Name _____ Date _____ Class _____

CHAPTER 17 REVIEW ACTIVITY

Text Reference: Section 17-13

Reaction Rate

Choose words from the list to fill in the blanks in the paragraphs.

Word List

activated complex
activation energy
catalyst
heat of reaction
heterogeneous reaction
homogeneous reaction
kinetics
potential energy
rate-determining step
reaction mechanism

The branch of chemistry concerned with the rates of chemical changes is called __(1)__. A chemical change in which all the reactants are in the same phase is called a(n) __(2)__. One in which reactants are in different phases in called a(n) __(3)__. A substance that speeds up a chemical change without being permanently altered is called a(n) __(4)__.

The series of steps by which reacting particles rearrange themselves to form products is called the __(5)__. The slowest step in such a series is the __(6)__. A short-lived, high-energy particle that is formed when reacting particles collide at the proper angle with the proper amount of energy is a(n) __(7)__. The minimum amount of energy needed to form this particle is called the __(8)__. Because this energy is stored in the particle, it is an example of __(9)__. The products and the reactants of any reaction have different amounts of this kind of stored energy. The difference between these two amounts of energy is the __(10)__.

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____
8. _____
9. _____
10. _____

Name _____ Class _____ Date _____

Reaction Mechanisms

A reaction mechanism is the series of steps by which substances react. The slowest step in the series is the rate-determining step. Changes in concentration of a substance can change the rate of a reaction if the substance is involved in the rate-determining step.

Answer the following questions, given the following reaction mechanism:

Step 1 (rate-determining step): $W + X \rightarrow I_1$
Step 2: $I_1 + X \rightarrow I_2$
Step 3: $I_2 + Y \rightarrow 2Z$

where I_1 and I_2 stand for reaction intermediates.

1. Write the net equation.

1. _____

2. What will be the effect on the reaction rate if the concentration of W is increased? Explain your answer in terms of the collision theory of reactions.

2. _____

3. What will be the effect on the reaction rate if the concentration of X is decreased? Why?

3. _____

Name _____ Class _____ Date _____

Reaction Mechanisms (*Continued*)

4. What will be the effect on the reaction rate if the concentration of Y is increased? Why?

4. _____

5. What will be the effect on the reaction rate if the temperature is increased? Why?

5. _____

6. a. What will be the effect on the reaction rate if a catalyst is added?

6a. _____

b. What will be the effect on the catalyst itself?

b. _____

c. What effect will the catalyst have on the reaction mechanism?

c. _____

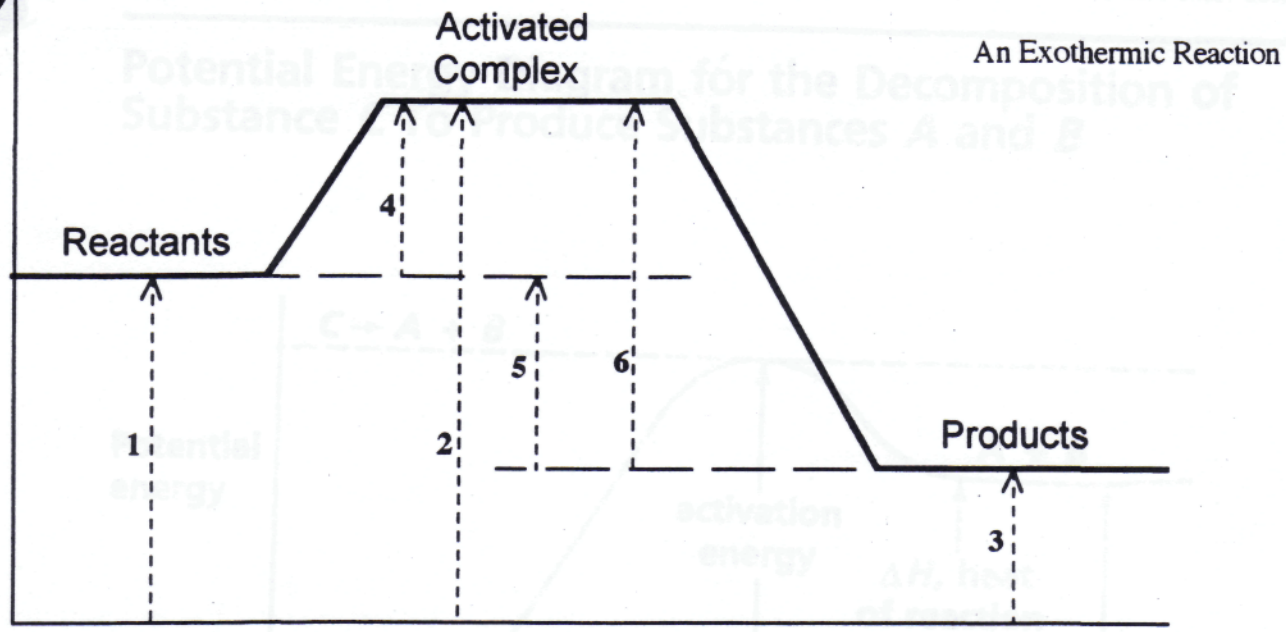
d. What effect will the catalyst have on the activation energy?

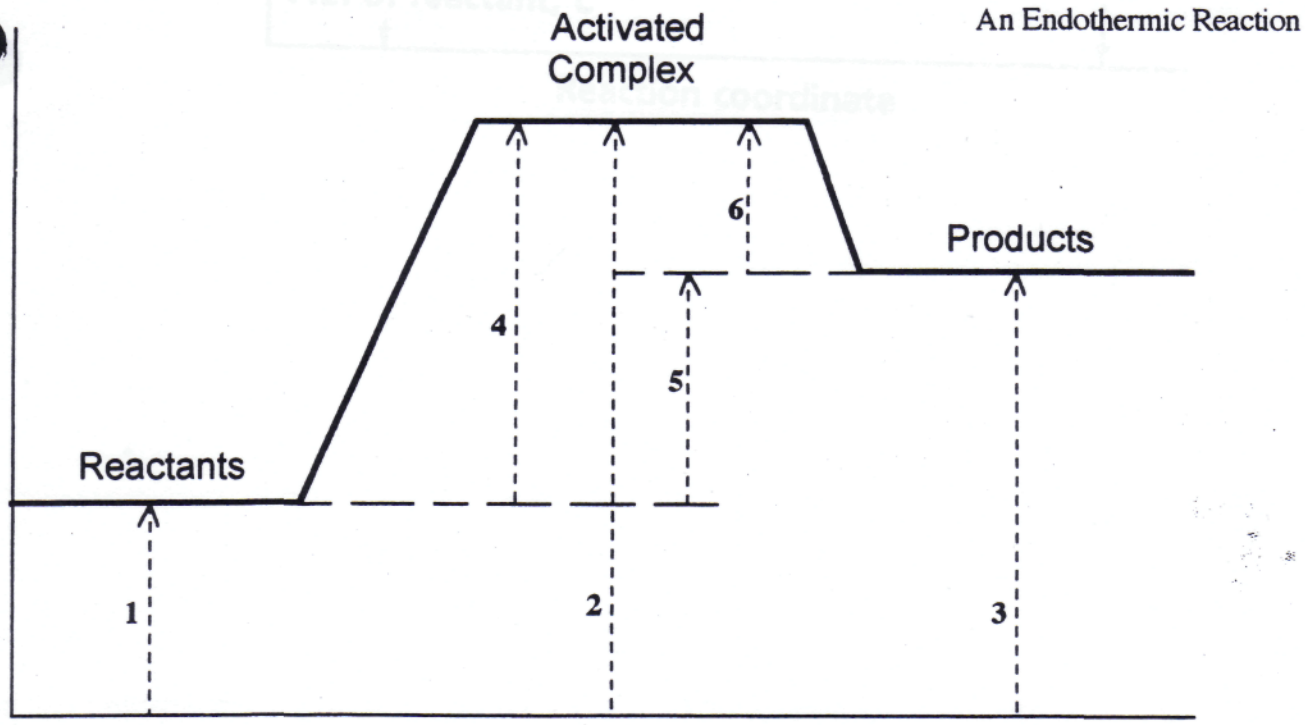
d. _____

e. What effect will the catalyst have on the net energy change of the reaction?

e. _____

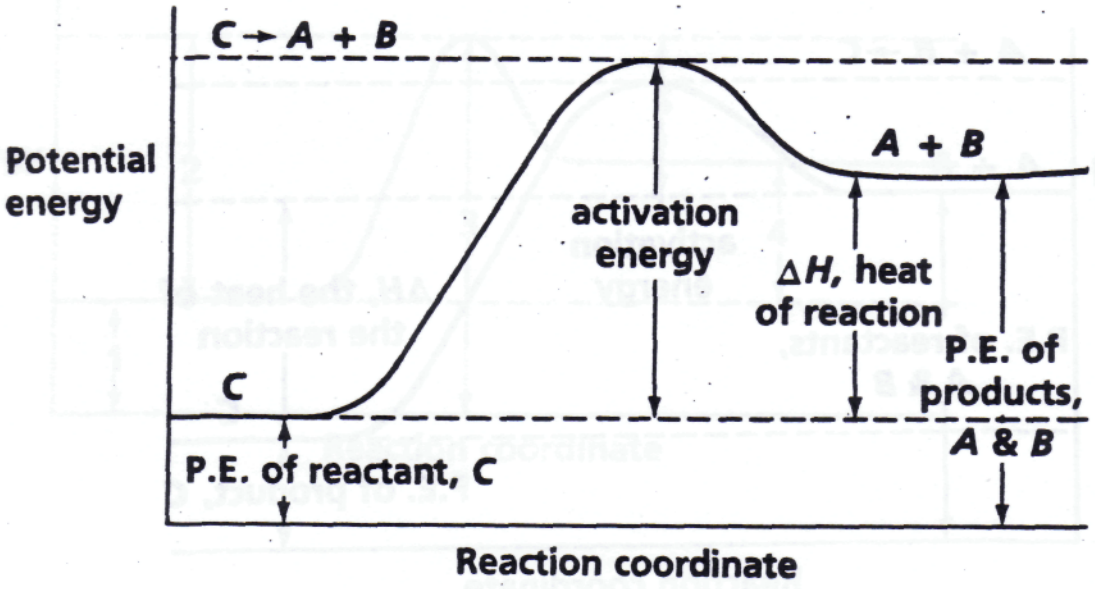
ENTHALPY CHANGES





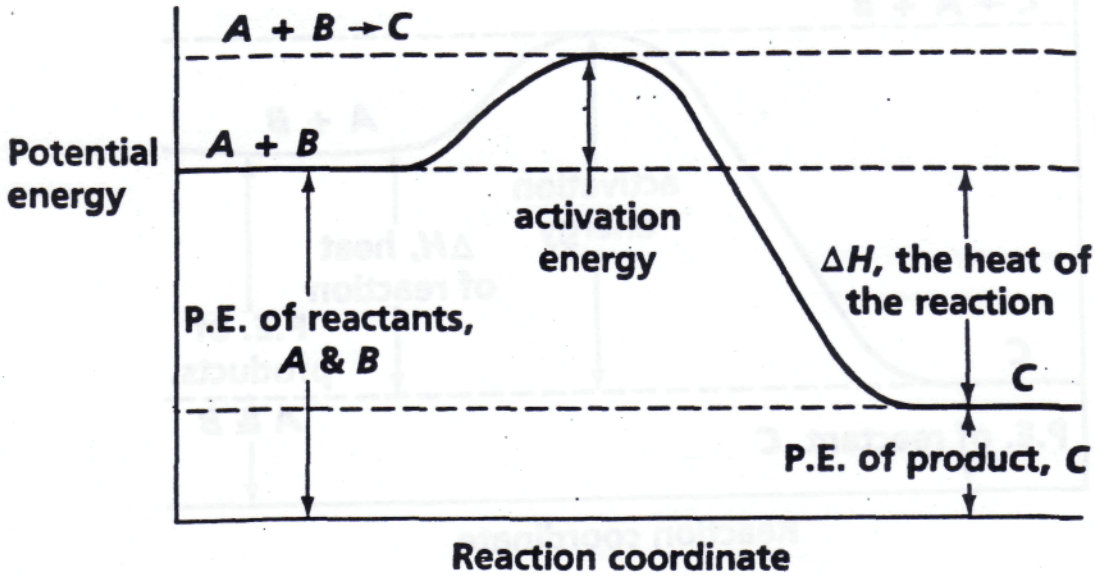
1- Potential Energy of the Reactants
2-Potential energy of the Activated Complex
3- Potential Energy of the Products
4-Activation Energy
5- (Net) Heat of the Reaction
6- Activation Energy of the reverse reaction

Potential Energy Diagram for the Decomposition of Substance *C* To Produce Substances *A* and *B*

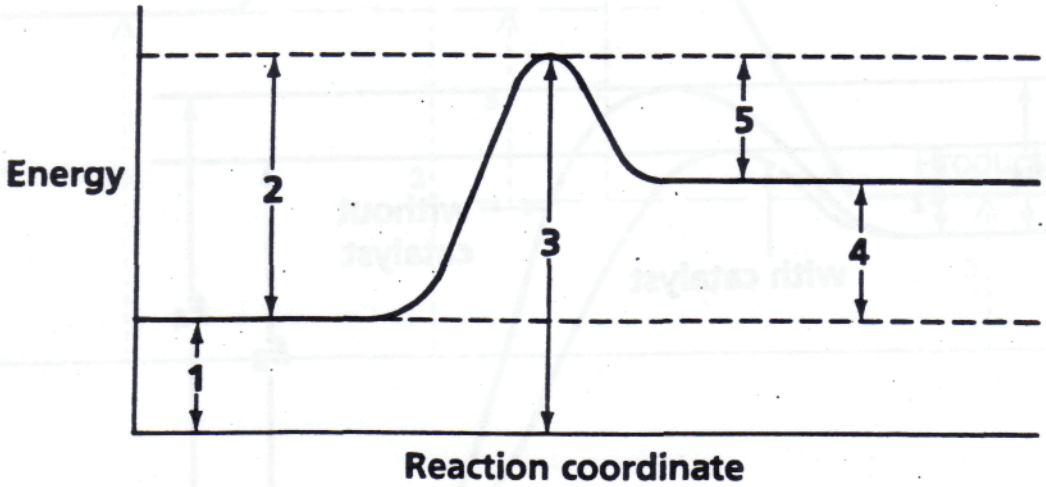


II

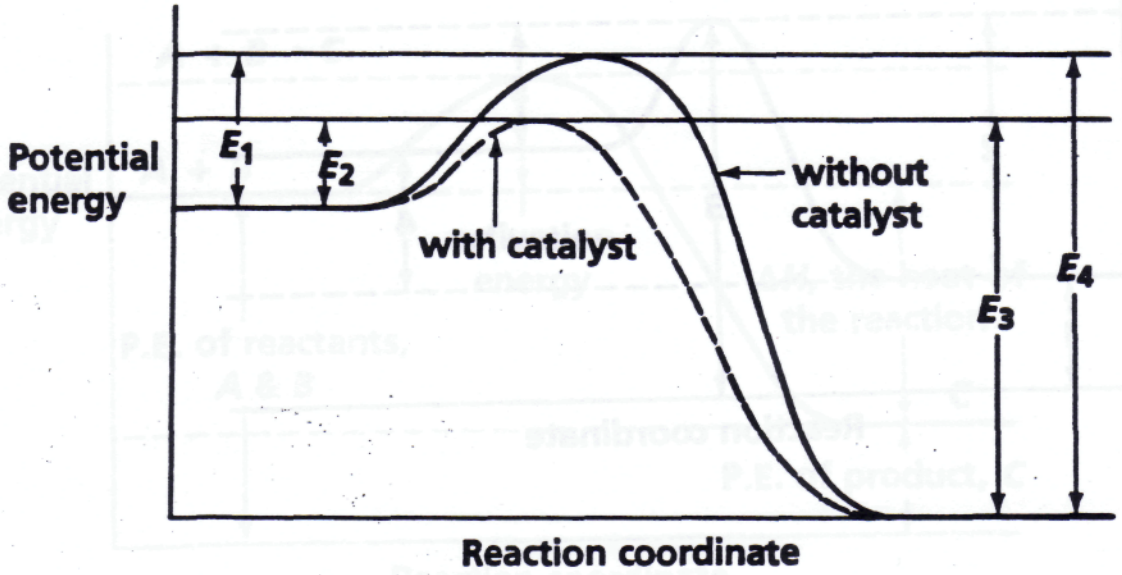
Potential Energy Diagram for the Reaction between Substances *A* and *B* To Produce Substance *C*



Identifying Energies on a Potential Energy Diagram

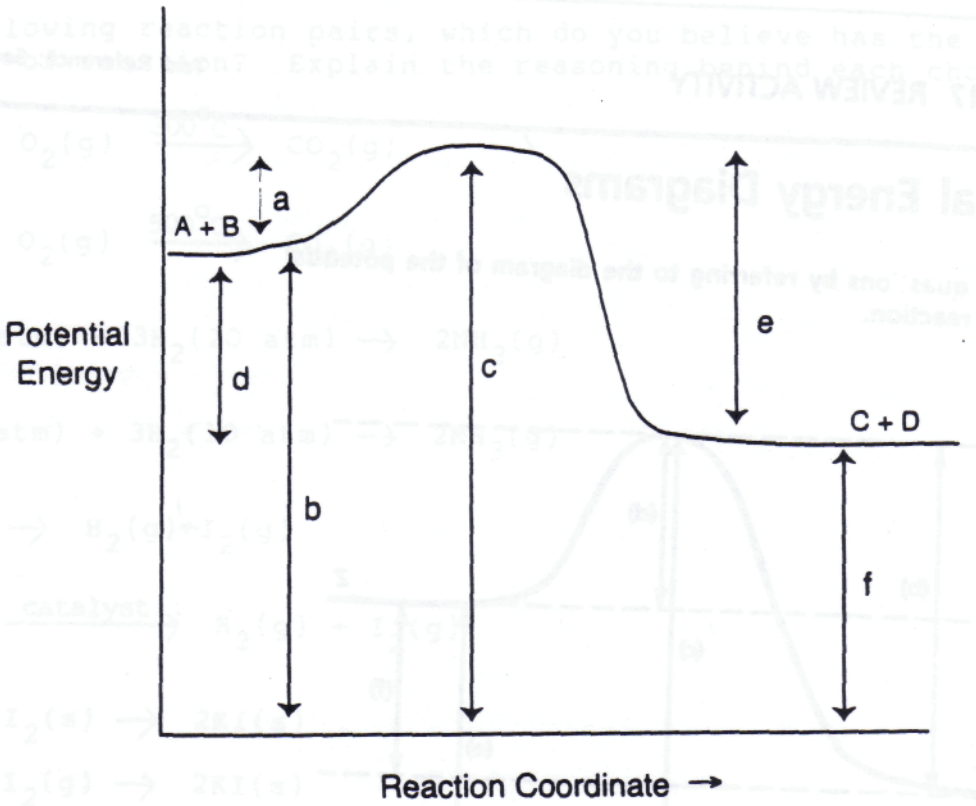


Potential Energy Diagram Showing the Effect of a Catalyst



POTENTIAL ENERGY DIAGRAM

Name _____



A + B ↔ C + D + energy

Answer the questions using the graph above.

1. Is the above reaction endothermic or exothermic? _____
2. What letter represents the potential energy of the reactants? _____
3. What letter represents the potential energy of the products? _____
4. What letter represents the heat of reaction (ΔH)? _____
5. What letter represents the activation energy of the forward reaction? _____
6. What letter represents the activation energy of the reverse reaction? _____
7. What letter represents the potential energy of the activated complex? _____
8. Is the reverse reaction endothermic or exothermic? _____
9. If a catalyst were added, what letter(s) would change? _____

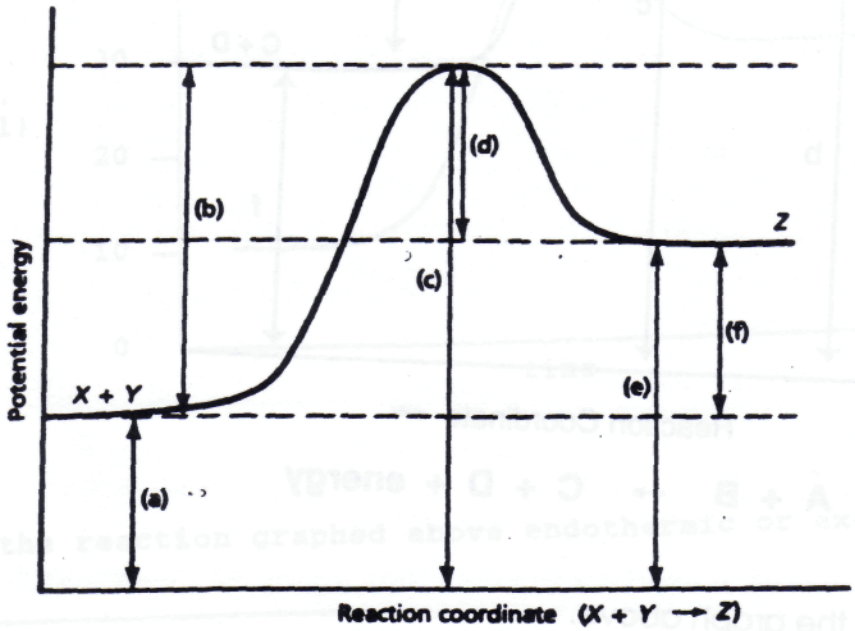
Name _____ Date _____ Class _____

CHAPTER 17 REVIEW ACTIVITY

Text Reference: Section 17-13

Potential Energy Diagrams

Answer the questions by referring to the diagram of the potential energy of a reaction.



1. Which of the letters (a)–(f) in the diagram represents the potential energy of the products? 1. _____
2. Which letter indicates the potential energy of the activated complex? 2. _____
3. Which letter indicates the potential energy of the reactants? 3. _____
4. Which letter indicates the activation energy? 4. _____
5. Which letter indicates the heat of reaction? 5. _____
6. Is the reaction exothermic or endothermic? 6. _____
7. Which letter indicates the activation energy of the reverse reaction? 7. _____
8. Which letter indicates the heat of reaction of the reverse reaction? 8. _____
9. Is the reverse reaction exothermic or endothermic? 9. _____
10. a. If a catalyst were added, which lettered quantities, if any, would change? 10. a. _____

    b. Would the activation energy increase, decrease, or remain unchanged? b. _____

    c. Would the heat of reaction increase, decrease, or remain unchanged? c. _____

Date _____

TIONS AND PROBLEMS

Of the following reaction pairs, which do you believe has the more rapid rate of reaction? Explain the reasoning behind each choice.

a) $C(s) + O_2(g) \xrightarrow{300^\circ C} CO_2(g)$

$C(s) + O_2(g) \xrightarrow{500^\circ C} CO_2(g)$

b) $N_2(20\ atm) + 3H_2(20\ atm) \rightarrow 2NH_3(g)$

$N_2(10\ atm) + 3H_2(10\ atm) \rightarrow 2NH_3(g)$

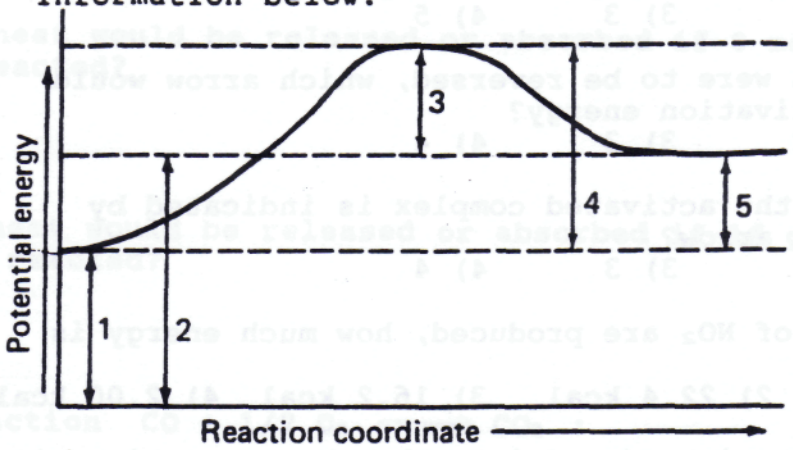
c) $2HI(g) \rightarrow H_2(g) + I_2(g)$

$2HI(g) \xrightarrow{catalyst} H_2(g) + I_2(g)$

d) $K(s) + I_2(s) \rightarrow 2KI(s)$

$K(s) + I_2(g) \rightarrow 2KI(s)$

Directions: Base your answers to questions 2 through 6 on the information below:



$\frac{1}{2} N_2(g) + O_2(g) = NO_2(g) \quad \Delta H = +8.10$ kcal/mole

2. The heat of reaction is represented by number (1) 5, (2) 2, (3) 3, (4) 4.

3. The potential energy of the reactants is indicated by number (1) 1, (2) 2, (3) 5, (4) 4.

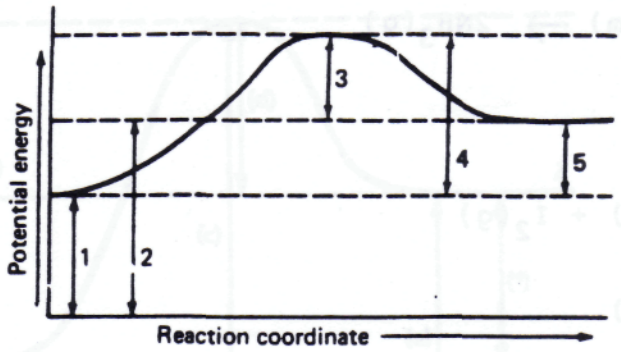
4. The position of the activated complex is indicated by the top of the arrow numbered (1) 1, (2) 2, (3) 3, (4) 5.

DRILL TI'E - POTENTIAL ENERGY DIAGRAMS

NAME_____

Base your answers to question 1-5 on the potential energy diagram below for the following reaction:

$1/2\ N_{2(g)} + O_{2(g)} \rightarrow NO_{2(g)}$ $\Delta H = +8.10$ kcal/mole



1. The potential energy of the reactants is indicated by arrow number
   1) 1 2) 2 3) 3 4) 5

2. The heat of reaction is represented by arrow number
   1) 1 2) 2 3) 3 4) 5

3. If this reaction were to be reversed, which arrow would indicate the activation energy?
   1) 1 2) 2 3) 3 4) 4

4. The position of the activated complex is indicated by the top of which arrow?
   1) 1 2) 2 3) 3 4) 4

5. When 2.00 moles of NO_2 are produced, how much energy is absorbed?
   1) 8.10 kcal 2) 22.4 kcal 3) 16.2 kcal 4) 2.00 kcal

6. If a catalyst were introduced into the above reaction, it would change arrows
   1) 1 and 2, only 2) 4 and 5, only
   2) 2 and 3, only 4) 3 and 4, only

7. Is the above reaction a homogeneous reaction?

Name _____ Date _____

Worksheet: Kinetics Period _____

1. a) Write a balanced chemical equation for the synthesis of ~~lead (II) oxide~~. aluminum oxide

_____

b) What is the enthalpy when one mole of ~~PbO~~ Al_2O_3 is produced?

_____

c) How much heat is absorbed or produced when two moles of ~~PbO~~ Al_2O_3 are produced?

d) Add the appropriate ~~kilocalories~~ kilojoules of heat to the reaction you wrote above.

e) Is this reaction endothermic or exothermic? _____

omit f) Is this reaction spontaneous? Explain your answer.

_____

_____

g) How much heat would be released or absorbed if 8 moles of ~~lead~~ aluminum reacted?

h) How much heat would be released or absorbed if 16 grams of oxygen reacted?

2. Given the reaction $CO + 1/2\ O_2 \longrightarrow CO_2$:

a) What is the enthalpy of this reaction? _____

b) Is this reaction endothermic or exothermic? _____

c) How much heat would be released or absorbed if one mole of O_2 reacted?

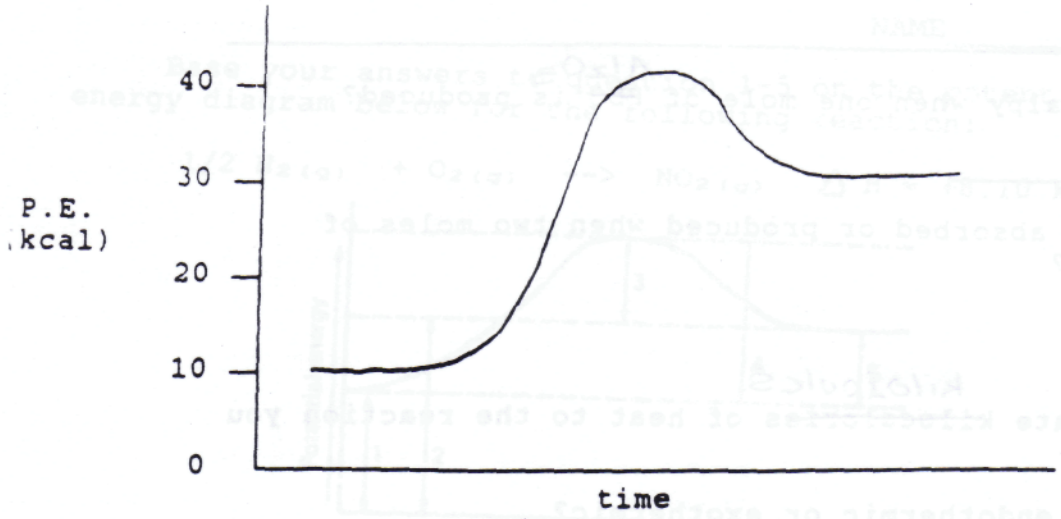
_____

How much heat would be released or absorbed if 66 grams of CO_2 were produced?

e) Rewrite the reaction and include the ~~kcals~~ kilojoules of heat involved.

_____

Refer to the following potential energy diagram.



Is the reaction graphed above endothermic or exothermic?

_____

b) What is the enthalpy of the reaction? _____

c) What is the activation energy of the forward reaction?

_____

d) What is the activation energy of the reverse reaction?

_____

e) What is the potential energy of the products? _____

f) What is the potential energy of the activated complex?

_____

4. How much energy is required to make ethene from carbon and hydrogen? _____

5. What is the heat of reaction for $H^+ + OH^- \longrightarrow H_2O$? _____

omit

Is the formation of MgO from its elements a spontaneous reaction? _____

omit

What is the free energy of a reaction where the enthalpy = -400 kcal and the entropy = -50 kcal at 80°C ?

Name _____ Class _____ Date _____

Heat Summation

Hess's law states that when a reaction can be stated as the algebraic sum of two or more other reactions, the heat of the reaction is the algebraic sum of the heats of these other reactions. If these other reactions are syntheses from elements or decompositions into elements, their heats of reaction can be found in tables of heats of formation.

Use Hess's law to calculate ΔH for each of the following reactions, given the standard heats of formation (ΔH_f°) of the substances involved. Show your work, including the summation of the proper equations and the heats of reaction involved. After each answer, state whether the reaction is exothermic or endothermic.

1. $2NO(g) + O_2(g) \rightarrow 2NO_2(g)$
ΔH_f° of $NO(g) = +21.6$ kcal/mole
ΔH_f° of $NO_2(g) = +8.1$ kcal/mole

1. _____

_____

2. $H_2O(l) \rightarrow H_2O(g)$
ΔH_f° of $H_2O(l) = -68.3$ kcal/mole
ΔH_f° of $H_2O(g) = -57.8$ kcal/mole

2. _____

_____

3. $CHCl_3(l) + 3HCl(g) \rightarrow CH_4(g) + 3Cl_2(g)$
ΔH_f° of $CHCl_3(l) = -31.5$ kcal/mole
ΔH_f° of $CH_4(g) = -17.9$ kcal/mole
ΔH_f° of $HCl(g) = -22.1$ kcal/mole

3. _____

_____

ENTROPY

Name _____

Entropy is the degree of randomness in a substance. The symbol for change in entropy is ΔS.

Solids are very ordered and have low entropy. Liquids and aqueous ions have more entropy because they move about more freely, and gases have an even larger amount of entropy. According to the Second Law of Thermodynamics, nature is always proceeding to a state of higher entropy.

Determine whether the following reactions show an increase or decrease 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. $CO_2(s) \rightarrow CO_2(g)$ _____
7. $H^+(aq) + C_2H_3O_2^-(aq) \rightarrow HC_2H_3O_3(l)$ _____
8. $C(s) + O_2(g) \rightarrow CO_2(g)$ _____
9. $H_2(g) + Cl_2(g) \rightarrow 2HCl(g)$ _____
10. $Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$ _____
11. $2N_2O_5(g) \rightarrow 4NO_2(g) + O_2(g)$ _____
12. $2Al(s) + 3I_2(s) \rightarrow 2AlI_3(s)$ _____
13. $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$ _____

$2NO(g) \rightarrow N_2(g) + O_2(g)$ _____

15. $H_2O(g) \rightarrow H_2O(l)$ _____

The Effect of the Signs of ΔH and ΔS on Spontaneous Change

Situation	Signs of ΔH and ΔS	Comment
1	$\Delta H = -$ (favorable) $\Delta S = +$ (favorable)	Both factors are favorable for spontaneous change. The reaction can occur.
2	$\Delta H = +$ (unfavorable) $\Delta S = -$ (unfavorable)	Neither factor favors spontaneous change. The reaction cannot occur.
3	$\Delta H = -$ (favorable) $\Delta S = -$ (unfavorable)	The change in enthalpy is favorable, but the change in entropy is unfavorable. The reaction can occur only if the effect of the change in enthalpy is greater than the effect of the change in entropy.
4	$\Delta H = +$ (unfavorable) $\Delta S = +$ (favorable)	The change in enthalpy is unfavorable, but the change in entropy is favorable. The reaction can occur only if the effect of the change in entropy is greater than the effect of the change in enthalpy.

The Effect of Changes in Enthalpy and Changes in Entropy on the Change in Free Energy

Situation	Signs of ΔH and ΔS	Signs of terms ΔH and $-T\Delta S$	Comment
1	$\Delta H = -$ (favorable) $\Delta S = +$ (favorable)	$\Delta G = \underbrace{\Delta H}_{-} - \underbrace{T\Delta S}_{+}$ $-$	Both terms, ΔH and $-T\Delta S$, are negative. Therefore, ΔG is negative at all temperatures T. The reaction can occur at all temperatures.
2	$\Delta H = +$ (unfavorable) $\Delta S = -$ (unfavorable)	$\Delta G = \underbrace{\Delta H}_{+} - \underbrace{T\Delta S}_{-}$ $+$	Both terms are positive. Therefore, ΔG is positive at all temperatures T. The reaction cannot occur at any temperature.
3	$\Delta H = -$ (favorable) $\Delta S = -$ (unfavorable)	$\Delta G = \underbrace{\Delta H}_{-} - \underbrace{T\Delta S}_{-}$ $+$	ΔG will be positive when T is a high temperature. ΔG will be negative when T is a low temperature. Reaction can occur only at sufficiently low temperature.
4	$\Delta H = +$ (unfavorable) $\Delta S = +$ (favorable)	$\Delta G = \underbrace{\Delta H}_{+} - \underbrace{T\Delta S}_{+}$ $-$	ΔG will be negative when T is a high temperature. ΔG will be positive when T is a low temperature. Reaction can occur only at sufficiently high temperature.

Name _____ Date _____ Class _____

CHAPTER 17 REVIEW ACTIVITY

Text Reference: Section 17-23

Enthalpy and Entropy

Choose words from the list to fill in the blanks in the paragraphs.

Word List

endothermic reaction
enthalpy
entropy
exothermic reaction
free energy
free energy of formation
Gibbs equation
heat of formation
heat of reaction
Hess's law
kelvin temperature
standard heat of formation

The heat content of a substance is called its __(1)__. The change in this quantity that occurs during a chemical reaction is called the __(2)__, ΔH. If the chemical change is the production of a compound from its elements, this quantity is called the __(3)__. At 298K and 101.3 kPa, this quantity is called the __(4)__. The sign of the quantity ΔH is positive in the case of a(n) __(5)__. It is negative in the case of a(n) __(6)__.

When a reaction can be expressed as the algebraic sum of two or more other reactions, its heat of reaction is equal to the algebraic sum of the heats of these other reactions. This relationship is called __(7)__.

A measure of the randomness of a system is its __(8)__. If, in any reaction, the change in this quantity is multiplied by the __(9)__ and subtracted from ΔH for the reaction, the result is called the __(10)__ of the reaction. If the reaction is the production of a compound from its elements, the above result is called the __(11)__ of the compound. This relationship is expressed in the __(12)__.

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____
8. _____
9. _____
10. _____
11. _____
12. _____

GIBBS FREE ENERGY

Name _____

For a reaction to be spontaneous, the sign of ΔG (Gibbs Free Energy) must be negative. The mathematical formula for this value is:

$$\Delta G = \Delta H - T\Delta S$$

where ΔH = change in enthalpy or heat of reaction
T = temperature in Kelvin
ΔS = change in entropy or randomness

Complete the table for the sign of ΔG; +, – or undetermined. When conditions allow for an undetermined sign of ΔG, temperature will decide spontaneity.

ΔH	ΔS	ΔG
–	+	
+	–	
–	–	
+	+	

Answer the questions below.

1. The conditions in which ΔG is always negative is when ΔH is _____ and ΔS is _____.
2. The conditions in which ΔG is always positive is when ΔH is _____ and ΔS is _____.
3. When the situation is indeterminate, a low temperature favors the (entropy / enthalpy) factor, and a high temperature favors the (entropy / enthalpy) factor.

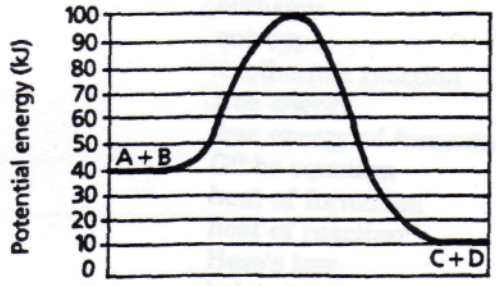
Answer Problems 4-6 with always, sometimes or never.

4. The reaction: $Na(OH)_s \rightarrow Na^+(aq) + OH^-(aq)$ + energy will _____ be spontaneous.
5. The reaction: energy + $2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$ will _____ be spontaneous.
6. The reaction: energy + $H_2O(s) \rightarrow H_2O(l)$ will _____ be spontaneous.
7. What is the value of ΔG if ΔH = -32.0 kJ, ΔS = +25.0 kJ/K and T = 293 K? _____
8. Is the reaction in Problem 7 spontaneous? _____
9. What is the value of ΔG if ΔH = +12.0 kJ, ΔS = -5.00 kJ/K and T = 290. K? _____
10. Is the reaction in Problem 9 spontaneous? _____

Practice Problems

1. The graph below is a potential-energy diagram for the hypothetical reaction

$$A + B \rightarrow C + D$$



a. Is the forward reaction endothermic or exothermic? Calculate the value of ΔH for this reaction.

b. Is the reverse reaction endothermic or exothermic? Calculate the value of ΔH for this reaction.

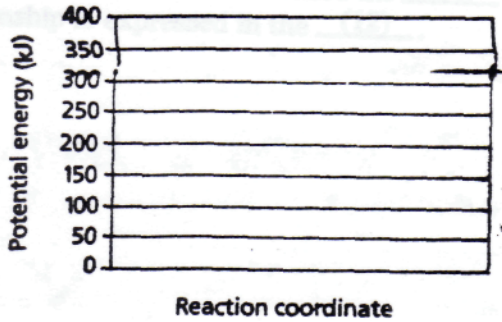
c. What is the value of the potential energy of the activated complex?

d. Calculate the activation energy for the forward reaction.

2. a. On the graph below, draw a potential-energy diagram for the following reaction

$$Q + R \rightarrow S + T$$

given the following assumptions: the potential energy of $Q + R$ is 150 kJ; the potential energy of $S + T$ is 250 kJ; the potential energy of the activated complex is 375 kJ.



b. Is the forward reaction endothermic or exothermic? Calculate the value of ΔH for this reaction.

c. Calculate the activation energy for the forward reaction.

Refer to Figures ~~17-22 and 17-36 in the textbook~~ table II when answering the questions below.

3. a. Calculate the amount of energy, in kilojoules, that is involved when 112.0 g of sodium chloride (NaCl) is produced from its elements. (Na = 23.0 g/mol; Cl = 35.5 g/mol)

b. Is the energy absorbed or released? How can you tell?

4. a. Calculate the heat of reaction (ΔH), in kilojoules, for the reaction

$$4CO_2(g) \rightarrow 2O_2(g) + 4CO(g)$$

b. Is the reaction endothermic or exothermic? How can you tell?

5. a. Calculate the heat of reaction (ΔH), in kilojoules, for the reaction

$$2NO_2(g) + 3H_2(g) \rightarrow 2NH_3(g) + 2O_2(g)$$

b. Is the reaction endothermic or exothermic? How can you tell?

6. a. Calculate the heat of reaction (ΔH) for the reaction

$$3S(s) + 3O_2(g) \rightarrow 3SO_2(g)$$

b. Is the reaction endothermic or exothermic? Does the heat of reaction favor the forward reaction? How can you tell?

c. Calculate the entropy change (ΔS) for this reaction at 298 K.

d. Does the entropy increase or decrease for the forward reaction? How can you tell? Does this change, taken by itself, favor the forward reaction?

e. Does the reaction proceed spontaneously forward? How can you tell?

7. a. Using the appropriate values for ΔG_f° given in the Fig. 17-36, calculate ΔG for the reaction

$$6CO_2(g) \rightarrow 6CO(g) + 3O_2(g)$$

b. Does the forward reaction proceed spontaneously? How can you tell?