Chemistry 12

Equilibrium II

Name:
Date:
Block:

1. **Le Châtelier's Principle**
2. **Equilibrium Graphs**

Le Châtelier's Principle

When a person is stressed, their body will work in some way to alleviate the imposed stress.

Le Châtelier's Principle: An equilibrium system subjected to a stress will _____ to partially alleviate the stress and _____ equilibrium.

- Whenever a system is stressed, it alleviates it by altering the concentration of reactants or products.

When a system responds by changing some **reactants into products**, the response is referred to as "_____ _____" because the products are on the right side of the chemical equation.

When a system responds by changing some **products back into reactants**, the response is referred to as "_____ _____" because the reactants are on the left side of the chemical equation.

Stresses – Changes in conditions:

1. **Concentration**

$$2\ NOCl_{(g)} \leftrightharpoons 2\ NO_{(g)} + Cl_{2\ (g)}$$

In which direction will the reaction shift to alleviate the stress. Compare the concentration of each substance before the stress:

- Addition of $NOCl_{(g)}$:
  - Shift:
  - [NOCl] [NO] $[Cl_2]$
- Addition of $NO_{(g)}$:
  - Shift:
  - [NOCl] [NO] $[Cl_2]$
- Removal of $NO_{(g)}$:
  - Shift:
  - [NOCl] [NO] $[Cl_2]$
- Removal of $Cl_{2(g)}$:
  - Shift:
  - [NOCl] [NO] $[Cl_2]$

$$H_{2\,(g)} + I_{2\,(g)} \leftrightharpoons 2\,HI_{(g)}$$

In which direction will the reaction shift to alleviate the stress:

- Addition of $HI_{(g)}$:

- Addition of $H_{2\,(g)}$:

- Removal of $HI_{\,(g)}$:

Consider the following equilibrium system:

$$2\ SO_{2\ (g)} + O_{2\ (g)} \leftrightharpoons 2\ SO_{3\ (g)}$$

Explain in terms of forward and reverse reaction rates how the equilibrium would respond to each of the following changes:

1. Addition of $SO_{2\ (g)}$

2. Removal of $O_{2\ (g)}$

3. Addition of $SO_{3\ (g)}$

4. Removal of $SO_{3\ (g)}$

Application:

Hemoglobin is the protein in red blood cells that transports oxygen to cells throughout your body. Each hemoglobin (Hb) molecule attaches to four oxygen molecules:

$$Hb_{\ (aq)} + 4\ O_{2\ (aq)} \leftrightharpoons Hb(O_2)_{4\ (aq)}$$

In which direction does the above equilibrium shift in each of the following situations:

a) At high elevations the air pressure is lowered reducing the $[O_2]$ in the blood.

b) At high altitude, climbers breathe pressurized oxygen from a tank to increase the $[O_2]$ in the blood.

c) People who live at higher altitudes produce more hemoglobin.

d) Carbon monoxide poisoning occurs when carbon monoxide molecules bind to hemoglobin instead of oxygen molecules. Carboxyhemoglobin is even redder than oxyhemoglobin; therefore, one symptom of carbon monoxide poisoning is a flushed face.

2. Temperature

- The system will shift to remove some of the added kinetic energy or to replace some of the remove kinetic energy.

$$N_{2\,(g)} + O_{2\,(g)} \leftrightharpoons 2\,NO_{(g)} \qquad \Delta H = +181\ kJ/mol$$

1. Is this an endothermic or exothermic reaction?

2. Rewrite the equation with "heat" as a reactant or product.

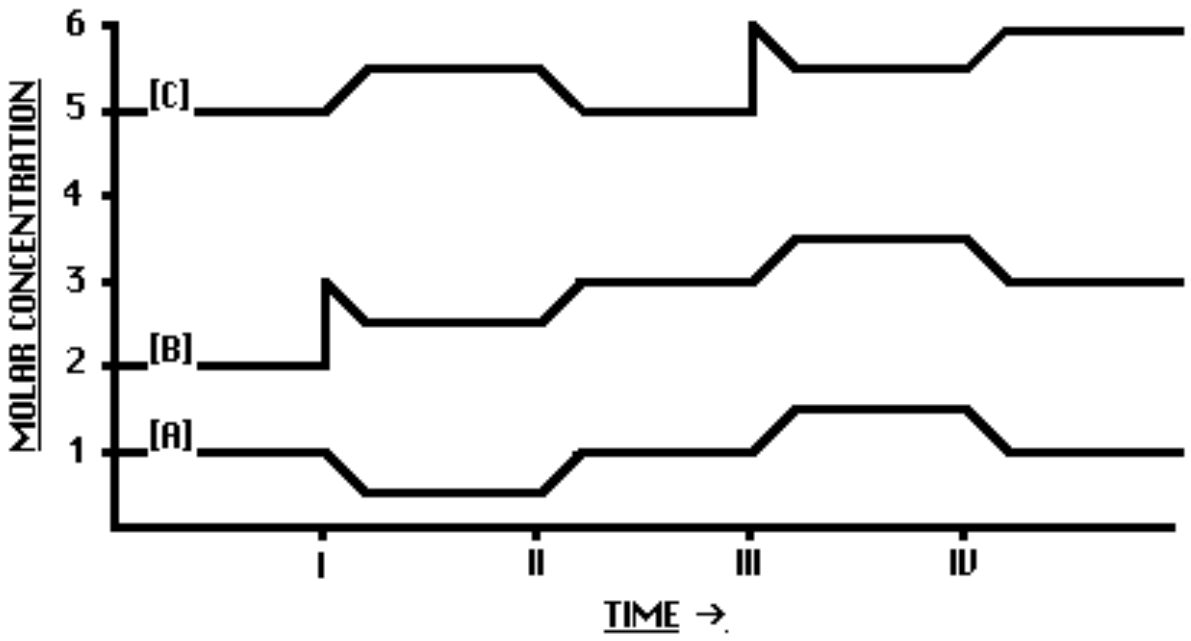
3. If the system is heated, in which direction will the system shift to restore equilibrium?
   - *Think of the term "heat" as a reactant or product that is being added or consumed.*

4. If the system is cooled, in which direction will the system shift to restore equilibrium?
   - *Think of the term "heat" as a reactant or product that is being added or consumed.*

Example:

Given the following graph showing the concentrations of species A, B and C, state what changes in **temperature** or **concentration** are responsible for each of the shifts shown on the graph. The equilibrium equation is:

$$A(g) + B(g) \rightleftarrows C(g) \qquad \Delta H = -65\ kJ$$



a) At time I, the reaction shifted _____. The stress is _____.

b) At time II, the reaction shifted _____. The stress is _____.

c) At time III, the reaction shifted _____. The stress is _____.

d) At time IV, the reaction shifted _____. The stress is _____.

3. Pressure/Volume (only gases)

- The system will respond to volume changes by shifting to relieve some of the added pressure or to replace some of the lost pressure.
- Recall from Chemistry 11:
  - *Avogadro's Hypothesis: Equal volumes of different gases, measured the same temperature and pressure, have equal numbers of particles.*

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

1. How many moles of gases are on each side?

2. If the volume was increased… (or pressure was _____)
   a. What would happen to the concentration of each gas?

   b. Will the equilibrium shift? If so, towards which side?

3. If the pressure was increased… (or volume was _____)
   a. What would happen to the concentration of each gas?

   b. Will the equilibrium shift? If so, towards which side?

$$H_{2\,(g)} + F_{2\,(g)} \leftrightharpoons 2\,HF_{\,(g)}$$

1. How many moles of gases are on each side?

2. If the volume was increased… (or pressure was _____)
   a. What would happen to the concentration of each gas?

   b. Will the equilibrium shift? If so, towards which side?

3. If the pressure was increased… (or volume was _____)
   a. What would happen to the concentration of each gas?

   b. Will the equilibrium shift? If so, towards which side?

4. Catalyst

- Does not change or shift the equilibrium
- Forward and reverse rates are increased by same amount

$2\ NOCl_{(g)} \leftrightharpoons 2\ NO_{(g)} + Cl_{2\,(g)} + heat$

Stress:	**Equilibrium shift:**
1. Increase in volume	
2. Decrease in volume	
3. Addition of reactant	
4. Addition of NO	
5. Removal of Cl_2	
6. Increase heat	

$CO_{2\,(g)} + H_{2\,(g)} + \text{heat} \leftrightharpoons CO_{(g)} + H_2O_{(g)}$

Stress:	**Equilibrium shift:**
1. Increase in volume	
2. Increase in pressure	
3. Addition of catalyst	
4. Addition of CO_2	
5. Addition of CO	
6. Removal of H_2	
7. Removal of H_2O	
8. System cooled down	

Worksheet

Hebden Workbook Read Pg. 50-53, Questions #17-28