AP Chemistry
Ms. Ye

Name _____
Date _____Block _____

So far, when we've looked at chemical reactions, we've assumed that if the reaction occurs, it goes to completion. However, many chemical reactions can occur in reverse as well.

What happens when a reverse and forward reaction occur simultaneously?

You are going to simulate the forward and reverse reaction of $A \rightleftharpoons B$

In pairs, assign one person to represent the reactant side (A) and one to represent the product side (B).

1. Start with 40 paper clips on the reactant side and 0 paper clips on the products side. During each "transfer", both the forward and reverse reaction will occur.
   a. Every time the **forward reaction** occurs, 1/2 of the reactant paper clips are transferred to the product side (round up if it's a fraction ex. 7.5=8)
   b. Every time the **reverse reaction** occurs, 1/4 of the product paper clips are transferred to the reactant side (round up if it's a fraction ex. 7.5=8)
2. Record the number of paper clips you have on each side after every transfer of the reaction in the table.

	A (Reactant Side)		**B (Product Side)**	
	# of clips	**# transferred**	**# transferred**	**# of clips**
Initial	40			0
1st Transfer		→ 20	0 ←	
Outcome				
2nd Transfer		→	←	
Outcome				
3rd Transfer		→	←	
Outcome				
4th Transfer		→	←	
Outcome				
5th Transfer		→	←	
Outcome				

Questions:

1. Looking at your results, after which transfer does this process (reaction) reach equilibrium?

2. **Once the reaction is at equilibrium**,
   a. What happens to the concentration (# of clips) of the reactants (A)?

   b. What happens to the concentration (# of clips) of the products (B)?

   c. Are the concentrations of the reactants (A) and the products (B) the same?

   d. How does the transfer of clips from the reactants to the products side compare to the transfer of clips from the products to the reactants side?

3. How many clips would be transferred on the 100^{th} cycle?

Dynamic Equilibrium

- Equilibrium occurs when the _____ of the forward reaction equals the _____ of the reverse reaction in a closed system.
- ***When equilibrium is reached, the _____ of reactants and products are _____, but they _____ necessarily _____ to each other
- Equilibrium is represented by _____ arrows instead of a single arrow. This allows us to illustrate the reactions are proceeding in _____ directions (_____ and _____)
- Equilibrium is _____ which means that it is constantly _____ (the reaction doesn't stop just because it's at equilibrium)

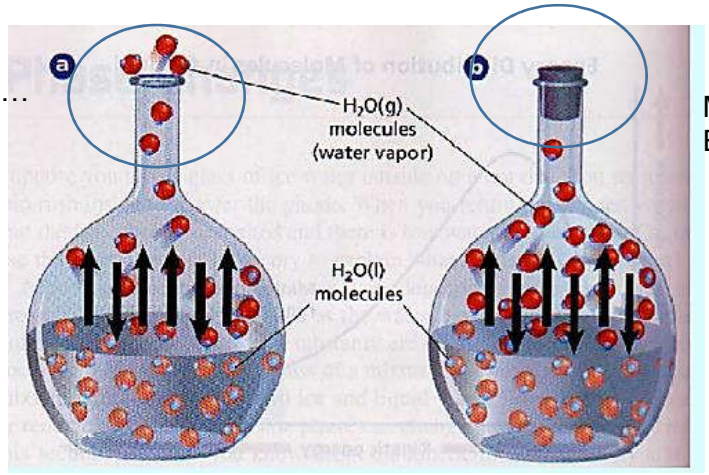
At Equilibrium

- What are **Equal**: _____ of _____
- What are **Constant**: _____ of _____

Equilibrium can only be established in a _____ system!

- No substances can enter or escape the container!
- The concentration of reactants and products must _____

Molecules can escape…
No equilibrium can be established.



Molecules can't escape…
Equilibrium can be established.

Types of Equilibrium:

1) Chemical Equilibrium:
   Ex: Chemical reaction in closed container that has reached equilibrium
   Rate of Forward Reaction = Rate of Reverse Reaction

2) Phase Equilibrium: Occurs during a phase change
   Ex: Closed container of water at 100°C.
   $H_2O(l) \rightleftharpoons H_2O(g)$: Rate of Evaporation = Rate of Condensation

3) Solution Equilibrium: occurs when a solution is saturated
   Ex: Closed container of saturated NaCl.
   $NaCl(s) \rightleftharpoons NaCl(aq)$: Rate of Dissolving = Rate of Crystallization

Concept Check:

1. Given the equation representing a closed system: $N_2O_4(g) \rightleftharpoons 2NO_2(g)$

   Which statement describes this system at equilibrium?

A. The volume of the $NO_2(g)$ is greater than the volume of the $N_2O_4(g)$.
B. The volume of the $NO_2(g)$ is less than the volume of the $N_2O_4(g)$.
C. The rate of the forward reaction and the rate of the reverse reaction are equal.
D. The rate of the forward reaction and the rate of the reverse reaction are unequal.

2. Given the equation representing a reaction: $N_2O_4(g) \rightleftharpoons 2NO_2(g)$

   Which statement describes this reaction at equilibrium?

A. The concentration of $N_2O_4(g)$ must equal the concentration of $NO_2(g)$.
B. The concentration of $N_2O_4(g)$ and the concentration of $NO_2(g)$ must be constant.
C. The rate of the forward reaction is greater than the rate of the reverse reaction.
D. The rate of the reverse reaction is greater than the rate of the forward reaction.

<u>Le Chatelier's Principle</u>: Explains how a system at equilibrium will respond to stress

Stress=any change in _____, _____, or _____ put upon a system at equilibrium

When a STRESS is added to a system at equilibrium, the system will SHIFT in order to relieve that stress and reach a new equilibrium.

Shift= an _____in the _____ of either the _____ OR the _____ reaction

Ex: Consider the following reaction at equilibrium:

$$2H_2(g) + O_2(g) \leftrightarrow 2H_2O(g) + \text{heat}$$

Stress	**Result of Stress**	**Direction of Shift to Return to Equilibrium**	**Effect on Concentration of H_2**	**Effect on Concentration of O_2**	**Effect on Concentration of H_2O**
Increase Concentration of H_2 (Add H_2)					

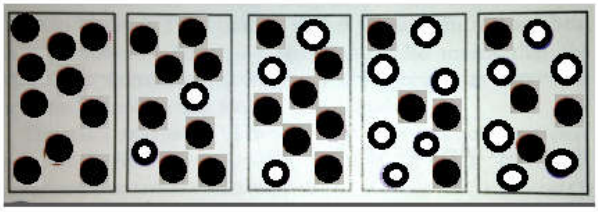
Practice: Determine the effects of the following stresses on the reaction at equilibrium

$$2H_2\,(g) + O_2\,(g) \leftrightarrow 2H_2O\,(g) + \text{heat}$$

Stress	**Result of Stress**	**Direction of Shift to Return to Equilibrium**	**Effect on Concentration of H_2**	**Effect on Concentration of O_2**	**Effect on Concentration of H_2O**
Decrease Concentration of H_2 (Remove H_2)					
Increase Concentration of O_2 (Add O_2)					
Decrease Concentration of O_2 (Remove O_2)					
Increase Concentration of H_2O (Add H_2O)					
Decrease Concentration of H_2O (Remove H_2O)					
Increase Temperature (Add heat)					
Decrease Temperature (Remove heat)					
Increase Pressure (Stress is on side with more moles of gas)					
Decrease Pressure (Stress is on side with less moles of gas)					

Equilibrium Intro Problem Set

1. The following diagrams represent a hypothetical reaction A → B, with A represented by black spheres and B represented by white spheres. The sequence from left to right represents the system as time passes. Do the diagrams indicate the system reaches an equilibrium state? Explain.



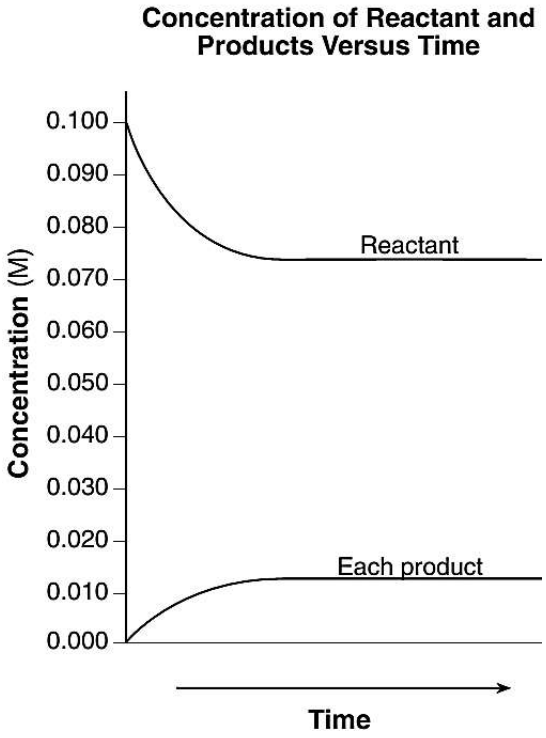
2. In a laboratory, 0.100 mole of colorless hydrogen iodide gas at room temperature is placed in a 1.00-liter flask. The flask is sealed and warmed, causing the HI(g) to start decomposing to $H_2(g)$ and $I_2(g)$. The reaction at equilibrium can be represented by the equation:

$2HI(g) \leftrightarrow H_2(g) + I_2(g) + 53\ kJ$

a. State, ***in terms of concentration***, evidence that indicates the system in the flask has reached equilibrium.

b. If the system is at equilibrium, describe the rate of forward reaction compared to the rate of reverse reaction.

c. Explain why the container had to be sealed in order for the reaction to reach and maintain equilibrium



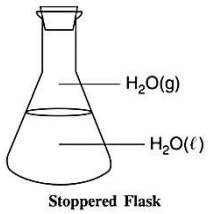
d. If more H_2 gas is added to the flask:

i. What direction will the reaction shift in order to reestablish equilibrium?

ii. What will happen to the concentration of I_2?

iii. What will happen to the concentration of HI?

3. Given the diagram representing a closed system at constant temperature:



Which statement describes this system at equilibrium?

a. The mass of $H_2O(l)$ equals the mass of $H_2O(g)$
b. The volume of $H_2O(l)$ equals the volume of $H_2O(g)$
c. The number of moles of $H_2O(l)$ equals the number of moles of $H_2O(g)$
d. The rate of evaporation of $H_2O(l)$ equals the rate of condensation of $H_2O(g)$

4. Given the equation representing a reaction at equilibrium:

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

Which change causes the equilibrium to shift to the right?

a. Decreasing the concentration of $H_2(g)$
b. Decreasing the pressure
c. Increasing the concentration of $N_2(g)$
d. Increasing the temperature

5. Given the equation representing a reaction at equilibrium:

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

What occurs when the concentration of $H_2(g)$ is increased?

a. The equilibrium shifts to the left, and the concentration of $N_2(g)$ decreases
b. The equilibrium shifts to the left, and the concentration of $N_2(g)$ increases
c. The equilibrium shifts to the right, and the concentration of $N_2(g)$ decreases
d. The equilibrium shifts to the right, and the concentration of $N_2(g)$ increases

6. Given the system at equilibrium:

$2POCl_3(g) + \text{energy} \leftrightarrow 2PCl_3(g) + O_2(g)$

Which changes occur when $O_2(g)$ is added to this system?

a. The equilibrium shifts to the right and the concentration of $PCl_3(g)$ increases
b. The equilibrium shifts to the right and the concentration of $PCl_3(g)$ decreases
c. The equilibrium shifts to the left and the concentration of $PCl_3(g)$ increases
d. The equilibrium shifts to the left and the concentration of $PCl_3(g)$ decreases

7. Given the equation representing a system at equilibrium:

$$AgCl(s) \overset{H_2O}{\rightleftharpoons} Ag^+(aq) + Cl^-(aq)$$

When the concentration of Cl-(aq) is increased, the concentration of Ag+(aq)

a. Decreases, and the amount of AgCl(s) increases
b. Decreases, and the amount of AgCl(s) decreases
c. Increases, and the amount of AgCl(s) increases
d. Increases, and the amount of AgCl(s) decreases