SURREY SUPPLEMENT: EQUILIBRIUM

1) Calculate K_c for the following reactions:

   a) $CO(g) + Cl_2(g) \rightleftharpoons COCl_2(g)$ $K_p = 3.9 \times 10^{-2}$ at 1000 K **[3.2]**
   b) $S_2(g) + C(s) \rightleftharpoons CS_2(g)$ $K_p = 28.5$ at 500 K **[28.5]**

2) At 25°C, $K_p = 1.08$ for the equilibrium

   $H_2(g) + Cl_2(g) \rightleftharpoons 2HCl(g)$

   The three gases, each at a partial pressure of 1.00 bar, are introduced into a reaction vessel.

   a) Determine the direction of the reaction. **[to the right]**
   b) Determine the equilibrium partial pressure of each gas.
      [$P_{H2} = P_{Cl2} = 0.987$ bar; $P_{HCl} = 1.026$ bar]

3) An important industrial source of ethanol is the reaction of steam with ethylene derived from oil:

   $C_2H_4(g) + H_2O(g) \rightleftharpoons C_2H_5OH(g)$ $\Delta H°_{rxn} = -47.8$ kJ; $K_c = 9 \times 10^3$ at 600K

   The reaction is catalyzed by H_3PO_4.

   a) At equilibrium the pressure of ethanol is 200. bar and the pressure of steam is 400. bar. Calculate the equilibrium pressure of ethylene. **[3×10^{-3} bar]**
   b) Is the highest yield of ethanol obtained at high or low pressure? At high or low temperature? **[high P, low T]**
   c) Calculate K_c at 450 K. **[3×10^5]**
   d) In NH_3 production, the yield is increased by condensing the NH_3 to a liquid and removing it. Would condensing the ethanol have the same effect in ethanol production? Explain. **[No]**

4) Aluminum can be produced at high temperatures from the decomposition of molten cryolite, Na_3AlF_6:

   $Na_3AlF_6(l) \rightleftharpoons 3Na(l) + Al(l) + 3F_2(g)$ $K_c = 2 \times 10^{-104}$ at 1300 K

   What is the concentration of F_2 in moles/L and molecules/cm^3 at this temperature? **[2.7×10^{-35} M, or 16 molecules/km^3]**

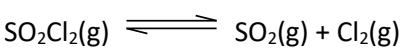
5) How will the color of the equilibrium mixture:

   $Cr_2O_7^{2-}(aq) + 2OH^-(aq) \rightleftharpoons 2CrO_4^{2-}(aq) + H_2O(l)$

   be affected by the addition of:
   a) sodium hydroxide. **[rxn shifts right]**
   b) hydrochloric acid. **[rxn shifts left]**

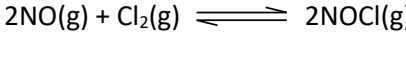
6) A mixture of 3.00 voumes of H_2 and 1.00 volumes of N_2 reacts at 344°C to form ammonia. The equilibrium mixture had a total pressure of 110. bar and contained 41.49% NH_3 by volume. Calculate K_p for the reaction. Assume that the gases behave ideally. **[1.15×10^{-3}]**

7) At 100°C, K_p is 2.65 for the equilibrium



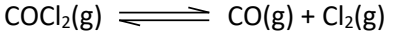
If $\Delta H° = +93.1$ kJ for the reaction, calculate K_p at 200°C. **[1.5×10^{3}]**

8) For the equilibrium



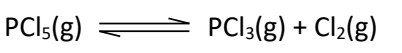
$K_p = 2.72$ at 300°C, and $\Delta H°$ for the reaction is -75.6 kJ. Calculate K_p at 500°C. **[0.045]**

9) For the equilibrium



K_c is 7.6×10^{-4} at 400°C and 2.2×10^{-10} at 100°C. Calculate $\Delta H°$ for this reaction. **[109 kJ/mol]**

10) The equilibrium



was studied at each of the following temperatures, and the equilibrium total pressure recorded. At each temperature the initial pressure was 0.500 bar of PCl_5 (and no other reagent):

T (°C)	100	150	200	250	300
P_{total} (bar)	0.513	0.571	0.727	0.908	0.980

a) Is the reaction exothermic or endothermic? EXPLAIN. **[endothermic]**
b) Calculate $\Delta H°$ for this reaction. **[92.6 kJ/mol]**