Quantitative Equilibrium Problems

1. A substance (CD) decomposes into C and D.

$$CD(g) \rightleftharpoons C(g) + D(g)$$

At the temperature of the experiment, 15.0% of CD is decomposed when equilibrium is established. (a) If the initial concentration of CD is 0.200 kmol/m^3, what are the equilibrium concentrations of CD, C, and D? (b) What is K for the reaction at this temperature?

2. A reaction may be represented by

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

At a given temperature 1.0 mol of A and 1.0 mol of B are placed in the 1.0 L reaction vessel and allowed to reach equilibrium. Analysis revealed that the equilibrium concentration of AB was 0.40 kmol/m^3. What percent of A had been converted to products?

3. Gas X_2 reacts with gas Y_2 according to the equation

$$X_2 + Y_2 \rightleftharpoons 2XY$$

0.50 mol each of X_2 and Y_2 are placed in a 1.0 L vessel and allowed to reach equilibrium at a given temperature. The equilibrium concentration of XY is found to be 0.025 kmol/m^3. What is the equilibrium constant for this reaction?

4. Given the equilibrium reaction

$$A(g) \rightleftharpoons 2B(g) + C(g)$$

when 1.00 mol of A is placed in a 4.00 L container at temperature T, the concentration of C at equilibrium is 0.050 kmol/m^3. What is the equilibrium constant for the reaction at temperature T?

5. The equilibrium constant for

$$2X(g) \rightleftharpoons Y(g) + Z(g)$$

is 3.0. What amount of X is present at equilibrium when 1.00 mol each of Y and Z are placed in a 5.00 L container?
Ans. 0.450 mol.

6. Under a given set of conditions, an equilibrium mixture

$$SO_2(g) + NO_2(g) \rightleftharpoons SO_3(g) + NO(g)$$

in a 1.00 L container was analyzed and found to contain 0.300 mol of SO_3, 0.200 mol of NO, 0.0500 mol of NO_2, and 0.400 mol of SO_2. Calculate the equilibrium constant for this reaction. **Ans. K = 3.00.**

7. At 55°C, the K for the reaction

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

is 1.15. (a) Write the equilibrium expression. (b) Calculate the concentration of $N_2O_4(g)$ present in equilibrium with 0.50 kmol/m^3 of NO_2. **Ans. 0.29 kmol/m^3.**

8. (a) Calculate the K for this reaction from the data $CO_2(g) + H_2(g) \rightleftharpoons CO(g) + H_2O(g)$ $[CO_2] = 1.17 \times 10^{-3}$ kmol/m^3, $[H_2] = 1.17 \times 10^{-3}$ kmol/m^3, $[CO] = 1.33 \times 10^{-3}$ kmol/m^3, $[H_2O] = 1.33 \times 10^{-3}$ kmol/m^3.
Ans. 1.29.

9. One mole of NH_3 was injected into a 1 L flask at a certain temperature. The equilibrium mixture

$$2NH_3 \rightleftharpoons N_2 + 3H_2$$

was then analyzed and found to contain 0.300 mol of H_2. (a) Calculate the concentration of N_2 at equilibrium. (b) Calculate the concentration of NH_3 at equilibrium. (c) Calculate the equilibrium constant for this system at this temperature and pressure. (d) Which way would the equilibrium be shifted if 0.600 mol of $H_2(g)$ were injected into the flask? (e) How would the injection of hydrogen into the flask affect the equilibrium constant? (f) How would the equilibrium constant be affected if the pressure of this system were suddenly increased?

Ans. (a) 0.100 kmol of N_2/m^3, (b) 0.800 kmol of NH_3/m^3, (c) 0.0042, (d) favoring the formation of NH_3, (e) no effect, (f) unchanged.

10. When 0.5 mol of CO_2 and 0.5 mol of H_2 were forced into a 1 L reaction container, and equilibrium was established:

$$CO_2(g) + H_2(g) \rightleftharpoons H_2O(g) + CO(g)$$

Under the conditions of the experiment, K = 2.00. (a) Find the equilibrium concentration of each reactant and product. (b) How would the equilibrium concentrations differ if 0.50 mol of H_2O and 0.50 mol of CO had been introduced into the reaction vessel instead of the CO_2 and H_2?

11. An equilibrium mixture

$$H_2(g) + CO_2(g) \rightleftharpoons H_2O(g) + CO(g)$$

in a 10.00 L container at a certain temperature was analyzed and found to contain $H_2(g)$ = 1.17 mol, $CO_2(g)$ = 1.17 mol, $H_2O(g)$ = 1.33 mol, and $CO(g)$ = 1.33 mol. (a) Calculate the equilibrium constant. (b) How would equilibrium quantity (moles) of H_2O be affected by an increase in the total volume of the system? (c) How would equilibrium concentration of water be affected by the increase in total volume? (d) How would the equilibrium constant be affected by an increase in total volume? (e) How many moles of water vapor would have to be injected into the original equilibrium mixture to increase the H_2 concentration to 0.150 kmol/m^3.

Answers 1b) $K_{eq} = 5.29 \times 10^{-3}$ 3. $K_{eq} = 2.63 \times 10^{-3}$ 5. 0.448 mol 7. $[N_2O_4] = 0.288$ M

2. 40% 4. $K_{eq} = 2.5 \times 10^{-3}$ 6. $K_{eq} = 3$ 8. K_{eq} 1.29