Unit 6 – Kinetics and Equilibrium

At the end of this unit, you'll be familiar with the following:

Kinetics:

- Reaction Rate
- Collision Theory
- Reaction Mechanism
- Factors Affecting Rate of Reaction:
    - Nature of Reactants
    - Concentration
    - Surface Area
    - Pressure
    - Catalyst
    - Temperature

Thermodynamics:

- Potential Energy Diagrams
- Heat of Reactions
- Endothermic Reactions
- Exothermic Reactions
- Activated Complex
- Activation Energy
- Effect of Catalyst on Reaction
- Stability (Table I)

Equilibrium:

- Physical Equilibrium
- Phase Equilibrium
- Solution Equilibrium
- Chemical Equilibrium
- Le Chatelier's Principle
    - Temperature Changes
    - Pressure Changes
    - Effect of a Catalyst
- Enthalpy
- Entropy

Term	Definition
Activated Complex	an intermediate structure formed in the conversion of reactants to products. The activated complex is the structure at the maximum energy point along the reaction path
Activation Energy	The minimum energy required to convert reactants into products; the difference between the energies of the activated complex and the reactants
Catalyst effect on the rate chemical of rxn	a substance that is neither a reactant nor a product, but functions to speed up the rate of a chemical reaction by lowering activation energy/providing a shorter or “alternate” pathway
Chemical Equilibrium	in a chemical reaction, when the forward and reverse reactions are occurring at equal rates
Collision Theory	in order for a chemical reaction/effective collision to occur, particles must collide with proper energy AND proper alignment.
Concentration effect on the rate chemical of rxn	an increase in concentration of reactants will increase the rate of a chemical reaction
Endothermic Reactions	chemical reactions that consume or require energy; chemical reactions in which energy is a reactant
Enthalpy	the heat energy absorbed or released during a chemical reaction
Entropy	a measure of the randomness or chaos associated with a chemical reaction
Equilibrium	when two opposing processes are occurring at equal rates
Exothermic Reactions	chemical reactions that produce or release energy; chemical reactions in which energy is a product
Le Chatelier’s Principle	predicts that when a stress is applied to an equilibrium mixture, the equilibrium will shift to relieve the stress (stresses include temperature, pressure, concentration)
Nature of Reactants effect on the rate chemical of rxn	reactions involving ionic substances tend to have faster rates than reactions involving covalent substances.
Phase Equilibrium	when the processes of freezing and melting or evaporating and condensing are occurring at equal rates
Physical Equilibrium	when two opposing physical processes are occurring at equal rates; ex: phase equilibrium, solution equilibrium (saturation)
Potential Energy Diagrams	used to illustrated the energy lost or gained (the reaction pathway) for a given chemical reaction
Pressure effect on the rate chemical of rxn	an increase in pressure will increase the rate of a chemical reaction (only for reactions involving GASES!)
Reaction Mechanism	the specific set of steps/reactions involved in an overall chemical reaction
Reaction Rate	the speed at which reactants are converted into products in a chemical reaction.

Term	Definition
Solution Equilibrium	when the processes of dissolving and precipitating are occurring at equal rates; when a solution has reached its saturation point
Surface Area effect on the rate chemical of rxn	an increase in the surface area of reactants will increase the rate of a chemical reaction
Temperature effect on the rate chemical of rxn	an increase in temperature will increase the rate of a chemical reaction

Name _____ Date _____
Period _____

Collision Theory

Read and summarize the following

Kinetics

Kinetics is a branch of Chemistry that studies the rate or speed of chemical reactions. There are many factors that determine the rate of reactions including temperature, the nature of reactants, concentration of reactants, pressure, surface area, and the presence of a catalyst. To understand how each of these factors affects the rate of a chemical reaction you must first understand the collision theory. The collision theory is one of the basic concepts of kinetics and it states that in order for a reaction to occur, reactant particles must collide. Collisions between particles will result in a chemical reaction if they collide with the proper alignment and amount of energy. The following discusses the various factors what will alter the rate of a chemical reaction. All of these factors affect the rate of a reaction by affecting the rate of collisions that take place between particles.

Nature of Reactants

All reactions involve the breaking of existing bonds and the formation of new bonds. As a general rule covalent compounds take more time to break down than ionic compounds. This is due to the fact that in covalent compounds more bonds must be broken than in ionic compounds. Relating the nature of reactants to the collision theory, the breaking of more bonds requires that particles have more energy when they collide, thus covalent compounds take more time to react.

Concentration of Reactants

The collision theory states that particles must collide with proper alignment and energy. Therefore, it is logical that the more particles that are present in a given area (which happens when you increase concentration) the more likely particles are to collide with one another. Therefore, as a general rule chemical reactions will proceed faster if the concentration of one or more of the reactants are increased.

Pressure

Pressure has little to no effect on the rate of reactions between solids and liquids. However, pressure does play a role in the rate of reaction among gases. As pressure is increased gases are compressed making gas particles closer together and more likely to collide. Therefore, an increase of pressure will increase the rate of reaction **FOR GASES ONLY**.

Temperature

Recall that temperature measures the average kinetic energy of particles. Therefore, the higher the temperature the faster the particles are moving. If particles are moving faster they are much more likely to collide. We can relate this to the collision theory (which says that particles MUST collide) by reasoning that a higher temperature will result in more collisions and a faster rate of a chemical reaction. Additionally, at a higher temperature particles are not just moving faster they also have a greater energy. Therefore, not only will more collisions occur, but the reacting particles will collide with more energy, making the collisions more effective! For example, milk will sour faster at room temperature than it does in the refrigerator.

Surface Area

When more surface area of a reactant is exposed to the air there are more chances for reactant particles to collide, therefore increasing the reaction rate. Given this, a finely divided powder will react more rapidly than a single lump of the same mass. Think about which will dissolve faster - a cube of sugar or individual granules of sugar? The granules of sugar will dissolve faster because they have more surface area exposed to the air or the solvent that it is being dissolved in.

Catalyst

A catalyst is a substance that is neither a reactant nor a product, but functions to speed up the rate of a chemical reaction by lowering activation energy. Another way of saying this is that the catalyst "provides a shorter or alternate pathway" for a reaction to occur. It is important to note that the catalyst does take part in a reaction, but remains unchanged when the reaction is complete. Your body is loaded with enzymes, which are natural catalysts that perform several important jobs like breaking down carbohydrates and proteins in your stomach and small intestine.

Name _____ Date _____
Period _____

Collision Theory

1. As the number of effective collisions between reacting particles increases what will happen to the rate of the reaction? _____ Explain. _____

   _____

   _____

2. Which of the following pairs of reactants will react most quickly? Be sure to give an explanation for your answer.

   a) sodium chloride and silver nitrate

   b) ethane (C2H6) and oxygen (O2)

   Reason: _____

3. Given the reaction: $2\ Mg(s) + O_2(g) \rightarrow 2\ MgO(s)$

   List four ways that you could speed up the rate of the reaction:

   1. _____ 3. _____

   2. _____ 4. _____

4. Why does raising the temperature speed up the rate of reaction? _____

   _____

5. Factors that affect the rate of reaction are:

   a) _____, or the substances used

   b) _____, or the average kinetic energy of the molecules

   c) _____, or the amount of contact between reactants

   d) _____, which determines how close particles are to one another.

   e) _____, which lowers the activation energy for a reaction.

6. Explain how rate determining step and reaction rate are related. _____

   _____

   _____

Name _____ Date _____
Period _____

7. What is the area of chemistry concerned with the speed of reactions? _____

_____

8. Do all chemical reactions take place at the same speed? _____ Why or why not? _____

_____

_____

9. Which statement most correctly describes the collision theory?
   a) if molecules collide with either proper alignment or enough energy, then a reaction will occur
   b) when molecules collide a reaction always occurs
   c) collisions between particles often result in a reaction
   d) if molecules collide with enough energy and proper alignment, then a reaction will occur

Name _____ Date _____
Period _____

Heats of Reaction

Use Table I to complete the following.

Reaction	ΔH (kJ)	Endothermic or Exothermic
$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(\ell)$		
$2H_2(g) + O_2(g) \rightarrow 2H_2O(g)$		
$C_2H_5OH(\ell) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(\ell)$		
$C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(\ell)$		
$4H_2O(\ell) + 3CO_2(g) \rightarrow C_3H_8(g) + 5O_2(g)$		
$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$		
$CO_2(g) \rightarrow C(s) + O_2(g)$		
$NH_4Cl(s) \rightarrow NH_4^+(aq) + Cl^-(aq)$		
$2CO_2(g) + 4H_2O(\ell) \rightarrow 2CH_3OH(\ell) + 3O_2(g)$		
$2Al_2O_3(s) \rightarrow 4Al(s) + 3O_2(g)$		
$*CO(g) + \frac{1}{2}O_2(g) \rightarrow CO_2(g)$		
$*4NO(g) \rightarrow 2N_2(g) + 2O_2(g)$		

Name _____ Date _____
Period _____

1. If you reverse a reaction, what happens to the magnitude of ΔH? What happens to the sign?

2. If you double the concentration of the reactants and the products, what happens to the magnitude of ΔH? What happens to the sign?

3. If the ΔH for a given forward reaction is positive, will the reverse reaction be endothermic or exothermic?

4. If a given reaction is exothermic, will heat be found on the reactants side of the equation or the products side?

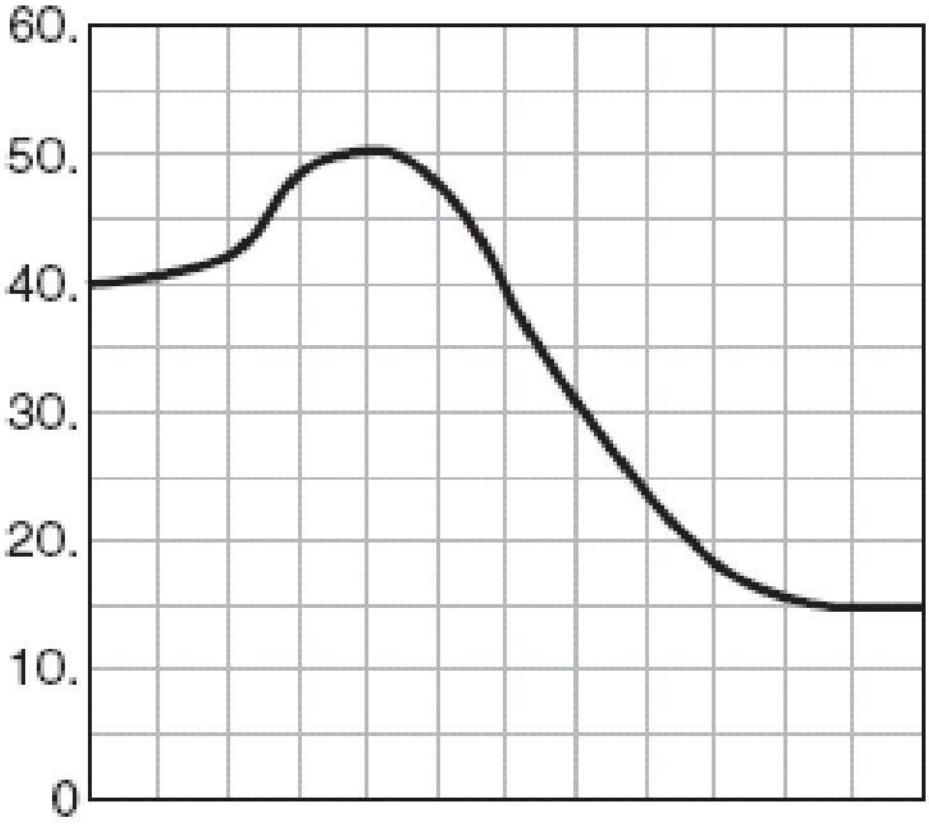
5. If a given reaction is endothermic, what will be the sign for ΔH for the reverse reaction?

Name _____ Date _____
Period _____

PE Diagrams

1. Write the formula for determining ΔH

2. A potential energy diagram is shown below Label the X and Y axes as well as the values indicated by letters a -- e located below the diagram. Also determine the actual values for a -- e in the space provided.



a. activation energy for the forward reaction
b. potential energy of the reactants for the forward reaction
c. potential energy of the products for the reverse reaction
d. activation energy for the reverse reaction
e. heat of the reaction (ΔH)
f. potential energy of the activated complex

3. Is the forward reaction endothermic or exothermic? _____

4. Is ΔH positive or negative for the forward reaction? _____

Name _____ Date _____
Period _____

5. Write a possible reaction for the forward reaction below (Use Table I). Include the heat of reaction in your overall chemical equation:

6. Is the reverse reaction endothermic or exothermic? _____

7. Is ΔH positive or negative for the reverse reaction? _____

8. Write a possible reaction for the reverse reaction below. Include the heat of reaction in your overall chemical equation:

9. What effect does a catalyst have on a reaction in terms of activation energy?

_____

10. What effect does a catalyst have on a reaction in terms of reaction rate?

_____

11. Which letter(s) would a catalyst change? _____

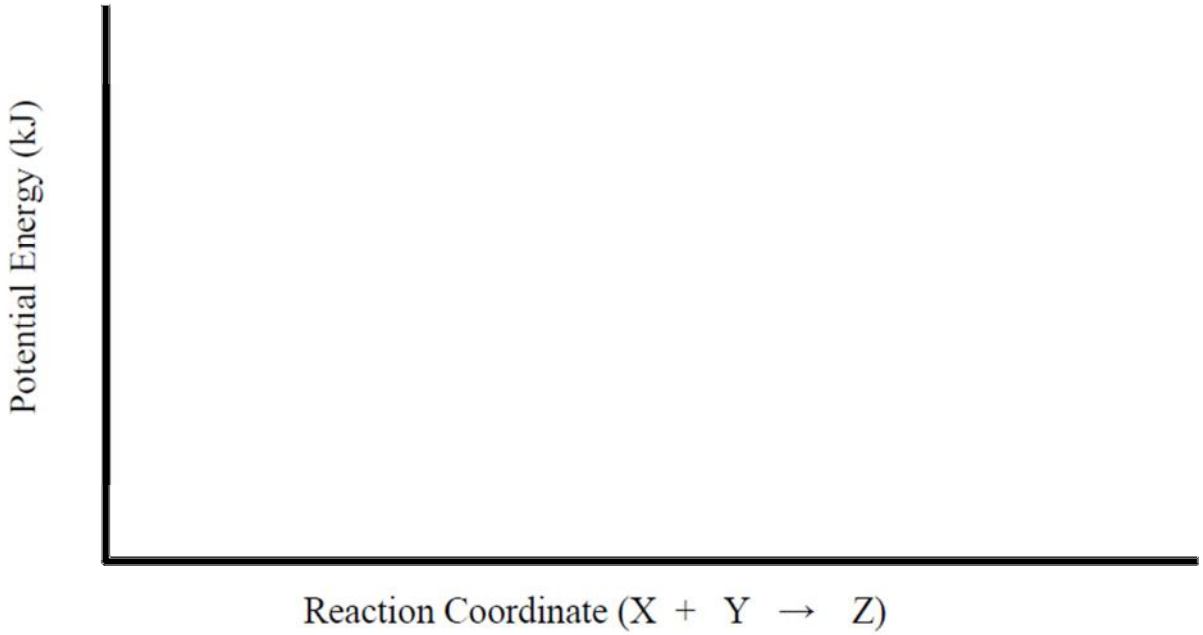
12. Draw a dotted line on the diagram that would illustrate the general reaction path of a catalyst.

Name _____ Date _____
Period _____

More PE Diagrams

1. Using the graph below please draw a reaction potential energy diagram for a reaction with the following characteristics:

Potential Energy of Reactants = 350 kJ/mole
Activation Energy of Forward Reaction = 100 kJ/mole
Potential Energy of Products = 150 kJ/mole



2. Is the reaction from question #1 an endothermic or exothermic reaction? _____
3. Please identify the following on the diagram you created in question #1. Place this letter above its corresponding line segment on the graph and the value in the adjacent column.

Component of Potential Energy Diagram	Symbol	Value
Potential Energy of Reactants	A	
Potential Energy of Products	B	
Potential Energy of Activated Complex	C	
Heat of Reaction	D	
Activation Energy of Forward Reaction	E	
Activation Energy of Reverse Reaction	F	

4. Using a dotted line, show how the reaction potential energy diagram would be altered upon the addition of a catalyst to the reaction in the graph above.
5. If a catalyst were added, which lettered quantities, if any would change? _____
6. How would the addition of a catalyst affect the heat of reaction?
   _____

Name _____ Date _____

Period _____

Equilibrium

1. Which statement must be true for any chemical reaction at equilibrium?

   A) The concentration of the products is less than the concentration of the reactants.
   B) The concentration of the products and the concentration of the reactants are equal.
   C) The concentration of the products and the concentration of the reactants are constant.
   D) The concentration of the products is greater than the concentration of the reactants.

2. A chemical reaction is at equilibrium. Compared to the rate of the forward reaction, the rate of the reverse reaction is

   A) faster and more product is produced
   B) the same and the reaction continues in both directions
   C) faster and more reactant is produced
   D) the same and the reaction has stopped

3. Which factors must be equal in a reversible chemical reaction at equilibrium?

   A) the concentrations of the reactants and products
   B) the potential energies of the reactants and products
   C) the rates of the forward and reverse reactions
   D) the activation energies of the forward and reverse reactions

4. Given the reaction at equilibrium:

   $$H_2(g) + Br_2(g) \leftrightarrow 2\ HBr(g)$$

   The rate of the forward reaction is

   A) independent of the rate of the reverse reaction
   B) greater than the rate of the reverse reaction
   C) equal to the rate of the reverse reaction
   D) less than the rate of the reverse reaction

5. Which type or types of change, if any, can reach equilibrium?

   A) a chemical change, only
   B) both a chemical and a physical change
   C) neither a chemical nor a physical change
   D) a physical change, only

6. A chemical reaction has reached equilibrium when

   A) the reverse reaction begins
   B) the forward reaction ceases
   C) the concentrations of the reactants and products become equal
   D) the concentrations of the reactants and products become constant

7. Given the system at chemical equilibrium:

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

   The concentration of O_3 and O_2 must be

   A) constant B) equal
   C) increasing D) decreasing

8. Given the reaction at equilibrium:

   $$2\ CO(g) + O_2(g) \leftrightarrow 2\ CO_2(g)$$

   Which statement regarding this reaction is always true?

   A) The rates of the forward and reverse reactions are equal.
   B) The concentrations of the reactants and the products are equal.
   C) The masses of the reactants and the products are equal.
   D) The reaction occurs in an open system.

9. Given the equation representing a system at equilibrium:

   $$2SO_2(g) + O_2(g) \leftrightarrow 2SO_3(g)$$

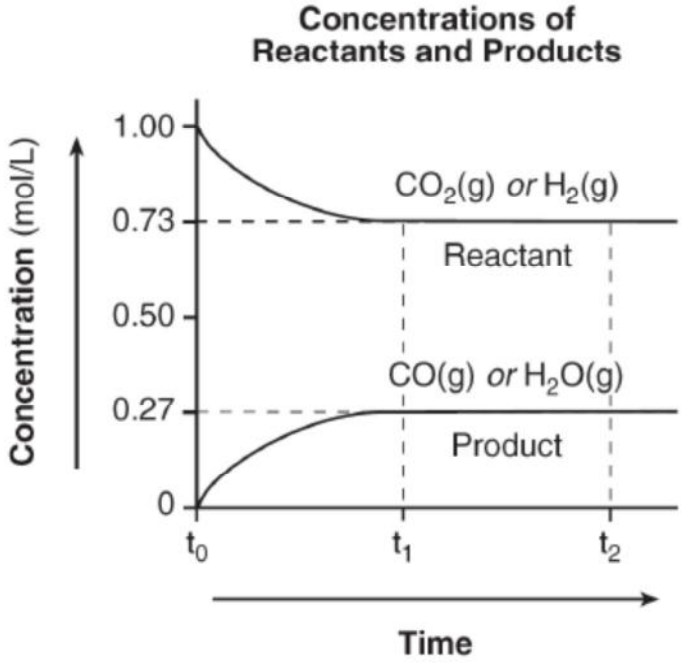
   At equilibrium, the concentration of

   A) $SO_2(g)$ must equal the concentration of $SO_3(g)$
   B) $SO_2(g)$ must be constant
   C) $O_2(g)$ must equal the concentration of $SO_2(g)$
   D) $O_2(g)$ must be decreasing

Name _____ Date _____
Period _____

10. Base your answer to the following question on the information below.

At 550°C, 1.00 mole of $CO_2(g)$ and 1.00 mole of $H_2(g)$ are placed in a 1.00-liter reaction vessel. The substances react to form $CO(g)$ and $H_2O(g)$. Changes in the concentrations of the reactants and the concentrations of the products are shown in the graph below.



What can be concluded from the graph about the concentrations of the reactants and the concentrations of the products between time t_1 and time t_2?

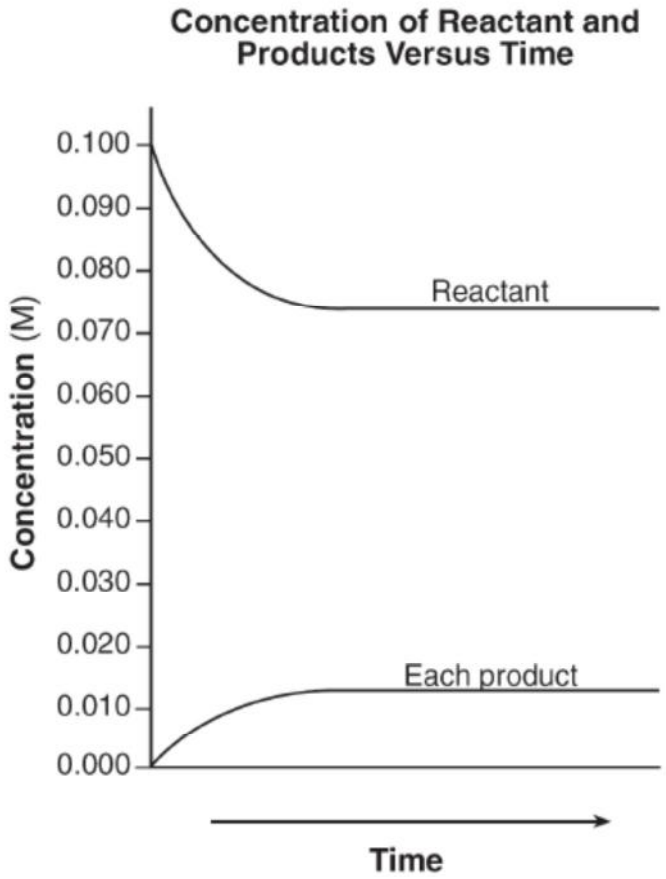
Name _____ Date _____

Period _____

11. Base your answer to the following question on the information below.

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 $I_2(g)$. Then the temperature of the contents of the flask is kept constant.

During this reaction, the contents of the flask change to a pale purple-colored mixture of HI(g), $H_2(g)$, and $I_2(g)$. When the color of the mixture in the flask stops changing, the concentration of $I_2(g)$ is determined to be 0.013 mole per liter. The relationship between concentration and time for the reactant and products is shown in the graph below.



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

Name _____ Date _____
Period _____

LeChatlier's Principle

Le Chatelier's Principle says that when a system at equilibrium is subjected to a stress, the system will shift its equilibrium in order to relieve the stress. Additionally, all the species inside the reaction either increase or decrease in concentration.

Complete the following charts by writing left (←), right (→), or no shift (N/A) for the equilibrium shift that takes place in each column. For the concentration columns (the ones with brackets) write decreases (-), increases (+), or remains the same (0). Remember that [ ] = concentration or amount of substance (the brackets will be seen surrounding that particular substance.

CHART #1:

$$N_{2(g)} + 3H_{2(g)} \leftrightarrows 2NH_3(g) + 22.0\ kcal$$

Stress	Equilibrium Shift	[N2]	[H2]	[NH3]
1. Add N2				
2. Add H2				
3. Add NH3				
4. Remove N2				
5. Remove H2				
6. Remove NH3				
7. Increase temperature				
8. Decrease temperature				
9. Increase pressure				
10. Decrease pressure				

Name _____ Date _____

Period _____

CHART #2:

$$12.6\ kcal + H_{2(g)} + I_{2(g)} \leftrightarrows 2HI_{(g)}$$

Stress	Equilibrium Shift	[H2]	[I2]	[HI]
1. Add H2				
2. Add I2				
3. Add HI				
4. Remove H2				
5. Remove I2				
6. Remove HI				
7. Increase temperature				
8. Decrease temperature				
9. Increase pressure				
10. Decrease pressure				

CHART #3:

$$NaOH_{(s)} \leftrightarrows Na^{+}_{(aq)} + OH^{-}_{(aq)} + 10.6\ kcal$$

Stress	Equilibrium Shift	Amount $NaOH_{(s)}$	$[Na^{+}]$	$[OH^{-}]$
1. Add $NaOH_{(s)}$				
2 . Add NaCl (Adds Na^{+})				
3. Add KOH (Adds OH^{-})				
4. Add H^{+} (Removes OH^{-})				
5. Increase temperature				
6. Decrease temperature				
7. Increase Pressure				
8. Decrease pressure				

Name _____ Date _____

Period _____

LeChatlier's Principle Q's

1. In which reaction will the point of equilibrium shift to the left when the pressure on the system is increased?

   A) $CaCO_3(s) \leftrightarrow CaO(s) + CO_2(g)$
   B) $2\,Mg(s) + O_2(g) \leftrightarrow 2\,MgO(s)$
   C) $2\,H_2(g) + O_2(g) \leftrightarrow 2\,H_2O(g)$
   D) $C(s) + O_2(g) \leftrightarrow CO_2(g)$

2. Given the system at equilibrium:

   $N_2O_4(g) + 58.1\ kJ \leftrightarrow 2\,NO_2(g)$

   What will be the result of an increase in temperature at constant pressure?

   A) The equilibrium will shift to the right, and the concentration of $NO_2(g)$ will decrease.
   B) The equilibrium will shift to the left, and the concentration of $NO_2(g)$ will decrease.
   C) The equilibrium will shift to the right, and the concentration of $NO_2(g)$ will increase.
   D) The equilibrium will shift to the left, and the concentration of $NO_2(g)$ will increase.

3. Given the reaction at equilibrium:

   $C_2(g) + D_2(g) \leftrightarrow 2\,CD(g) + energy$

   Which change will cause the equilibrium to shift?

   A) addition of a catalyst
   B) increase in volume
   C) increase in pressure
   D) addition of heat

4. Given the reaction at equilibrium:

   $2\,SO_2(g) + O_2(g) \leftrightarrow 2\,SO_3(g)$

   As the pressure is increased at constant temperature, the number of moles of $SO_3(g)$ produced will

   A) decrease B) increase
   C) remain the same

5. Given the reaction at equilibrium:

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

   Increasing the concentration of $N_2(g)$ will increase the forward reaction rate due to

   A) a decrease in the activation energy
   B) a decrease in the number of effective collisions
   C) an increase in the activation energy
   D) an increase in the number of effective collisions

6. Given the reaction at equilibrium:

   $C(s) + CO_2(g) + heat \leftrightarrow 2CO(g)$

   Which stress on the system would favor the production of $CO(g)$?

   A) an increase in the pressure
   B) an increase in the temperature
   C) a decrease in the amount of $C(s)$
   D) a decrease in the amount of $CO_2(g)$

7. Given the system at equilibrium:

   $H_2(g) + F_2(g) \leftrightarrow 2\,HF(g) + heat$

   Which change will *not* shift the point of equilibrium?

   A) changing the concentration of $H_2(g)$
   B) changing the temperature
   C) changing the pressure
   D) changing the concentration of $HF(g)$

8. Given the closed system at equilibrium:

   $CO_2(g) \leftrightarrow CO_2(aq)$

   As the pressure on the system increases, the solubility of the $CO_2(g)$

   A) decreases B) increases
   C) remains the same

Name _____ Date _____

Period _____

9. Given the reaction at equilibrium:

$$2\ CO(g) + O_2(g) \leftrightarrow 2\ CO_2(g)$$

When the reaction is subjected to stress, a change will occur in the concentration of

A) reactants, only
B) products, only
C) both reactants and products
D) neither reactants nor products

10. Given the reaction at equilibrium:

$$H_2(g) + Cl_2(g) \leftrightarrow 2\ HCl(g)$$

As the pressure increases at constant temperature, the number of moles of HCl

A) decreases B) increases
C) remains the same

11. Given the equation representing a reaction at equilibrium:

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

Which change causes the equilibrium to shift to the right?

A) decreasing the pressure
B) decreasing the concentration of $H_2(g)$
C) increasing the temperature
D) increasing the concentration of $N_2(g)$

12. What occurs when the temperature is increased in a system at equilibrium at constant pressure?

A) The rate of the forward reaction increases, and the rate of the reverse reaction decreases.
B) The rate of the forward reaction decreases, and the rate of the reverse reaction increases.
C) The rate of the exothermic reaction decreases.
D) The rate of the endothermic reaction increases.

13. Given the reaction at equilibrium:

$$2\ SO_2(g) + O_2(g) \leftrightarrow 2\ SO_3(g) + \text{heat}$$

Which change will shift the equilibrium to the right?

A) decreasing the amount of $SO_2(g)$
B) decreasing the amount of $O_2(g)$
C) increasing the pressure
D) increasing the temperature

14. Given the equation representing a system at equilibrium:

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

Which changes occur when the temperature of this system is *decreased*?

A) The concentration of $H_2(g)$ decreases and the concentration of $NH_3(g)$ decreases.
B) The concentration of $H_2(g)$ decreases and the concentration of $N_2(g)$ increases.
C) The concentration of $H_2(g)$ increases and the concentration of $N_2(g)$ increases.
D) The concentration of $H_2(g)$ decreases and the concentration of $NH_3(g)$ increases.

15. 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

Name _____ Date _____

Period _____

16. Given the reaction at STP and at equilibrium:

$H_2(g) + Cl_2(g) \leftrightarrow 2\ HCl(g)$

Which change will result in an increase in the concentration of $Cl_2(g)$?

A) increasing the concentration of HCl(g)
B) decreasing the pressure of the system
C) decreasing the concentration of HCl(g)
D) increasing the concentration of $H_2(g)$

17. Ammonia is produced commercially by the Haber reaction:

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

The formation of ammonia is favored by

A) removal of $N_2(g)$
B) removal of $H_2(g)$
C) a decrease in pressure
D) an increase in pressure

18. Given the reaction at equilibrium:

$A(g) + B(g) \leftrightarrow C(g) + D(g)$

The addition of a catalyst will

A) shift the equilibrium to the left
B) have no effect on the forward or reverse reactions
C) increase the rate of forward and reverse reactions equally
D) shift the equilibrium to the right

19. Given the reversible reaction

$A(g) + B(g) \leftrightarrow C(g)$ at equilibrium.

If the concentration of *A* is increased at constant temperature and pressure, which will also increase?

A) the rate of the forward reaction
B) the activation energy
C) the concentration of *B*
D) the value of the equilibrium constant

20. Given the reaction:

$A(g) + B(g) \leftrightarrow AB(g)$

As the pressure increases at a constant temperature, the rate of the forward reaction will

A) decrease B) increase
C) remain the same

21. The addition of a catalyst to a system at equilibrium will increase the rate of

A) the forward reaction, only
B) the reverse reaction, only
C) both the forward and reverse reactions
D) neither the forward nor reverse reaction

Name _____ Date _____

Period _____

22. Given the balanced equation representing a reaction:

$2HCl(aq) + Na_2S_2O_3(aq) \rightarrow S(s) + H_2SO_3(aq) + 2NaCl(aq)$

Decreasing the concentration of $Na_2S_2O_3(aq)$ decreases the rate of reaction because the

A) activation energy increases
B) frequency of effective collisions decreases
C) activation energy decreases
D) frequency of effective collisions increases

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23. Given the reaction:

$$CO(g) + \tfrac{1}{2} O_2(g) \leftrightarrow CO_2(g) + 67.7 \text{ kcal}$$

As the temperature increases, the rate of the forward reaction

A) decreases B) increases
C) remains the same

24. Which system at equilibrium will be *least* affected by a change in pressure?

A) $2\ S(s) + 3\ O_2(g) \leftrightarrow 2\ SO_3(g)$
B) $3\ H_2(g) + N_2(g) \leftrightarrow 2\ NH_3(g)$
C) $AgCl(s) \leftrightarrow Ag^+(aq) + Cl^-(aq)$
D) $2\ HgO(s) \leftrightarrow 2\ Hg(\ell) + O_2(g)$

25. Given the equilibrium reaction:

$$N_2(g) + O_2(g) \leftrightarrow 2\ NO(g)$$

An increase in pressure produced by a decrease in volume at constant temperature would produce an increase in the concentration of

A) N_2, only B) NO, only
C) N_2 and O_2, only D) N_2, O_2, and NO

26. Given the reaction at equilibrium:

$$X_2(g) + 2\ Y_2(g) \leftrightarrow 2\ XY_2(g) + 80 \text{ kcal}$$

The equilibrium point will shift to the right if the pressure is

A) decreased and the temperature is decreased
B) increased and the temperature is decreased
C) increased and the temperature is increased
D) decreased and the temperature is increased

27. Given the reaction at equilibrium:

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

The concentration of the product could be increased by

A) increasing the concentration of Y
B) adding more heat to the system
C) adding a catalyst
D) decreasing the concentration of X

28. Given the reaction at equilibrium:

$$2\ A(g) + 3\ B(g) \leftrightarrow A_2B_3(g) + \text{heat}$$

Which change will not affect the equilibrium concentrations of $A(g)$, $B(g)$, and $A_2B_3(g)$?

A) increasing the temperature
B) adding a catalyst
C) adding more $A(g)$
D) increasing the pressure

29. Given the equation representing a reaction at equilibrium:

$H_2(g) + I_2(g) + \text{heat} \leftrightarrow 2HI(g)$

Which change favors the reverse reaction?

A) increasing the pressure
B) increasing the concentration of $I_2(g)$
C) decreasing the concentration of $HI(g)$
D) decreasing the temperature

Name _____ Date _____

Period _____

30. Given the reaction at equilibrium:

$H_2(g) + Cl_2(g) \leftrightarrow 2\ HCl(g)$

As the pressure increases at constant temperature, the mass of $H_2(g)$

A) decreases B) increases
C) remains the same

31. Given the reaction at equilibrium:
$A(g) + B(g) \rightleftharpoons AB(g) + \text{heat}$
The concentration of $A(g)$ can be increased by

A) increasing the concentration of $B(g)$
B) lowering the temperature
C) increasing the concentration of $AB(g)$
D) adding a catalyst

32. Given the reaction at equilibrium:

$N_2(g) + O_2(g) + \text{energy} \leftrightarrow 2\ NO(g)$
Which change will result in a *decrease* in the amount of NO(g) formed?

A) increasing the temperature
B) increasing the concentration of $O_2(g)$
C) decreasing the concentration of $N_2(g)$
D) decreasing the pressure

33. Given the reaction:

$Zn(s) + HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$

As the concentration of the HCl(aq) decreases at constant temperature, the rate of the reaction

A) decreases B) increases
C) remains the same

34. Given the reaction at equilibrium:

$2\ SO_2(g) + O_2(g) \leftrightarrow 2\ SO_3(g) + \text{heat}$

The rate of the forward reaction can be increased by adding more SO_2 because the

A) number of molecular collisions between reactants will increase
B) forward reaction is endothermic
C) temperature will increase
D) reaction will shift to the left

Name _____ Date _____
Period _____

More LeChatlier's Principle Q's

Match the change to the equilibrium system below with the letter of the appropriate response. Each letter can be used once, more than once, or not at all.

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

_____ 1) O_2 is added to the reaction
_____ 2) SO_3 is removed from the reaction
_____ 3) SO_3 is added to the reaction
_____ 4) The pressure is increased

a) The equilibrium shifts to the right
b) The equilibrium shifts to the left
c) there is no change in the equilibrium

If the statement is true, write "true." If it is false, change the underlined word or words to make the statement true. Write your answer on the line provided.

$$NH_4Cl_{(s)} + \text{heat} \leftrightarrows NH_{3(g)} + HCl_{(g)}$$

_____ 5) The above reaction is <u>exothermic.</u>

_____ 6) The production of ammonia from ammonium chloride will <u>increase</u> at higher temperature.

_____ 7) For the above reaction at equilibrium, an increase in pressure on the system causes a <u>decrease</u> in gaseous ammonia concentration.

8) Describe Le Chatelier's Principle. _____

_____

_____

9) How is changing the concentration of a reactant in a reaction related to a shift in equilibrium? _____

_____

10) For the following reaction, what will occur if pressure is increased? Why?

$$2NO_{2(g)} \leftrightarrows N_2O_{4(g)}$$

_____

Name _____ Date _____

Period _____

11) Given the reaction at equilibrium $A_{(g)} + B_{(g)} \leftrightarrows C_{(g)} + D_{(g)}$

The addition of a catalyst will:

a) shift equilibrium to the right
b) shift equilibrium to the left
c) increase the rate of the forward and reverse reactions
d) have no effect on the rate of the forward and reverse reactions

12) Consider the equation of the following reaction at equilibrium:

$$X + Y \leftrightarrows 2Z + \text{heat}$$

The concentration of the product can be increased by

a) adding a catalyst
b) adding more heat to the system
c) increasing the concentration of Y
d) decreasing the concentration of Z

13) Consider the following equation: $H_{2(g)} + Cl_{2(g)} \leftrightarrows 2HCl_{(g)}$

Which change will result in an increase in the concentration of chloride gas?

a) decreasing the pressure on the system
b) decreasing the concentration of HCl
c) increasing the concentration of H_2
d) increasing the concentration of HCl

14) Consider the following equation:

$$N_{2(g)} + O_{2(g)} \leftrightarrows 2NO_{(g)}$$

As the concentration of $N_{2(g)}$ increases, the concentration of $O_{2(g)}$ will

a) decrease b) increase c) remain the same d) vary directly

Name _____ Date _____

Period _____

Entropy

Determine whether the following reactions show an increase or decrease in entropy and specify the phase change or change in # of moles.

1. $2KClO_3(s) \rightarrow 2KCl(s) + 3O_2(g)$ _____
2. $H_2O(l) \rightarrow H_2O(s)$ _____
3. $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$ _____
4. $NaCl(s) \rightarrow Na^+(aq) + Cl^-(aq)$ _____
5. $KCl(s) \rightarrow KCl(l)$ _____
6. $C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(l)$ _____
7. $CO_2(s) \rightarrow CO_2(g)$ _____
8. $H^+(aq) + C_2H_3O_2^-(aq) \rightarrow HC_2H_3O_2(l)$ _____
9. $C(s) + O_2(g) \rightarrow CO_2(g)$ _____
10. $2CH_3OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 4H_2O(l)$ _____
11. $H_2(g) + Cl_2(g) \rightarrow 2HCl(g)$ _____
12. $Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$ _____
13. $2N_2O_5(g) \rightarrow 4NO_2(g) + O_2(g)$ _____
14. $2Al(s) + 3I_2(s) \rightarrow 2AlI_3(s)$ _____
15. $C_6H_{12}O_6(s) + 6O_2(g) \rightarrow 6CO_2(g) + 6H_2O(l)$ _____
16. $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$ _____
17. $2NO(g) \rightarrow N_2(g) + O_2(g)$ _____
18. $H_2O(g) \rightarrow H_2O(l)$ _____
19. $4Al(s) + 3O_2(g) \rightarrow 2Al_2O_3(s)$ _____
20. $2C_8H_{18}(l) + 25O_2(g) \rightarrow 16CO_2(g) + 18H_2O(l)$ _____

Name _____ Date _____

Period _____

Review

Fill in the blanks using the word bank provided below. Only one word in the bank is used TWICE.

activated complex	Le Chatelier's Principle	entropy
heterogeneous reaction	double arrow	reaction mechanism
activation energy	potential energy	exothermic reaction
homogeneous reaction	endothermic reaction	shift
catalyst	rate	heat of reaction
kinetics	enthalpy	stress
chemical equilibrium	rate-determining step	

The branch of chemistry concerned with the rates of chemical changes is called _____. A chemical change in which all the reactants are in the same phase is called a(n) _____. One in which the reactants are in different phases is called a(n) _____. A substance that speeds up a chemical change without being permanently altered or affecting the nature of the reaction is called a(n) _____.

The series of steps by which reacting particles rearrange themselves to form products is called the _____. The slowest step in such a series is the _____. A short-lived, high-energy arrangement of particles that is formed when reacting particles collide at the proper angle with the proper amount of energy is a(n) _____. The minimum amount of energy needed to form this arrangement is called the _____. Because this energy is stored inside the particles, it is an example of _____. The reactants and the products of any reaction have different amounts of this kind of stored energy. The difference between these two amounts of energy is the _____.

The heat content of a substance is called its _____. The change in this quantity that occurs during a chemical reaction is called the _____, ΔH. The sign of the quantity ΔH is positive in the case of a(n) _____. It is negative in the case of a(n) _____.

When forward and backward reactions occur at the same _____, a state of _____ exists. A(n) _____ is used in an equation to symbolize this state.

When conditions such as temperature are changed, a chemical reaction is said to be placed under a(n) _____. Under such changing conditions, equilibrium can undergo a(n) _____ in direction that tends to counteract the imposed changes. This generalization is known as _____. The measure of the randomness of a system is its _____.

Name _____ Date _____

Period _____

1) If you were given the ΔH value of a reaction, you could determine whether the reaction was exothermic or endothermic. Explain how you could do so.

_____

_____

_____

2) In an exothermic reaction, $H_{products}$ will always be (larger/smaller) than $H_{reactants}$

Process	ΔH	Exo or Endo	Entropy change
1. $2H_{2(g)} + O_{2(g)} \rightarrow 2H_2O_{(l)}$			
2. $C_{(s)} + O_{2(g)} \rightarrow CO_{2(g)}$			
3. $CO_{2(g)} \rightarrow C_{(s)} + O_{2(g)}$			
4. $2C_{(s)} + H_{2(g)} \rightarrow C_2H_{2(g)}$			
5. $2H_{2(g)} + O_{2(g)} \rightarrow 2H_2O_{(g)}$			
6. $C_6H_{12}O_{6(s)} + 6O_{2(g)} \rightarrow 6CO_{2(g)} + 6H_2O_{(l)}$			
7. $Br^-_{(aq)} + Li^+_{(aq)} \rightarrow LiBr_{(s)}$			
8. $H_{2(g)} + I_{2(g)} \rightarrow 2HI_{(g)}$			
9. $NaOH_{(s)} \rightarrow Na^+_{(aq)} + OH^-_{(aq)}$			
10. $2CO_{2(g)} \rightarrow O_{2(g)} + 2CO_{(g)}$			

Enthalpy and Table I

Look in your Reference Tables (Table I) and state whether the following reactions are exothermic or endothermic.

	Exo or Endo
1. Methane (CH_4) combining with oxygen to produce carbon dioxide and water	
2. Potassium nitrate dissociating into a positive potassium ion and a negative nitrate ion	
3. Sodium hydroxide dissociating into a positive sodium ion and a negative hydroxide ion	
4. Carbon monoxide combining with oxygen to form carbon dioxide	
5. **A positive lithium ion combining with a negative bromine ion to form lithium bromide	

Name _____ Date _____

Period _____

Unit 6 Practice Test

_____1. After being ignited in a Bunsen burner flame, a piece of magnesium ribbon burns brightly, giving off heat and light. In this situation, the Bunsen burner flame provides

A) heat of vaporization B) activation energy
C) heat of reaction D) ionization energy

_____2. As the number of effective collisions between reacting particles increases, the rate of reaction

A) decreases B) increases
C) remains the same

_____3. A piece of Mg(s) ribbon is held in a Bunsen burner flame and begins to burn according to the equation:

$$2Mg(s) + O_2(g) \rightarrow 2MgO(s).$$

The reaction begins because the reactants

A) are activated by heat from the burning magnesium
B) are activated by heat from the Bunsen burner flame
C) underwent a decrease in entropy
D) underwent an increase in entropy

_____4. Increasing the temperature increases the rate of a reaction by

A) increasing the activation energy
B) lowering the activation energy
C) lowering the frequency of effective collisions between reacting molecules
D) increasing the frequency of effective collisions between reacting molecules

_____5. As the temperature increases, the rate of an exothermic reaction

A) decreases B) increases
C) remains the same

_____6. If the pressure on gaseous reactants is increased, the rate of reaction is increased because there is an increase in the

A) volume B) activation energy
C) heat of reaction D) concentration

_____7. Given the reaction:

$$A(s) + B(aq) \rightarrow C(aq) + D(s)$$

Which change would increase the rate of this reaction?

A) an increase in pressure
B) a decrease in pressure
C) a decrease in temperature
D) an increase in temperature

Base your answers to questions **8** and **9** on the table below, which represents the production of 50 milliliters of CO_2 in the reaction of HCl with $NaHCO_3$. Five trials were performed under different conditions as shown. (The same mass of $NaHCO_3$ was used in each trial.)

Trial	Particle Size of $NaHCO_3$	Concentration of HCl	Temperature (°C) of HCl
A	small	1 M	20
B	large	1 M	20
C	large	1 M	40
D	small	2 M	40
E	large	2 M	40

_____8. Which two trials could be used to measure the effect of surface area?

A) trials *A* and *B* B) trials *A* and *C*
C) trials *A* and *D* D) trials *B* and *D*

_____9. Which trial would produce the fastest reaction?

A) trial *A* B) trial *B*
C) trial *C* D) trial *D*

_____

_____10. As the number of moles per liter of a reactant in a chemical reaction increases, the number of collisions between the reacting particles

A) decreases B) increases
C) remains the same

_____11. Given the reaction:
$A + B \rightarrow AB$

The table below shows student data obtained about the rate of reaction when the concentration of solution *A* is kept constant and the concentration of solution *B* is changed by adding H_2O. Based on the data, the student should conclude that the

Trial	Volume of Solution *A*	Volume of Solution *B*	Volume of H_2O Added	Reaction Time
1	10 mL	10 mL	0 mL	2.8 sec
2	10 mL	5 mL	5 mL	4.9 sec
3	10 mL	3 mL	7 mL	10.4 sec

A) reaction rate decreased as solution *B* was diluted
B) reaction rate increased when H_2O was added
C) reaction rate increased as solution *B* was diluted
D) concentration has no effect on the reaction rate

_____12. Given the reaction:

$$Zn(s) + 2\ HCl(aq) \rightarrow Zn^{2+}(aq) + 2\ Cl^-(aq) + H_2(g)$$

If the concentration of HCl(aq) is increased, the frequency of reacting collisions will
A) decrease, producing a decrease in the reaction rate
B) increase, producing an increase in the reaction rate
C) increase, producing a decrease in the reaction rate
D) decrease, producing an increase in the reaction rate

_____13. Four aluminum samples are each reacted with separate 1 M copper sulfate solutions under the same conditions of temperature and pressure. Which aluminum sample would react most rapidly?
A) 1 gram of Al pellets B) 1 gram bar of Al
C) 1 gram of Al powder D) 1 gram of Al ribbon

_____14. Which statement explains why the speed of some chemical reactions is increased when the surface area of the reactant is increased?
A) This change increases the concentration of the reactant.
B) This change alters the electrical conductivity of the reactant particles.
C) This change increases the density of the reactant particles.
D) This change exposes more reactant particles to a possible collision.

_____15. Beaker *A* contains a 1 gram piece of zinc and beaker *B* contains 1 gram of powdered zinc. If 100 milliliters of 0.1 M HCl is added to each of the beakers, how does the rate of reaction in beaker *A* compare to the rate of reaction in beaker *B*?
A) The rate in *A* is greater due to the smaller surface area of the zinc.
B) The rate in *A* is greater due to the larger surface area of the zinc.
C) The rate in *B* is greater due to the smaller surface area of the zinc.
D) The rate in *B* is greater due to the larger surface area of the zinc.

_____16. Which will occur if a catalyst is added to a reaction mixture?
A) Only the rate of the reverse reaction will be increased.
B) The energy change (ΔH) of the reaction will be decreased.
C) The activation energy will be changed.
D) Only the rate of the forward reaction will be increased.

_____17. Adding a catalyst to a chemical reaction results in
A) an increase in activation energy and a decrease in the reaction rate
B) an increase in activation energy and an increase in the reaction rate
C) a decrease in activation energy and an increase in the reaction rate
D) a decrease in activation energy and a decrease in the reaction rate

____18. Given the reaction:

$A + B \rightarrow C + D$

The reaction will most likely occur at the greatest rate if *A* and *B* represent
A) nonpolar molecular compounds in the solid phase
B) ionic compounds in the solid phase
C) solutions of ionic compounds
D) solutions of nonpolar molecular compounds

____19. Which change is exothermic?
A) sublimation of iodine
B) freezing of water
C) vaporization of ethanol
D) melting of iron

____20. Salt *A* and salt *B* were each dissolved in separate beakers of water at 21°C. The temperature of the salt *A* solution decreased, and the temperature of the salt *B* solution increased.

Based on these results, which conclusion is correct?
A) The water gained energy from both salt *A* and salt *B*.
B) The water gained energy from salt *A* and lost energy to salt *B*.
C) The water lost energy to both salt *A* and salt *B*.
D) The water lost energy to salt *A* and gained energy from salt *B*.

____21. A student observed that when sodium hydroxide was dissolved in water, the temperature of the water increased. The student should conclude that the dissolving of sodium hydroxide
A) produces an acid solution
B) is endothermic
C) produces a salt solution
D) is exothermic

____22. The burning of wood is best described as an
A) endothermic physical change
B) exothermic physical change
C) exothermic chemical change
D) endothermic chemical change

____23. In what type of reaction do the products of the reaction always possess more potential energy than the reactants?
A) exothermic B) spontaneous
C) endothermic D) redox

____24. Given the balanced equation:

$$KNO_3(s) + 34.89\ kJ \xrightarrow{H_2O} K^+(aq) + NO_3^-(aq)$$

Which statement best describes this process?
A) It is exothermic and entropy increases.
B) It is exothermic and entropy decreases.
C) It is endothermic and entropy decreases.
D) It is endothermic and entropy increases.

____25. Which expression represents the ΔH for a chemical reaction in terms of the potential energy, *PE*, of its products and reactants?
A) *PE* of products × *PE* of reactants
B) *PE* of products − *PE* of reactants
C) *PE* of products + *PE* of reactants
D) *PE* of products ÷ *PE* of reactants

____26. Given the balanced equation:

$4Fe(s) + 3O_2(g) \rightarrow 2Fe2O_3(s) + 1640\ kJ$

Which phrase best describes this reaction?
A) exothermic with $\Delta H = -1640$ kJ
B) exothermic with $\Delta H = +1640$ kJ
C) endothermic with $\Delta H = +1640$ kJ
D) endothermic with $\Delta H = -1640$ kJ

____27. According to Table I, which salt releases energy as it dissolves?
A) NH_4NO_3 B) KNO_3
C) NaCl D) LiBr

____28. According to Reference Table I, which statement best describes the formation of HI(*g*)?
A) It is endothermic, and heat is released.
B) It is exothermic, and heat is absorbed.
C) It is endothermic, and heat is absorbed.
D) It is exothermic, and heat is released.

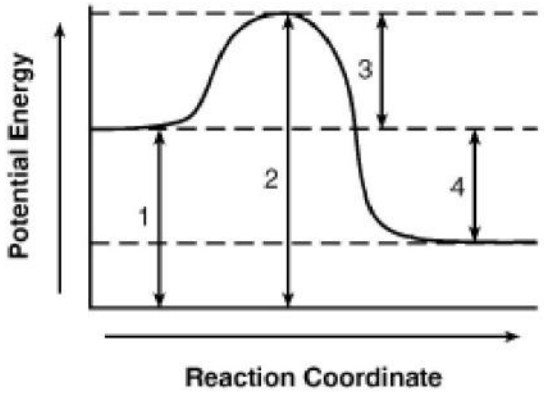
____29. Which statement best describes a chemical reaction in which energy is released?

A) It is exothermic and has a positive ΔH.
B) It is exothermic and has a negative ΔH.
C) It is endothermic and has a positive ΔH.
D) It is endothermic and has a negative ΔH.

____30. According to Reference Table I, which compound is formed from its elements during an exothermic reaction?

A) NO(g) B) $NO_2(g)$
C) HI(g) D) $CO_2(g)$

____31. Given the potential energy diagram for a reaction:



Which interval on this diagram represents the difference between the potential energy of the products and the potential energy of the reactants?

A) 3 B) 4
C) 1 D) 2

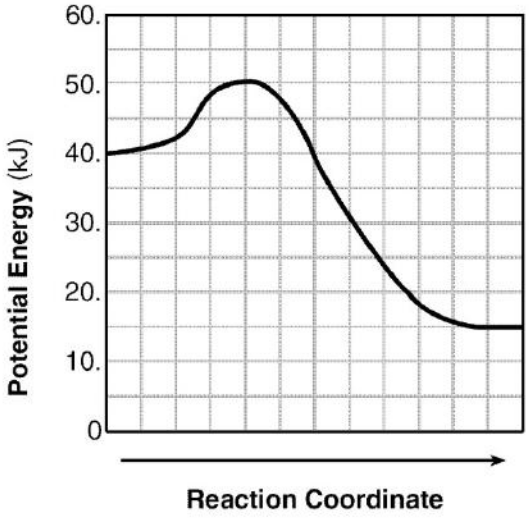
____32. In a chemical reaction, the difference between the potential energy of the products and the potential energy of the reactants is defined as the

A) activation energy B) ionization energy
C) heat of vaporization D) heat of reaction

____33. A chemical reaction is at equilibrium. Compared to the rate of the forward reaction, the rate of the reverse reaction is

A) faster and more reactant is produced
B) the same and the reaction continues in both directions
C) the same and the reaction has stopped
D) faster and more product is produced

____34. Given the potential energy diagram for a chemical reaction:



Which statement correctly describes the energy changes that occur in the forward reaction?

A) The activation energy is 50. kJ and the reaction is endothermic.
B) The activation energy is 50. kJ and the reaction is exothermic.
C) The activation energy is 10. kJ and the reaction is exothermic.
D) The activation energy is 10. kJ and the reaction is endothermic.

____35. Which information about a chemical reaction is provided by a potential energy diagram?

A) the average kinetic energy of the reactants and products
B) the change in solubility of the reacting substances
C) the energy released or absorbed during the reaction
D) the oxidation states of the reactants and products

____36. Which type or types of change, if any, can reach equilibrium?

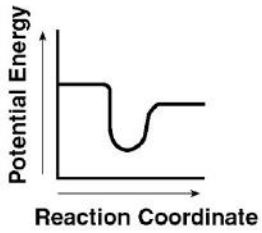
A) a chemical change, only
B) a physical change, only
C) both a chemical and a physical change
D) neither a chemical nor a physical change

____37. Given the reaction:

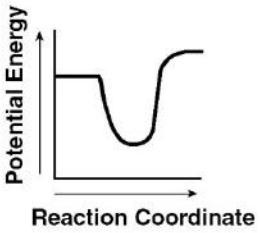
$$S(s) + O_2(g) \rightarrow SO_2(g) + \text{energy}$$

Which diagram best represents the potential energy changes for this reaction?

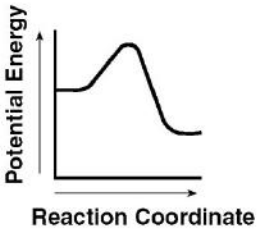
A)



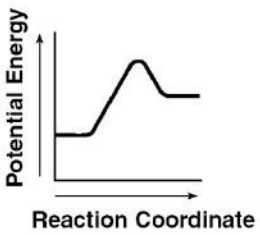
B)



C)



D)



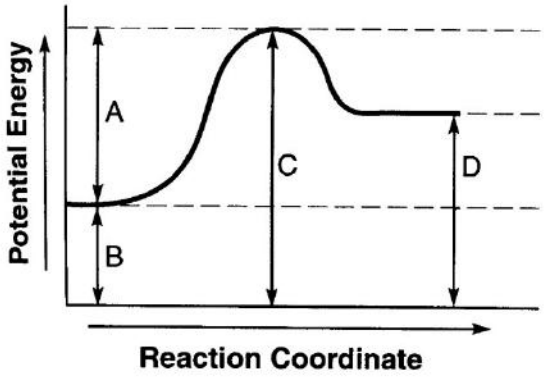
____38. Given the reaction system in a closed container at equilibrium and at a temperature of 298 K:

$$N_2O_4(g) \leftrightarrow 2NO_2(g)$$

The measurable quantities of the gases at equilibrium must be

A) constant B) decreasing
C) increasing D) equal

____39. Given the potential energy diagram of a chemical reaction:



Which arrow represents the potential energy of the reactants?

A) *A* B) *B*
C) *C* D) *D*

____40. In a reversible reaction, chemical equilibrium is attained when the

A) concentration of the products remains constant
B) rate of the reverse reaction is greater than the rate of the forward reaction
C) rate of the forward reaction is greater than the rate of the reverse reaction
D) concentration of the reactants reaches zero

____41. Ammonia is produced commercially by the Haber reaction:

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

The formation of ammonia is favored by

A) a decrease in pressure
B) removal of $N_2(g)$
C) removal of $H_2(g)$
D) an increase in pressure

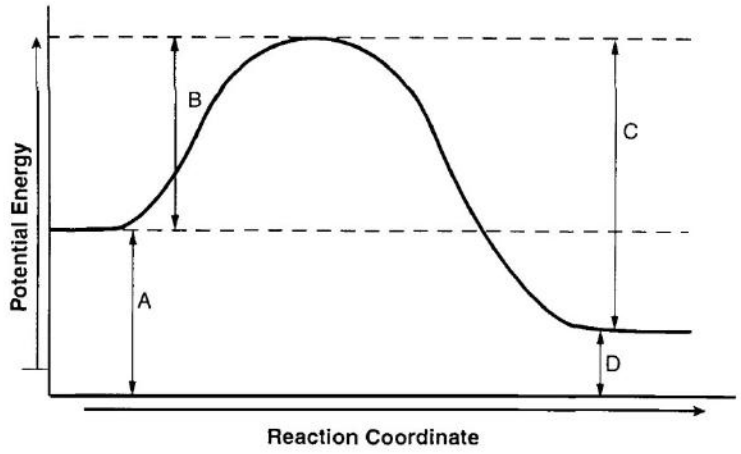
____42. Which list of the phases of H_2O is arranged in order of increasing entropy?

A) steam, ice, and liquid water
B) ice, liquid water, and steam
C) ice, steam, and liquid water
D) steam, liquid water, and ice

Name _____ Date _____

Period _____

___45. A potential energy diagram is shown below.



Which letters represent the activation energy of the forward and reverse reactions, respectively?

A) *A* and *C* B) *A* and *D* C) *B* and *C* D) *B* and *D*

____46. Given the reaction at equilibrium:

$2\ A(g) + 3\ B(g) \leftrightarrow A_2B_3(g) + \text{heat}$

Which change will not affect the equilibrium concentrations of *A*(*g*), *B*(*g*), and $A_2B_3(g)$?

A) adding more *A*(*g*)
B) increasing the pressure
C) adding a catalyst
D) increasing the temperature

____47. Given the reaction at equilibrium:

$N_2(g) + 3H_2(g) \leftrightarrow 2NH_3(g) + 91.8kJ$

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

A) The rate of the forward reaction and the concentration of $N_2(g)$ both decrease.
B) The rate of the forward reaction and the concentration of $N_2(g)$ both increase.
C) The rate of the forward reaction decreases and the concentration of $N_2(g)$ increases.
D) The rate of the forward reaction increases and the concentration of $N_2(g)$ decreases.

____48. Given the Haber reaction at equilibrium:

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

Which stress on the system will decrease the production of $NH_3(g)$?

A) decreasing the temperature on the system
B) decreasing the concentration of $H_2(g)$
C) increasing the concentration of $N_2(g)$
D) increasing the pressure on the system

____49. Given the reaction at equilibrium:

$A(g) + B(g) \rightleftharpoons AB(g) + \text{heat}$

The concentration of *A*(g) can be increased by

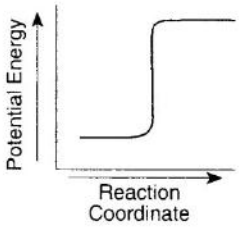
A) increasing the concentration of *B*(g)
B) increasing the concentration of *AB*(g)
C) adding a catalyst
D) lowering the temperature

____50. At STP, a sample of which element has the highest entropy?

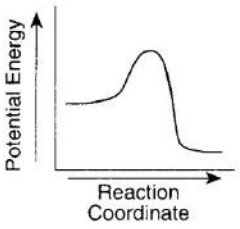
A) Na(s) B) $F_2(g)$
C) $Br_2(\ell)$ D) $Hg(\ell)$

____43. When a spark is applied to a mixture of hydrogen and oxygen, the gases react explosively. Which potential energy diagram best represents the reaction?

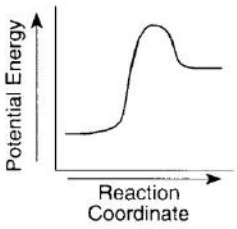
A)



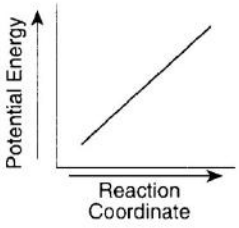
B)



C)



D)



____44. Given the system at equilibrium:

$$H_2(g) + F_2(g) \leftrightarrow 2\ HF(g) + \text{heat}$$

Which change will *not* shift the point of equilibrium?

A) changing the temperature
B) changing the pressure
C) changing the concentration of $H_2(g)$
D) changing the concentration of HF(g)

Name _____ Date _____

Period _____

_____51. Given the system at equilibrium:

$N_2O_4(g) + 58.1\ kJ \leftrightarrow 2\ NO_2(g)$

What will be the result of an increase in temperature at constant pressure?

A) The equilibrium will shift to the right, and the concentration of $NO_2(g)$ will increase.
B) The equilibrium will shift to the left, and the concentration of $NO_2(g)$ will increase.
C) The equilibrium will shift to the right, and the concentration of $NO_2(g)$ will decrease.
D) The equilibrium will shift to the left, and the concentration of $NO_2(g)$ will decrease.

_____52. What occurs when the temperature is increased in a system at equilibrium at constant pressure?

A) The rate of the exothermic reaction decreases.
B) The rate of the forward reaction increases, and the rate of the reverse reaction decreases.
C) The rate of the forward reaction decreases, and the rate of the reverse reaction increases.
D) The rate of the endothermic reaction increases.

_____53. Systems in nature tend to undergo changes toward

A) higher energy and higher entropy
B) higher energy and lower entropy
C) lower energy and lower entropy
D) lower energy and higher entropy

_____54. Even though the process is endothermic, snow can sublime. Which tendency in nature accounts for this phase change?

A) a tendency toward less energy
B) a tendency toward greater energy
C) a tendency toward less entropy
D) a tendency toward greater entropy

_____55. Which phase change represents a *decrease* in entropy?

A) solid to gas B) gas to liquid
C) solid to liquid D) liquid to gas

_____56. Which reaction has the greatest increase in entropy?

A) $2\ H_2O(g) \rightarrow 2\ H_2(g) + O_2(g)$
B) $H_2O(g) \rightarrow H_2O(\ell)$
C) $H_2O(\ell) \rightarrow H_2O(s)$
D) $2\ H_2O(\ell) \rightarrow 2\ H_2(g) + O_2(g)$