\[ P_{H_2O} = 0.849 \]

(a) Although this was hard, conc. vs. pressures.

(c) If the pressure is increased at constant temperature, does the equilibrium concentration of H$_2$O increase or decrease, and why?

Lee notes: decreases — system tries to respond to stress by lowering pressure, so Rx goes backwards since no gases on reactant side of equation (Le Chatelier principle)

7. (10 pts) The $K_a$ of H$_3$PO$_4$ is 2.12, and the $K_a$ of HIO$_3$ is 0.8. Is the equilibrium constant $K$ greater than 1, equal to 1, or less than 1 for the following reaction?

H$_3$PO$_4$(aq) + IO$_3^-$ (aq) ⇌ HIO$_3$(aq) + H$_2$PO$_4^-$ (aq)

Lee notes: short way: $K_a$ (H$_3$PO$_4$) is larger (note: $K_a$ not pH...)

so H$_3$PO$_4$ is stronger acid, so it is more likely to give up its proton than HIO$_3$ is, so Rx goes forward, so $K > 1$

Long way: The Rx is a sum of 2 acid Rxs

\[
\begin{align*}
\text{H}_3\text{PO}_4\text{(aq)} + \text{H}_2\text{O} & \rightleftharpoons \text{H}_3\text{O}^+\text{(aq)} + \text{H}_2\text{PO}_4^-\text{(aq)} \quad K_a = 2.12 \\
\text{H}_3\text{O}^+\text{(aq)} + \text{IO}_3^-\text{(aq)} & \rightleftharpoons \text{HIO}_3\text{(aq)} + \text{H}_2\text{O} \quad K = 1/0.8 \\
\text{H}_3\text{PO}_4\text{(aq)} + \text{IO}_3^-\text{(aq)} & \rightleftharpoons \text{HIO}_3\text{(aq)} + \text{H}_2\text{PO}_4^-\text{(aq)} \quad K = \frac{2.12}{0.8} = 2.65 > 1
\end{align*}
\]
8. (15 pts) If the $K_a$ of HF is $6.6 \times 10^{-4}$, calculate the pH and the percent ionization of a 1M aqueous solution of HF.

\[
\begin{align*}
\text{Initial} & : 1 \\
\text{Final} & : 1-x, +x, +x \\
\end{align*}
\]

\[
K_c = 6.6 \times 10^{-4} = \frac{x^2}{1-x} = \frac{x^2}{1} \\
x = 2.6 \times 10^{-2} \quad \text{pH} = -\log_{10}[H_3O^+] \\
\text{pH} = 1.59 \quad \text{(or 2% to 15%)}
\]

% ionized = \frac{2.6 \times 10^{-2}}{1} = 2.6\% \text{ or about 3%}

9. (15 pts)

(a) Write an expression for the solubility product $K_{sp}$ for the dissociation reaction

\[
\text{AgAsO}_4(s) \rightleftharpoons 3 \text{Ag}^+(aq) + \text{AsO}_4^{3-}(aq)
\]

\[
K_{sp} = [\text{Ag}^+]^3[\text{AsO}_4^{3-}]
\]

(b) If a solution is supersaturated, is the amount of solute dissolved more or less than its equilibrium concentration?

lec notes 9-2 more