Chemistry 30

Chemical Equilibrium 50

I. Multiple Choice 15

1. B	6. B	11. C
2. D	7. B	12. B
3. C	8. B	13. C
4. A	9. A	14. C
5. A	10. A	15. A

II. Short Answer 35

1. Write the equilibrium constant expression for the following equilibrium. Be sure to pay attention to the physical state.

a. $3\ O_{2(g)} \rightleftharpoons 2\ O_{3(g)}$ $K_{eq} = \dfrac{[O_3]^2}{[O_2]^3}$

b. $2\ NO_{(g)} + Cl_{2(g)} \rightleftharpoons 2\ NOCl_{(g)}$ $K_{eq} = \dfrac{[NOCl]^2}{[NO]^2[Cl_2]}$

c. $CaCO_{3\,(s)} \rightleftharpoons CaO_{(s)} + CO_{2(g)}$ $K_{eq} = [CO_2]$

2. For systems involving gases, the equilibrium constant is often determined by using partial pressure instead of concentration. Given the following reaction at equilibrium at the partial pressures of the participants,

$H_{2(g)} + I_{2(g)} \rightleftharpoons 2\ HI_{(g)}$ Partial Pressures: $P_{HI} = 4 \times 10^{-3}$ atm

$P_{H2} = 7.5 \times 10^{-3}$ atm

$P_{I2} = 4.3 \times 10^{-5}$ atm

a. Calculate K_{eq} for this reaction, carried out at a constant temperature. Begin by writing the equilibrium constant expression for the reaction. Show your work. **3**

$$K_{eq} = \frac{[HI]^2}{[H_2][I_2]} = \frac{(4\times10^{-3})^2}{(7.5\times10^{-3})(4.3\times10^{-5})} = 49.6$$

b. Are the reactants (H_2 and I_2) or products (HI) favored at equilibrium at this temperature? **2**

How do you know?

Products are favored; $K_{eq} > 1$

3. For the equilibrium system at a certain temperature, described by the equation

$PCl_{3(g)} + Cl_{2(g)} \rightleftharpoons PCl_{5(g)}$

$K_{eq} = 60$ $[PCl_3] = 0.2$ M $[Cl_2] = 0.1$ M

a. Calculate the equilibrium concentration of PCl_5. **3**

$$K_{eq} = \frac{[PCl_5]}{[PCl_3][Cl_2]} \qquad 60 = \frac{x}{(0.2)(0.1)} \qquad x = [PCl_5] = 1.2\ \text{M}$$

b. Are reactants or products favored at equilibrium for this system? **1**

products are favored; $K_{eq} = 60$ is greater than 1

4. Each of the following systems has come to equilibrium. The systems are then subjected to the changes indicated.

   Tell how the concentrations of the following substances will change as a result of the stress – will their concentrations **increase**, **decrease**, or undergo **no change** when the indicated change is made: **5**

   a. $Cu^{2+}_{(aq)} + 4\ NH_{3(g)} \rightleftharpoons Cu(NH_3)_4{}^{2+}_{(aq)}$ More Cu^{2+} is added

      $[NH_3]$ will **decrease**

      $[Cu(NH_3)_4{}^{2+}]$ will **increase**

   b. $CO_{(g)} + ½\ O_{2(g)} \rightleftharpoons CO_{2(g)}$ + energy The system is put on ice

      $[CO]$ will **decrease**

      $[O_2]$ will **decrease**

      $[CO_2]$ will **increase**

5. For the reaction $PBr_{3(g)} + Br_{2(g)} \rightleftharpoons PBr_{5(g)}$ + heat **3**

   How will the reaction shift (**forward**; **reverse**; **no change**) if:

   a. the pressure is increased **forward**

   b. concentration of Br_2 is decreased **reverse**

   c. temperature is increased **reverse**

6. The following system is allowed to reach equilibrium:

$$CO_{(g)} + 2\ H_{2(g)} \rightleftharpoons CH_3OH_{(g)}$$

   At a given temperature, K_{eq} for the reaction = 12, and the following concentrations are noted:

   $[CO] = 0.02$ M $[H_2] = 0.35$ M $[CH_3OH] = ???$

   Calculate the concentration of CH_3OH at equilibrium. Begin by writing the equilibrium constant expression.

$$K_{eq} = \frac{[CH_3OH]}{[CO][H_2]^2} \qquad 12 = \frac{x}{(0.02)(0.35)^2} \qquad x = [CH_3OH] = 2.94\times10^{-2}\ \text{M}$$

3

7. Consider the following system at equilibrium:

$2\ NaOH_{(aq)} + CaCO_{3\,(aq)} \rightleftharpoons Na_2CO_{3\,(aq)} + Ca(OH)_{2\,(s)} + energy$

a. Write the equilibrium constant expression for this reaction. **1**

$$K_{eq} = \frac{[Na_2CO_3]}{[NaOH]^2[CaCO_3]}$$

b. Predict the effect of increasing the concentration of NaOH to the system: **4**

Select the appropriate answer in each case

The reaction will shift to the (right / left)	**right**
$[CaCO_3]$ will (increase / decrease / no change)	**decrease**
$[Na_2CO_3]$ will (increase / decrease / no change)	**increase**
The value of K_{eq} will (increase / decrease / not change)	**not change**

c. What will happen to the system if the temperature of the system is increased and the volume is kept constant? **4**

The reaction will shift to the (right / left)	**left**
$[CaCO_3]$ will (increase / decrease / no change)	**increase**
$[Na_2CO_3]$ will (increase / decrease / no change)	**decrease**
The value of K_{eq} will (increase / decrease / no change)	**decrease**

8. A flask is filled with some $HI_{(g)}$ and allowed to reach equilibrium.

$$2\ HI_{(g)} \rightleftharpoons H_{2(g)} + I_{2(g)} \qquad K_{eq} = 0.25$$

At equilibrium the concentration of [HI] = 0.80 M. What is the concentration of H_2 at equilibrium?

[Hint: you will also be finding $[I_2]$ – consider how $[H_2]$ and $[I_2]$ compare to each other] **3**

$$K_{eq} = \frac{[HI]^2}{[H_2][I_2]} \qquad 0.25 = \frac{x^2}{(0.8)^2} = \frac{x^2}{0.64} \qquad x^2 = 0.16$$

$$x = [H_2] = 0.4\ M$$