Due: **Tuesday, 19-February-2008** at the beginning of class. Remember this is really meant to be your own work. (Problem set is 2 pages.)

1) Phosgene was used as a poisonous gas in World War I. At high temperatures it decomposes as follows

\[ \text{COCl}_2(g) \rightleftharpoons \text{CO}(g) + \text{Cl}_2(g) \]

with \( K_c = 4.6 \times 10^{-3} \) at 800 K.

a) A sample of 6.75 g of COCl\(_2\) is placed in a 1.25-L reaction vessel and heated to 800 K. What are the equilibrium concentrations of all the species?

b) What fraction of the COCl\(_2\) has decomposed?

c) If 3.0 g of CO is inserted into the reaction vessel, what qualitative effect would this have on the fraction of COCl\(_2\) that has decomposed?

2) Gaseous acetic acid molecules have a certain tendency to form dimers. (We saw this last term on the last problem set.) (A dimer is a molecule formed by the association of two identical, simpler molecules.) The equilibrium constant \( K_p \) at 25°C for this reaction is \( 1.3 \times 10^3 \).

a) If the initial pressure of CH\(_3\)COOH monomer (the simpler molecule) is 7.5 x 10\(^{-3}\) atm, what are the pressures of the monomer and dimer when the system comes to equilibrium? (The simpler quadratic is obtained by assuming that all the molecules have dimerized, and then some dissociates to monomer.)

b) Why do the acetic acid molecules dimerize? What type of structure would you draw for the dimer? (This is asking for a drawing of the dimer!)

c) As the temperature increases, would you expect the percentage of dimer to increase or decrease? Explain.

3) The following equilibrium was studied by analyzing the equilibrium mixture for the amount of HCl produced.

\[ \text{LaCl}_3(s) + \text{H}_2\text{O}(g) \rightleftharpoons \text{LaOCl}_2(s) + 2\text{HCl}(g) \]

A vessel whose volume was 1.45 L was filled with 0.0145 mol of lanthanum (III) chloride, LaCl\(_3\), and 0.0290 mol H\(_2\)O. After the mixture came to equilibrium in the closed vessel at 619°C, the gaseous mixture was removed and dissolved in more water. Sufficient silver (I) ion was added to precipitate the chloride ion completely as silver chloride, AgCl. If 3.59 g of AgCl was obtained, what is the value of \( K_c \) at 619°C?
4) One of the most important industrial sources of ethanol (EtOH) is the exothermic reaction of steam with ethene (C\textsubscript{2}H\textsubscript{4}) derived from crude oil:

\[
\text{C}_2\text{H}_4(\text{g}) + \text{H}_2\text{O}(\text{g}) \rightleftharpoons \text{C}_2\text{H}_5\text{OH}(\text{g}) \quad \Delta H_{\text{rxn}} = -47.8 \text{ kJ} \quad K_c = 9 \times 10^3 \text{ at 600K}
\]

a) At equilibrium \(P_{\text{EtOH}} = 200\) atm and \(P_{\text{water}} = 400\) atm. Calculate \(P_{\text{ethene}}\).

b) Is the highest yield of ethanol obtained at high or low pressures? High or low temperatures?

c) In the manufacture of ammonia, the yield of ammonia is increased by condensing it to a liquid, and removing it from the vessel. Would condensing the \(\text{C}_2\text{H}_5\text{OH}\) work in this process? Explain.