Exercise 18.1a

Equilibrium Expressions

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The equilibrium constant (*K*) is the ratio of the equilibrium concentration (or pressure) of product(s) to the equilibrium concentration (or pressure) of reactant(s). The same expression can be used to calculate the reaction quotient, (*Q*):

$$2\,NO_{2\,(g)} + 7\,H_{2\,(g)} \rightleftharpoons 2\,NH_{3\,(g)} + 4\,H_2O_{\,(l)}$$

$$K_C = \frac{[NH_3]^2_{eq}}{[NO_2]^2_{eq}[H_2]^7_{eq}} \quad (at\ equilibrium) \quad ; \quad Q = \frac{[NH_3]^2}{[NO_2]^2[H_2]^7} \quad (at\ any\ moment/point)$$

The coefficients from the balanced equation become exponents. Liquids and solids never appear in the expressions, because their concentrations (or pressures) do not change throughout the reaction.

DIRECTIONS: Answer the following in the space provided.

1. Write the expressions for the equilibrium constants K_{eq} for each of the following reversible reactions.

   a. $H_2O(g) + CO(g) \rightleftarrows CO_2(g) + H_2(g)$

   b. $N_2(g) + H_2(g) \rightleftarrows NH_3(g)$

   c. $NH_3(g) + O_2(g) \rightleftarrows NO(g) + H_2O(l)$

2. Determine the equilibrium constant (K_{eq}) for the following reaction if the equilibrium concentrations of $[N_2O_4] = 0.00150$ and $[NO_2] = 0.571$. *Write the equilibrium expression, then substitute the values.*

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

3. For the reaction $2SO_2(g) + O_2(g) \rightleftarrows 2SO_3(g)$, the equilibrium concentrations of the sulfur oxides are $[SO_2] = 2.00$ and $[SO_3] = 10.0$. What is the concentration of oxygen when the $K_{eq} = 800.0$ for the reaction?

4. Nitrogen and hydrogen react together in a 4.00 liter container at 450°C. At equilibrium, $[N_2] = 0.130$, $[H_2] = 0.220$, and $[NH_3] = 0.650$. Calculate the equilibrium constant (K_{eq}) for this reaction.

Answers: 2) 217 3) 0.0312 *M* 4) 305 5) 4.68 6a) 0.133 6b) 641000 7) 34.4, forward

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5. For the reaction, $NO_2(g) \rightleftarrows N_2O_4(g)$, the equilibrium concentrations are: $[NO_2] = 3.1 \times 10^{-2}$ and $[N_2O_4] = 4.5 \times 10^{-3}$. From this data, calculate K_{eq} for the reaction at this temperature.

6. Write the equilibrium expression for each equation then calculate the value of the equilibrium constant (K_{eq}). In each case, the concentrations listed are in the order of compounds in the equation.
   a. $PCl_3(g) + Cl_2(g) \rightleftarrows PCl_5(g)$ (1.00 M, 0.900 M, 0.120 M at room temperature)

   b. $NO(g) + O_2(g) \rightleftarrows NO_2(g)$ (3.49×10^{-4} M, 0.800 M, 0.250 M at 500K)

7. At 448°C, $K_{eq} = 50.5$ for the reaction $H_2(g) + I_2(g) \rightleftarrows HI$ (g). Find Q and predict how the reaction proceeds if $[H_2] = 0.150M$, $[I_2] = 0.175M$, and $[HI] = 0.950M$.

Answers: 2) 217 3) 0.0312 *M* 4) 305 5) 4.68 6a) 0.133 6b) 641000 7) 34.4, forward