Name…… **Period……**

Unit 11: Kinetics And Equilibrium

Skills

1. Understand theory of reaction kinetics
2. Understand factors affecting reaction rate
3. Using Table I
4. Drawing and interpreting PE diagrams
5. Distinguishing between endo/exo PE diagrams
6. Defining and identifying changes in entropy
7. Understanding and defining equilibrium
8. Understanding equilibrium through Le Chatelier's Principle
9. Applying Le Chatelier with types of stressors

Unit 11: Vocabulary: **Complete throughout unit. Due on test day!**

Word	Definition
Kinetics	
Rate Determining Step	
Effective Collision	
Exothermic	
Endothermic	
Potential Energy	
Enthalpy	
Activation Energy	
Activated Complex	
Forward Reaction	
Entropy	
Chemical Equilibrium	
Le Chatelier's Principle	
Stress	

Skill 1: Understand the theory of reaction kinetics

- **Kinetics** = study of the _____ or _____ at which reactions occur
- A **REACTION** is the BREAKING and REFORMING of _____ to make entirely new compounds as products
- Reaction Mechanism = STEP BY STEP PROCESS needed to make a product; how you get from "a" to "b" (like a recipe)

REACTANTS → PRODUCTS

Just like when we bake a cake we must follow directions o CAN'T OMIT any STEPS!

- CAN'T CHANGE THE ORDER of the steps!
- CAN'T OMIT any REACTANTS (ingredients)

Determine whether each of the following chemical reactions is an example of a slow or fast reaction. Explain why knowing this relative rate of rxn is significant.

Rusting _____
Alka seltzer in water _____
Styrofoam decomposing _____

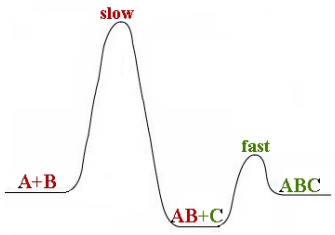
Weathering of rocks _____
Bleach removing color _____

WHAT DETERMINES THE RATE OF A REACTION? Time to Race!!

1. **NUMBER OF STEPS** = more steps can mean a slower reaction
2. **RATE DETERMINING STEP =** the _____ _____ of the reaction; most important factor influencing reaction rate

Rate Determining Step

$A + B + C \rightarrow ABC$ (2 steps)
$A + B \rightarrow AB$ (slow)
$AB + C \rightarrow ABC$ (fast)

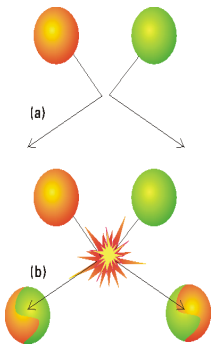


Collision Theory: In order for are action to occur, reactant PARTICLES MUST _____and have the following when doing so:

1. Proper amount of energy

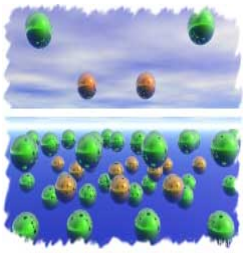
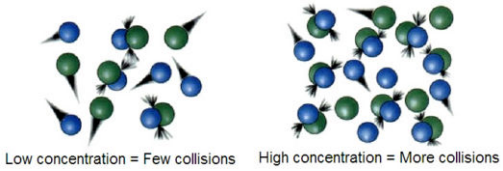
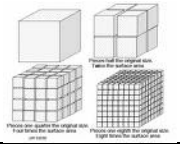
2. Proper ALIGNMENT/DIRECTION/ORIENTATION

*



Only when particles collide with these two conditions are met will there be an _____ COLLISION, resulting in a reaction

Skill 2: Identify and understand 6 Factors Affecting Rate of Reaction:

Factor	How Rate Affected	Why does it increase the rate?
1. Nature of Reactants	_____ substances react FASTER _____ substances react SLOWER	☐ Ionic = smaller→ (Fewer bonds to break; Fewer Steps!) ☐ Covalent = larger (MORE bonds to break; MORE steps):
2. Concentration  	INCREASE concentration, _____ rxn rate	The MORE PARTICLES in a given space, the LESS SPACE b/w particles → MORE COLLISIONS 
	Why does concentration affect the rate of reaction?	
3. Pressure	INCREASE pressure, INCREASE rxn rate (affects GASES ONLY!)	Increasing pressure _____VOLUME which DECREASES SPACE b/w particles → MORE COLLISIONS
4. Temperature	INCREASE temperature, INCREASE rxn rate	Greater SPEED → _____ total COLLISIONS Greater AVERAGE KE→ collisions take place with MORE energy
5. Catalyst	SPEEDS UP THE RXN WITHOUT CHANGING THE NATURE OF THE REACTANTS/PRODUCT	Provides a SHORTCUT or _____ _____ for the mechanism Lowers the ACTIVATION ENERGY for the reaction
	Define Catalysis:	
6. Surface Area	INCREASE the surface area (by making PIECES SMALLER) INCREASES the rxn rate (How many surfaces are there?)	Increasing surface area EXPOSES MORE REACTANT PARTICLES to possible collisions 

Answer the following based on this lab and your knowledge of reaction rates:

1. Which event must always occur for a chemical reaction to take place?

   (1) Formation of a precipitate
   (2) Effective collisions between reaction particles
   (3) Formation of a gas
   (3) addition of a catalyst to the reaction system

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

   (1) lowering the activation energy
   (2) increasing the activation energy
   (3) lowering the frequency of a effective collisions between reacting molecules
   (4) Increasing the frequency of effective collisions between reacting molecules

3. A 5.0 gram sample of zinc and a 50. Millimeter sample of hydrochloric acid are using in a chemical reaction. Which combination of these samples has the FASTEST reaction rate?

   (1) Zinc strip and 1.0 M HCl
   (2) Zinc powder and 1.0M HCl
   (3) Zinc strip and 3.0M HCl
   (3) Zinc powder and 3.0M HCl

4. What is required for a chemical reaction to occur?

   A) standard temperature and pressure
   B) a catalyst added to the reaction system
   C) effective collisions between reactant particles
   D) an equal number of moles of reactants and products

5. Given the balanced equation representing a reaction:
   $2HCl + Na_2SO_3\ (aq) \rightarrow S(s) + H_2SO_3 + 2NaCl\ (aq)$

   (1) Activation energy decreases
   (2) Frequency of effective collision decreases
   (3) Activation energy increases
   (4) Frequency of effective collision increases

6. A student conducts an experiment to determine how the temperature of water affects the rate at which an antacid tablet dissolves in the water. The student has three antacid tablets of the same size and compositions.

Dissolving Data for Three Antacid Tablets

Beaker	Original Temperature of Water (°C)	Time for Tablet to Dissolve (s)
1	20.	40.
2	30.	25
3	40.	10.

(A) Describe the effect of water temp on the rate of dissolving

(B) Explain in terms of collision theory, how water temperature influence the rate of dissolving

Skill 3: Using Table I

Table I (of the Reference Tables) tells us if particular reactions are exothermic or endothermic based on sign of the Δ H value!

Δ H: Enthalpy of a Reaction, how much _____is gained or _____during a reaction. Equal to the **PE OF THE PRODUCTS - PE OF THE REACTANTS.**

RECALL; Two types of chemical reactions:

1. Exothermic: Reactions that _____ energy.
   - Δ H = negative value (-) energy released (on right)
   - A + B → C + D + energy

   Example: Sodium in water – lots of heat (and fire!) produced as product; heat felt on a test tube during a reaction

2. Endothermic: Reactions that _____ energy.
   - Δ H = positive value (+) energy absorbed (on left)
   - A + B + ENERGY→ C + D

   Example: baking (need oven to supply heat)

Determine if the following reactions are endo or exothermic:

1. $N_2(g) + 2O_2(g) \rightarrow 2NO_2(g)$ _____
2. $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$ _____
3. $2NH_3(g) \rightarrow N_2(g) + 3H_2(g)$ _____

The * at the bottom of TABLE I tells you all you need to remember…

Practice:

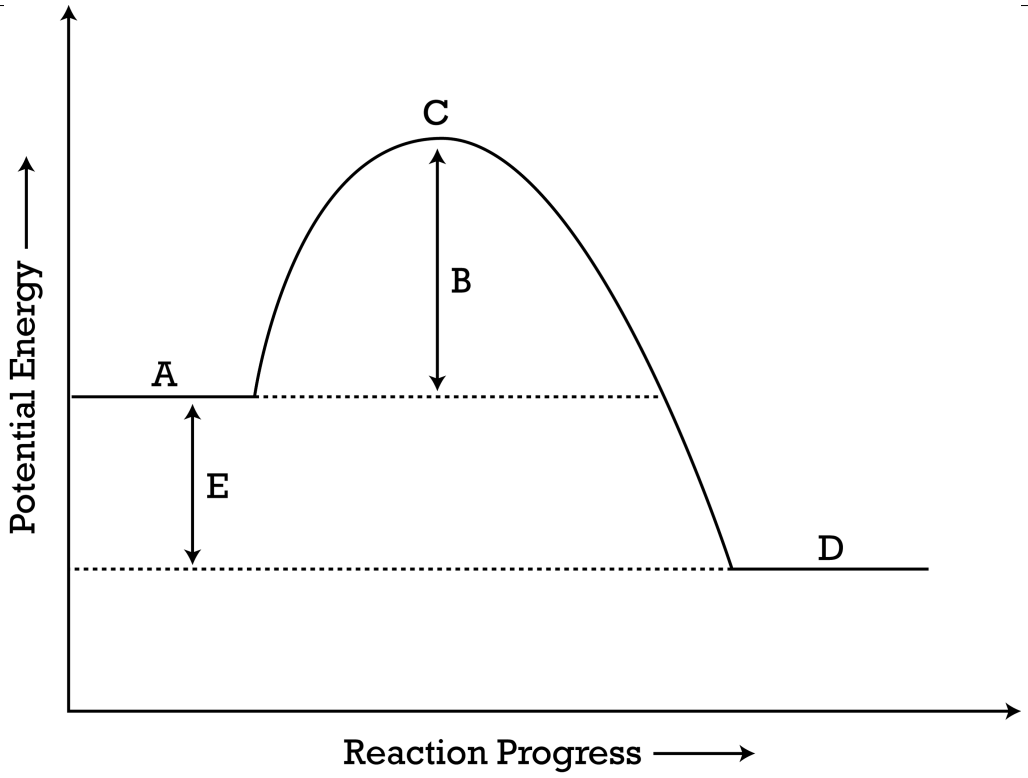
Reaction	**ΔH (kJ)**	**Endothermic or Exothermic**
$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$		
$2H_2(g) + O_2(g) \rightarrow 2H_2O(g)$		
$C_2H_5OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l)$		
$*CO(g) + 1/2O_2(g) \rightarrow CO_2(g)$		
$*4NO(g) \rightarrow 2N_2(g) + 2O_2(g)$		

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?

Skill 4: Drawing and interpreting Potential Energy Diagrams

Potential Energy Diagrams: Recall, we have talked about chemical bonds having stored energy (AKA potential energy). For that reason, chemists use diagrams called Potential Energy Diagrams to illustrate the potential (or stored) energy changes that occur during specific chemical reactions

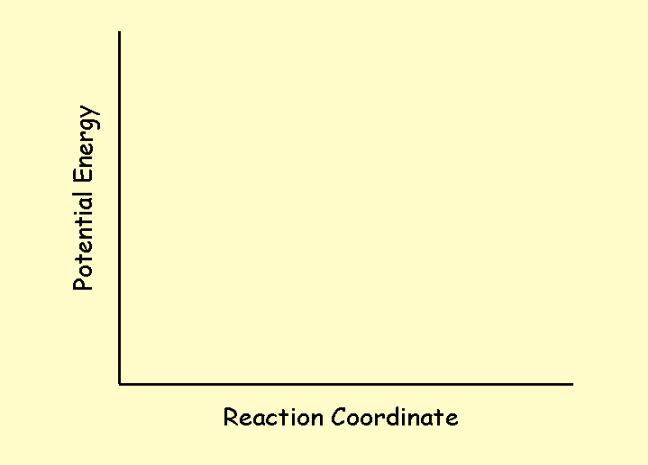


Vocabulary of a Potential Energy Diagram:

- **Potential Energy of the Reactants:**
  - The amount of energy that a system _____ with (the starting point in the graph.
- **Potential Energy of the Products:**
  - The amount of energy that the system _____ with.
- **ACTIVATED COMPLEX: (The PEAK)**
  - _____energy point of the reaction; this is where full _____of the reactants occurs. Remember, this **must** happen for the reaction to be successful.
- **Activation Energy:**
  - Amount of ENERGY NEEDED TO GET A _____ _____or to FORM THE ACTIVATED COMPLEX of a reaction (you must get "over the hump" in order for a reaction to occur)
- **Activation energy of the Forward reaction:**
  - Energy needed to get "over the hump" going forward (left to right).
- **Activation Energy of the Reverse reaction:**
  - Energy needed to get "over the hump" going backward (right to left).
- **Heat of the Reaction**
  - ($\Delta H=H_p - H_r$)

Skill 5: Distinguish between Endo and Exothermic potential energy diagrams

- ☐ **ENDOTHERMIC Potential Energy Diagrams** →POSITIVE ΔH
  - **Product** side (to the R) always HIGHER than the **reactant** side (to the L) meaning that ENERGY is _____.



- ☐ **EXOTHERMIC Potential Energy Diagrams** → NEGATIVE ΔH
  - **Product** side (to the R) always LOWER than the **reactant** side (to the L) meaning that ENERGY is _____.
  - Most common types of rxns because less energy has to be put in to get the rxn started (LOWER activation energy)

Label the following:
A = Potential Energy of the Reactants

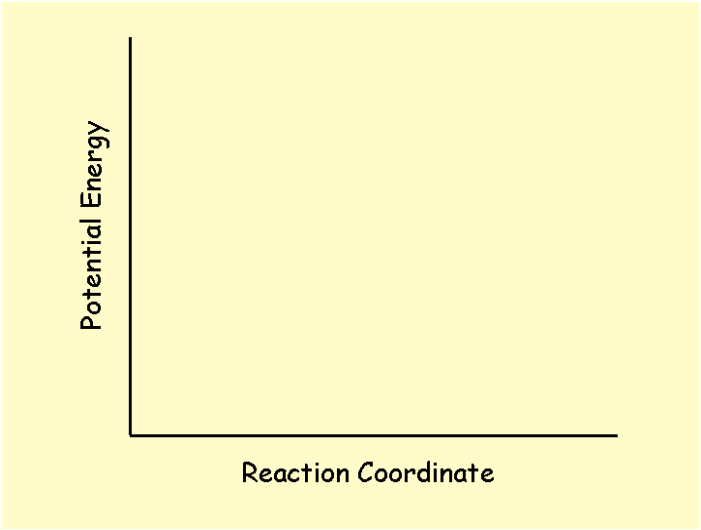
B = Potential Energy of the Products

C = Potential Energy of the Activated Complex

D = Activation energy of the Forward rxn

E = Activation Energy of the Reverse rxn

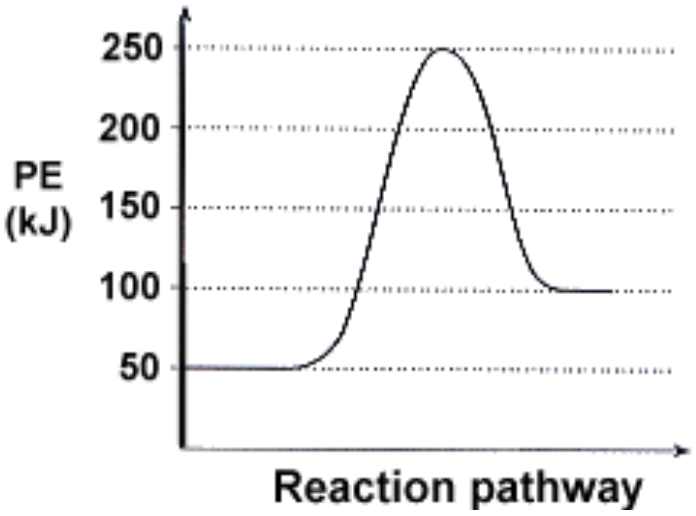
F=Heat of the Reaction($\Delta H=H_p - H_r$)



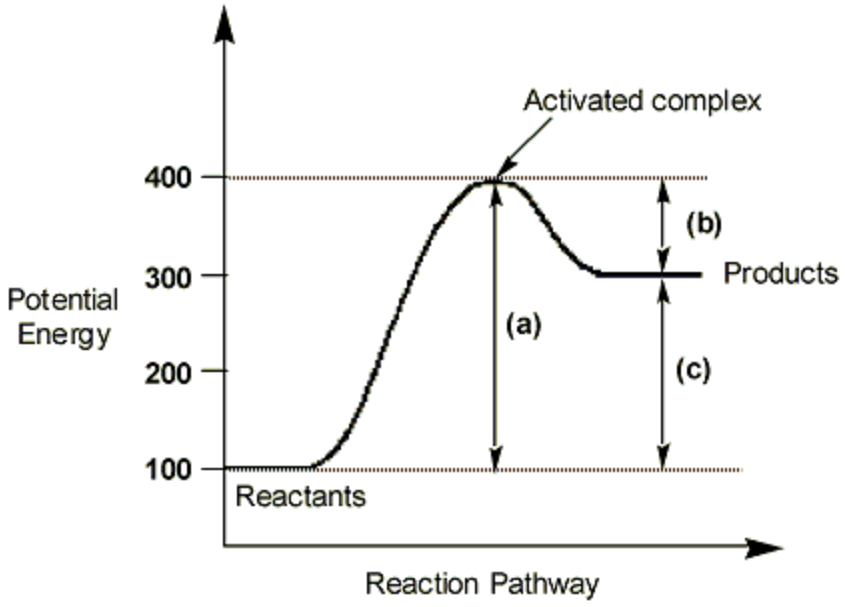
HOW EXACTLY DOES A CATALYST SHORTEN THE REACTION TIME NEEDED FOR A REACTION TO COMPLETE and how do we show it?

The _____ _____ is lowered ...
OR
The ACTIVATION ENERGY is decreased ...
OR
The REACTION _____ is shortened.

Draw the catalyzed reaction pathway on the diagram to the right→



PE Diagram Calculations:



Part 1:

Determine the values of the following from the graph above:

PE $_{Reactants}$:_____ **Energy:** A + B → C + D

PE $_{Products}$: _____

Activated complex: _____

Enthalpy of Rxn: _____

Activation Energy forward: _____

Activation Energy Reverse: _____

Endo or Exo?: _____

Part 2

Using "Increase" or "Decrease" or "Remains the Same" to describe how adding a catalyst would affect the following:

PE $_{Reactants}$:_____

PE $_{Products}$: _____

Activated complex: _____

Enthalpy of Rxn: _____

Activation Energy forward: _____

Activation Energy Reverse: _____

Skill 6: Defining and identifying changes in ENTROPY (ΔS)

- **Entropy (ΔS):** Degree of _____, CHAOS, DISORDER or "MESSINESS" in a system; nature tends to proceed to a state of GREATER entropy, or disorder.
  - The MORE ORDER you have, the _____ ENTROPY in your system.
  - The LESS ORDER you have, the _____ ENTROPY in your system.
- _____ _____ is the most significant factor in determining ΔS:

Changing from **(s) →(l) →(aq) → (g)** = INCREASED ENTROPY

Draw particle diagrams to illustrate each of the following phases:

(s) (l) (aq) (g)

*Entropy _____ when a compound is broken down.

*Entropy _____ when a compound is created and bonds are formed.

NOTE: If there is no phase change, count up the # molecules on each side

RULE: # moles↓ = ENTROPY ↓ = -ΔS, **AND** **If** # moles ↑ = ENTROPY ↑ = +ΔS)

For the following determine if there is an **increase, decrease, or no change in entropy**

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. $CO_2(s) \rightarrow CO_2(g)$ _____

Skill 7: Understanding and Defining Equilibrium:

- Equilibrium occurs **WHEN THE _____OF THE FORWARD REACTION EQUALS THE _____OF THE REVERSE REACTION** in a closed system.

- When equilibrium is reached, **IT DOES NOT MEAN** that the reactants and products are of equal **QUANTITIES**. So...

  - **DOUBLE ARROWS (⇌)** instead of a single arrow. This allows us to illustrate that the reactions are proceeding in both directions (forward and reverse).

  - Equilibrium is _____ which means that it is constantly CHANGING or FLUCTUATING

  - Equilibrium means that reactant and product _____ are CONSTANT. ***Equilibrium does NOT mean that reactant and product concentrations are equal.***

TIME FOR BAILING BEAKERS……WHO WILL BE VICTORIOUS?

- **TYPES OF EQUILIBRIUM** (all occur in _____ _____) ***IT'S ALL ABOUT THE EQUAL RATES***

  1. Physical Equilibrium: Equilibrium that involves physical changes

  - **Phase Equilibrium –** occurs during a PHASE CHANGE

    RATE of MELTING = RATE of FREEZING (sealed container @ $0^{o}C$)

    RATE of EVAPORATION = RATE of CONDENSATION (sealed container @ $100^{0}C$)

  - **Solution Equilibrium** – occurs at a solution's _____ POINT RATE of DISSOLVING = RATE of CRYSTALLIZATION example: $NaCl_{(s)} \leftarrow \rightarrow NaCl_{(aq)}$

  2. Chemical Equilibrium:

  - _____ of the FORWARD RXN = _____ of the REVERSE RXN

    OR

  - _____ of BREAKING BONDS = _____ of FORMING BONDS

1. Which statement describes a chemical reaction at equilibrium?
   A) The products are completely consumed in the reaction.
   B) The reactants are completely consumed in the reaction.
   C) The reaction rates of the products and reactants are equal.
   D) The reaction rates of the products and reactants are constant.

2. Which two processes are at equilibrium in a saturated sugar solution?

   a. evaporation and condensation
   b. dissolving and crystallization
   c. decomposition and synthesis
   d. ionization and recombination

Skill 7: Understanding Equilibrium through LE CHATELIER's PRINCIPLE

Le Chatelier's principle explains HOW A SYSTEM AT EQUILIBRIUM WILL RESPOND TO _____.

- **STRESS** = Any change in TEMPERATURE, CONCENTRATION, or PRESSURE put upon an system at equilibrium
- When a STRESS is added to a system at equilibrium, the system will _____ in order to relieve that stress and reach a new equilibrium.
- **SHIFT =** an increase in the _____of EITHER the forward OR the reverse rxn
- **SHIFT TO RIGHT (TOWARD PRODUCTS):**
  - Rate of FORWARD reaction INCREASES (→)
  - Reactants $\rightarrow_{\leftarrow}$ Products *Favors PRODUCTS
- **SHIFT TO LEFT (TOWARD REACTANTS):**
  - Rate of REVERSE reaction INCREASES (←)
  - Reactants $\leftarrow_{\rightarrow}$ Products *Favors REACTANTS

Skill 7a: Applying Le Chatelier with Types of Stressors

Initial Stress: Concentration

ADD, AWAY

☐ When the concentration of a reactant or product is INCREASED, the reaction will SHIFT _____ from the increase (use up the excess.

Example 1: $4NH_3(g) + 5O_2(g) \leftarrow \rightarrow 4NO(g) + 6H_2O(g) + HEAT$

1. If we add H_2O (g), the system would shift to the _____ and the [NH_3] would _____.
2. If we add O_2(g), the system would shift to the _____ and the [NO] would _____.
3. If we add H_2O (g), the system would shift to the _____ and the [NO] would _____.

Take, Towards

☐ When the concentration of a reactant or product is **DECREASED:** The reaction will SHIFT _____ the side that has experienced the decrease in concentration (replaces what was taken)

Example 2: $4NH_3(g) + 5O_2(g) \leftarrow \rightarrow 4NO(g) + 6H_2O(g) + HEAT$

1. If we remove oxygen, the system will shift to the _____ and the [NH_3] will _____.
2. If we remove water, the system will shift to the _____ and the [NO] will _____.
3. If we remove ammonia, which concentration(s) will decrease? _____
4. If we remove NO(g), which concentration(s) would increase? _____

Initial Stress: Temperature (involves increasing or decreasing the "HEAT" component of a reaction)

- ☐ **When temperature (or HEAT) is decreased:** The reaction will SHIFT _____ the rxn side containing "HEAT" (in the EXOTHERMIC direction)

Take, Towards

$A + B \leftrightarrow C + D + HEAT$

Example 1: $4NH_3(g) + 5O_2(g) \leftrightarrow 4NO(g) + 6H_2O(g) + HEAT$

1. If we remove heat, which concentration(s) will decrease? _____
2. If we remove heat, which concentration(s) will increase?_____

- ☐ **When temperature (or HEAT) is increased:** **When temperature (or HEAT) is increased:** The reaction will SHIFT _____ from the rxn side containing "HEAT" (in the ENDOTHERMIC direction)

ADD, AWAY

$A + B + energy \leftrightarrow C + D$

Example 2: $4NH_3(g) + 5O_2(g) \leftrightarrow 4NO(g) + 6H_2O(g) + HEAT$

3. If we added heat, which concentration(s) will decrease? _____
4. If we added heat, which concentration(s) will increase?_____

Initial Stress: Pressure…..EFFECTS GASES ONLY!!!!

- ☐ **INCREASE PRESSURE:** rxn shifts to side with _____ # GAS MOLECULES (or least # moles of gas)
- ☐ **DECREASE PRESSURE**: rxn shifts to side with GREATEST # GAS MOLECULES (or greatest # moles of gas)

NOTE: If the rxn contains **NO GAS MOLECULES** or if the rxn has the **SAME # GAS MOLECULES** on each side, there is **NO EFFECT** and **NO SHIFT** results from an increase or decrease in pressure

Example 1: **$CO_2(g) \leftrightarrow CO_2(aq)$**

4. If we increase the pressure, the concentrations of which species will increase? _____

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

1. If we increase the pressure, in which direction will the equilibrium shift? (Count Moles) _____
2. If we increase the pressure, the concentration of which species will increase initially? _____
3. If we decrease the pressure, the concentration of which species will decrease initially? _____
4. If we decrease the pressure, the concentration of which species will increase initially? _____

Practice:

Chemical System: **$2SO_3$ + heat ←→ $2SO_2$ (g) + O_2 (g)**

a) Stress: Increasing Temperature:

a. Reaction will shift _____ Concentration of SO_3 _____
b. Rate of forward reaction _____ Concentration of SO_2_____
c. Rate of reverse reaction_____ Concentration of O_2 _____

b) Stress: Increasing Pressure:

a. Reaction will shift _____ Concentration of SO_3 _____
b. Rate of forward reaction _____ Concentration of SO_2_____
c. Rate of reverse reaction_____ Concentration of O_2 _____

b) Stress: Decreasing Pressure:

a. Reaction will shift _____ Concentration of SO_3 _____
b. Rate of forward reaction _____ Concentration of SO_2_____
c. Rate of reverse reaction_____ Concentration of O_2 _____

Chemical System: **$3H_2$(g) + N_2 ←→ 2 NH_3 (g) + heat**

a) Stress: Increasing Temperature:

a. Reaction will shift _____ Concentration of H_2 _____
b. Rate of forward reaction _____ Concentration of N_2_____
c. Rate of reverse reaction_____ Concentration of NH_3 _____

b) Stress: Decreasing temperature

a. Reaction will shift _____ Concentration of H_2 _____
b. Rate of forward reaction _____ Concentration of N_2_____
c. Rate of reverse reaction_____ Concentration of NH_3 _____

c) Stress: Adding NH_3:

a. Reaction will shift _____ Concentration of H_2 _____
b. Rate of forward reaction _____ Concentration of H_2_____
c. Rate of reverse reaction_____ Concentration of NH_3 _____

Chemical System: **$BaSO_4$(s) ←→ Ba^{2+} (aq) + SO_4^{2-} (aq)**

a) Stress: Adding $Ba(NO_3)_2$ (s)

a. Reaction will shift _____ Concentration of Ba^{2+}_____
b. Rate of forward reaction _____ Concentration of SO_4^{2-}_____
c. Rate of reverse reaction_____

b) Stress: Removing $Ba(NO_3)_2$ (s)

a. Reaction will shift _____ Concentration of Ba^{2+}_____
b. Rate of forward reaction _____ Concentration of SO_4^{2-}_____
c. Rate of reverse reaction_____

c) Stress: Removing SO_4^{2-}

a. Reaction will shift _____ Concentration of Ba^{2+}_____
b. Rate of forward reaction _____ Concentration of SO_4^{2-}_____
c. Rate of reverse reaction_____

Name_____ Le Chatelier's Principle

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.

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

_____ 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

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

Using directional arrows, describe what would happens if:

a. Increase Temperature: Shifts to the _____, _____ [HI], _____ [H_2], _____ [I_2]

b. Increase [H_2 (g)]: Shifts to the _____, _____ [HI], _____ [I_2]

c. Increase [HI (g)]: Shifts to the _____, _____ [H_2], _____ [I_2]

d. Decrease Pressure:

6) $PCl_5(g)$ + heat $\leftrightarrow$ $PCl_3(g) + Cl_2(g)$

What happens if:

a. Adding Cl_2: Shifts to the _____, _____ [PCl_5], _____ [PCl_3]

b. Increasing Pressure: Shifts to the _____, _____ [PCl_5], _____ [PCl_3], _____ [Cl_2]

c. Lowering Temperature: Shifts to the _____, _____ [PCl_5], _____ [PCl_3], _____ [Cl_2]

d. Removing PCl_3: Shifts to the _____, _____ [PCl_5], _____ [PCl_3]

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

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

---

8) Given the reaction at equilibrium :$A_{(g)} + B_{(g)} \leftrightarrow C_{(g)} + D_{(g)}$ 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

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

$X + Y \leftrightarrow 2Z + heat$

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

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

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

11) Consider the following equation:

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

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

12) Referencing the equation in question 11, why does increasing the pressure increase the rate of the forward reaction?

Kinetics & Equilibrium Review

Fill in the blanks using the word bank. 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 _____.

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 $H_{reactants}$

Enthalpy and Table I

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

_____

3. Sodium hydroxide dissociating into a positive sodium ion and a negative hydroxide ion

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

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

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. $2CO_2(g) \rightarrow O_2(g) + 2CO(g)$			