LE CHATELIER'S PRINCIPLE

Name _____

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 relieve 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.

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

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					

LE CHATELIER'S PRINCIPLE CONTINUED

Name _____

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

Stress	Equilibrium Shift	$[H_2]$	$[I_2]$	[HI]	K
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.)

Stress	Equilibrium Shift	Amount NaOH(s)	$[Na^+]$	$[OH^-]$	K
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					
Decrease Pressure					

Name _____ Class _____ Date _____

Le Chatelier's Principle

According to Le Chatelier's Principle, when a system at equilibrium is subjected to a stress (a change in concentration, temperature, or pressure), the equilibrium will shift in the direction that tends to counteract the effect of the stress.

For each of the following systems at equilibrium, predict the effect of the given change on the concentration of the specific substances. Write I if the concentration increases, D if the concentration decreases, or R if the concentration remains the same.

REDS $NH_3(g) \rightleftharpoons N_2(g) + 3H_2(g)$ + heat

↓ ncentration

1. Change: increase in $[N_2]$ — 1a. _____
   What is the effect on the concentration of:
   a. $[NH_3]$ b. $[H_2]$ — b. _____

mp

2. Change: increase in temperature — 2a. _____
   What is the effect on the concentration of:
   a. $[N_2]$ b. $[NH_3]$ — b. _____

ssure

3. Change: increase in pressure — 3a. _____
   What is the effect on the:
   a. number of moles of N_2 — b. _____
   b. number of moles of NH_3

$2NO(g) \rightleftharpoons N_2(g) + O_2(g)$ + heat

4. Change: decrease in $[O_2]$ — 4a. _____
   What is the effect on the concentration of:
   a. $[N_2]$ b. $[NO]$ — b. _____

5. Change: decrease in temperature — 5a. _____
   What is the effect on the concentration of:
   a. $[O_2]$ b. $[NO]$ — b. _____

ure

6. Change: increase in pressure — 6a. _____
   What is the effect on the:
   a. number of moles of O_2 — b. _____
   b. number of moles of NO

$2SO_3(g)$ + heat $\rightleftharpoons 2SO_2(g) + O_2(g)$

7. Change: increase in $[SO_2]$ — 7a. _____
   What is the effect on the concentration of:
   a. $[O_2]$ b. $[SO_3]$ — b. _____

mp

8. Change: increase in temperature — 8a. _____
   What is the effect on the concentration of:
   a. $[SO_2]$ b. $[SO_3]$ — b. _____

ssure

9. Change: decrease in pressure — 9a. _____
   What is the effect on the:
   a. number of moles of O_2 — b. _____
   b. number of moles of SO_3

Displacing Equilibrium (LeChatelier's Principle)

Each equation represents a reversible reaction at equilibrium. Note the letters in parentheses showing the state of each substance.

For each reaction, tell which way the equilibrium will shift (using R for right and L for left), if at all, when the conditions are changed as indicated. Each change is independent of the others.

1. $N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)} + \text{heat}$

   a) concentration of H_2 is increased
   b) pressure is decreased
   c) temperature is increased

2. $CaCO_{3(s)} + \text{heat} \rightleftharpoons CaO_{(s)} + CO_{2(g)}$

   a) concentration of CO_2 is increased
   b) pressure is increased
   c) temperature is decreased

3. $CO_{(g)} + NO_{2(g)} \rightleftharpoons CO_{2(g)} + NO_{(g)} + \text{heat}$

   a) concentration of NO_2 is decreased
   b) pressure is increased
   c) heat is added (Temp)

4. $N_2O_{4(g)} + \text{heat} \rightleftharpoons 2NO_{2(g)}$

   a) concentration of NO_2 is increased
   b). pressure is decreased
   c) the reaction is cooled (Temp)

5. $4Fe_{(s)} + 3O_{2(g)} \rightleftharpoons 2Fe_2O_{3(s)} + \text{heat}$

   a) more O_2 is added (conc)
   b) pressure is decreased
   c) the reaction is cooled (Temp

6. $N_{2(g)} + O_{2(g)} = 2NO_{(g)}$ forward reaction is endothermic

   a) some NO is removed (conc)
   b) pressure is decreased
   c) the temperature of the reaction is increased

EQUILIBRIUM CONSTANT (K)

Name _____

Write the expression for the equilibrium constant K for the reactions below.

1. $N_2(g) + 3H_2(g) \leftrightarrow 2NH_3(g)$

2. $2KClO_3(s) \leftrightarrow 2KCl(s) + 3O_2(g)$

3. $H_2O(l) \leftrightarrow H^+(aq) + OH^-(aq)$

4. $2CO(g) + O_2(g) \leftrightarrow 2CO_2(g)$

5. $Li_2CO_3(s) \rightarrow 2Li^+(aq) + CO_3^{-2}(aq)$

CALCULATIONS USING THE EQUILIBRIUM CONSTANT

Name _____

Using the equilibrium constant expressions you determined on page 79, calculate the value of K when:

1. $[NH_3]$ = 0.0100 M, $[N_2]$ = 0.0200 M, $[H_2]$ = 0.0200 M

2. $[O_2]$ = 0.0500 M

3. $[H^+]$ = 1×10^{-8} M, $[OH^-]$ = 1×10^{-6} M

4. [CO] = 2.0 M, $[O_2]$ = 1.5 M, $[CO_2]$ = 3.0 M

5. $[Li^+]$ = 0.2 M, $[CO_3^{-2}]$ = 0.1 M

SOLUBILITY PRODUCT CONSTANT (K_{SP})

Name _____

1. What is the solubility, in moles/liter, of AgBr if the $K_{SP} = 5.0 \times 10^{-13}$?

2. If the solubility of Li_2CO_3 = 0.15 moles/liter, what is its K_{SP} at this temperature?

3. What is the solubility, in moles/liter, of PbI_2 if the $K_{SP} = 8.5 \times 10^{-9}$?

4. If the solubility of $Ag_2CrO_4 = 7.2 \times 10^{-5}$ moles/liter, what is its K_{SP}?

5. How many moles of AgCl will dissolve in 500. mL of water if the $K_{SP} = 1.7 \times 10^{-10}$?

Name _____ Class _____ Date _____

Solubility Product Expression

Choose words from the list to fill in the blanks in the paragraphs.

Word List

dissociation equation
ion-product
K_{sp}
precipitate
saturated solution
solubility product constant
solubility product expression

The concentration of an ionic solid in contact with a(n) __(1)__ of that solid is a constant. This constant can be combined with the solution equilibrium constant to produce the __(2)__, whose symbol is __(3)__. Given a(n) __(4)__ showing the formation of ions from a solid, we may write an expression, called a(n) __(5)__, to show what concentrations of ions, raised to appropriate powers and divided, produce the constant. Such an expression is sometimes called a(n) __(6)__.

Expressions such as those described above, used with a knowledge of the constants involved, make it possible to predict whether or not a solid product will form when aqueous ionic solutions are combined. Such a solid is called a(n) __(7)__.

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____

Name _____ Class _____ Date _____

Calculations Involving Solubility Product

Given a dissociation equation, a solubility product expression can be written by setting the mass-action expression (the product of the solubilities of ions, raised to appropriate powers) equal to the solubility product constant, K_{sp}. Such expressions allow calculation of equilibrium concentrations, prediction of precipitation, or calculation of K_{sp}, if it is not already known.

Solve the following problems. Show your work.

1. The equilibrium concentrations of Ag^+ and Br^- ions are both 7.1×10^{-7} *M*. Write the balanced dissociation equation and the solubility product for AgBr, and calculate K_{sp}.

1. _____

2. The value of K_{sp} for CdS is 1.0×10^{-28}. Write the balanced dissociation equation and the solubility product for CdS, and calculate the equilibrium concentrations of Cd^{2+} and S^{2-}.

2. _____

3. A solution contains CO_3^{2-} ions and Ba^{2+} ions in equilibrium. K_{sp} for $BaCO_3$ equals 2×10^{-9}, and $[CO_3^{2-}]$ equals 1.0×10^{-2} *M*. Calculate $[Ba^{2+}]$. (First, write the balanced equation and solubility product expression.)

3. _____

Name _____ Date _____ Class _____

REVIEW ACTIVITY

Text Reference: Section 18-9

Equilibrium

Choose words from the list to fill in the blanks in the paragraphs.

Word List

chemical equilibrium	Le Chatelier's principle
coefficient	mass-action expression
concentration	precipitate
dissociation equation	rate
double arrow	reversible reaction
equilibrium constant	saturated solution
Haber process	shift
ion product	solubility product constant
K	solubility product expression
K_{sp}	stress

A chemical change in which the reactants can be re-formed from the products is called a(n) __(1)__. When forward and backward reactions occur at the same __(2)__, a state of __(3)__ exists. A(n) __(4)__ is used in an equation to symbolize this state.

According to the law of chemical equilibrium, the __(5)__, symbolized by __(6)__, is numerically equal to the fraction formed by the __(7)__ of the reactants and the products raised to a power equal to the __(8)__ of each in the balanced equation. This fraction is called the __(9)__.

When conditions such as temperature are changed, a chemical reaction is said to be placed under a(n) __(10)__. Under such changing conditions, equilibrium can undergo a(n) __(11)__ in the direction that tends to counteract the imposed changes. This generalization is known as __(12)__, which has been applied to the manufacture of ammonia by a method called the __(13)__.

The concentration of an ionic solid in contact with a(n) __(14)__ of that solid is a constant. This constant can be combined with the solution equilibrium constant to produce the __(15)__, whose symbol is __(16)__. Given a(n) __(17)__ showing the formation of ions from a solid, we may write an expression, called a(n) __(18)__, to show what concentrations of ions, raised to appropriate powers and divided, produce the constant. Such an expression is sometimes called a(n) __(19)__.

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____
8. _____
9. _____
10. _____
11. _____
12. _____
13. _____
14. _____
15. _____
16. _____
17. _____
18. _____
19. _____

Name _____ Date _____ Class _____

Practice Problems

1. Write the mass-action expression for the equilibrium system that is represented by the balanced chemical equation

$$2H_2(g) + O_2(g) \rightleftharpoons 2H_2O(g)$$

2. What is the mass-action expression for the equilibrium system described by the balanced chemical equation

$$2Cl_2(g) + CH_4(g) \rightleftharpoons CCl_4(g) + 2H_2(g)$$

3. The balanced chemical equation for the equilibrium system that contains nitrogen gas (N_2), fluorine gas (F_2), and nitrogen trifluoride gas (NF_3) is

$$N_2(g) + 3F_2(g) \rightleftharpoons 2NF_3(g)$$

Write the mass-action expression for this equilibrium system.

4. The equilibrium system that contains hydrogen bromide gas (HBr), chlorine gas (Cl_2), hydrogen chloride gas (HCl), and bromine gas (Br_2) is represented by the following balanced chemical equation:

$$2HBr(g) + Cl_2(g) \rightleftharpoons 2HCl(g) + Br_2(g)$$

What is the mass-action expression for this equilibrium system?

5. A certain equilibrium system is represented by the following chemical equation:

$$A(g) + 2B(g) \rightleftharpoons 2C(g)$$

(where the letters A, B, and C stand for the chemical formulas of three substances).

a. Write the equilibrium expression for the system.

b. At a particular temperature, $[A]$ (that is, the concentration of A) = 0.88 mol/dm^3, $[B]$ = 0.45 mol/dm^3, and $[C]$ = 0.000 22 mol/dm^3. Calculate the value of K for the system at this temperature.

c. Are the reactants or the products favored at equilibrium? How can you tell?

6. An equilibrium system is represented by the following chemical equation:

$$2G(g) + H(g) \rightleftharpoons I(g)$$

a. Write the equilibrium expression for this system.

b. At equilibrium, at a given temperature, there are 1.20 moles of G, 0.866 mole of H, and 4.17×10^{-6} mole of I in the 4.00-dm^3 vessel that contains the equilibrium system. Calculate the concentration, in moles per cubic decimeter, of each of the substances present.

c. Calculate the value of K for the system under the conditions given in step *b*.

d. Are the reactants or the products favored at equilibrium? How can you tell?

7. A system at equilibrium is represented by the following chemical equation:

$$2L(g) + M(g) \rightleftharpoons 3N(g)$$

a. Write the equilibrium expression for this system.

b. At a given temperature, at equilibrium, the reaction vessel, whose volume is 0.800 dm^3, contains 2.60×10^{-5} mole of L, 5.43×10^{-5} mole of M, and 9.34×10^{-1} mole of N. Calculate the concentration, in moles per cubic decimeter, of each of the substances present.

c. Calculate the value of the constant K for the system under the conditions given in step *b*.

d. Are the reactants or the products favored at equilibrium? How can you tell?

8. At room temperature, the solubility constant, K_{sp}, of barium carbonate ($BaCO_3$) is 2×10^{-9}.

a. Write the dissociation equation for barium carbonate.

b. Write the solubility product expression for this compound.

c. Calculate the molar solubility of this compound, in moles per cubic decimeter, at this same temperature.

9. At room temperature, the solubility product constant, K_{sp}, for iron(II) sulfide (FeS) is 4×10^{-19}.

a. Write the dissociation equation.

b. Write the solubility product expression for this compound.

c. Calculate the molar solubility of this compound, in moles per cubic decimeter, at this same temperature.