Equilibrium and Le Chatelier's Principle Practice Problems

1.

$$N_2(g) + 3H_2(g) \leftrightarrow 2NH_3(g)$$

For the synthesis of ammonia at 500°C, the equilibrium constant is 6.0×10^{-2}. Predict the direction in which the system will shift to reach equilibrium in each of the following cases:

a. $[NH_3]_0 = 1.0 \times 10^{-3}$ *M*; $[N_2]_0 = 1.0 \times 10^{-5}$ *M*; $[H_2]_0 = 2.0 \times 10^{-3}$ *M*
b. $[NH_3]_0 = 2.00 \times 10^{-4}$ *M*; $[N_2]_0 = 1.50 \times 10^{-5}$ *M*; $[H_2]_0 = 3.54 \times 10^{-1}$ *M*
c. $[NH_3]_0 = 1.0 \times 10^{-4}$ *M*; $[N_2]_0 = 5.0$ *M*; $[H_2]_0 = 1.0 \times 10^{-2}$ *M*

2. Carbon monoxide reacts with steam to produce carbon dioxide and hydrogen. At 700 K the equilibrium constant is 5.10. Calculate the equilibrium concentrations of all species if 1.000 mol of each component is mixed in a 1.000-L flask.

3. Assume that the reaction for the formation of gaseous hydrogen fluoride from hydrogen and fluorine has an equilibrium constant of 1.15×10^2 at a certain temperature. In a particular experiment, 3.000 mol of each component was added to a 1.500-L flask. Calculate the equilibrium concentrations of all species.

4. Dinitrogen tetroxide in its liquid state was used as one of the fuels on the lunar lander for the NASA Apollo missions. In the gas phase it decomposes to gaseous nitrogen dioxide:

$$N_2O_4(g) \leftrightarrow 2NO_2(g)$$

Consider an experiment in which gaseous N_2O_4 was placed in a flask and allowed to reach equilibrium at a temperature where Kp = 0.133. At equilibrium, the pressure of N_2O_4 was found to be 2.71 atm. Calculate the equilibrium pressure of $NO_2(g)$.

5. Assume that gaseous hydrogen iodide is synthesized from hydrogen gas and iodine vapor at a temperature where the equilibrium constant is 1.00×10^2. Suppose HI at 5.000×10^{-1} atm, H_2 at 1.000×10^{-2} atm, and I_2 at 5.000×10^{-3} atm are mixed in a 5.000-L flask. Calculate the equilibrium pressures of all species.

6. At a certain temperature a 1.00-L flask initially contained 0.298 mol $PCl_3(g)$ and 8.70×10^{-3} mol $PCl_5(g)$. After the system had reached equilibrium, 2.00×10^{-3} mol $Cl_2(g)$ was found in the flask. Gaseous PCl_5 decomposes according to the reaction

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

Calculate the equilibrium concentrations of all species and the value of K.

7. Arsenic can be extracted from its ores by first reacting the ore with oxygen (called *roasting*) to form solid As_4O_6, which is then reduced using carbon:

$$As_4O_6(s) + 6\,C(s) \leftrightarrow As_4(g) + 6\,CO(g)$$

Predict the direction of the shift of the equilibrium position in response to each of the following changes in conditions.

a. Addition of carbon monoxide
b. Addition or removal of carbon or tetraarsenic hexoxide (As_4O_6)
c. Removal of gaseous arsenic (As_4)

8. Predict the shift in equilibrium position that will occur for each of the following processes when the volume is reduced.
   a. The preparation of liquid phosphorus trichloride by the reaction:
   $$P_4(s) + 6\ Cl_2(g) \leftrightarrow 4\ PCl_3(l)$$
   b. The preparation of gaseous phosphorus pentachloride according to the equation:
   $$PCl_3(g) + Cl_2(g) \leftrightarrow PCl_5(g)$$
   c. The reaction of phosphorus trichloride with ammonia:
   $$PCl_3(g) + 3\ NH_3(g) \leftrightarrow P(NH_2)_3(g) + 3\ HCl(g)$$

9. For each of the following reactions, predict how the value of *K* changes as the temperature is increased.
   a. $N_2(g) + O_2(g) \leftrightarrow 2\ NO(g)$ $\Delta H° = 181$ kJ
   b. $2\ SO_2(g) + O_2(g) \leftrightarrow 2\ SO_3(g)$ $\Delta H° = -198$ kJ

Answers

1.	(NMSI ex. 7)	A: shift left	B: no shift	C: shift right
2.	(NMSI ex. 10)	$[CO] = [H_2O] = 0.613$ M		
		$[CO_2] = [H_2] = 1.387$ M		
3.	(NMSI ex. 11)	$[H_2] = [F_2] = 0.472$ M		
		HF] = 5.056 M		
4.	(NMSI ex. 8)	$[NO_2] = 0.600$ atm		
5.	(NMSI ex. 12)	$P_{HI} = 4.29 \times 10^{-1}$ atm		
		$P_{H2} = 4.55 \times 10^{-2}$ atm		
		$P_{I2} = 4.05 \times 10^{-2}$ atm		
6.	(NMSI ex. 9)	$[Cl_2] = 2.00 \times 10^{-3}$ M		
		$[PCl_3] = 0.300$ M		
		$[PCl_5] = 6.70 \times 10^{-3}$ M		
		$K = 8.96 \times 10^{-2}$		
7.	(NMSI ex. 13)	A: shift left	B: no shift	C: shift right
8.	(NMSI ex. 14)	A: shift right	B: shift right	C: no shift
9.	(NMSI ex. 15)	A: increases	B: decreases	

Go to NMSI website to watch how to solve these problems:

http://vimeo.com/16781414

http://edutube.org/en/video/ap-chemistry-general-equilibrium-lecture-notes-part-ii (try this one if in school and the first link is blocked)