1. At a certain temperature, $K_p = 0.25$ for the reaction: $N_2O_4 (g) \rightarrow 2NO_2(g)$. For the following, state whether the reaction is at equilibrium. If not, state in which direction the system will shift.

a. A flask containing $N_2O_4$ at a pressure of 1.00 atm and $NO_2$ at a pressure of 0.50 atm.

$$Q = \left( \frac{P_{NO_2}}{P_{N_2O_4}} \right)^2 = \left( \frac{0.5}{1.00} \right)^2 = 0.25$$

$rxn$ is at equilibrium

$$K = Q$$

b. A flask containing $N_2O_4$ at pressure 0.60 atm and $NO_2$ at a pressure of 3.20 atm.

$$Q = \left( \frac{3.2}{0.60} \right)^2 = 17$$

$K < Q$

$rxn$ not at equilibrium,

$rxn$ shifts $\leftarrow$

2. For the following reaction, $K = 51$. Determine the concentrations of all species at equilibrium for each of the following cases.

$$H_2 (g) + I_2 (g) \rightarrow 2HI(g)$$

a. 1.0 mol of HI is placed in a 2.5 L flask.

$$Q = \frac{[HI]^2}{[H_2][I_2]} = 1$$

$rxn$ is at equilibrium

$$[HI] = \frac{1.0 \text{ mol}}{2.5 \text{ L}} = 0.4 \text{ M}$$

$$I_2 \quad 0 \quad 0 \quad 0.4 \text{ M}$$

$$C \quad +x \quad +x \quad -2x$$

$$E \quad x \quad x \quad 0.4-2x$$

$$x = 0.044 \text{ M}$$

$$[H_2] = \frac{0.044 \text{ M}}{x} \quad [I_2] = \frac{0.044 \text{ M}}{x}$$

$$K = 51 = \left( \frac{0.4-2x}{x} \right)^2$$

b. 1.0 mol each of $H_2$, $I_2$ and HI are placed in a 1.00 L flask.

$$Q = \frac{[I_2]^2}{[H_2]^2} = 1$$

$rxn$ is at equilibrium

$$[HI] = 1 - 0.68 = 0.32 \text{ M}$$

$$[I_2] = 1 - 0.68 = 0.32 \text{ M}$$

$$[H_2] = 1 + 2(0.68) = 2.36 \text{ M}$$
3. At 25 °C, \( K_p = 1.89 \times 10^{-6} \) for the following reaction: \( 2 \text{NH}_3 (g) \rightarrow \text{N}_2 (g) + 3 \text{H}_2 (g) \)

If ammonia is placed into an evacuated flask at an initial pressure of 0.88 atm, calculate the total pressure at equilibrium.

\[
\frac{2 \text{NH}_3}{\text{N}_2 + 3 \text{H}_2} \quad 0.88 \text{ atm} \quad 0 \quad 0 \\
\text{C} \quad -2x \quad +x \quad +3x \\
\text{E} \quad 0.88 - 2x \quad x \quad 3x
\]

\[
K_p = 1.89 \times 10^{-6} = \frac{(x)(3x)^3}{(0.88 - 2x)^2} \approx \frac{(x)(3x)^3}{(0.88)^2}
\]

\[
x = 0.015 \text{ atm}
\]

\[
P_{\text{total}} = P_{\text{N}_2} + P_{\text{H}_2} + P_{\text{NH}_3}
\]

\[
= x + 3x + 0.88 - 2x = 0.88 + 2x = 0.88 + 2(0.015) = 0.91 \text{ atm}
\]

4. Consider the following reaction, which is endothermic: \( 2\text{SO}_3 (s) \rightarrow 2\text{SO}_2 (g) + \text{O}_2 (g) \)

How will the position of the equilibrium be shifted for each of the following changes?

a. \( \text{O}_2 \) (g) is added

b. \( \text{SO}_2 \) (g) is removed

c. \( \text{SO}_3 \) (s) is added

no change (solid)

d. The volume of the container is decreased

(less moles of gas)

e. \( \text{Ne} \) (g) is added, increasing the total pressure

no change

f. The temperature is raised

(\& \ K \ increases)

5. For the reaction below, in which direction will the equilibrium be shifted for each of the following?

\( \text{Ni}^{2+} (aq) + 4 \text{Cl}^- (aq) \rightarrow \text{NiCl}_2 (aq) \)

a. Water is added, increasing the volume

(\& \ more \ moles)

b. \( \text{NaCl} \) is added

\( \text{Cl}^- \) is removed by \( \text{rxn} \)

c. \( \text{AgNO}_3 \) is added (\( \text{AgCl} \) is insoluble)

(\& \ Ag^+ \ & \ Cl^- \rightarrow \text{AgCl(s)})