Practice Questions Section 2.2

The Equilibrium Constant

1. Write balanced chemical equations for each of the following. Pay close attention to the physical states!

   Also - you must include the charge when writing ions, otherwise your answer is incorrect.

   Do not balance these equations using fractions for coefficients.

   sulfur dioxide gas combines with oxygen gas to produce sulfur trioxide gas

   carbon monoxide gas burns in gaseous oxygen to produce carbon dioxide gas

   hydrogen chloride gas is produced from hydrogen gas and chlorine gas.

   nitrogen gas and oxygen gas combine to produce gaseous dinitrogen oxide.

   solid hydrogen cyanide dissolves to produce hydrogen ions and cyanide ions in solution.

   solid silver chloride dissolves to produce silver ions and chloride ions in solution.

   calcium ions and phosphate ions come out of solution to produce solid calcium phosphate.

2. For each of the above reactions, write the equilibrium expression, Keq, for the reaction. Remember not to include solids or liquids in the equilibrium constant expression.

3. The equilibrium equation for the formation of ammonia is

   $N_{2\,(g)} + 3\ H_{2\,(g)} \leftrightarrow 2\ NH_{3\,(g)}$

   At 200°C the concentrations of nitrogen, hydrogen, and ammonia at equilibrium are measured and found to be:

   $[N_2] = 2.12$ $[H_2] = 1.75$ $[NH_3] = 84.3$

   Calculate K_{eq} at this temperature.

4. For each of the following equilibrium systems, identify whether the reactants or products are favored at equilibrium, or whether they are equally favored.

$COCl_{2\,(g)} \leftrightarrow CO_{(g)} + Cl_{2\,(g)}$	$K_{eq} = 8.2\times 10^{-2}$ at 627°C
$C_{(s)} + 2\ H_{2\,(g)} \leftrightarrow CH_{4\,(g)}$	$K_{eq} = 8.1\times 10^{8}$ at 25°
$PCl_{5\,(g)} \leftrightarrow PCl_{3\,(g)} + Cl_{2\,(g)}$	$K_{eq} = 2.24$ at 227°C
$H_{2\,(g)} + Cl_{2\,(g)} \leftrightarrow 2\ HCl_{(g)}$	$K_{eq} = 1.8 \times 10^{33}$ at 25°C
$C_{(s)} + H_2O_{\,(g)} \leftrightarrow CO_{(g)} + H_{2\,(g)}$	$K_{eq} = 1.96$ at 1000°C
$Mg(OH)_{2\,(s)} \leftrightarrow Mg^{2+}_{(aq)} + 2\ OH^{-}_{(aq)}$	$K_{eq} = 1.2\times 10^{-11}$ at 25°C

5. For the reaction: carbon monoxide burns in oxygen to produce carbon dioxide

   You are given the following equilibrium conditions:

   $[O_2] = 1.30 \times 10^{-3}$ $[CO_2] = 2.50 \times 10^{-4}$ $K_{eq} = 3.60 \times 10^{-3}$

   Calculate [CO]

Practice Questions Section 2.2

The Equilibrium Constant Answers

1. Write balanced chemical equations for each of the following. Pay close attention to the physical states!

   Also - you must include the charge when writing ions, otherwise your answer is incorrect.

   Do not balance these equations using fractions for coefficients.

   sulfur dioxide gas combines with oxygen gas to produce sulfur trioxide gas

   $2\ SO_{2\,(g)} + O_{2\,(g)} \leftrightarrow 2\ SO_{3\,(g)}$

   carbon monoxide gas burns in gaseous oxygen to produce carbon dioxide gas

   $2\ CO_{\,(g)} + O_{2\,(g)} \leftrightarrow 2\ CO_{2\,(g)}$

   hydrogen chloride gas is produced from hydrogen gas and chlorine gas.

   $H_{2\,(g)} + Cl_{2\,(g)} \leftrightarrow 2\ HCl_{\,(g)}$

   nitrogen gas and oxygen gas combine to produce gaseous dinitrogen oxide.

   $2\ N_{2\,(g)} + O_{2\,(g)} \leftrightarrow 2\ N_2O_{\,(g)}$

   solid hydrogen cyanide dissolves to produce hydrogen ions and cyanide ions in solution.

   $HCN(s) \leftrightarrow H^{+}_{(aq)} + CN^{-}_{(aq)}$

   solid silver chloride dissolves to produce silver ions and chloride ions in solution.

   $AgCl_{(s)} \leftrightarrow Ag^{+}_{(aq)} + Cl^{-}_{(aq)}$

   calcium ions and phosphate ions come out of solution to produce solid calcium phosphate.

   $3\ Ca^{2+}_{(aq)} + 2\ PO_4^{3-}{}_{(aq)} \leftrightarrow Ca_3(PO_4)_{2\,(s)}$

2. For each of the above reactions, write the equilibrium expression, Keq, for the reaction. Remember not to include solids or liquids in the equilibrium constant expression.

   $2\ SO_{2\,(g)} + O_{2\,(g)} \leftrightarrow 2\ SO_{3\,(g)}$ $\qquad K_{eq} = \dfrac{[SO_3]^2}{[SO_2]^2[O_2]}$

   $2\ CO_{\,(g)} + O_{2\,(g)} \leftrightarrow 2\ CO_{2\,(g)}$ $\qquad K_{eq} = \dfrac{[CO_2]^2}{[CO\ ]^2[O_2]}$

   $H_{2\,(g)} + Cl_{2\,(g)} \leftrightarrow 2\ HCl_{\,(g)}$ $\qquad K_{eq} = \dfrac{[HCl]}{[H_2]\ [Cl_2]}$

   $2\ N_{2\,(g)} + O_{2\,(g)} \leftrightarrow 2\ N_2O_{\,(g)}$ $\qquad K_{eq} = \dfrac{[N_2O]^2}{[N_2]^2[O_2]}$

$HCN(s) \leftrightarrow H^+_{(aq)} + CN^-_{(aq)}$ $K_{eq} = [H^+][CN^-]$

$AgCl_{(s)} \leftrightarrow Ag^+_{(aq)} + Cl^-_{(aq)}$ $K_{eq} = [Ag^+][Cl^-]$

$3\ Ca^{2+}_{(aq)} + 2\ PO_4^{3-}_{(aq)} \leftrightarrow Ca_3(PO_4)_{2\ (s)}$ $K_{eq} = \dfrac{1}{[Ca^{2+}]^3[PO_4^{3-}]^2}$

3. The equilibrium equation for the formation of ammonia is

$N_{2\ (g)} + 3\ H_{2\ (g)} \leftrightarrow 2\ NH_{3\ (g)}$

At 200°C the concentrations of nitrogen, hydrogen, and ammonia at equilibrium are measured and found to be:

$[N_2] = 2.12$ $[H_2] = 1.75$ $[NH_3] = 84.3$

Calculate K_{eq} at this temperature.

Solution:

$$K_{eq} = \frac{[NH_3]^2}{[N_2]\ [H_2]^3} = \frac{(84.3)^2}{(2.12)(1.75)^3} = \frac{7.11\times10^3}{(2.12)(5.36)} = 626$$ **answer**

4. For each of the following equilibrium systems, identify whether the reactants or products are favored at equilibrium, or whether they are equally favored.

		Answer
$COCl_{2\ (g)} \leftrightarrow CO_{(g)} + Cl_{2\ (g)}$	$K_{eq} = 8.2\times 10^{-2}$ at 627°C	reactants; $COCl_{2\ (g)}$
$C_{(s)} + 2\ H_{2\ (g)} \leftrightarrow CH_{4\ (g)}$	$K_{eq} = 8.1\times 10^{8}$ at 25°	products; $CH_{4\ (g)}$
$PCl_{5\ (g)} \leftrightarrow PCl_{3\ (g)} + Cl_{2\ (g)}$	$K_{eq} = 2.24$ at 227°C	equal
$H_{2\ (g)} + Cl_{2\ (g)} \leftrightarrow 2\ HCl_{(g)}$	$K_{eq} = 1.8 \times 10^{33}$ at 25°C	products; HCl(g)
$C_{(s)} + H_2O_{\ (g)} \leftrightarrow CO_{(g)} + H_{2\ (g)}$	$K_{eq} = 1.96$ at 1000°C	equal
$Mg(OH)_{2\ (s)} \leftrightarrow Mg^{2+}_{(aq)} + 2\ OH^-_{(aq)}$	$K_{eq} = 1.2\times 10^{-11}$ at 25°C	reactants; $Mg(OH)_{2\ (s)}$

5. For the reaction: carbon monoxide burns in oxygen to produce carbon dioxide

You are given the following equilibrium conditions:

$[O_2] = 1.30 \times 10^{-3}$ $[CO_2] = 2.50 \times 10^{-4}$ $K_{eq} = 3.60 \times 10^{-3}$

Calculate [CO]

Solution:

Begin by writing a balanced equation for the reaction:

$$2\ CO_{(g)} + O_{2\ (g)} \leftrightarrow 2\ CO_{2\ (g)}$$

Next, set up the equilibrium constant expression and solve for the unknown, [CO]. You will find it easier to let [CO] = χ while you rearrange the equation:

$$K_{eq=} = \frac{[CO_2]^2}{[CO]^2[O_2]}$$

$$3.60\times10^{-3} = \frac{(2.50\times10^{-4})^2}{(\chi)^2(1.30\times10^{-3})}$$

$$(3.60\times10^{-3})(1.30\times10^{-3})(\chi^2) = (2.50\times10^{-4})^2$$

$$(4.68\times10^{-6})(\chi^2) = 6.25\times10^{-8}$$

$$\chi^2 = 0.0134$$

$$\chi = [CO] = 0.116\ \ M$$