Equilibrium Problems

1. At 250°C the equilibrium constant for the following gaseous reaction is 0.041.

$$PCl_{5(g)} \rightarrow PCl_{3(g)} + Cl_{2(g)}$$

Calculate the concentrations of all of the substances present at equilibrium if 0.20 mol of PCl_5 are placed in a 4.0 L reaction vessel.

2. At 448°C the equilibrium constant for the following reaction is 50.0.

$$H_{2(g)} + I_{2(g)} \rightarrow 2HI_{(g)}$$

a) How many moles of HI will be present at equilibrium when 1.0 mol of $H_{2(g)}$ and 1.0 mol of $I_{2(g)}$ are allowed to react in a 1.0 L container?
b) How many moles of H_2 and I_2 remain unreacted?
c) If the container was an open system and the reaction of H_2 and I_2 was complete (ie not an equilibrium reaction), how many moles of HI should be produced?
d) What is the percent yield of the equilibrium mixture?

3. A 1.0 L container contains 0.750 mol of CO and 0.275 mol of H_2O. After one hour, equilibrium is reached according the following equation:

$$CO_{(g)} + H_2O_{(g)} \rightarrow CO_{2(g)} + H_{2(g)}$$

Analysis shows that 0.25 mol of CO_2 is present. What is the equilibrium constant for the reaction?

4. Consider the equilibrium:

$$3I_{2(g)} + 6F_{2(g)} \rightarrow 2IF_{5(g)} + I_4F_{2(g)}$$

a) At a certain temperature, 3.0 mol of F_2 and 2.0 mol of I_2 are placed into a 10.0 L container. At equilibrium, the concentration of IF_5 is 0.020 mol/L. Calculate Keq for the reaction.
b) At a different temperature (this means that Keq will be different than part a)), 6.0 mol of IF_5 and 8.0 mol of I_4F_2 are placed in a 10.0 L container. At equilibrium, 6.0mol of I_4F_2 are left. Calculate the Keq for the new temperature.

5. At a certain temperature, Keq = 4.0 for the following reaction.

$$2HF_{(g)} \rightarrow H_{2(g)} + F_{2(g)}$$

Predict the direction in which the reaction will shift, if any, when the following amounts of substances are introduced into a 1.0 L container.

a) 3.0 mol of HF, 2.0 mol of H_2 and 4.0 mol of F_2
b) 0.20 mol of HF, 0.50 mol of H_2 and 0.60 mol of F_2
c) 0.30 mol of HF, 1.8 mol of H_2 and 0.20 mol of F_2

6. The equilibrium constant for the following reaction is 7.0.

$$Br_{2(g)} + Cl_{2(g)} \rightarrow 2BrCl_{(g)}$$

If 0.080 mol of Br_2 and 0.60 mol of Cl_2 are placed into a 2.0 L container, what are the equilibrium concentrations for the reaction?

7. At 425°C, the equilibrium constant is 1.82×10^{-2} for the reaction:

$$2HI_{(g)} \rightarrow H_{2(g)} + I_{2(g)}$$

Equilibrium is reached by adding HI to the reaction vessel.

a) What are the concentrations of H_2 and I_2 in equilibrium with 0.0100 mol/L HI?
b) What was the initial concentration of HI (i.e. before equilibrium was reached)?
c) What percent of HI reacted?

8. 1.00 mol of CO(g) and 1.00 mol $H_2O_{(g)}$ are placed in a 10.0 L container. At equilibrium, 0.665 mol of CO_2 and 0.665 mol of H_2 are present. The reaction proceeds as follows:

$$CO_{(g)} + H_2O_{(g)} \rightarrow CO_{2(g)} + H_{2(g)}$$

a) What are the equilibrium concentrations of all four gases?
b) What is the value of Keq?

9. Using the reaction below and assuming that equilibrium has already been established.

$$A(g) + B(g) \rightarrow C(g) + \text{heat}$$

How would the concentration of C change with:

a) an increase in temperature?
b) an increase in pressure?
c) an addition of A?
d) the addition of a catalyst?
e) the removal of B?
f) the removal of C?

How would the value of Keq change with

g) an addition of A?
h) an increase in temperature?
i) an addition of a catalyst?

10. For each of the following equilibrium systems:
    a. Write the equilibrium expression
    b. State which direction the reaction would shift to re-establish equilibrium.

i) $2SO_{2(g)} + O_{2(g)} \rightarrow 2SO_{3(g)}$ (exothermic, temperature decrease)

ii) $C_{(s)} + CO_{2(g)} \rightarrow 2CO_{(g)}$ (endothermic, increase in temperature)

iii) $N_2O_{4(g)} \rightarrow 2NO_{2(g)}$ (increased pressure)

iv) $CO_{(g)} + H_2O_{(g)} \rightarrow CO_{2(g)} + H_{2(g)}$ (decrease in pressure)

v) $2NOBr_{(g)} \rightarrow 2NO_{(g)} + Br_{2(g)}$ (decrease pressure)

vi) $2O_{2(g)} + 3Fe_{(s)} + 4H_{2(g)} \rightarrow Fe_3O_{4(s)} + 4H_{2(g)}$ (add Fe)

vii) $2SO_{2(g)} + O_{2(g)} \rightarrow 2SO_{3(g)}$ (add a catalyst)

viii) $CaCO_{3(s)} \rightarrow CaO_{(s)} + CO_{2(g)}$ (remove CO2)

ix) $N_{2(g)} + 3H_{2(g)} \rightarrow 2NH_{3(g)}$ (add $H_{2(g)}$)

11. When at equilibrium, a reaction mixture contains: 0.20 mol H_2, 0.70 mol CO_2, 0.20 mol CO and 0.30 mol H_2O in a 1.0 L container. The reaction is as follows:

$$CO_{(g)} + H_2O_{(g)} \rightarrow CO_{2(g)} + H_{2(g)}$$

How many moles of CO_2 would have to be added to increase the amount of CO to 0.30 mol?