Worksheet #1: Equilibrium Constants

Write the expression for the equilibrium constant K_{eq} for the reaction below:	Using the equilibrium constant expressions you determined in column 1, calculate the value of K_{eq} when the following concentrations are present:
1) $N_2(g) + 3H_2(g) \Leftrightarrow 2NH_3(g)$	$[NH_3] = 0.0100$ M; $[N_2] = 0.0200$ M; $[H_2] = 0.0200$
2) $2KClO_3(s) \Leftrightarrow 2KCl(s) + 3O_2(g)$	$[O_2] = 0.0500$ M; $[KCl] = 0.00250$ M; $[KClO_3] = 2.00$ M
3) $H_2O(l) \Leftrightarrow H^+(aq) + OH^-(aq)$	$[H^+] = 1 \times 10^{-8}$ M; $[OH^-] = 1 \times 10^{-6}$ M; $[H_2O] = 1 \times 10^{-14}$ M,
4) $2CO(g) + O_2(g) \Leftrightarrow 2CO_2(g)$	$[CO] = 2.0$ M; $[O_2] = 1.5$ M; $[CO_2] = 3.0$ M
5) $Li_2CO_3(s) \Leftrightarrow 2Li^+(aq) + CO_3^{-2}(aq)$	$[Li^+] = 0.20$ M; $[CO_3^{-2}] = 0.10$ M; $[Li_2CO_3] = 6.0$ M

Worksheet 2 - Equilibrium Expressions and Calculations (K_{eq} and Q)

1. Write the equilibrium expression for the oxidation of hydrogen to form water vapor.
   $2H_2(g) + O_2(g) \Leftrightarrow 2H_2O(g)$

2. Write the equilibrium expression for the formation of nitrosyl bromide.
   $2NO(g) + Br_2(g) \Leftrightarrow 2NOBr(g)$

3. Write the equilibrium expression for the following reaction:
   $NO(g) + O_3(g) \Leftrightarrow O_2(g) + NO_2(g)$

4. Write the equilibrium expression for the following reaction:
   $CH_4(g) + Cl_2(g) \Leftrightarrow CH_3Cl(g) + HCl(g)$

5. Write the equilibrium expression for the following reaction:
   $CH_4(g) + H_2O(g) \Leftrightarrow CO(g) + 3H_2(g)$

6. Write the equilibrium expression for the following reaction:
   $CO(g) + 2H_2(g) \Leftrightarrow CH_3OH(g)$

7. Write the equilibrium expression for the combustion of ethane at high temperature.
   $2C_2H_6(g) + 7O_2(g) \Leftrightarrow 4CO_2(g) + 6H_2O(g)$

8. Write the equilibrium expression for the decomposition of ethane.
   $C_2H_6(g) \Leftrightarrow C_2H_4(g) + H_2(g)$

Worksheet 2 - Equilibrium Expressions and Calculations (K_{eq} and Q) continued…

9. Ammonia is synthesized from nitrogen and hydrogen in the following reaction:
   $N_2(g) + 3H_2(g) \Leftrightarrow 2NH_3(g)$
   At 500 ºC, the equilibrium constant for this reaction is 0.080.
   Given that $[NH_3] = 0.0596$ M, $[N_2\} = 0.600$ M, and $[H_2] = 0.420$ M, find Q and predict how the reaction will proceed.

10. The decomposition of antimony pentachloride ($SbCl_5$) is described by the following equation:
    $SbCl_5(g) \Leftrightarrow SbCl_3(g) + Cl_2(g)$
    At 448 ºC, the equilibrium constant for this reaction is 0.0251. What is the value of Q if $[SbCl_5\} = 0.095$ M, $[SbCl_3] = 0.020$ M, and $[Cl_2] = 0.050$ M? How will this reaction proceed?

11. At 1000 ºC, $K_{eq} = 1.0 \times 10^{-13}$ for the decomposition of hydrofluoric acid (HF), as described in the reaction **$2HF(g) \Leftrightarrow H_2(g) + F_2(g)$.**
    If $[HF] = 23.0$ M, $[H_2] = 0.540$ M, and $[F_2] = 0.380$ M, determine the value of Q and predict how the reaction will proceed.

12. At 1227 ºC, K_{eq} for the following reaction is 0.15: **$2SO_2(g) + O_2(g) \Leftrightarrow 2SO_3(g)$**
    If $[SO_2] = 0.344$ M, $[O_2] = 0.172$ M, and $[SO_3] = 0.056$ M, find Q and determine how the reaction will proceed.

Worksheet #3: LE CHATELIER'S PRINCIPLE

Le Chatelier's Principle states that when a system at equilibrium is subjected to a stress, the system will shift its equilibrium point in order to relive the stress.

Complete the following chart by writing left, right or none for equilibrium shift, and decreases, increases or remains the same for the concentrations of reactants and products, and for the value of K.

$$N_2(g) + 3H_2(g) \leftrightarrow 2NH_3(g) + 22.0\ kcal$$

Stress	**Equilibrium Shift**	**$[N_2]$**	**$[H_2]$**	**$[NH_3]$**	**K**
1. Add N_2	Right	____	decreases	increases	Remains the same
2. Add H_2			____		
3. Add NH_3				____	
4. Remove N_2		____			
5. Remove H_2			____		
6. Remove NH_3				____	
7. Increase Temperature					
8. Decrease Temperature					
9. Increase Pressure					
10. Decrease Pressure					

WS #3: LE CHATELIER'S PRINCIPLE continued…

$12.6\ kcal + H_2(g) + I_2(g) \leftrightarrow 2HI(g)$

Stress	Equilibrium Shift	$[H_2]$	$[I_2]$	[HI]	K_{eq}
1.Add H_2	right	____	decreases	increases	Remains the same
2.Add I_2			____		
3.Add HI				____	
4.Remove H_2		____			
5.Remove I_2			____		
6.Remove HI				____	
7.Increase Temperature					
8.Decrease Temperature					
9.Increase Pressure					
10.Decrease Pressure					

$NaOH(s) \leftrightarrow Na^+(aq) + OH^-(aq) + 10.6\ kcal$

(Remember that pure solids and liquids do not affect equilibrium values.)

Stess	Equilibrium Shift	Amount of NaOH(s)	$[Na^+]$	$[OH^-]$	K_{eq}
1.Add NaOH(s)		____			
2.Add NaCl (adds Na^+)			____		
3.Add KOH (adds OH^-)				____	
4.Add H^+ (removes OH^-)				____	
5.Increase temperature					
6. Decrease temperature					
7. Increase Pressure					
8. Decrease Pressure					

Worksheet #4: Equilibrium Problem Set

1. For each of the following reactions, describe what effect and **<u>increase in pressure</u>** would have on the equilibrium position of the reaction (i.e. shift right, shift left, no change)

a) $2H_2S(g) <===> 2H_2(g) + S_2(g)$
b) $2N_2O_5(g) <===> 4NO_2(g) + O_2(g)$
c) $4NO(g) + 2O_2(g) <===> 2N_2O_4(g)$
d) $2NO(g) + Br_2(g) <===> 2NOBr(g)$
e) $CO(g) + 2H_2(g) <===> CH_3OH(g)$
f) $SO_2(g) + NO_2(g) <===> SO_3(g) + NO(g)$

2. In which direction would the equilibrium shift for the equation in 1a if S_2 were removed from the reaction vessel?

3. In which direction would the equilibrium shift for the equation in 1b if N_2O_5 were added?

4. In which direction would the equilibrium shift for the equation in 1c if O_2 were removed?

5. In which direction would the equilibrium shift for the equation in 1d if pressure were decreased?

6. In which direction would the equilibrium shift for the equation in 1e if CH_3OH were removed?

7. In which direction would the equilibrium shift for the equation in 1f if heat were added? (the rxn is endothermic).

8. What would be the effect on the equilibrium position of an equilibrium mixture of Br_2, F_2, and BrF_5 if the total pressure of the system were decreased? $2BrF_5(g) <===> Br_2(g) + 5F_2(g)$

9. What would be the effect on the equilibrium position of an equilibrium mixture of carbon, oxygen, and carbon monoxide if the total pressure of the system were decreased?
   $2C_2(s) + O_2(g) <===> 2CO(g)$

10. A weather indicator can be made with a hydrate of cobalt (II) chloride, which changes color as a result of the following reaction:

$CoCl_2 \bullet 6H_2O(s) <===> CoCl_2(s) + 6H_20(g)$
pink blue

Does a pink color indicate "moist" or "dry" air? Explain.

11. Consider the reaction:

$CaCO_3(s) <===> CaO(s) + CO_2(g)$

Will the mass of $CaCO_3$ at equilibrium increase, decrease or remain the same if
(a) CO_2 is added to the equilibrium system?
(b) the pressure is increased?
(c) solid CaO is removed?

WS #4: Equilibrium Problem Set Continued…

12. The reaction between NO and O_2 is exothermic.

    $2NO(g) + O_2(g) \leftrightarrows 2NO_2(g)$

    Will the concentration of NO_2 at equilibrium increase, decrease, or remain the same if
    (a) additional $O_2$is introduced?
    (b) additional NO is introduced?
    (c) the total pressure is decreased?
    (d) the temperature is increased?

13. Predict whether the equilibrium for the photosynthesis reaction described by the equation:

    $6CO_2(g) + 6H_20(\ell) \leftrightarrows C_6H_{12}O_6(s) + 6O_2(g)$ $\quad \Delta H° = 2801.69$ kJ/mol

    would shift to the right, shift to the left, or remain unchanged if
    (a) $[CO_2]$ were increased;
    (b) P_{O2} were increased;
    (c) one half of the $C_6H_{12}O_6$ were removed;
    (d) the total pressure were decreased;
    (e) the temperature were decreased;
    (f) a catalyst were added.

14. What would be the effect of increasing the temperature on each of the following systems at equilibrium?
    a) $H_2(g) + I_2(g) \leftrightarrows 2HI(g) + 9.45$ kJ
    b) $PCl_5(g) + 92.5$ kJ $\leftrightarrows PCl_3(g) + Cl_2(g)$
    c) $2SO_2(g) + O_2(g) \leftrightarrows 2SO_3(g)$; $\Delta H° = -198$ kJ/mol
    d) $2NOCl(g) \leftrightarrows 2NO(g) + Cl_2(g)$; $\Delta H° = 75$ kJ/mol
    e) $C(s) + H_2O(g) + 131$ kJ $\leftrightarrows CO(g) + H_2(g)$

15. What would be the effect of increasing the pressure by decreasing the volume on each of the following systems at equilibrium?
    a) $2CO(g) + O_2(g) \leftrightarrows 2CO_2(g)$
    b) $2NO(g) \leftrightarrows N_2(g) + O_2(g)$
    c) $N_2O_4(g) \leftrightarrows 2NO_2(g)$
    d) $Ni(s) + 4CO(g) \leftrightarrows Ni(CO)_4(g)$
    e) $N_2(g) + 3H_2(g) \leftrightarrows 2NH_3(g)$

16. The value of K_c is 0.020 at 2870° for the reaction shown below. There are 0.800 mole of N_2, 0.500 mole of O_2, and 0.400 mole of NO in a 1.00-liter container at 2870°C. Is the system at equilibrium or must the forward or reverse action occur to a greater extent to bring the system to equilibrium?

    $N_2(g) + O_2(g) \leftrightarrows 2NO(g)$

17. Given: $A(g) + B(g) \leftrightarrows C(g) + D(g)$
    At equilibrium a 1.00-liter container was found to contain 1.60 mole of C, 1.60 mol of D, 0.40 mol of A, and 0.40 mole of B. Calculate the equilibrium constant for this reaction.