Equilibrium Worksheet No. 1

1. Equilibrium is said to be dynamic. Explain why this is so and give an example of a dynamic equilibrium.

2. Indicate in each of the following reactions whether the tendency towards maximum entropy favors reactants or products.

a. $N_{2(g)} + 2O_{2(g)}$ + heat <===> $2NO_{2(g)}$
b. $N_{2(g)} + 3H_{2(g)}$ <===> $2NH_{3(g)}$ + heat
c. $CH_{4(g)} + H_2O_{(g)}$ + heat <===> $CO_{(g)} + 3H_{2(g)}$
d. $CS_{2(g)} + 4H_{2(g)}$ <===> $CH_{4(g)} + 2H_2S_{(g)}$ + heat

3. In each of the following reactions show the direction the reaction must proceed in to attain minimum enthalpy and maximum entropy.

a. $3O_{2(g)}$ ---> $2O_{3(g)}$ $\Delta H = +285$ kJ
b. $1/2N_{2(g)} + O_{2(g)}$---> $NO_{2(g)}$ $\Delta H = +34$ kJ
c. $2\ H_2O_{(g)}$ ----> $2H_{2(g)} + O_{2(g)}$ $\Delta H = +484$ kJ
d. $P_{4(s)} + 6H_{2(g)}$ ----> $4PH_{3(g)}$ $\Delta H = +37$ kJ

4. In which of the following reactions will the entropy favour the reactants while enthalpy favours the products?

a. $Cl_{2(g)}$ <====> $Cl_{2(aq)}$ + 25 kJ
b. $P_{4(s)} + 6H_{2(g)}$ + 37 kJ <====> $4PH_{3(g)}$
c. $PCl_{5(g)}$ <====> $PCl_{3(g)} + Cl_{2(g)}$; $\Delta H = +92.5$ kJ
d. $NO_{2(g)}$ <====> $½N_{2(g)} + O_{2(g)}$; $\Delta H = -33.8$ kJ

5. For each of the following reactions determine the direction of the enthalpy drive and the direction of the entropy drive. Then determine which one factor is responsible for the forward reaction.

a. heat + $N_2O_{3(g)}$ <---> $NO_{(g)} + NO_{2(g)}$
b. $2H_{2(g)} + 2NO_{(g)}$ <--> $N_{2(g)} + 2H_2O_{(g)}$ + heat
c. $CO_{(g)} + 1/2O_{2(g)}$ <--> $CO_{2(g)}$ $\Delta H = -283$ kJ
d. $I_{2(g)} + Cl_{2(g)}$ <----> $2ICl_{(g)}$ $\Delta H = 35$ kJ
e. $H_2O_{(l)}$ <-------> $H_2O_{(g)}$ $\Delta H = 41$ kJ

Equilibrium #2

Describe the effect on the equilibrium when the following changes take place for each reaction.

1. $N_{2(g)} + 3H_{2(g)} <\text{-----}> 2NH_{3(g)}$ $\Delta H = -92$ kJ

   (a) increase the $[N_2]$
   (b) increase the temperature
   (c) increase the volume
   (d) increase the pressure by changing volume

2. $2HF_{(g)} <\text{-----}> F_{2(g)} + H_{2(g)}$ $\Delta H = 536$ kJ

   (a) decrease the temperature
   (b) decrease the $[H_2]$
   (c) decrease the amount of HF at constant volume
   (d) decrease the volume
   (e) increase the partial pressure of $H_{2(g)}$

3. $SnO_{2(s)} + 2CO_{(g)} <\text{-----}> Sn_{(s)} + 2CO_{2(g)}$ $\Delta H = 13$ kJ

   (a) increase the temperature
   (b) increase the $[CO_2]$
   (c) add a catalyst
   (d) add $Kr_{(g)}$ at constant volume
   (e) add $Kr_{(g)}$ at constant pressure
   (f) add SnO_2

4. $CO_{(g)} + H_2O_{(g)} <\text{-----}> CO_{2(g)} + H_{2(g)}$ $\Delta H = -41$ kJ

   (a) add CO_2
   (b) increase the temperature
   (c) remove some H_2O
   (d) decrease the pressure by changing the volume
   (e) add CO
   (f) add a catalyst
   (g) adding a catalyst.

Equilibrium #3

Describe how each of the following changes listed below each equation will affect the **amount** of substance that is highlighted.

1. $N_{2(g)}$ + $\mathbf{3H_{2(g)}}$ <-----> $2NH_{3(g)}$ ▲H = -92 kJ

   (a) increase the $[N_2]$
   (b) increase the temperature
   (c) increase the volume
   (d) increase the pressure by changing volume

2. $2HF_{(g)}$ <-----> $\mathbf{F_{2(g)}}$ + $H_{2(g)}$ ▲H = 536 kJ

   (a) decrease the temperature
   (b) decrease the $[H_2]$
   (c) decrease the amount of HF at constant volume
   (d) decrease the volume
   (e) increase the partial pressure of $H_{2(g)}$

3. $SnO_{2(s)}$ + $\mathbf{2CO_{(g)}}$ <-----> $\mathbf{Sn_{(s)}}$ + $2CO_{2(g)}$ ▲H =13 kJ

   (a) increase the temperature
   (b) increase the $[CO_2]$
   (c) add a catalyst
   (d) add $Kr_{(g)}$ at constant volume
   (e) add $Kr_{(g)}$ at constant pressure
   (f) add SnO_2

4. $CO_{(g)}$ + $H_2O_{(g)}$ <-----> $CO_{2(g)}$ + $\mathbf{H_{2(g)}}$ ▲H = -41 kJ

   (a) add CO_2
   (b) increase the temperature
   (c) remove some H_2O
   (d) decrease the pressure by changing the volume
   (e) add CO
   (f) add a catalyst
   (g) adding a catalyst.

Equilibrium #3b

Describe the effect of the changes on each equilibrium.

1. $2ICl_{(g)} <----> I_{2(g)} + Cl_{2(g)} \quad \Delta H = +$
   a. increase volume
   b. decrease temperature
   c. increase partial pressure of $I_{2(g)}$
   d. effect of c. on $Cl_{2(g)}$ concentration

2. $N_{2(g)} + O_{2(g)} <----> 2NO_{(g)} \quad \Delta H = -$
   a. decrease volume
   b. increase temperature
   c. increase partial pressure of $O_{2(g)}$
   d. effect of c. on $N_{2(g)}$ concentration

3. $3O_{2(g)} <----> 2O_{3(g)} \quad \Delta H = -$
   a. decrease volume
   b. increase temperature
   c. increase partial pressure of $O_{2(g)}$
   d. effect of c. on $O_{3(g)}$ concentration

4. $N_2O_{3(g)} <----> NO_{(g)} + NO_{2(g)} \quad \Delta H = +$
   a. increase volume
   b. decrease temperature
   c. increase partial pressure of $NO_{2(g)}$
   d. effect of c. on $NO_{(g)}$ concentration

5. $2H_{2(g)} + 2NO_{(g)} <----> N_{2(g)} + 2H_2O_{(g)} \quad \Delta H = -$
   a. decrease volume
   b. increase temperature
   c. increase partial pressure of $N_{2(g)}$
   d. effect of c. on $NO_{(g)}$ concentration

6. $2Bi^{3+}{}_{(aq)} + 3H_2S_{(g)} <----> Bi_2S_{3(s)} + 6H^{+}{}_{(aq)} \quad \Delta H = -$
   a. increase volume
   b. increase $[H^+]$ (decrease pH)
   c. add more $Bi_2S_{3(s)}$
   d. add NaOH

7. $CaCO_{3(s)} <----> CaO_{(s)} + CO_{2(g)} \quad \Delta H = +$
   a. decrease volume
   b. add $Ar_{(g)}$ at constant **volume**
   c. add $Ar_{(g)}$ at constant **pressure**
   d. add a catalyst

8. $CaC_{2(s)} + 2H_2O_{(l)}$ <----> $C_2H_{2(g)} + Ca(OH)_{2(s)}$ $\Delta H = +$
a. add more water
b. increase pressure by changing volume
c. add more $CaC_{2(s)}$
d. heat up the mixture

9. $C_6H_{6(l)} + Br_{2(l)}$ <----> $C_6H_5Br_{(l)} + HBr_{(g)}$ $\Delta H = +$
a. add more $C_6H_5Br_{(l)}$
b. decrease pressure by changing volume
c. increase the temperature
d. add a catalyst

10. $Cu_{(s)} + 2Ag^+_{(aq)}$ <----> $Cu^{2+}_{(aq)} + 2Ag_{(s)}$
a. add more $Cu_{(s)}$
b. add some HCl
c. add some $Cu(NO_3)_2$
d. add more $Ag_{(s)}$

11. $4NH_{3(g)} + 5O_{2(g)}$ <----> $6H_2O_{(g)} + 4NO_{(g)}$ $\Delta H = +$
a. increase the partial pressure of $NO_{(g)}$
b. decrease the temperature
c. add $Ne_{(g)}$ at constant pressure
d. add $Ne_{(g)}$ at constant volume

12. $H_{2(g)} + \frac{1}{2}O_{2(g)}$ <----> $H_2O_{(l)}$ $\Delta H = -$
a. add $H_2O_{(l)}$
b. decrease the partial pressure of $O_{2(g)}$
c. increase the temperature
d. decrease the volume

13. $CO_{(g)} + \frac{1}{2}O_{2(g)}$ <----> $CO_{2(g)}$ $\Delta H = -$
a. add $CO_{2(g)}$
b. decrease the partial pressure of $O_{2(g)}$
c. increase the temperature
d. decrease the volume

14. $I_{2(g)} + Cl_{2(g)}$ <----> $2ICl_{(g)}$ $\Delta H = -$
a. add $Cl_{2(g)}$
b. decrease the partial pressure of $I_{2(g)}$
c. increase the temperature
d. decrease the volume

Equilibrium #4

Write the equilibrium constant expression for each equilibrium.

1. $2ICl_{(g)} \quad <----> \quad I_{2(g)} \quad + \quad Cl_{2(g)}$

2. $N_{2(g)} \quad + \quad O_{2(g)} \quad <----> \quad 2NO_{(g)}$

3. $3O_{2(g)} \quad <----> \quad 2O_{3(g)}$

4. $N_2O_{3(g)} \quad <----> \quad NO_{(g)} \quad + \quad NO_{2(g)}$

5. $2H_{2(g)} \quad + \quad 2NO_{(g)} \quad <----> \quad N_{2(g)} \quad + \quad 2H_2O_{(g)}$

6. $2Bi^{3+}{}_{(aq)} \quad + \quad 3H_2S_{(g)} \quad <----> \quad Bi_2S_{3(s)} \quad + \quad 6H^{+}{}_{(aq)}$

7. $CaCO_{3(s)} \quad <----> \quad CaO_{(s)} \quad + \quad CO_{2(g)}$

8. $CaC_{2(s)} \quad + \quad 2H_2O_{(l)} \quad <----> \quad C_2H_{2(g)} \quad + \quad Ca(OH)_{2(s)}$

9. $C_6H_{6(l)} \quad + \quad Br_{2(l)} \quad <----> \quad C_6H_5Br_{(l)} \quad + \quad HBr_{(g)}$

10. $Cu_{(s)} \quad + \quad 2Ag^{+}{}_{(aq)} \quad <----> \quad Cu^{2+}{}_{(aq)} \quad + \quad 2Ag_{(s)}$

11. $4NH_{3(g)} + 5O_{2(g)} <----> 6H_2O_{(g)} + 4NO_{(g)}$

12. $H_{2(g)} + \frac{1}{2}O_{2(g)} <----> H_2O_{(l)}$

13. $CO_{(g)} + \frac{1}{2}O_{2(g)} <----> CO_{2(g)}$

14. $I_{2(s)} + Cl_{2(g)} <----> 2ICl_{(g)}$

15. $SnO_{2(s)} + 2CO_{(g)} <----> Sn_{(s)} + 2CO_{2(g)}$

16. $Fe^{3+}{}_{(aq)} + SCN^{-}{}_{(aq)} <----> FeSCN^{2+}{}_{(aq)}$

17. $2CrO_4^{2-}{}_{(aq)} + 2H^{+}{}_{(aq)} <----> Cr_2O_7^{2-}{}_{(aq)} + H_2O_{(l)}$

18. $Fe^{3+}{}_{(aq)} + 4Cl^{-}{}_{(aq)} <----> FeCl_4^{-}{}_{(aq)}$

19. $H_2O_{(l)} <----> H^{+}{}_{(aq)} + OH^{-}{}_{(aq)}$

20. $BaSO_{4(s)} <----> Ba^{2+}{}_{(aq)} + SO_4^{2-}{}_{(aq)}$

Equilibrium Worksheet 5 Name____________________

Solve each of the following problems. Show your work in the space provided. Write your final answer on the blank line.

Part A

1. Write an equilibrium expression for the following reaction:

$A_{(g)} + B_{(g)} <=====> AB_{(g)}$

Then calculate the value of K_{eq} given that [A] = 1.1×10^{-3}M, [B] = 4.4M, and [AB] = 1.5×10^{-8}M. Finally, tell whether reactants or products are favored, and why.

2. Write an equilibrium expression for the following reaction:

$A_{2(g)} + B_{(s)} <=====> A_2B_{(g)}$

Then calculate the value of K_{eq} given that [A_2] = 1.9×10^{-3}M, and [A_2B] = 1.4×10^{-5}M. Finally, tell whether reactants or products are favored, and why.

3. Write an equilibrium expression for the following reaction:

$2A_{(g)} + B_{(g)} <=====> A_2B_{(g)}$

Then calculate the value of K_{eq} given that [A] = 1.0×10^{-6}M, [B] = 2.2×10^{-4}M, and [A_2B] = 6.5×10^{-1}M. Finally, tell whether reactants or products are favored, and why.

4. Write an equilibrium expression for the following reaction:

$A_{(s)} + B_{2(g)} <====> AB_{(s)} + B_{(g)}$

Then calculate the value of K_{eq} given that $[B_2] = 5.5 \times 10^{-4}$M, and $[B] = 3.9 \times 10^{-7}$M. Finally, tell whether reactants or products are favored, and why.

5. Write an equilibrium expression for the following reaction:

$2A_{(g)} + 3B_{(g)} <====> A_2B_{3(s)}$

Then calculate the value of K_{eq} given that $[A] = 4.6 \times 10^{-3}$M, and $[B] = 1.5 \times 10^{-5}$M. Finally, tell whether reactants or products are favored, and why.

Part B

6. Write an equilibrium expression for the following reaction:

$AB_{2(s)}$ + energy $<====> A_{(s)} + B_{2(g)}$

Then calculate the value of K_{eq} given that $[B_2] = 1.3 \times 10^{-9}$M. Finally, predict the effect of increased temperature on the value of K_{eq} and explain your answer.

7. Write an equilibrium expression for the following reaction:

$2A_{(g)} + B_{(g)} + \text{energy} <====> A_2B_{(g)}$

Then calculate the value of K_{eq} given that $[A] = 1.6 \times 10^{-2}M$, $[B] = 1.4 \times 10^{-4}M$, and $[A_2B] = 3.6 \times 10^{-1}$ M. Finally, predict the effect of decreased temperature on the value of K_{eq} and explain your answer.

____

____

____

Part C

8. Write an equilibrium expression for the following reaction:

$A_{2(g)} + B_{(s)} <====> A_{(g)} + AB_{(s)}$

Then calculate the concentration of $A_{(g)}$ given that $K_{eq} = 1.5 \times 10^{-3}$, and $[A_2] = 2.5 \times 10^{-4}$ M. Finally, predict the effect of adding some $A_{2(g)}$ on the values for [A], and explain your answer.

____

____

____

9. Write an equilibrium expression for the following reaction:

$2A_{(g)} + B_{2(g)} <====> A_2B_{(g)} + B_{(g)}$

Then calculate the concentration of A_2B, given that $K_{eq} = 7.1 \times 10^{4}$, $[A] = 1.9 \times 10^{-2}$ M, $[B_2] = 4.1 \times 10^{-3}$ M, and $[B] = 8.4 \times 10^{-3}$ M. Finally, predict the effect of adding some $A_{(g)}$ on the values for $[B_2]$, $[A_2B]$, and [B], and explain your answer.

____

____

____

Equilibrium #6

A. Reactant/Product Concentration Graph

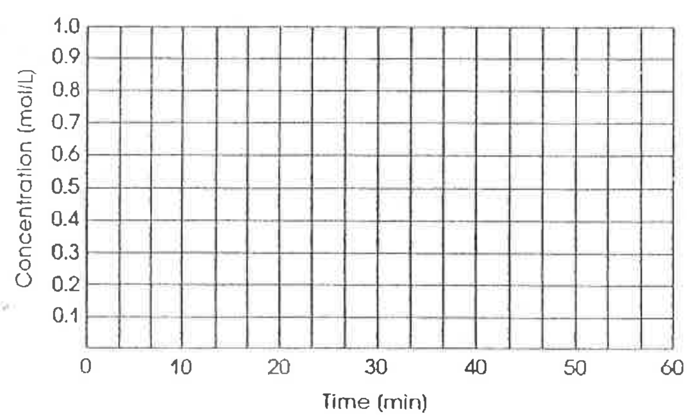
The decomposition of phosphorus pentachloride, PCl_5, into phosphorus trichloride and chlorine gas is a reversible reaction that reaches a state of chemical equilibrium. The equilibrium reaction is

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

One mole of PCl_5 is placed in a sealed one-liter container and heated to 250 °C. The concentrations of reactant and products are measured at ten-minute intervals. The following data are collected.

TIME (MINUTES)	CONCENTRATIONS (MOLES PER LITER)		
	$[PCl_5]$	$[PCl_3]$	$[Cl_2]$
0	1.00	0.00	0.00
10	0.90	0.10	0.10
20	0.85	0.15	0.15
30	0.82	0.18	0.18
40	0.80	0.20	0.20
50	0.80	0.20	0.20
60	0.80	0.20	0.20

Plot this data on the grid provided. Answer the questions that follow.



1. How long did it take for the reaction to reach equilibrium?

____

2. What is the equilibrium concentration of each reaction component?

____

3. Why would you expect the concentration of PCl_3 to equal that of Cl_2?

____

4. Predict the concentration of each component at 70 minutes.

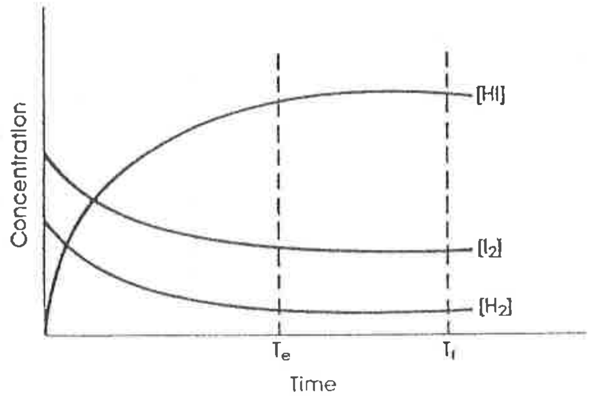
____

B. Predicting Reactant/Product Concentrations

The synthesis of hydrogen iodide is a reversible exothermic reaction that proceeds as follows.

$$H_2(g) + I_2(g) \leftrightarrows 2HI(g)$$

In a laboratory experiment, hydrogen gas and iodine gas are placed in a sealed reaction flask. The gases react to produce hydrogen iodide until equilibrium is established. The concentrations of reactants and product are plotted in the graph that follows. Assume equilibrium is reached at point T_e.



The following changes are introduced at time T_f. Determine which situation best describes how the graph would be changed to the right of T_f. Write your answer in the space provided.

1. Concentration of I_2 is increased ______________
   a. The HI curve rises, the I_2 curve drops, the H_2 curve remains the same.
   b. The HI curve drops, the I_2 curve rises, the H_2 curve drops.
   c. The HI curve rises, the I_2 curve rises, the H_2 curve drops.

2. Temperature of the system is increased ______________
   a. The curves for all three components rise.
   b. The H_2 and I_2 curves rise, the HI curve drops.
   c. The H_2 and I_2 curves drop, the HI curve rises.

3. Pressure of the system is increased ______________
   a. All curves rise.
   b. The H_2 and I_2 curves drop, the HI curve rises.
   c. All curves remain the same.

4. If a catalyst is present at the initial introduction of reactants, how would the graph differ from the one shown?

____

____

Name ____________________

Class ____________ Date ____________

1. 0.0040 mol of NO and 0.0030 mol of O_2 are introduced into a 1.0 L flask, and the reaction $2NO(g) + O_2(g) \rightleftharpoons 2NO_2(g)$ occurs. At equilibrium, it is determined that $[NO_2] = 0.0035$ mol/L. What is the value of K_{eq} for the reaction?

2. 0.020 mol of each of SO_2, O_2, and SO_3 is placed in a 1.0 L flask and allowed to come to equilibrium. The equilibrium $[SO_2]$ is found to be 0.0080 mol/L. What is the value of K_{eq} for the reaction $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$?

3. A solution initially contains 0.35*M* of A and 0.75*M* of B. A reaction occurs according to the equation $2A + B \rightleftharpoons 3C + D$. At equilibrium, [D] is found to be 0.10*M*. What is the value of K_{eq}?

4. For the equilibrium reaction $CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g)$, the K_{eq} value at 690°C is 10.0. A mixture of 0.300 mol of CO, 0.300 mol of H_2O, 0.500 mol of CO_2, and 0.500 mol of H_2 is placed in a 1.0 L flask.

a. Show that the reaction is not at equilibrium.

b. Determine the direction in which the reaction will shift to reach equilibrium.

c. Calculate the equilibrium concentrations of all four species.

5. The K_{eq} for the reaction $2HI(g) \rightleftharpoons H_2(g) + I_2(g)$ has a value of 1.85×10^{-2} at 425°C. If 0.18 mol of HI is placed in a 2.0 L flask and allowed to come to equilibrium at this temperature, what will be the equilibrium $[I_2]$?

6. For the reaction $2A(g) \rightleftharpoons 2B(g) + C(s)$, the value of K_{eq} is known to be 6.8×10^{2}. If 0.42 mol of A is placed in a 3.0 L container and allowed to reach equilibrium, what is the equilibrium [B]?

Equilibrium #7

1. Consider the following equilibrium system:

$CO_{(g)} + H_2O_{(g)} \text{<---->} CO_{2(g)} + H_{2(g)}$ $K_{eq} = 4.0$

The equilibrium concentrations of a particular mixture in a 2.0 L reaction vessel are:

$[CO] = 0.10\ M$ $[CO_2] = 0.20\ M$
$[H_2O] = 0.10\ M$ $[H_2] = 0.20\ M$

How many moles of CO_2 must now be injected into the vessel in order to create a new equilibrium where the $[CO] = 0.20\ M$?

2. Consider the equilibrium system:

$2NO_{(g)} + O_{2(g)} \text{<---->} 2NO_{2(g)}$

In an experiment, 0.30 mol of NO and 0.80 mol of NO_2 are placed in a 5.0 L container of 10^{oC}. When equilibrium is reached, it is found that the $[O_2]$ is 0.020 M. Calculate the value of K_{eq} for this reaction at 10°C.

3. Consider the reaction:

$2NO_{(g)} + Cl_{2(g)} \text{<---->} 2NOCl_{(g)}$

A mixture consisting of 2.00 moles of NO and 2.00 moles of Cl_2 is placed in a 5.0 L container. When the system reaches equilibrium, 30% of the original NO is used up. Calculate the equilibrium constant for the reaction.

4. In a reaction:

$A_{2(g)} + B_{2(g)} \text{<---->} 2AB_{(g)}$

there are found to be 2.00 mol of A_2 and 2.00 mol of B_2 in equilibrium with 4.00 mol of AB in a 10.0 L container. If 1.00 mol of AB is then added and the system is allowed to re-establish equilibrium, find the new concentration of AB.

5. For the reaction:

$C_2 + D_2 \text{<---->} 2\ CD$

the value of K_{eq} is found to be 9.0×10^{-2}. If the initial concentration of both C_2 and D_2 is 0.24 M, calculate the equilibrium $[C_2]$.

Equilibrium #8

1. Consider the following equilibrium at constant temperature:

   $CaCO_{3(s)}$ <----> $Ca)_{(s)}$ + $CO_{2(g)}$

   At time t_o, the system is at equilibrium. At time t_1, the volume of the system is suddenly decreased to one-half the original volume. At time t_2, the system reestablishes equilibrium Sketch a graph representing the changes in the $[CO_2]$ from time t_o to time t_3. (Vetical axis = $[CO_2]$, horizontal = time; t_o, t_1, t_2 and t_3)

2. Consider the following equilibrium:

   $CO_{(g)} + H_2O_{(g)}$ <----> $CO_{2(g)} + H_{2(g)}$ $\qquad K_{eq} = 16$

   A 1.0 L flask is filled with 0.30 mol CO, 0.30 mol H_2O, 0.90 mol CO_2 and 0.90 mol H_2 at a constant temperature. Calculate the equilibrium $[CO_2]$.

3. Consider the following equilibrium:

   $2NO_{2(g)}$ <----> $N_2O_{4(g)}$ + 59 kJ $\qquad K_{eq} = 1.20$

   What happens to the value of K_{eq} when the temperature is increased by 20° C? Explain.

4. Consider the following equilibrium:

   $CO_{(g)} + 2H_{2(g)}$ <----> $CH_3OH_{(g)}$ + energy

   (a) What happens to the $[CH_3OH]$ when the volume is decreased at constant temperature. Explain.

   (b) What happens to the [CO] when a catalyst is added at constant volume and temperature?

5. Consider the following equilibrium:

   $Fe^{3+}_{(aq)} + SCN^-_{(aq)}$ <----> $FeSCN^{2+}_{(aq)}$

   When 10.0 mL of 5.20×10^{-3} M $Fe(NO_3)_3$ and 10.0 mL of 2.00 M KSCN are mixed, the equilibrium $[FeSCN^{2+}]$ is 2.8×10^{-4} M. Calculate the value of K_{eq}.

6. Consider the following equilibrium:

   $2NO_{(g)} + Br_{2(g)}$ <----> $2NOBr_{(g)}$ $\quad K_{eq} = 1.0 \times 10^2$

   An unknown amount of NOBr is placed into a 2.00 L container. At equilibrium, the $[Br_2]$ is 0.0400 mol/L. Calculate the moles of NOBr initially placed in the container.

7. Consider the following equilibrium:

   $N_2H_{4(g)} + 2O_{2(g)}$ <----> $2NO_{(g)} + 2H_2O_{(g)}$

   More oxygen is added to the above equilibrium. After the system re-establishes equilibrium, identify the substance(s), if any, that have a net (a) increase in concentration and, (b) decrease in concentration.

8. Given the following equilibrium:

$$H_{2(g)} + I_{2(g)} <----> 2HI_{(g)}$$

Initially, 0.200 mol H_2 and 0.200 mol I_2 were placed into a 1.0 L container. At equilibrium, the $[I_2]$ is 0.040 mol/L. Calculate the K_{eq}.

9. Consider the following equilibrium:

$$2CH_{4(g)} <----> C_2H_{2(g)} + 3H_{2(g)}$$

A 0.180 mol sample of CH_4 is added to an empty 1.00 L container. At equilibrium, the $[C_2H_2]$ is 0.0800 mol/L. Calculate the K_{eq}.

10. Consider the following equilibrium:

$$2NO_{(g)} + O_{2(g)} <----> 2NO_{2(g)} \qquad K_{eq} = 6.45\text{x}10^5$$

(a) Write the K_{eq} expression

(b) Explain why the $[NO_2]$ is greater than the [NO] at equilibrium when the $[O_2]$ is 1.0 mol/L.

11. Consider the following equilibrium:

$$2HI_{(g)} <----> H_{2(g)} + I_{2(g)} \qquad K_{eq} = 81.0$$

A 1.00 L container is initially filled with 4.00 mol HI. Calculate the [HI] at equilibrium.

12. Consider the following equilibrium:

$$2CrO_4^{2-}{}_{(aq)} + H_2O_{(l)} <----> Cr_2O_7^{2-}{}_{(aq)} + 2OH^-{}_{(aq)}$$

yellow — orange

When HCl is added drop-by-drop to the yellow solution above, the solution turns orange. Explain.

13. Consider the following equilibrium:

$$2NO_{(g)} + O_{2(g)} <----> 2NO_{2(g)}$$

At 227° C in a 2.00 L container there are 0.044 mol NO, 0.100 mol O_2 and 7.88 mol NO_2 at equilibrium. Calculate K_{eq}.

Chemistry 12
Equilibrium Review
Part I - Qualitative

1. What characterizes a "state of equilibrium".

2. What is meant by "dynamics of equilibrium". Consider the graphs showing concentration versus RC.

3. What states of matter are and are not included in an equilibrium.

4. Describe the exact effect a catalyst has on the rate of reaction, on establishing an equilibrium, and on an equilibrium.

5. Describe the Heat Content of reactants and products for both endothermic and exothermic reactions. Show the ▲H for each case and indicate how the ▲H would be included within the equation.

6. State two factors that control all equilibria. Describe four possible combinations of these factors and indicate which two lead to equilibria.

7. For equations in which the two factors that control equilibria oppose each other, indicate under what condition each factor is responsible for the forward and reverse reaction.

8. State "Le Chatelier's Principle" and indicate what factors will affect an equilibrium.

9. Consider the "Haber Process" and describe the effect that each factor will have on the equilibrium, on each amount of material, on the ▲H, and on the equilibrium constant:
increase and decrease of each individual concentration
addition and removal of each individual substance
increase and decrease of volume of container
increase and decrease of pressure by changing volume
addition and removal of a solid catalyst
increase and decrease in temperature

10. Write the equilibrium expression for the "Haber Process" and indicate the factors that affect and do not affect the equilibrium constant. What states of matter are never included in the equilibrium expression and explain why not.

11. How does the equilibrium constant change when:
the temperature increases/decreases for both endothermic and exothermic reactions.
the stoichiometric ratios in the equilibrium are enlarged or decreased by a factor of five.
the equation is written reversed.
a catalyst is added to the reaction

12. How does the magnitude of the equilibrium constant relate to the:
abundance of reactants
abundance of products
tendency to favor products
tendency to favor reactants
presence of a catalyst
relationship between entropy and enthalpy drives

Part II - Quantitative

1. Calculation of K_{eq} from initial and equilibrium concentrations.

2. Calculation of equilibrium concentrations from initial concentration knowing the K_{eq}

3. Calculation of equilibrium concentrations from initial equilibrium concentrations which undergo a change in amount to produce a new equilibrium.

4. Calculation of concentration curves in concentration versus RC graph

5. Interpretation of concentration versus RC graphs for possible changes in
amount of reactant
amount of product
temperature
establishing whether reaction is endothermic or exothermic
volume
pressure

6. Analysis, interpretation and explanation of experimental results regarding
Chromate - dichromate equilibrium
Fe^{3+} - $FeSCN^{2+}$ equilibrium