Chemistry H

Exercise 18.1a(H)

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*):

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

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

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

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

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

   d. __SO3 (g) ⇌ __SO2 (g) + __O2 (g)

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.*

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

3. For the reaction $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$, 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.

5. For the reaction, $NO_2(g) \rightleftharpoons N_2O_4(g)$, 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. $PCl_3(g) + Cl_2(g) \rightleftharpoons PCl_5(g)$ (1.00 M, 0.900 M, 0.120 M at room temperature)
   b. $NO(g) + O_2(g) \rightleftharpoons NO_2(g)$ (3.49×10^{-4} M, 0.800 M, 0.250 M at 500K)

Answers: 2) 217 3) 0.0313 *M* 4) 305 5) 4.68 6a) 0.133 6b) 641000 7) 34.4, forward 8) 1.70×10^{-3} *M* 9) 0.65, forward 10) 290. equilibrium 11) 3.11×10^{-14}, reverse 12) 1.89×10^{-4}, forward 13) 9.63×10^{-60}, reverse

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

8. Nitrogen and oxygen react according to the following reaction. K_{eq} for the reaction is 1.2 x 10^{-4}. At equilibrium, the concentrations of N_2 and O_2 are 0.166M and 0.145M respectively. What is the concentration of NO?

$$N_2(g) + O_2(g) \rightleftharpoons 2NO(g)$$

9. For the gaseous reaction, $2H_2 + 2NO \rightleftarrows 2H_2O + N_2$, K_p at 120°C = 2.42. At a given moment, it is found that the partial pressures of H_2, NO, H_2O and N_2 are 1.1, 1.3, 0.78 and 2.2 atm, respectively. Calculate the value of Q_p and determine the direction of the reaction, if not at equilibrium.

10. At 430ºC, the K_{eq} = 290. for the reaction $CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g)$. At a certain point in time, the concentrations of the components were measured at [CO] = 0.250 *M*, $[H_2]$ = 0.250 *M*, and $[CH_3OH]$ = 4.53 *M*. Calculate the reaction quotient Q. Predict in what direction the reaction will proceed, if it is not at equilibrium.

11. For the reaction $2CO(g) \rightleftharpoons C(s) + CO_2(g)$, K_{eq} = 7.7 x 10^{-15}. At a particular time, the following concentrations are measured: [CO] = 0.034*M*, $[CO_2]$ = 3.6 x 10^{-17}*M*. Has this reaction reached equilibrium? If not, in which direction will the reaction proceed?

12. At a certain point in time a system described by the equation $PCl_3\ (g) + Cl_2\ (g) \rightleftharpoons PCl_5\ (g)$ contains the following concentrations of substances: 9.4 x 10^{-3} *M* PCl_3, 6.2 x 10^{-2} *M* Cl_2, and 1.1 x 10^{-7} *M* PCl_5. Calculate the reaction quotient for the system at that time. K_{eq} = 25. Is the system at equilibrium? In what direction will it proceed to reach equilibrium?

13. K_{eq} for the reaction $2\ H_2O\ (g) \rightleftharpoons 2\ H_2\ (g) + O_2\ (g)$ is 2.9 x 10^{-82}. What does the value of K_{eq} reveal about the reaction? Suppose a container holds 1.55 *M* H_2O (*g*), 7.00 x 10^{-23} *M* H_2 (*g*), and 4.72 x 10^{-15} *M* O_2 (*g*). Is the system at equilibrium? If not, in what direction will the reaction proceed?

Answers: 2) 217 3) 0.0313 *M* 4) 305 5) 4.68 6a) 0.133 6b) 641000 7) 34.4, forward 8) 1.70 x 10^{-3} *M* 9) 0.65, forward 10) 290. equilibrium 11) 3.11 x 10^{-14}, reverse 12) 1.89 x 10^{-4}, forward 13) 9.63 x 10^{-60}, reverse