Equilbirum (no calculator)

(All questions may be completed without the use of a calculator. All answers given were generated without a calculator.)

1) Calculate K_c for each of the following equilibria:

   $CO(g) + Cl_2(g) \rightleftharpoons COCl_2(g)$; $K_p = 5 \times 10^{-2}$ at 1200 K **[5]**
   $S_2(g) + C(s) \rightleftharpoons CS_2(g)$; $K_p = 28.5$ at 500 K **[28.5]**

2) In an analysis of interhalogen reactivity, 0.500 mol of ICl was placed in a 5.00 L flask, where it decomposed at a high temperature:

   $2ICl(g) \rightleftharpoons I_2(g) + Cl_2(g)$

   If $K_c = 1$ at the temperature used, calculate the equilibrium concentrations of all species. **(Answer: $[I_2] = [Cl_2] = [ICl] = 0.033$ M)**

3) At 25°C, $K_p = 4.0$ 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. **[The reaction moves to the right to produce HCl]**
   b) Determine the equilibrium partial pressure of each gas. **[$H_2 = Cl_2 = 0.75$ bar and HCl = 1.50 bar]**

4) The formation of methanol is important in the processing of new fuels. At 298 K, $K_p = 2 \times 10^4$ for the reaction:

   $CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(l)$

   If $\Delta H°_{rxn} = 128$ kJ, calculate K_p at 125°C. **(Answer: $K_p \cong 0.1$)**

5) One of the most important industrial sources of ethanol is the reaction of steam with ethane derived from crude oil:

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

a) At equilibrium, $P_{C2H5OH} = 200$ bar and $P_{H2O} = 400$ bar. Calculate P_{C2H4} at equilibrium. **[3×10^{-3} atm]**
b) Is the highest yield of ethanol obtained at high or low pressures, and at high or low temperatures? **[High pressure and low temperature]**
c) Calculate K_c at 450 K. **[$K_c \cong 10^5$]**
d) In manufacturing, the yield of ammonia is increased by condensing it to a liquid and removing it from the vessel. Would condensing the ethanol and removing it from the reaction vessel increase the yield? Explain. **[No.]**

6) Aluminum is one of the most versatile metals. It is produced by the Hall-Heroult process, in which cryolite, Na_3AlF_6, is used as a solvent for the aluminum ore. Cryolite undergoes very slight decomposition with heat to produce a tiny amount of F_2, which escapes into the atmosphere above the solvent. K_c is 2×10^{-104} at 1300 K for the reaction:

$Na_3AlF_6(l) \rightleftharpoons 3Na(l) + Al(l) + 3F_2(g)$

What is the concentration of $F_2(g)$ over molten cryolite at this temperature? Give your answer in moles/L and in molecules/km^3. **(Answer: [F_2] $\cong 3 \times 10^{-35}$ M or 16 molecules/km^3)**

7) How will the color of the equilibrium mixture:

$Cr_2O_7^{-2}(aq) + 2OH^{-1}(aq) \rightleftharpoons 2CrO_4^{-2}(aq) + H_2O(l)$

be affected by the addition of:

a) sodium hydroxide. **(Answer: equilibrium will shift to the right (more yellow color))**
b) hydrochloric acid. **(Answer: equilibrium will shift to the left (more orange color))**

8) A mixture of 3.00 volumes of H_2 and 1.00 volumes of N_2 reacts at 344°C to form ammonia. The equilibrium mixture at 100 bar contains 60% NH_3 by volume. Calculate K_p for the reaction, assuming the gases behave ideally. **(Answer: $K_p = 1.3 \times 10^{-2}$)**

9) At 125°C K_p is 2.0 for the equilibrium

$AB(g) \rightleftharpoons A(g) + B(g)$

for which $\Delta H° = +80$ kJ. Calculate the approximate value of K_p at 225°C.
(Answer: Kp ≅ 2 x 10^2)

10) For the equilibrium

$2X(g) + Y_2(g) \rightleftharpoons 2XY(g)$

at 225°C, $K_p = 5 \times 10^{-2}$ and $\Delta H°$ for the reaction is -27 kJ. Estimate the value of K_p at 525°C.
(Answer: K_p ≅ 5 x 10^{-3})

11) For the equilibrium

$COCl_2(g) \rightleftharpoons CO(g) + Cl_2(g)$

K_c is 1 x 10^{-4} at 525°C and 2 x 10^{-10} at 125°C. Calculate the approximate $\Delta H°$ for this reaction. **(Answer: ΔH° ≅ +96 kJ)**

12) The equilibrium

$PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$

was studied a series of temperatures. A plot of $\ln(K_p)$ vs 1/T gave a line with a slope = -1.1 x 10^4.

a) Is the reaction exothermic or endothermic? EXPLAIN.
b) What are the units for the slope?
c) Calculate ΔH for this reaction in kJ/mol. **(Answer: + 91 kJ/mol)**