Equilibrium Constant
- Practice Problems for Assignment 5

1. Consider the following reaction

   $$2\ SO_2\ (g) + O_2\ (g) \rightleftharpoons 2\ SO_3\ (g)$$

   Write the equilibrium expression, K_c.

2. Consider the following reaction

   $$CaCO_3\ (s) \rightleftharpoons CaO\ (s) + O_2\ (g)$$

   Write the equilibrium expression, K_c.

3. Consider the following reaction

   $$2\ SO_2\ (g) + O_2\ (g) \rightleftharpoons 2\ SO_3\ (g)$$

   Write the equilibrium expression, K_p.

4. Consider the following reaction

   $$H_2O\ (g) + C\ (s) \rightleftharpoons H_2\ (g) + CO\ (g)$$

   Write the equilibrium expression, K_p.

5. Consider the decomposition of nitrous oxide, laughing gas,

   $$2N_2O\ (g) \rightleftharpoons 2\ N_2\ (g) + O_2\ (g)$$

   At 25°C, K_c is 7.3×10^{34}.

   (a) Based on the information given, what can you say about the rate of decomposition of the reaction?
   (b) Based on the information given, does nitrous oxide have a tendency to decompose into nitrogen and oxygen?
   (c) What is the value of K_p for the reaction at 25°C?

6. Consider the following reaction

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

   Calculate the value of the equilibrium constant, K_c , for the above system, if 0.1908 moles of CO_2, 0.0908 moles of H_2, 0.0092 moles of CO, and 0.0092 moles of H_2O vapour were present in a 2.00 L reaction vessel at equilibrium.

7. Consider the following reaction

$$C_2H_4\ (g) + H_2\ (g) \rightleftharpoons C_2H_6\ (g) \qquad K_c = 0.99$$

What is the concentration for each substance at equilibrium if the initial concentration of ethene, C_2H_4 (g) , is 0.335 M and that of hydrogen is 0.526 M?

8. Consider the following reaction

$$2\ NO\ (g) + 2\ H_2\ (g) \rightleftharpoons N_2\ (g) + 2\ H_2O\ (g)$$

Determine the value of the equilibrium constant, K_c, for the reaction. Initially, a mixture of 0.100 M NO, 0.050 M H_2, 0.100 M H_2O was allowed to reach equilibrium (initially there was no N_2). At equilibrium the concentration of NO was found to be 0.062 M.

9. Consider the following reaction

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

A reaction flask is charged with 3.00 atm of dinitrogen tetroxide gas and 2.00 atm of nitrogen dioxide gas. At 25^{o}C, the gases are allowed to reach equilibrium. The pressure of the nitrogen dioxide was found to have decreased by 0.952 atm. Estimate the value of K_p for this system.

10. Consider the following reaction. The initial concentrations are $[HSO_4^-]$ = 0.50 M, $[H_3O^+]$ = 0.020 M, $[SO_4^{2-}]$ = 0.060 M.

$$HSO_4^-\ (aq) + H_2O\ (l) \rightleftharpoons H_3O^+\ (aq) + SO_4^{2-}\ (aq) \qquad K = 0.012$$

(a) Which way would the reaction shift to reach equilibrium?
(b) What are the equilibrium concentrations of the products and reactants.

Answers:

1. $K_c = \dfrac{[SO_3]^2}{[SO_2]^2[O_2]}$

2. $K_c = [O_2]$

3. $K_p = \dfrac{{p_{SO_3}}^2}{{p_{SO_2}}^2 p_{O_2}}$

4. $K_p = \dfrac{p_{H_2} p_{CO}}{p_{H_2O}}$

5. (a) Based on the information given, you cannot predict the rate of decomposition of nitrous oxide.
   (b) From the value of the K_{eq}, nitrous oxide has a strong tendency to decompose into nitrogen and oxygen.
   (c) $K_p = 1.8 \times 10^{36}$

6. $[CO_2] = 0.1908$ mol CO_2/2.00 L = 0.0954 M
   $[H_2] = 0.0454$ M
   $[CO] = 0.0046$ M
   $[H_2O] = 0.0046$ M

   $K = \dfrac{(0.0046)(0.0046)}{(0.0954)(0.0454)} = 0.0049 \text{ or } 4.9 \times 10^{-3}$

7.

	C_2H_4	H_2	C_2H_6
[I]	0.335	0.526	0
[C]	-x	-x	+x
[E]	0.335 -x	0.526 -x	+x

$K = \dfrac{x}{(0.335 - x)(0.526 - x)}$ = 0.0995 or ~~1.77~~*

* x=1.77 is not possible because the concentration of C_2H_4 will result in a negative value.

$[C_2H_4] = 0.236$ M
$[H_2] = 0.526 - x = 0.526 - 0.0995 = 0.427$ M
$[C_2H_6] = 0.0995$ M

8.

	NO	H_2	N_2	H_2O
[I]	0.100	0.0500	0	0.100
[C]	-2x	-2x	+x	+2x
[E]	0.062			
From ICE table	2x = 0.038			

Therefore, substitute for x and calculate [E] for each species:

	NO	H_2	N_2	H_2O
[I]	0.100	0.0500	0	0.100
[C]	- 0.038	- 0.038	+0.019	+0.038
[E]	0.062	0.012	0.019	0.138

$$K = \frac{(0.019)(0.138)^2}{(0.062)^2(0.012)^2} = 6.5 \times 10^2$$

9.

	N_2O_4	NO_2
[I]	3.00	2.00
[C]	+x	-2x = - 0.952
[E]		
From ICE table	x = 0.952/2	

Therefore, substitute for x and calculate [E] for each species:

	N_2O_4	NO_2
[I]	3.00	2.00
[C]	+0.476	-0.952
[E]	3.476	1.048

$$K = \frac{(1.048)^2}{(3.476)} = 0.316$$

10. (a) Use the trial K_{eq} , Q, to determine the reaction direction.

$$Q = \frac{(0.020)(0.060)}{(0.50)} = 0.0024$$

$Q < K_{eq}$, therefore, equilibrium will shift to the right to produce more products.

(b)

	HSO_4^-	H_3O^+	SO_4^{2-}
[I]	0.50	0.020	0.060
[C]	-x	+x	+x
[E]	0.50 -x	0.020+x	0.060+x

$$K = \frac{(0.020 + x)(0.060 + x)}{(0.050 - x)}$$

To solve, need to use the quadratic equation

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

x = 0.0372 or ~~-0.129~~ *

For x = 0.0372,
$[HSO_4^-]$ = 0.46 M; $[H_3O^+]$ = 0.057 M; $[SO_4^{2-}]$ = 0.097 M

* For x = -0.129,
$[HSO_4^-]$ = 0.63 M; $[H_3O^+]$ = -0.109 M; $[SO_4^{2-}]$ = -0.069 M
it yields negative concentrations.

Therefore, the correct equilibrium concentrations are:
$[HSO_4^-]$ = 0.46 M; $[H_3O^+]$ = 0.057 M; $[SO_4^{2-}]$ = 0.097 M