CHEMICAL EQUILIBRIUM

**Practice Questions: Reversible Reactions- (WS #1& 2)**

1. Write reversible reactions for each of the following situations (be sure to balance your equations):
   a. Hydrogen iodide gas (HI) decomposes into its elements.
   b. Hydrogen and nitrogen gases combine to form ammonia gas, NH3.

2. Describe two different mixtures of starting materials that can be used to produce the equilibrium
   $A + B \leftrightarrow C + D$

3. If the system represented by the following equation is found to be at equilibrium at a specific temperature, which of the following statements is true? Explain your answers.
   H2O(g) + CO(g) ↔ H2 (g) + CO2 (g)
   a. All species must be present in the same concentration.
   b. The rate of the forward reaction equals the rate of the reverse reaction.
   c. We can measure continual changes in the reactant concentrations.

4. Would you expect the combustion of methane, CH4 with oxygen to form carbon dioxide and water, to be a reversible reaction?
   Hint: Methane, or natural gas, is an important energy source. Considering this, what did you learn in the last unit that will help you predict whether or not the reverse reaction is likely to be spontaneous?

**Practice Questions: The Equilibrium Constant**

1. Write equilibrium expressions for the following reversible reactions:

| | |
|---|---|
| a. | $2\ NO_{2\ (g)} \leftrightarrow N_2O_{4\ (g)}$ |
| b. | $N_{2\ (g)} + 3\ H_{2\ (g)} \leftrightarrow 2\ NH_{3\ (g)}$ |
| c. | $2\ SO_{2\ (g)} + O_{2\ (g)} \leftrightarrow 2\ SO_{3\ (g)}$ |

2. For the equilibrium system described by $2\ SO_{2\ (g)} + O_{2\ (g)} \leftrightarrow 2\ SO_{3\ (g)}$ at a particular temperature the equilibrium concentrations of $SO_2$, $O_2$ and $SO_3$ were 0.75 M, 0.30 M, and 0.15 M, respectively. At the temperature of the equilibrium mixture, calculate the equilibrium constant, $K_{eq}$, for the reaction.

3. For the equilibrium system described by: $PCl_{5\ (g)} \leftrightarrow PCl_{3\ (g)} + Cl_{2\ (g)}$

   $K_{eq}$ equals 35 at 487°C. If the concentrations of the $PCl_5$ and $PCl_3$ are 0.015 M and 0.78 M, respectively, what is the concentration of the $Cl_2$?

# WS #3 - The Magnitude of Keq

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.

a. Sulfur dioxide gas combines with oxygen gas to produce sulfur trioxide gas.
b. Carbon monoxide gas burns in gaseous oxygen to produce carbon dioxide gas.
c. Hydrogen chloride gas is produced from hydrogen gas and chlorine gas.
d. Nitrogen gas and oxygen gas combine to produce gaseous dinitrogen oxide.
e. Solid hydrogen cyanide dissolves to produce hydrogen ions and cyanide ions in solution.
f. Solid silver chloride dissolves to produce silver ions and chloride ions in solution.
g. 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, $K_{eq}$, for the reaction. Remember **not** to include solids or liquids in the equilibrium constant expression.

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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 $[N_2] = 2.12$; $[H_2] = 1.75$, and $[NH_3] = 84.3$. 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.

a. $COCl_{2\,(g)} \leftrightarrow CO_{(g)} + Cl_{2\,(g)}$ $K_{eq} = 8.2\times 10^{-2}$ at 627°C

b. $C(s) + 2\,H_{2\,(g)} \leftrightarrow CH_{4\,(g)}$ $K_{eq} = 8.1\times 10^{8}$ at 25°C

c. $PCl_{5\,(g)} \leftrightarrow PCl_{3\,(g)} + Cl_{2\,(g)}$ $K_{eq} = 2.24$ at 227°C

d. $H_{2\,(g)} + Cl_{2\,(g)} \leftrightarrow 2\,HCl_{(g)}$ $K_{eq} = 1.8 \times 10^{33}$ at 25°C

e. $C_{(s)} + H_2O_{\,(g)} \leftrightarrow CO_{(g)} + H_{2\,(g)}$ $K_{eq} = 1.96$ at 1000°C

f. $Mg(OH)_{2\,(s)} \leftrightarrow Mg^{2+}_{\,aq} + 2\,OH^{-}_{(aq)}$ $K_{eq} = 1.2\times 10^{-11}$ at 25°C

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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]

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**WS #4 = Practice Questions - Le Châtelier's Principle**

1. The pressure on each of the following systems is increased by decreasing the volume of the container. Explain whether each system would shift in the forward direction, the reverse direction, or stay the same.

   a. $2\ SO_{2\ (g)} + O_{2\ (g)} \rightleftarrows 2\ SO_{3\ (g)}$

   b. $H_{2\ (g)} + I_{2\ (g)} \rightleftarrows 2\ HI_{(g)}$

   c. $CaCO_{3\ (s)} \rightleftarrows CaO_{(s)} + CO_{2\ (g)}$

   d. $AgCl_{(s)} \rightleftarrows Ag^{1+}{}_{(aq)} + Cl^{1-}{}_{(aq)}$

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2. List three ways that the following equilibrium reaction could be forced to shift to the right:

$$2\ NO_{2\ (g)} \rightleftarrows 2\ NO_{(g)} + O_{2\ (g)}$$

3. Given the following equilibrium reaction:

$$2\ C_{(s)} + O_{2\ (g)} \rightleftarrows 2\ CO_{(g)}$$

   what will be the effect of the following disturbances to the system:

   a. adding CO (at constant volume and temperature)

   b. addition of $O_2$(at constant volume and temperature)

   c. addition of solid carbon (at constant temperature)

   d. decreasing the volume of the container

4.
   1. Use LeChatelier's principle to explain why carbonated drinks go flat when their containers are left open.
   2. Can a pressure change be used to shift the position of equilibrium in every reversible reaction? Explain.
   3. Carbon disulfide can be made by the reaction of carbon dioxide and sulfur trioxide.

$2\ SO_{3\ (g)} + CO_{2(g)} + \text{heat} \longrightarrow CS_{2\ (g)} + 4\ O_{2\ (g)}$

Assuming that the reaction is at equilibrium what effect do the following changes have on the equilibrium position?

A) addition of $CO_2$
B) addition of heat
C) decrease in the pressure
D) removal of $O_2$
E) addition of a catalyst