Name: _____ Period: _____

Notes and Homework Packet
Unit 9: Rates and Equilibrium

Unit 9 Test Date: _____

- All homework is due by the date of the test
- All quizzes and quiz retakes are due by the date of the test
- All labs are due by the date of the test

Course calendar and additional resources are available at:
www.bazatachemistry.weebly.com or www.whsblendedchem.weebly.com

Unit 9 Vocab

Term	Definition
activated complex	
activation energy	
catalyst	
chemical equilibrium	
collision theory	
completion reaction	
concentration	
endothermic	
exothermic	
heterogeneous equilibrium	
homogeneous equilibrium	
Keq	
Keq < 1	
Keq > 1	
Ksp	
Law of Chemical Equilibrium	

Le Chatelier's Principle	
reaction rate	
reversible reactions	
solute	
solvent	
transition state	

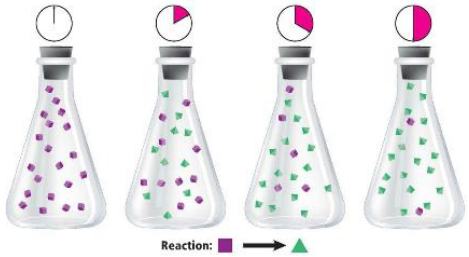
Guided Notes: Reaction Kinetics and Collision Theory

Expressing Reaction Rates

- Some chemical reactions are _____ and others are _____, but chemists need to be more _____.
- What is a rate?
- How do we use rates in everyday life?

- How would we measure the rate of a reaction?

- Equation for rate



- What happens to the amount of reactants over time? _____
- What happens to the amount of products over time? _____
- Do you think you would observe the same changes in reactants and products for every reaction? Explain.

Reaction Rate

- Reaction rate for chemistry is defined as: _____
  _____
- Concentration: _____
  - solute: _____
  - solvent: _____
  - ex: salt in water, salt is the _____, water is the _____
  - unit typically used for concentration in chemistry: _____,which means: _____
- Reaction rates are determined _____ by measuring the _____ of the reactants and/or products in a _____ _____.
- Reaction rates CANNOT by calculated from a _____.
- Reaction rates must always be _____.

Collision Theory

- In order for a reaction to occur:
  - reactants must _____
  - collisions must be in the _____
  - collisions must have a _____ for bonds to break
- Activated Complex: a temporary, unstable arrangement of atoms in which _____ and _____.
- _____ is another name for activated complex.
- Collisions with the correct orientation must also have a sufficient amount of _____.
- This amount of energy is called the _____.
- Symbol: _____
- How would a high vs. a low activation energy affect the speed of a reaction?

Activation Energy

- Reaction #1:

- Reaction #2:

- Which graph is exothermic? _____ How do you know?
- Which graph is endothermic? _____ How do you know?
- Which graph has a higher activation energy? _____
- Which reaction in the graphs will be faster? Explain.

Factor Affecting Reaction Rate:

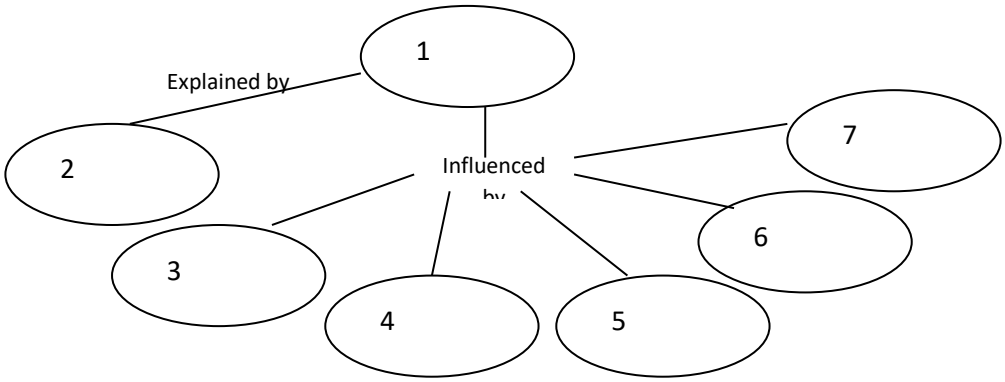
- _____
- _____
- _____
- _____
- _____
    - substance that _____ the rate of reaction _____.
    - creates a lower _____
    - _____
    - Sketch:

HOMEWORK: Kinetics (Reaction Rate) Practice

Complete the following concept map using the following terms:

Surface area *Temperature* *Concentration* *Catalyst*

Collision theory *Reaction rates* *Reactivity*



1. Define reaction rate. What does the reaction rate indicate about a particular chemical reaction?

2. In addition to colliding, what else must happen in order for a reaction to occur?

3. Use the collision theory to discuss how the following factors affect the rate of a chemical reaction:
   a. Temperature

   b. Concentration

   c. Surface area

4. What role does the reactivity of the reactants play in determining the rate of a chemical reaction?

5. *Answer the following questions about catalysts:*
   a. How does a catalyst affect the activation energy for a chemical reaction?

   b. What is the result of adding a catalyst to a reaction?

6. Would the changes listed below increase or decrease the rate of the following reaction:

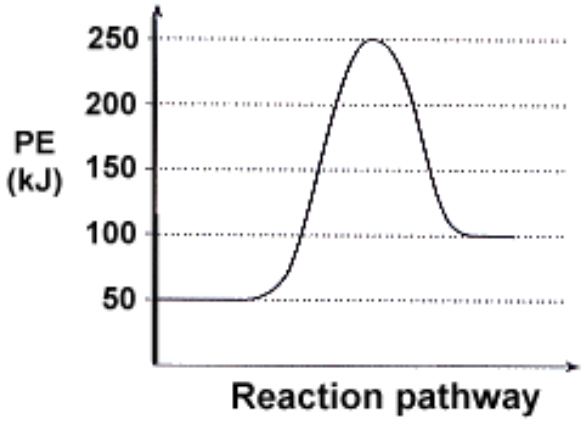
$$\mathbf{I_2\,(s) + Cl_2\,(g) \rightarrow 2ICl\,(g)}$$

   a. decreasing temperature_____ c. crushing I_2 _____

   b. Increasing $[Cl_2]$ _____ d. adding a catalyst _____

Activation Energy Diagrams

Use the graph below to answer questions 1-7: Include labels on any numerical values.



1. Label the position of the ***reactants*** on the graph.
2. Label the position of the ***products*** on the graph.
3. Lable the position of the ***activated complex*** on the graph.
4. How much energy do the reactants have at the start of the reaction? _____
5. What is the activation energy for this reaction? _____ Label this on the graph.
6. How much energy do the products have at the end of the reaction? _____
7. Is this reaction exothermic or endothermic? Explain your answer using evidence from the graph.

8. Draw an energy diagram on the axes below using the given information. Be sure to include labels and units on both the x-axis and y-axis.

   Potential energy of reactants = 350 kJ/mole
   Activation energy = 100 kJ/mole
   Potential energy of products = 250 kJ/mole

9. Is this reaction exothermic or endothermic? Explain your answer using evidence from the graph.

10. You add a catalyst to the reaction you graphed in question 8, which lowers the activation energy of the reaction from 100 kJ/mole to 50 kJ/mole. Draw the energy diagram of the catalyzed reaction on the same set of axes above (use a dashed line or a different color and label the reaction with the catalyst)

Guided Notes: Keq

2 Types of Reactions:

1. Completion Reactions:
   a. Results in a complete _____ of _____ to _____
      i. Example:
   b. 2 indicators of a completion reaction are formation of a _____ or formation of a _____
   c. most reactions ____ _____ go to completion
   d. have a _____ sided arrow in its equation
2. Reversible Reactions:
   a. Can occur in both the _____ and _____ directions
   b. Example:
      i. equations have a _____ sided arrow
   c. forward arrow indicates _____
      i.
   d. reverse arrow indicates _____
      i.
   e. both reactions will _____

Chemical Equilibrium:

A state in which the _____ and _____reactions take place at _____ rates.

_____ = _____

- The amount of the _____ and _____ are _____ at equilibrium
- Equilibrium is _____ - reactions are still occurring, even though we may not be able to see it
  - Sketch the graph below and describe what is being shown about the concentrations of the substances.

- What happens to the forward rate as it approaches equilibrium?
- What happens to the reverse rate as it approaches equilibrium?
- What is true about the forward and the reverse rate at equilibrium?

The Law of Chemical Equilibrium:

- At a given _____, a chemical system may reach a state in which a particular _____ of _____ and _____ concentrations has a constant value.
- General example reaction:
  - What do the lower case letters represent?
  - What do the capital letters represent?
- Write the general equilibrium constant expression:
  - [ ] = _____

- Keq:
  - _____
  - _____
  - _____
  - _____
- If Keq > 1
  - _____
  - _____
- if Keq < 1
  - _____
  - _____
  - Which is better for business?

2 <u>Types of Equilibrium:</u>

1. <u>Homogenous equilibrium</u>:

   _____

2. Heterogeneous equilibrium:

   _____

   a. if any of the substances in the reactions are _____or _____, leave them **out** of Keq
   b. only use _____ and _____ solutions in the expression for Keq

Example 1: Write the equilibrium expression for the following equation:

$N_2O_{4\,(g)} \leftrightarrow 2NO_{2\,(g)}$

Keq =

Example 2: Write the equilibrium expression for the following equation:

$C_{\,(s)} + H_2O_{\,(g)} \leftrightarrow CO_{\,(g)} + H_{2\,(g)}$

Keq =

Example 3: Calculate Keq for the reaction below when $[SO_3]$=0.0160M, $[SO_2]$=0.00560M, and $[O_2]$=0.0210M. Are the products or the reactants favored?

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

<u>Check for Understanding</u>**:** Determine the value of Keq at 400K for the decomposition of phosphorous pentachloride if: $[PCl_5]$ = 0.135M , $[PCl_3]$ = 0.550M, and $[Cl_2]$=0.550 M. $PCl_5(g) \leftrightarrow PCl_{3(g)} + Cl_{2(g)}$

HOMEWORK: Equilibrium Constant (K_{eq}) - Chemistry

1. *Write the equilibrium constant (K_{eq}) expressions for the following homogeneous equilibria.*

   a. $C_2H_4O\ (g) \leftrightarrow CH_4\ (g) + CO\ (g)$

   b. $3O_2\ (g) \leftrightarrow 2O_3\ (g)$

   c. $2N_2O\ (g) + O_2\ (g) \leftrightarrow 4NO\ (g)$

   d. $4NH_3\ (g) + 3O_2\ (g) \leftrightarrow 2N_2\ (g) + 6H_2O\ (g)$

   e. $4HCl\ (g) + O_2\ (g) \leftrightarrow 2Cl_2\ (g) + 2H_2O\ (g)$

   f. $PCl_5\ (g) \leftrightarrow PCl_3\ (g) + Cl_2\ (g)$

2. *Write the equilibrium constant (K_{eq}) expressions for the following heterogeneous equilibria.*

   a. $C_4H_{10}\ (l) \leftrightarrow C_4H_{10}\ (g)$

   b. $NH_4HS\ (s) \leftrightarrow NH_3\ (g) + H_2S\ (g)$

   c. $CO\ (g) + Fe_3O_4\ (s) \leftrightarrow CO_2\ (g) + 3FeO\ (s)$

   d. $(NH_4)_2CO_3(s) \leftrightarrow 2NH_3(g) + CO_2(g) + H_2O(g)$

For the following problems, show <u>all</u> of your work including set-up (with K_{eq} expression) and answer with units if needed.

3. At 773 K, the reaction $2NO\ (g) + O_2\ (g) \leftrightarrow 2NO_2\ (g)$ produces the following concentrations: $[NO] = 3.49 \times 10^{-4}$ M; $[O_2] = 0.80$ M; $[NO_2] = 0.25$ M. Calculate the equilibrium constant (K_{eq}) for this reaction.

4. The chemical equation for the decomposition of formamide is: $HCONH_2\ (g) \leftrightarrow NH_3\ (g) + CO\ (g)$ Calculate K_{eq} using the following equilibrium data: $[HCONH_2] = 0.0637$ M, $[NH_3] = 0.518$ M and $[CO] = 0.518$ M.

5. Calculate K_{eq} for the reaction for iron and water if the equilibrium concentrations are as follows: $[H_2O] = 1.00$ M & $[H_2] = 4.50$ M. $2Fe\ (s) + 3H_2O\ (g) \leftrightarrow Fe_2O_3\ (s) + 3H_2\ (g)$

6. At 793 K, the equilibrium constant for the reaction NCl_3 (g) + Cl_2 (g) $\leftrightarrow$ NCl_5 (g) is 39.3.
   a. Do the products or the reactants dominate in this equilibrium? Explain your answer in complete sentences.

   b. If the equilibrium constant for this reaction were less than 1, would the reactants or products be dominant? Explain your answer in complete sentences.

7. The equilibrium constant is 9.36 for the following reaction: A (g) + 3B (g) $\leftrightarrow$ 2C (g). The table below provides concentration data for two different reaction mixtures of these gases.

	A (mol/L)	B (mol/L)	C (mol/L)
Mixture 1	0.716	0.208	0.425
Mixture 2	0.562	0.491	0.789

   a. Calculate the K_{eq} for each mixture. Use the back of the sheet to show your work.

   b. Are both reactions at equilibrium? Explain your answer in complete sentences.

<u>Guided Notes</u>: Le'Chatelier's Principle

Background Knowledge:

1. What happens if you are running on a treadmill and someone increases the speed?

2. What happens if you are riding your bike and the wind picks up?

-- These are _____ being put on you.
--Chemists put _____ on chemical reactions.
Why do chemists want to put stresses on chemical reactions?
--Chemists put stresses on chemical reactions to produce more _____.
--_____ chemists use this.

Le'Chatelier's Principle: If a _____ is applied to a system at _____, the system shifts in the direction that relieves the _____.

<u>Changes in Concentration:</u>
Adding Reactants

1. What will happen to the balance if you add more reactants?

2. What happens if I add more CO?

$CO(g) + 3H_2(g) \leftrightarrow CH_4 + H_2O$

3. The reaction will shift to the _____.

Removing Products

1. What will happen to the balance if you remove products?

2. What happens if I remove H_2O?

$CO(g) + 3H_2(g) \leftrightarrow CH_4 + H_2O$

3. The reaction will shift to the _____.

Adding Products

1. What will happen to the balance if you add products?

2. What happens if I add H_2O?

$CO(g) + 3H_2(g) \leftrightarrow CH_4 + H_2O$

3. The reaction will shift to the _____.

Changes in Volume and Pressure:

Decreasing the Volume

1. What happens to the pressure when volume is decreasing? _____
2. What happens to the number of collisions? _____
3. To determine if the reaction will shift, we need to look at the number of _____ of the reactants and products.

   $CO(g) + 3H_2(g) \leftrightarrow CH_4 + H_2O$

4. Which side of the reaction contains more moles? _____
5. Volume only has an effect on the reaction if the _____ of reactants differs from the number of products.
6. This reaction has more moles of _____, so the reaction will shift to the _____.

Changes in Temperature

1. Alters both the _____ and the _____.
2. Think of heat as either a _____ or _____.
3. Is this an exothermic or an endothermic reaction? _____
4. Is heat considered a product or reactant in the reaction below? _____

   $CO(g) + 3H_2(g) \leftrightarrow CH_4 + H_2O + heat$

5. In this reaction, adding more heat would shift the reaction to the _____.

Addition of a Catalyst

1. _____ up a reaction, but does so in both ways.
2. _____ is just reached _____.

Summary: **Le'Chatelier's Principle: Changes in _____, _____, and _____ make a difference in the amount of product formed in a reaction.**

Practice:

For the reaction below, which change will cause the reaction to shift to the right?

$CH_4(g) + 2H_2S(g) + heat <---> CS_2(g) + 4H_2(g)$

a. decrease the concentration of dihydrogen sulfide

b. increase the pressure on the system

c. increase the temperature on the system

d. increase the concentration of carbon disulfide

e. decrease the concentration of methane

HOMEWORK: Le Chatelier's Practice

When opposing forces or issues are balanced, a system is said to be in equilibrium. Equilibrium in chemical reactions is dynamic because the forward and reverse reactions are occurring continuously and simultaneously at the same rates. Placing a stress on any equilibrium system, whether it is chemical, biological, societal, environmental, or personal, causes the equilibrium position to change. Le Chatelier's Principle allows us to predict the results that follow from changing the conditions of a system at chemical equilibrium. This allows scientists to develop techniques to control chemical reactions in natural and industrial settings in order to obtain desired products.

MODEL 1: Dynamic Equilibrium

Acme Manufacturing has been restricted to 100 employees in the building at one time. Throughout the day, twenty employees go on break each hour as twenty other employees return from break.

Chemical Equilibrium

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

Questions:

1. How many employees move in and out of the factory building during each hour?
2. Are the employees who move in and out of the building each hour the same people? Explain your answer.

3. Does the number of employees in the building change from hour to hour? Explain your answer.

4. Over the course of a day, the employees in the Acme Manufacturing Plant are said to be in a "dynamic equilibrium." Based on your understanding of how the staff move in and out of the plant, explain what is meant by the term "dynamic equilibrium."

5. A new faster and simpler check-in/check-out process has been proposed for workers at the Acme Manufacturing Plant. Some workers have said that this new process acts like a catalyst. (A catalyst is a substance that speeds up a chemical reaction without changing the outcome of the reaction and without being used up in the process.)
   a. Would this new check-in/check-out process change the number of people in the building at any given time? Why or why not?

   b. What would be the effect of the new check-in/check-out process on the workers at the factory?

Like the Acme Manufacturing Plant, chemical reactions can also reach equilibrium. Answer the following question about the chemical equation in Model 1 by applying insight you gained from the Acme Manufacturing Plant questions.

$2\ H_2\ (g) + O_2\ (g) \leftrightarrow 2\ H_2O\ (g)$ + energy (heat)

6. When the reaction between hydrogen and oxygen **reaches equilibrium:**
   a. Does the number of molecules in the reaction container change? Explain.

   b. Is the reaction still proceeding in the forward direction?

   c. Is the reaction still proceeding in the reverse direction?

   d. Are the concentrations of the products and reactants changing?

   e. Are the rates of the forward and reverse reactions the same?

   f. Does the heat content of the system become constant?

MODEL 2: LE CHATELIER'S PRINCIPLE

Reactant: Increase (↑) causes the equilibrium to shift to the right (→)
Decrease (↓) causes the equilibrium to shift to the left (←)

Product: Increase (↑) causes the equilibrium to shift to the left (←)
Decrease (↓) causes the equilibrium to shift to the right (→)

Temperature: A change in temperature corresponds to a change in energy therefore by using the 'energy' term in the equation itself, it can be treated like a reactant or product (see above).

Pressure: An increase (↑) in pressure causes the equilibrium to shift towards the "smaller number of moles *of gas"* side.
A decrease (↓) in pressure causes the equilibrium to shift towards the "larger number of moles *of gas"* side.
Note: If the number of moles of gas is the same on both sides, then a change in pressure has no effect in the equilibrium.

The following equation describes a system that is at equilibrium:

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

In Table 1 apply Le Chatelier's Principle and indicate the direction of the shift in equilibrium if the indicated stress is applied to the reaction system. (The first one is completed for you.)

Table 1:

Stress	Shift Direction (left, right, no change)
Concentration H_2 increases	Shifts right
Concentration H_2 decreases	
Concentration O_2 increases	
Concentration O_2 decreases	
Concentration H_2O increases	
Concentration H_2O decreases	
Temperature increases	
Temperature decreases	
Pressure increases	
Pressure decreases	
Catalyst added	

Answer the following questions based on your answers to the table above:

1. In general terms, describe the direction of the equilibrium shift when the concentration of a reactant increased.

2. If an equilibrium shifts to the right, which reaction speeds up, the forward or the reverse?

3. What happens to the concentrations of the reactant H_2 and O_2 when the reaction in Model 2 shifts to the right?

4. What happens to the concentration of the product H_2O when the reaction in Model 2 shifts to the right?

5. If an equilibrium shifts to the left, which reaction speeds up, the forward or the reverse?

6. What happens to the concentrations of the reactants H_2 and O_2 when the reaction in Model 2 shifts to the left?

7. What happens to the concentration of the product H_2O when the reaction in Model 2 shifts to the left?

8. What is true of the reaction rates for the forward and reverse reactions when a new equilibrium is established?

Fill in the blanks in the chart below, given the reaction to form nitrogen oxide in a container.

N_2 (g) + O_2 (g) + heat ↔ 2 NO (g)

	Stress	**Shift** (right/left)	**Amount** (increases/decreases)
1.	N_2 added		of NO
2.	O_2 removed		of N_2
3.	NO removed		of N_2
4.	Heat added		of NO
5.	Catalyst added		of NO

Guided Notes: Ksp

Solubility Product Constant – K_{sp}

- K_{sp}:
  - General Equation:

- Since the reactant is ALWAYS a _____, K_{sp} = _____
  - b and c are the _____ on the ions
- The ***smaller*** K_{sp} is the _____ soluble salt
- K_{sp} can be used to calculate the _____ of _____.

Practice - K_{sp}

1. Write the K_{sp} expression for the solvation of Ag_2SO_4.

   First, determine the ions that will be formed:

   Put the ions in the K_{sp} expression (must include charges!):

   Use the coefficients to determine how many moles of each ion will be formed. Put those numbers in for b & c (as exponents):

   (if the exponent is _____, it is not used in the expression)

2. Write the K_{sp} expression for the solvation of magnesium hydroxide. Formula: _____

3. Write the Ksp expression for the solvation of calcium phosphate. Formula: _____

HOMEWORK: Ksp Practice Problems

1. What is the solubility product constant and when is it used?

2. How can you calculate ion concentration using the solubility product constant?

3. Write the Ksp expression for the following compounds:
   a. PbF_2

   b. $Zn(OH)_2$

   c. $MgCO_3$

HOMEWORK: Unit 9 Review

1. What is a reaction rate and what units are used with reaction rates?

2. What is the collision theory?

3. List the factors that affect the rate of a reaction. Explain how each factor affects the rate.

4. Draw a reaction diagram for an exothermic reaction and label the following: reactants, products, activation energy, activated complex.

5. What 2 factors will drive a reaction to completion?

a) _____ b) _____

6. Describe a reversible reaction. Give an example.

7. Describe dynamic equilibrium. Give an example.

8. At equilibrium how do the forward and reverse reaction rates compare? The forward rate _____ the reverse rate.

9. State Le Chatelier's Principle.

10. What are the 3 possible stresses we can apply to a system at equilibrium?

a) _____ b) _____ c) _____

11. Use the reaction ($2SO_{2(g)} + O_{2(g)} \leftrightarrows 2SO_{3(g)}$ + heat) to determine what will happen (shift left/right, no change) if the following stresses are applied:

a. SO_2 is added _____ b. Volume is increased _____ c. Heat is added _____

12. What is the general formula for the equilibrium constant, K_{eq}?

13. What does the value of K_{eq} tell a chemist about a reaction:
    If the value of K_{eq} is greater than 1 ……

    If the value of K_{eq} is less than 1 ….

14. Write the equilibrium constants for these reversible reactions – ALL CHEMICALS ARE GASES:

a. $2A + B \leftrightarrow C + 3D$ b. $NO + O_2 \leftrightarrow NO_3$ c. $CO_2 + H_2 \leftrightarrow CO + H_2O$

15. Calculate K_{eq} for reaction **14a** if the equilibrium concentrations are: [A]=0.100M, [B]=0.230M, [C]=1.17M, & [D]=2.19M.

16. The equilibrium constant in **14b** is .025. If [NO] = .36 M and $[O_2]$ = .21 M, what is the equilibrium concentration of NO_3?

17. If K_{eq} in **14c** is 6.37×10^{-3}, $[CO_2]$ = 0.037M, $[H_2]$ = 0.28M, and [CO] = 0.084M, calculate $[H_2O]$.

18. Describe K_{sp}.

19. What is the generic formula for K_{sp}? _____

20. Write the expression for K_{sp} for the following sparingly soluble salts:

    $PbBr_2$ _____

    $Ca_3(PO_4)_2$ _____

Daily Questions

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