Name: $\qquad$ Date: $\qquad$
Chemistry ~Ms. Hart Class: Anions or Cations

### 7.3 Le Chatelier's Principle

- Any change in $\qquad$ , $\qquad$ , or $\qquad$ on an equilibrium system is called a $\qquad$ .
- LeChatelier's Principle explains how a reaction system at equilibrium responds or
$\qquad$ to $\qquad$ the stress.


## Concentration Change:

Consider the following reaction:

$$
\mathrm{C}_{6} \mathrm{H}_{8} \mathrm{O}_{7}(\mathrm{aq})+3 \mathrm{NaHCO}_{3}(\mathrm{aq}) \rightleftharpoons 3 \mathrm{H}_{2} \mathrm{O}(\mathrm{l})+3 \mathrm{CO}_{2}(\mathrm{~g})+\mathrm{Na}_{3} \mathrm{C}_{6} \mathrm{H}_{5} \mathrm{O}_{7}
$$

When we add more reactants $\left(\mathrm{C}_{6} \mathrm{H}_{8} \mathrm{O}_{7}\right.$ and $\left.\mathrm{NaHCO}_{3}\right)$, we created a $\qquad$ on the system.

- Reaction went to the $\qquad$ : The rate of the $\qquad$ rxn increase and more $\qquad$ formed

What would happen if we added more $\mathrm{CO}_{2}(\mathrm{~g})$ ?

- Reaction will go to the $\qquad$ : The rate of the $\qquad$ rxn will increase and more $\qquad$ will form.


## Example:

The following example shows how a change in concentration affects equilibrium. A plus sign (+) means the concentration increases, and a minus sign (-) means that the concentration decreases.

$$
4 \mathrm{NH}_{3}(\mathrm{~g})+5 \mathrm{O}_{2}(\mathrm{~g}) \rightleftharpoons 4 \mathrm{NO}(\mathrm{~g})+6 \mathrm{H}_{2} \mathrm{O}(\mathrm{~g})+\text { heat }
$$

Stress: More $\mathrm{NH}_{3}(\mathrm{~g})$ is added
Response: $4 \mathrm{NH}_{3}(\mathrm{~g})+5 \mathrm{O}_{2}(\mathrm{~g}) \rightleftharpoons 4 \mathrm{NO}(\mathrm{g})+6 \mathrm{H}_{2} \mathrm{O}(\mathrm{g})+$ heat

Stress: More $\mathrm{H}_{2} \mathrm{O}$ is added
Response: $4 \mathrm{NH}_{3}(\mathrm{~g})+5 \mathrm{O}_{2}(\mathrm{~g}) \rightleftharpoons 4 \mathrm{NO}(\mathrm{g})+6 \mathrm{H}_{2} \mathrm{O}(\mathrm{g})+$ heat

Stress: $\mathrm{O}_{2}(\mathrm{~g})$ is removed
Response: $4 \mathrm{NH}_{3}(\mathrm{~g})+5 \mathrm{O}_{2}(\mathrm{~g}) \rightleftharpoons 4 \mathrm{NO}(\mathrm{g})+6 \mathrm{H}_{2} \mathrm{O}(\mathrm{g})+$ heat

## Temperature Change:

Consider the production of ammonia:

$$
\mathrm{N}_{2}(\mathrm{~g})+3 \mathrm{H}_{2}(\mathrm{~g}) \rightleftharpoons 2 \mathrm{NH}_{3}(\mathrm{~g})+\text { heat }
$$

Is heat on the product side or the reactant side? $\qquad$

- If we add more heat (raising temperature), the reaction will go to the $\qquad$ and more
$\qquad$ will form.
- If we release heat (lowering temperature), the reaction will go to the $\qquad$ and more
$\qquad$ will form.


## Example:

Given the following balanced equation:

$$
4 \mathrm{NH}_{3}(\mathrm{~g})+5 \mathrm{O}_{2}(\mathrm{~g}) \rightarrow 4 \mathrm{NO}(\mathrm{~g})+6 \mathrm{H}_{2} \mathrm{O}(\mathrm{~g})+\text { heat }
$$

## Stress: Raise temperature

Response: $4 \mathrm{NH}_{3}(\mathrm{~g})+5 \mathrm{O}_{2}(\mathrm{~g}) \rightarrow 4 \mathrm{NO}(\mathrm{g})+6 \mathrm{H}_{2} \mathrm{O}(\mathrm{g})+$ heat

## Stress: Lower temperature

Response: $4 \mathrm{NH}_{3}(\mathrm{~g})+5 \mathrm{O}_{2}(\mathrm{~g}) \rightarrow 4 \mathrm{NO}(\mathrm{g})+6 \mathrm{H}_{2} \mathrm{O}(\mathrm{g})+$ heat

Given the following balanced equation: (notice that heat is on the reactant side now)

$$
\mathrm{A}+\mathrm{B}+\text { heat } \rightarrow \mathrm{C}
$$

Stress: Raise temperature
Response: $\mathrm{A}+\mathrm{B}+$ heat $\rightarrow \mathrm{C}$

## Stress: Lower temperature

Response: $\mathrm{A}+\mathrm{B}+$ heat $\rightarrow \mathrm{C}$

## Pressure Changes:

An increase in pressure will favor the reaction toward the side with the fewer $\qquad$
(less $\qquad$ = fewer $\qquad$

$$
\mathrm{N}_{2}(\mathrm{~g})+3 \mathrm{H}_{2}(\mathrm{~g}) \rightarrow 2 \mathrm{NH}_{3}(\mathrm{~g})
$$

Step 1: What is the total number of moles of reactants? (hint: add the coefficient together on the left side) $\qquad$
Step 2: What is the total number of moles of products? (hint: add the coefficient together on the right side) $\qquad$
If pressure is increased, which way will the reaction go? $\qquad$
If pressure is decreased, which way will the reaction go? $\qquad$

## Example:

Consider the following balanced equation:

$$
4 \mathrm{NH}_{3}(\mathrm{~g})+5 \mathrm{O}_{2}(\mathrm{~g}) \rightleftharpoons 4 \mathrm{NO}(\mathrm{~g})+6 \mathrm{H}_{2} \mathrm{O}(\mathrm{~g})+\text { heat }
$$

If pressure is increased, which way will the reaction go? $\qquad$
If pressure is decreased, which way will the reaction go? $\qquad$
NOTE: Decrease in $\qquad$ $=$ $\qquad$ in PRESSURE

Increase in $\qquad$ $=$ $\qquad$ in PRESSURE

## Classwork:

Consider the equation for the following reaction at equilibrium and answer questions 1-5

$$
\mathrm{X}+\mathrm{Y} \leftrightarrow 2 \mathrm{Z}+\text { heat }
$$

1. If the concentration of $X$ is increased, which way will the reaction proceed according to Le Chatelier's Principle?
2. What will happen to the concentration of $Y$ once the reaction responds to the increase in $X$ ?
3. If the concentration of Z is increased, which way will the reaction proceed according to Le Chatelier's Principle?
4. The concentration of the product could be increased by
(1) adding catalyst
(2) adding more heat to the system
(3) increasing the concentration of $Y$
(4) decreasing the concentration of X
5. Which way will the reaction proceed if heat is added to the system?
6. Consider the following equation.

$$
\mathrm{N}_{2}(\mathrm{~g})+3 \mathrm{H}_{2}(\mathrm{~g}) \leftrightarrow 2 \mathrm{NH}_{3}(\mathrm{~g})+
$$

heat
What stress would cause the equilibrium to shift to the left?
(1) decreasing the temperature
(2) adding $\mathrm{N}_{2}(\mathrm{~g})$ to the system
(3) adding $\mathrm{H}_{2}(\mathrm{~g})$ to the system
(4) adding $\mathrm{NH}_{3}$ to the system
7. Consider the following equation.
$\mathrm{Zn}(\mathrm{s})+\mathrm{HCl}(\mathrm{aq}) \leftrightarrow \mathrm{ZnCl}_{2}(\mathrm{aq})+\mathrm{H}_{2}(\mathrm{~g})$
As the concentration of the $\mathrm{HCl}(\mathrm{aq})$ decreases at constant temperature, the rate of the forward reaction
(1) decreases
(3) remains the same
(2) increases
(4) equals the rate of the reverse reaction
8. Consider the following reaction.
$\mathrm{H}_{2}(\mathrm{~g})+\mathrm{Cl}_{2}(\mathrm{~g}) \leftrightarrow 2 \mathrm{HCl}(\mathrm{g})+$ heat Which change will result in an increase in the concentration of $\mathrm{Cl}_{2}(\mathrm{~g})$ ?
(1) decreasing the temperature of the system
(2) decreasing the concentration of HCl
(3) increasing the concentration of $\mathrm{H}_{2}(\mathrm{~g})$
(4) increasing the concentration of HCl
9. Consider the following equation.

$$
\mathrm{N}_{2}(\mathrm{~g})+\mathrm{O}_{2}(\mathrm{~g}) \leftrightarrow 2 \mathrm{NO}(\mathrm{~g})
$$

As the concentration of $\mathrm{N}_{2}(\mathrm{~g})$ increases, the concentration of $\mathrm{O}_{2}(\mathrm{~g})$ will
(1) decrease
(2) increase
(3) remain the same
(4) vary directly

Complete the following questions in FULL SENTENCES using the format in the example.
Methanol (methyl alcohol) can be manufactured using the following equilibrium reaction:

$$
\mathrm{CO}(\mathrm{~g})+2 \mathrm{H}_{2}(\mathrm{~g}) \leftrightarrow \mathrm{CH}_{3} \mathrm{OH}(\mathrm{~g})+\text { energy }
$$

Predict the effect of the following stresses on the equilibrium concentration of $\mathrm{CH}_{3} \mathrm{OH}(\mathrm{g})$. Note that you should first determine the shift.

EXAMPLE: Removing CO(g) to the system.
Answer: The equilibrium will shift to the left and the concentration of $\mathrm{CH}_{3} \mathbf{O H}$ will DECREASE.
10. Increasing the volume of the system.
11. Adding $\mathrm{H}_{2}(\mathrm{~g})$.
12. Increasing the pressure of the system.
13. Decreasing the temperature of the system.

Use the equation above to fill out the chart below. Write FORWARD or REVERSE in the right column.

| Direction of stress |  |
| :--- | :--- |
| Concentration of reactant decreases. |  |
| Temperature decreases. |  |
| Concentration of product increases. |  |
| Volume decreases (pressure increases) |  |
| Concentration of product decreases |  |
| Concentration of reactant increases |  |
| Temperature increases. |  |
| Volume increases (pressure decreases) |  |
| A catalyst is added. |  |

*Tarendash, A.S., Barron's Review: Chemistry The Physical Setting, pg. 284

## Concentration:

If the concentration of the (reactant/product)(increases/decreases), then the number of effective collisions (increases/decreases). To relieve this stress, the reaction equilibrium will shift (left/right) and make more (product/reactant).

## Volume:

If the volume (increases/decreases), then the pressure will (increase/decrease). To relieve the stress of this change in pressure, the reaction equilibrium will shift (left/right) to produce (fewer/more) molecules.

## Temperature:

If the temperature (increases/decreases), the reaction equilibrium will shift (left/right) towards heat being (produced/released).

## MORE PRACTICE

14. In the equilibrium reaction:

$$
2 \mathrm{SO} 2(\mathrm{~g})+\mathrm{O} 2(\mathrm{~g}) \leftrightarrow 2 \mathrm{SO}_{3}(\mathrm{~g})+\text { energy }
$$

a. What will be the change in the equilibrium concentration of $\mathrm{SO}_{3}$ if energy is added to the system?
b. What will be the change in the equilibrium concentration of $\mathrm{O}_{2}$ if the temperature of the system is decreased?
c. Should the temperature be increased or decreased in order to increase the concentration of NO?
d. Explain in words, using Le Chatelier's Principle, why decreasing the volume of the system results in an increase of oxygen being produced.
15. Use Le Chatelier's principle to predict how the changes listed will affect the following equilibrium reaction:

$$
9.4 \mathrm{~kJ}+2 \mathrm{HI}(\mathrm{~g}) \leftrightarrow \mathrm{H}_{2}(\mathrm{~g})+\mathrm{I}_{2}(\mathrm{~g})
$$

e. Explain why, using Le Chatelier's Principle, the concentration of HI increases when a small amount of $\mathrm{H}_{2}$ is added.
f. What is the effect on the concentration of HI if a catalyst is added?
g. EXPLAIN how an increase in the volume of the system affects the concentration of $\mathrm{I}_{2}(\mathrm{~g})$. Include your reasoning.
h. How does [HI] change if the temperature of the system is decreased?
i. If argon gas is added to the reaction, pressure does increased, but the equilibrium does NOT shift. Why not?
16. Methanol (methyl alcohol) can be manufactured using the following equilibrium reaction:

$$
\mathrm{CO}(\mathrm{~g})+2 \mathrm{H}_{2}(\mathrm{~g}) \leftrightarrow \mathrm{CH}_{3} \mathrm{OH}(\mathrm{~g})+\text { energy }
$$

Predict the effect of the following changes on the equilibrium concentration of $\mathrm{CH}_{3} \mathrm{OH}(\mathrm{g})$.
a. an increase in pressure
b. addition of $\mathrm{H}_{2}(\mathrm{~g})$
c. addition of a catalyst
d. removing $\mathrm{CO}(\mathrm{g})$
e. increasing the temperature of the reaction.
f. Using Le Chatelier's Priniciple, explain why an increase in the concentration of $\mathrm{CH}_{3} \mathrm{OH}(\mathrm{g})$ results in a increase in the concentration of $\mathrm{CO}(\mathrm{g})$.
17. For the following reaction:

$$
\mathrm{N}_{2} \mathrm{O}_{4}(\mathrm{~g})+58.9 \mathrm{~kJ} \leftrightarrow 2 \mathrm{NO}_{2}(\mathrm{~g})
$$

How will the equilibrium concentration of $\mathrm{NO}_{2}$ be affected by the following conditions?
g. the addition of Neon gas.
h. an increase in volume.
18. Explain one way (not involving a change in volume), that you could use to shift the equilibrium position in favor of increasing $\mathrm{N}_{2} \mathrm{O}_{4}(\mathrm{~g})$ concentration.
19. Explain, in terms of crowding, the effect a decrease in volume would have on the system.
20. Explain the main idea behind Le Chatelier's Principle in your own words.

