NAME Key DATE _____ DUE DATE _____

Assignment: Le Châtelier's Principle

1. State Le Chatelier's Principle.

PART A

When a system at equilibrium is subjected to a stress, it will attempt to relieve the stress and reach eq'm again.

2. List the three stresses that can affect the position of an equilibrium?

* change in concentration * change in pressure * change in temp.

NOTE: temperature is the ONLY stress that will cause the value of K_{eq} to change.

3. State the effect of a catalyst on equilibrium.

* Adding a catalyst does not favor R or P but speeds up both the forward and reverse rx so eq'm can be established sooner.

4. Methanol (methyl alcohol; CH_3OH) can be manufactured using the following equilibrium reaction:

$$CO(g) + 2\ H_2(g) \rightleftharpoons CH_3OH(g) + \text{energy}$$

Predict the effect of the following changes on the equilibrium concentration of $CH_3OH(g)$. Will it's concentration increase, decrease, or remain the same?

a) The temperature of the system is decreased. increase

b) The pressure of the system is increased. increase

c) More $H_2(g)$ is added. increase

d) A catalyst is added to the system. remain the same

5. Use Le Chatelier's Principle to predict how the changes listed will affect the following equilibrium reaction: $2\ HI\ (g) + 9.4\ kJ \rightleftharpoons H_2\ (g) + I_2\ (g)$

a) Will the concentration of HI increase, decrease, or remain the same if more H_2 is added? increase

b) What is the effect on the [HI] if the pressure of the system is increased? no change

c) What is the effect on the [HI] if the temperature of the system is increased? decrease

d) What is the effect on the [HI] if a catalyst is added to the system? no change

e) Write the equilibrium constant expression for this reaction.

$$K_{eq} = \frac{[H_2][I_2]}{[HI]^2}$$

f) At 435°C the equilibrium constant for this reaction is 1.88×10^{-2}. Does equilibrium favor the reactants or products?

Reactants $K_{eq} < 1$.

6. Suggest four ways to **increase the concentration of SO_3** in the following equilibrium reaction:

$$2\ SO_2(g) + O_2(g) \rightleftharpoons 2\ SO_3(g) + 192.3\ kJ$$

1) add more SO_2
2) add more O_2
3) increase pressure
4) decrease temp.

7. In the equilibrium reaction: $4\ HCl(g) + O_2(g) \rightleftharpoons 2\ H_2O(g) + 2\ Cl_2(g) + 114.4\ kJ$

Predict the direction of equilibrium shift (forward, reverse, no change) if the following changes occur:

a) the pressure is increased forward

b) heat is added reverse

c) oxygen is added forward

d) HCl is removed reverse

e) a catalyst is added no change

8. Nitric oxide, NO, releases 57.3 kJ/mol when it reacts with oxygen to give nitrogen dioxide.

a) Write a balanced equation for this reaction.

$$2\ NO + O_2 \longrightarrow 2\ NO_2 + 114.6\ KJ$$

b) Write the equilibrium constant expression for this reaction.

$$K_{eq} = \frac{[NO_2]^2}{[NO]^2[O_2]}$$

c) Predict the effect that increasing the temperature will have on:

i) the equilibrium concentration of all reaction participants (NO, O_2, and NO_2 will each of their concentrations go up, down or remain the same)

[NO] ↑ [O_2] ↑ [NO_2] ↓

ii) the numerical value of the equilibrium constant, K_{eq}

↓

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PART B

1. For the following system at equilibrium: $H_{2\,(g)} + I_{2\,(g)} \leftrightarrow 2\,HI_{\,(g)}$ ↑

   a. Predict the shift in equilibrium when more $HI_{(g)}$ is added to the system. LEFT

   b. How will the concentration of I_2 change? INCREASE

2. For the reaction below, predict the direction the equilibrium will shift given the following changes. Temperature and volume are held constant.

   $2\,NO_{2\,(g)} + 7\,H_{2\,(g)} \leftrightarrow 2\,NH_{3\,(g)} + 4\,H_2O_{(g)}$

   a. addition of ammonia LEFT

   b. removal of nitrogen dioxide LEFT

   c. removal of water vapour RIGHT

   d. addition of hydrogen RIGHT

3. At a particular temperature, the following reaction has an equilibrium constant, K_{eq} of 0.18

   $PCl_{3\,(g)} + Cl_{2\,(g)} \leftrightarrow PCl_{5\,(g)}$

   More PCl_3 is added to the system. Will the value of K_{eq} increase or decrease?

   no change

PART C

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. $2\,SO_{2\,(g)} + O_{2\,(g)} \equiv 2\,SO_{3\,(g)}$ forward

   b. $H_{2\,(g)} + I_{2\,(g)} \equiv 2\,HI_{(g)}$ stay the same

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

   d. $AgCl_{(s)} \equiv Ag^{1+}_{(aq)} + Cl^{1-}_{(aq)}$ stay the same

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

   $2\,NO_{2\,(g)} \equiv 2\,NO_{(g)} + O_{2\,(g)}$

   1) add NO_2
   2) decrease pressure
   3) remove NO
   4) remove O_2

3. Given the following equilibrium reaction: $2\ C_{(s)} + O_{2\,(g)} \equiv 2\ CO_{(g)}$

What will be the effect of the following disturbances to the system? (shift left, shift right, or no change)

a. adding CO LEFT

b. addition of O_2 RIGHT

c. addition of solid carbon (no change

d. decreasing the volume of the container LEFT
↑ pressure

PART C

1. For each of the following equilibria, predict whether the system will shift in the forward or reverse directions. Note the energy changes involved and assume that the volume remains constant.

a. heat is removed from: $A \leftrightarrow B$ $\Delta H° = +40.0$ kJ reverse

b. heat is removed from: $A + B \leftrightarrow 2\ C$ $\Delta H° = -25.5$ kJ forward

c. heat is added to: $A + 2B \leftrightarrow 3\ C$ $\Delta H° = -32.0$ kJ reverse

2. In each of the following equilibria, would you increase or decrease the temperature to force the reaction in the forward direction?

a. $H_{2\,(g)} + CO_{2\,(g)} \leftrightarrow H_2O_{(g)} + CO_{(g)}$ $\Delta H° = +41.0$ kJ increase

b. $2\ SO_{2\,(g)} + O_{2\,(g)} \leftrightarrow 2\ SO_{3\,(g)}$ $\Delta H° = -198$ kJ decrease

3. For each of the equilibria in Question 2 will the value for K_{eq} increase or decrease if the temperature is raised?

a. $H_{2\,(g)} + CO_{2\,(g)} \leftrightarrow H_2O_{(g)} + CO_{(g)}$ $\Delta H° = +41.0$ kJ increase

b. $2\ SO_{2\,(g)} + O_{2\,(g)} \leftrightarrow 2\ SO_{3\,(g)}$ $\Delta H° = -198$ kJ decrease

4. Explain the effect of using a platinum catalyst in the equilibrium reaction of ammonia with oxygen:
$4\ NH_{3\,(g)} + 5\ O_{2\,(g)} \leftrightarrow 4\ NO_{(g)} + 6\ H_2O_{(g)}$ + heat

x forward rx rate and reverse rx rate
will both speed up if a catalyst
is added

PART E EXTRA PRACTICE

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.

1)

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

Stress	Equilibrium Shift	$[N_2]$	$[H_2]$	$[NH_3]$	K_{eq}
1. Add N_2	right	—	decreases	increases	remains the same
2. Add H_2	RIGHT	↓	—	↑	"
3. Add NH_3	LEFT	↑	↑	—	"
4. Remove N_2	LEFT	—	↑	↓	"
5. Remove H_2	LEFT	↑	—	↓	"
6. Remove NH_3	RIGHT	↓	↓	—	"
7. Increase Temperature	LEFT	↑	↑	↓	↓
8. Decrease Temperature	RIGHT	↓	↓	↑	↑
9. Increase Pressure	RIGHT	↓	↓	↑	remains same
10. Decrease Pressure	LEFT	↑	↑	↓	"

LE CHATELIER'S PRINCIPLE CONTINUED

Name _____

2)

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

Stress	Equilibrium Shift	$[H_2]$	$[I_2]$	[HI]	K
1. Add H_2	right	——	decreases	increases	remains the same
2. Add I_2	Right	↓	——	↑	"
3. Add HI	Left	↑	↑	——	"
4. Remove H_2	Left	——	↑	↓	"
5. Remove I_2	Left	↑	——	↓	"
6. Remove HI	Right	↓	↓	——	"
7. Increase Temperature	Right	↓	↓	↑	↑
8. Decrease Temperature	left	↑	↑	↓	↓
9. Increase Pressure	no	change			remains same
10. Decrease Pressure		no	change		remains same.

3)

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

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

Stress	Equilibrium Shift	Amount NaOH(s)	$[Na^+]$	$[OH^-]$	K
1. Add NaOH(s)	no change	——			no change
2. Add NaCl (Adds Na^+)	left	increase	——	↓	no change
3. Add KOH (Adds OH^-)	left	increase	↓	——	"
4. Add H^+ (Removes OH^-)	right	decrease	↑	——	"
5. Increase Temperature	left	increase	↓	↓	decrease
6. Decrease Temperature	right	decrease	↑	↑	increase.
7. Increase Pressure	} no change.				
8. Decrease Pressure					