Equilibrium
7.4 Calculating the Equilibrium Constant
7.5 Magnitude of the Equilibrium Constant
7.6 Properties of the Equilibrium Constant

1) The equilibrium concentrations for the reaction below were found to be $[AgNO_3] = 0.0070\ M$, and $[Cu(NO_3)_2] = 0.48\ M$ at a certain temperature.

$$2\ AgNO_3(aq) + Cu(s) \rightleftharpoons Cu(NO_3)_2(aq) + 2\ Ag(s)$$

Find the equilibrium constant, K_c, for the reaction.

$$K_c = \frac{[Cu^{2+}]}{[Ag^+]^2} = \frac{(0.48M)}{(0.0070M)^2} = 9.8 \times 10^3$$

2) The equilibrium concentrations for the reaction below were found to be $[N_2] = 0.13\ M$, $[H_2] = 7.9\text{x}10^2\ M$, and $[NH_3] = 1.6\ M$ at a certain temperature. Find the equilibrium constant, K_c, at this temperature.

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

$$K_c = \frac{[NH_3]^2}{[N_2][H_2]^3} = \frac{(1.6)^2}{(0.13)(7.9 \times 10^2)^3} = 4.0 \times 10^{-8}$$

3) The equilibrium constant, K_c, for the reaction below is 0.10 at 25°C.

$$2\ ICl(g) \rightleftharpoons Cl_2(g) + I_2(g)$$

Find the equilibrium concentration of chlorine gas, $Cl_2(g)$, if the equilibrium concentrations of $ICl(g)$ and $I_2(g)$ are known to be 0.50 M and 0.40 M respectively.

$$K_c = \frac{[Cl_2][I_2]}{[ICl]^2}$$

$$[Cl_2] = \frac{K_c \times [ICl]^2}{[I_2]} = \frac{0.10 \times (0.50M)^2}{(0.40M)} = 0.063M = 6.3 \times 10^{-2} M$$

4) The equilibrium partial pressures for the reaction bellow are $P(CO) = 0.598$ atm and $P(CO_2) = 0.159$ atm at 1080 K.

$$CO_2(g) + C(graphite) \rightleftharpoons 2\ CO(g)$$

Find the value of the equilibrium constant, K_p.

$$K_p = \frac{{P_{CO}}^2}{P_{CO_2}} = \frac{(0.598)^2}{(0.159)} = 2.25$$

5) The equilibrium partial pressures for the reaction bellow are $P(PCl_3)$ = 0.12 atm, $P(Cl_2)$ = 0.16 atm and $P(PCl_5)$ = 1.30 atm at 455 K. Find the value of the equilibrium constant, K_p.

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

$$K_p = \frac{P_{Cl_5}}{(P_{Cl_2})(P_{PCl_3})} = \frac{(1.30)}{(0.16)(0.12)} = 68$$

6) The equilibrium partial pressures for the reaction bellow are $P(CO)$ = 1.31 atm, $P(H_2O)$ = 10.00 atm, $P(CO_2)$ = 6.10 atm, and $P(H_2)$ = 20.5 atm at 700 K. Find the value of the equilibrium constant, K_p.

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

$$K_p = \frac{(P_{CO_2})(P_{H_2})}{(P_{CO})(P_{H_2O})} = \frac{(6.10)(20.5)}{(1.31)(10.00)} = 9.55$$

7) When each of the following processes reach equilibrium, does the system in question contain mostly reactants, mostly products, or fairly equal concentrations of both reactants and products? Justify your answers.

a. $2\ H_2(g) + O_2(g) \rightleftharpoons 2\ H_2O(g)$ $\quad K_c = 9.1 \times 10^{80}$ at 25°C

The system contains mostly products. $K_c = \frac{[H_2O]^2}{[H_2]^2[O_2]}$ Because the value for K_c is much greater than 1, the numerator in the equilibrium expression must be much larger than the denominator. This means that the system contains more products than it does reactants. In this case, K_c is extremely large. Extremely large K_c values tell us that the system contains virtually all products when it reaches equilibrium.

b. $H_2(g) + Br_2(g) \rightleftharpoons 2HBr(g)$ $\quad K_c = 1.4 \times 10^{-21}$ at 25°C

The system contains mostly reactants. $K_c = \frac{[HBr]^2}{[H_2][Br_2]}$ Because the value for K_c is much less than 1, the numerator in the equilibrium expression must be much smaller than the denominator. This means that the system contains more reactants than it does products. In this case, K_c is extremely small. Extremely small K_c values tell us that the system contains virtually all reactants when it reaches equilibrium.

8) The equilibrium constant, K_c, for the following reaction is 6.44×10^5 at 230°C.

$$2\ NO(g) + O_2(g) \rightleftharpoons 2\ NO_2(g)$$

a. Calculate the equilibrium constant, K_c, for the reaction below at 230°C.

$$NO(g) + \tfrac{1}{2}\ O_2(g) \rightleftharpoons NO_2(g)$$

$$K_c^a = (K_c)^{1/2} = (6.44 \times 10^5)^{1/2} = 802$$

b. Calculate the equilibrium constant, K_c, for the reaction below at 230°C.

$$2\ NO_2(g) \rightleftharpoons 2\ NO(g) + O_2(g)$$

$K_c^b = 1/(K_c) = 1/(6.44 \times 10^5) = 1.55 \times 10^{-6}$

c. Calculate the equilibrium constant, K_c, for the reaction below at 230°C.

$$NO_2(g) \rightleftharpoons NO(g) + \tfrac{1}{2}\ O_2(g)$$

$K_c^c = 1/(K_c^a) = 1/(802) = 1.25 \times 10^{-3}$ or, $K_c^c = (K_c^b)^{1/2} = (1.55\text{x}10^{-6})^{1/2} = 1.24 \times 10^{-3}$

9) The equilibrium constant, K_p, for the following reaction is 1.3×10^{14} at 850°C.

$$C(s) + CO_2(g) \rightleftharpoons 2\ CO(g)$$

a. Calculate the equilibrium constant, K_p, for the reaction below at 850°C.

$$2\ C(s) + 2\ CO_2(g) \rightleftharpoons 4\ CO(g)$$

$K_p^a = (K_p)^2 = (1.3 \times 10^{14})^2 = 1.7 \times 10^{28}$

b. Calculate the equilibrium constant, K_p, for the reaction below at 850°C.

$$2\ CO(g) \rightleftharpoons C(s) + CO_2(g)$$

$K_p^b = 1/(K_p) = 1/(1.3 \times 10^{14}) = 7.7 \times 10^{-15}$

c. If the equilibrium constant, K_p, is 167 for $COCl_2(g) \rightleftharpoons CO(g) + Cl_2(g)$ at 850°C, find K_p for $COCl_{2(g)} \rightleftharpoons Cl_2(g) + \tfrac{1}{2}\ CO_2(g) + \tfrac{1}{2}\ C(s)$ at 850°C.

$COCl_2(g) \rightleftharpoons CO(g) + Cl_2(g)$	$K_p = 167$
$CO(g) \rightleftharpoons \tfrac{1}{2}\ C(s) + \tfrac{1}{2}\ CO_2(g)$	$K_p = (K_p^b)^{1/2} = (7.7 \times 10^{-15})^{1/2} = 8.8 \times 10^{-8}$
$COCl_2(g) \rightleftharpoons Cl_2(g) + \tfrac{1}{2}\ CO_2(g) + \tfrac{1}{2}\ C(s)$.	$K_p^c = (167)(8.8 \times 10^{-8})$ $K_p^c = 1.5 \times 10^{-5}$

10) The equilibrium constant, K_c^i, is 3.2×10^{-34} for $2HCl(g) \rightleftharpoons H_2(g) + Cl_2(g)$ at 25°C. The equilibrium constant, K_c^{ii}, is 0.10 for $2\ ICl(g) \rightleftharpoons Cl_2(g) + I_2(g)$ at 25°C.

a. Calculate the equilibrium constant, K_c, for the reaction below at 25°C.

$$Cl_2(g) + I_2(g) \rightleftharpoons 2\ ICl(g)$$

$K_c^a = 1/(K_c^{ii}) = 1/(0.10) = 10$

b. Calculate the equilibrium constant, K_c, for the reaction below at 25°C.

$$2\ HCl(g) + I_2(g) \rightleftharpoons 2\ ICl(g) + H_2(g)$$

$2\ HCl(g) \rightleftharpoons H_2(g) + Cl_2(g)$	$K_c^{i}, = 3.2 \times 10^{-34}$
$Cl_2(g) + I_2(g) \rightleftharpoons 2\ ICl(g)$	$K_c^{a} = 10$
$2\ HCl(g) + I_2(g) \rightleftharpoons 2\ ICl(g) + H_2(g)$	$K_c^{b} = (K_c^{i})(K_c^{a}) = (3.2 \times 10^{-34})(10)$ $K_c^{b} = 3.2 \times 10^{-33}$

c. Calculate the equilibrium constant, K_c, for the reaction below at 25°C.

$$HCl(g) + \tfrac{1}{2}\ I_2(g) \rightleftharpoons ICl(g) + \tfrac{1}{2}\ H_2(g)$$

$$K_c^{c} = (K_c^{b})^{1/2} = (3.2 \times 10^{-33})^{1/2} = 5.7 \times 10^{-17}$$

d. Calculate the equilibrium constant, K_c, for the reaction below at 25°C.

$$6\ HCl(g) + 3\ I_2(g) \rightleftharpoons 6\ ICl(g) + 3\ H_2(g)$$

$$K_c^{d} = (K_c^{b})^{3} = (3.2 \times 10^{-33})^{3} = 3.3 \times 10^{-98}$$