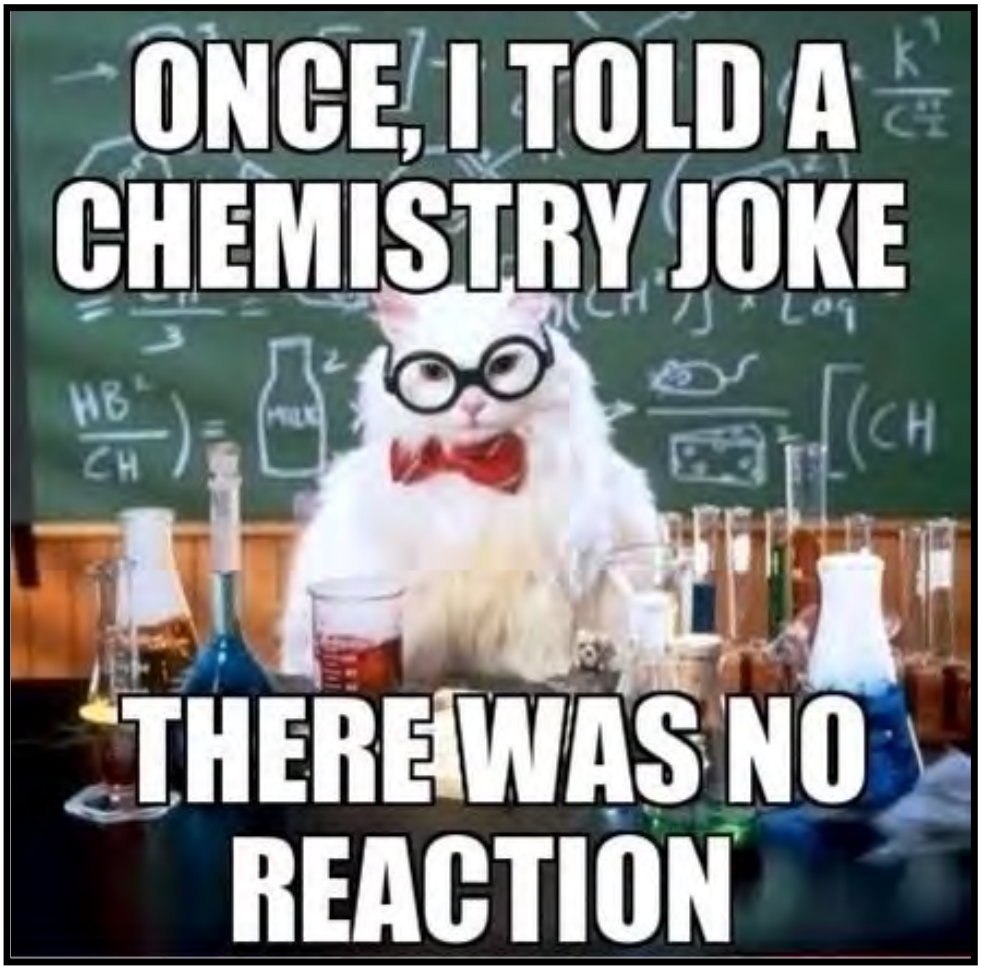
Name:

Regents Chemistry: Dr. Shanzer

Practice Packet

Chapter 12: Kinetics & Equilibrium



Regents Chemistry **Name _____**

VOCAB – Kinetics & Equilibrium **Period ____**

1. Reaction Rate – the speed at which reactants are converted into products in a chemical reaction.
2. Collision Theory – in order for a chemical reaction/effective collision to occur, particles must collide with proper energy AND proper alignment.
3. Reaction Mechanism – the specific set of steps/reactions involved in an overall chemical reaction

(#4-9 are defined in terms of their <u>GENERAL EFFECT</u> on the rate chemical of a reaction)

4. Nature of Reactants – reactions involving ionic substances tend to have faster rates than reactions involving covalent substances.
5. Concentration – an increase in concentration of reactants will increase the rate of a chemical reaction
6. Surface Area – an increase in the surface area of reactants will increase the rate of a chemical reaction
7. Pressure – an increase in pressure will increase the rate of a chemical reaction (only for reactions involving GASES!)
8. Catalyst – 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
9. Temperature – an increase in temperature will increase the rate of a chemical reaction
10. Equilibrium – when two opposing processes are occurring at equal rates
11. Physical Equilibrium – when two opposing physical processes are occurring at equal rates; ex: phase equilibrium, solution equilibrium (saturation)
12. Phase Equilibrium – when the processes of freezing and melting or evaporating and condensing are occurring at equal rates
13. Solution Equilibrium – when the processes of dissolving and precipitating are occurring at equal rates; when a solution has reached its saturation point
14. Chemical Equilibrium – in a chemical reaction, when the forward and reverse reactions are occurring at equal rates
15. 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)
16. Enthalpy – the heat energy absorbed or released during a chemical reaction
17. Entropy – a measure of the randomness or chaos associated with a chemical reaction
18. Potential Energy Diagrams – used to illustrated the energy lost or gained (the reaction pathway) for a given chemical reaction
19. Endothermic Reactions – chemical reactions that consume or require energy; chemical reactions in which energy is a reactant

20. Exothermic Reactions – chemical reactions that produce or release energy; chemical reactions in which energy is a product
21. 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
22. Activation Energy – The minimum energy required to convert reactants into products; the difference between the energies of the activated complex and the reactants

Factors that affect the rate of chemical reactions

Chemistry 200
Video Lesson 12.1

Objective:

How can different factors change the rate of a chemical reaction?

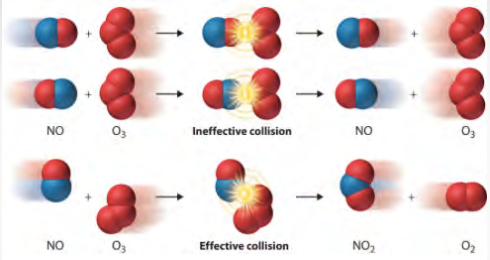
Kinetics

- the branch of chemistry dealing w/ rates of chem reaction

Collision Theory

- reactions occur when reactant particles collide. Anything that increases the number of collisions will increase the rate of the reaction.

Reactions only occur if the colliding particles positioning (orientation) is correct & they have enough kinetic energy to support the rxn. If either or both do not occur, no products are formed & no reaction has not occurred



Factors Affecting Rate of Rxn

1. Nature of Reactant

- covalent or molecular substances react slower than ionic substances because more bonds are present
- if more energy is needed to break bonds, less energy is available for reaction

2. Concentration

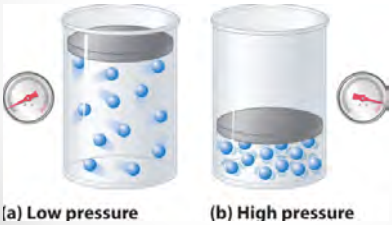
- rate of reaction will be faster if the concentration of one or more of the reactants is increased

3. Surface Area

- the greater the surface area exposed, the more possibility of collisions, therefore an increased rate of reaction

4. Pressure (little to no effect on solids or liquids, HUGE effect on gases)

- increasing pressure on a gas is like increasing concentration, resulting in an increased rate of reaction. The same mass of gas is squeezed into a smaller volume.



5. Presence of a Catalyst

- a catalyst is a substance that increases the rate of a reaction by creating an alternate pathway. This uses less energy & does not alter the product. Enzymes are a common example.

**** catalyst remains unchanged****

6. Temperature (measure of avg. Kinetic Energy)

- an increase results in increased K.E., therefore more mvmt & collisions of particles --> increase rate of reaction

Potential Energy Diagrams

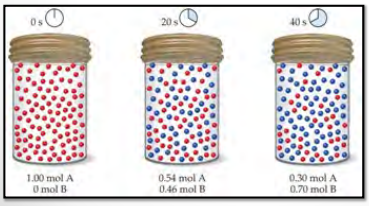
Chemistry 200
Video Lesson 12.2

Objectives

- Describe how to express the rate and heat of reaction using potential energy diagrams.

Rate of a Chemical Reaction

- The rate of a chemical change or the reaction rate is usually expressed as the amount of reactant changing per unit time.
- The more effective collisions between reacting particles the faster the rate of change from reactants to products.



Potential Energy Diagram

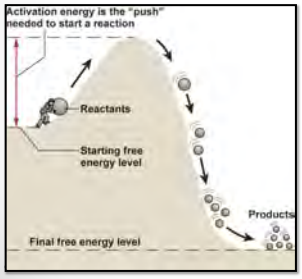
- Chemical Bonds have stored energy (AKA potential energy)
- Potential Energy Diagrams used to illustrate how energy changes during a chemical reaction

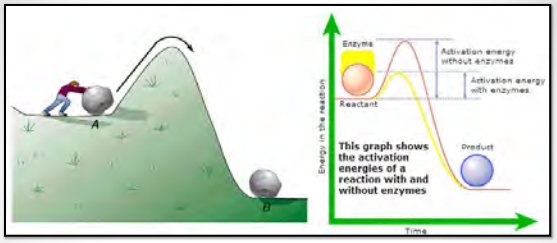
A + B → AB + energy

AB + energy → A + B

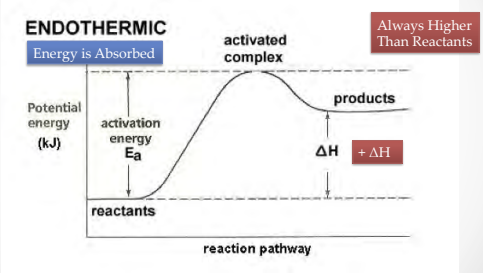
Activation Energy

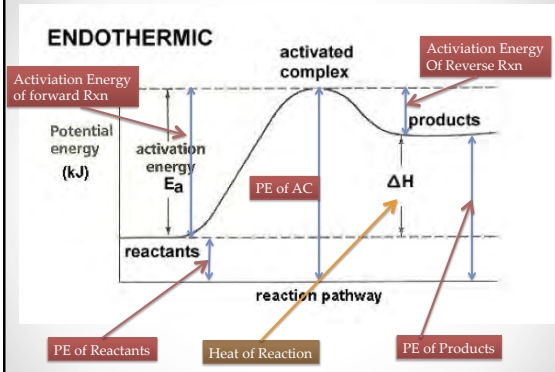
- The minimum energy that colliding particles must have in order to react is called the activation energy.



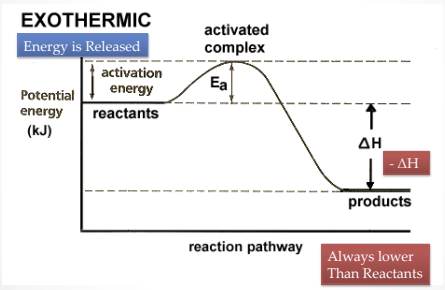


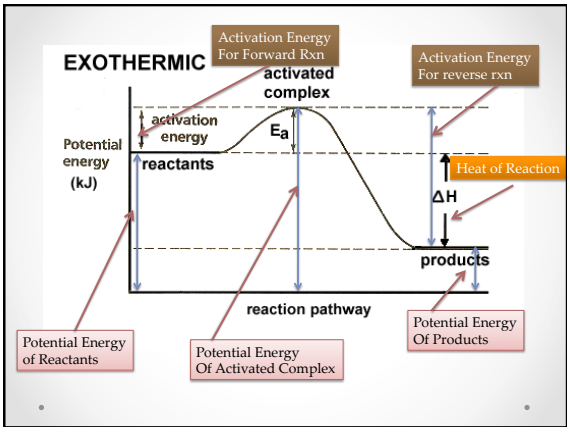
Potential Energy Diagram Endothermic

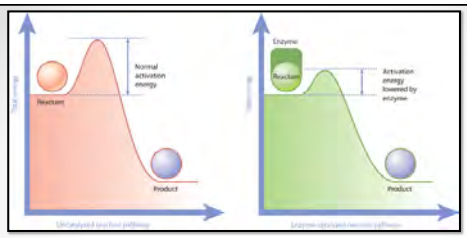


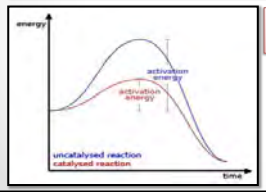


Potential Energy Diagram Exothermic









A Catalyst (enzyme): Lowers the amount of activation energy

Enthalpy & Entropy

Chemistry 200
Video Lesson 12.3

Objective:

How do we determine the heat of reaction, if particle disorder is increasing or decreasing and how these two factors influence the spontaneity of the reaction?

Enthalpy vs. Entropy

Enthalpy (Heat of reaction)

$\Delta H = H_P - H_R$ (*change in P.E. btwn reactants & products*) **kJ**

- in nature the tendency for rxns is to move towards a lower energy state or lower enthalpy **(-ΔH)**
- reactions tend to move in an exothermic direction **(-ΔH)** rather than endothermic **(+ΔH)** **
- This is due to activation energy being less for exothermic reactions vs. endothermic reactions**

Table I
Heats of Reaction at 101.3 kPa and 298 K

Reaction	ΔH (kJ)*
$CH_4(g) + 2O_2(g) \longrightarrow CO_2(g) + 2H_2O(\ell)$	-890.4
$C_3H_8(g) + 5O_2(g) \longrightarrow 3CO_2(g) + 4H_2O(\ell)$	-2219.2
$2C_8H_{18}(\ell) + 25O_2(g) \longrightarrow 16CO_2(g) + 18H_2O(\ell)$	-10943
$2CH_3OH(\ell) + 3O_2(g) \longrightarrow 2CO_2(g) + 4H_2O(\ell)$	-1452
$C_2H_5OH(\ell) + 3O_2(g) \longrightarrow 2CO_2(g) + 3H_2O(\ell)$	-1367
$C_6H_{12}O_6(s) + 6O_2(g) \longrightarrow 6CO_2(g) + 6H_2O(\ell)$	-2804
$2CO(g) + O_2(g) \longrightarrow 2CO_2(g)$	-566.0
$C(s) + O_2(g) \longrightarrow CO_2(g)$	-393.5
$4Al(s) + 3O_2(g) \longrightarrow 2Al_2O_3(s)$	-3351
$N_2(g) + O_2(g) \longrightarrow 2NO(g)$	+182.6
$N_2(g) + 2O_2(g) \longrightarrow 2NO_2(g)$	+66.4
$2H_2(g) + O_2(g) \longrightarrow 2H_2O(g)$	-483.6
$2H_2(g) + O_2(g) \longrightarrow 2H_2O(\ell)$	-571.6
$N_2(g) + 3H_2(g) \longrightarrow 2NH_3(g)$	-91.8
$2C(s) + 3H_2(g) \longrightarrow C_2H_6(g)$	-84.0
$2C(s) + 2H_2(g) \longrightarrow C_2H_4(g)$	+52.4
$2C(s) + H_2(g) \longrightarrow C_2H_2(g)$	+227.4
$H_2(g) + I_2(g) \longrightarrow 2HI(g)$	+53.0
$KNO_3(s) \xrightarrow{H_2O} K^+(aq) + NO_3^-(aq)$	+34.89
$NaOH(s) \xrightarrow{H_2O} Na^+(aq) + OH^-(aq)$	-44.51
$NH_4Cl(s) \xrightarrow{H_2O} NH_4^+(aq) + Cl^-(aq)$	+14.78
$NH_4NO_3(s) \xrightarrow{H_2O} NH_4^+(aq) + NO_3^-(aq)$	+25.69
$NaCl(s) \xrightarrow{H_2O} Na^+(aq) + Cl^-(aq)$	+3.88
$LiBr(s) \xrightarrow{H_2O} Li^+(aq) + Br^-(aq)$	-48.83
$H^+(aq) + OH^-(aq) \longrightarrow H_2O(\ell)$	-55.8

*The ΔH values are based on molar quantities represented in the equations. A minus sign indicates an exothermic reaction.

- -ΔH = exothermic *(look at the bottom)*
- Coefficients represent molar quantities.
- If molar quantities change, ΔH also changes proportionally.
- If the reaction in question is opposite the reaction on Table I, ΔH is reversed.

Entropy (ΔS)

- the more disorder a system gets, the more this system moves from a state of:
  low entropy (less disorder) ---> high entropy (great disorder)
  -ΔS +ΔS

ex: Phase Δ's

(s) <----------> (l) <------------> (g) <----> (aq)

less disorder low entropy	more disorder higher entropy	max. disorder highest entropy

Determining Change in Entropy (applied in this order)

Rule one (phase rule) – a reaction that involves making more disorganized phases of matter has an increase in entropy

$H_2O_{(s)} \rightarrow H_2O_{(l)}$	Entropy increases +ΔS
$CaCO_{3(s)} \rightarrow CaO_{(s)} + CO_{2(g)}$	Entropy increases +ΔS
$NaCl_{(s)} \rightarrow NaCl_{(aq)}$	Entropy increases +ΔS

Rule two (particle rule) – a rxn that involves creating more particles than you began w/ has an increase in entropy.

$2CO_{2(g)} \rightarrow 2CO_{(g)} + O_{2(g)}$	Entropy increases +ΔS
$3\ A_{(g)} + B_{(g)} \rightarrow 2\ C_{(g)} + D_{(g)}$	Entropy decreases -ΔS
$N_{2(g)} + O_{2(g)} \rightarrow 2NO_{(g)}$	Entropy remains the same ΔS = 0

Spontaneity **Has nothing to do w/ rate of reaction**

Will a reaction occur on its own?

Yes --> It's spontaneous

No --> It's not spontaneous, but can be forced to happen, just not by itself

Most Ideal Situation for a spontaneous rxn

low enthalpy & **high entropy**

-ΔH exothermic

+ΔS high disorder

ΔH Enthalpy	*ΔS Entropy*	***Spontaneous?***
↓ **(-ΔH)** Exothermic rxn	↑ **(+ΔS)**	Always
↑ **(+ΔH)** Endothermic rxn	↓ **(-ΔS)**	Never
↓ **(-ΔH)** Exothermic rxn	↓ **(-ΔS)**	Sometimes at low temps $H_2O_{(l)} \rightarrow H_2O_{(s)}$ + Energy
↑ **(+ΔH)** Endothermic rxn	↑ **(+ΔS)**	Sometimes at high temps $H_2O_{(l)}$ + Energy $\rightarrow H_2O_{(g)}$

Physical & Chemical Equilibrium

Chemistry 200
Video Lesson 12.4

Objective:

How do we determine the difference between physical & chemical equilibrium?

Equilibrium

Relationship btwn Forward & Reverse Rxns

Equilibrium

- when both the forward & reverse rxns occur at the same rate & time indicated w/ a ⟷ or ⇌

ex: A + B ⇌ C + D

- Concentrations of reactant & products of a system are at equilibrium when concentrations remain constant *(unchanged)*.
- Concentrations of reactant & product **do not** have to be equal to each other & usually are not.

Physical Equilibrium

- equilibrium occurring during a physical process like dissolving or a phase change

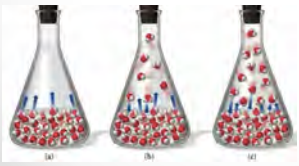
2 Types

A. **Phase Equilibrium** exists btwn the phases of the same substanc

$H_2O_{(s)} \rightleftharpoons H_2O_{(l)} \rightleftharpoons H_2O_{(g)}$

1. freezing/melting point of a solid
2. boiling/condensation point of a liquid

} phase Δ



B. **Solution Equilibrium** occurs in saturated solutions where the dissolved & undissolved solutes (solids or gases) are at equilibrium with each other.

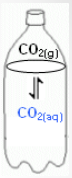
1. Solid in a liquid
   - solids dissolve in a liquid until the solid starts settling on the bottom. At this point, saturation has been reached & the system is at equilibrium.
     Rate of dissolving = Rate of recrystallization

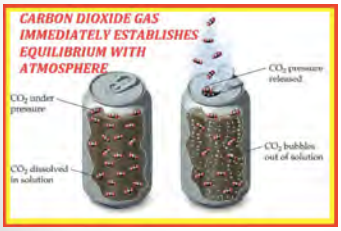
ex: $C_{12}H_{22}O_{11(s)} \rightleftharpoons C_{12}H_{22}O_{11(aq)}$

2. Gas in a liquid ***(closed system)***

- equilibrium reached when a gas is dissolved in a liquid & undissolved gas remains

ex: Closed can/bottle of soda $CO_{2(g)} \rightleftharpoons CO_{2(aq)}$



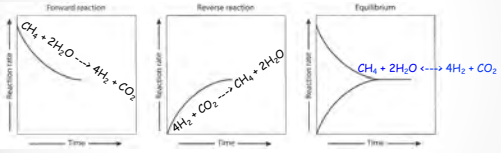


Chemical Equilibrium

- when the forward & reverse chemical reactions occur simulataneously at the same rates.

Observable changes (color, temp., pressure) no longer occur

ex: $CH_{4(g)} + 2H_2O_{(g)} \longleftrightarrow 4H_{2(g)} + CO_{2(g)}$



Le Chatelier's Principle

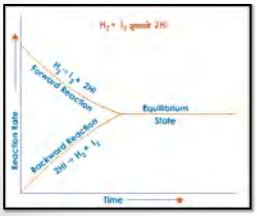
Chemistry 200
Video Lesson 12.5

Objectives

- Describe how the amounts of reactants and products change in a chemical system at equilibrium.
- Identify three stresses that can change the equilibrium position of a chemical system.

Chemical Equilibrium

- Rate of forward reaction equal rate of reverse reaction.
  - Rate at which products are made is equal to the rate in which reactants are made.



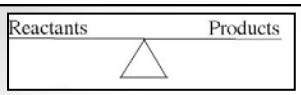
Le Chatielers Principle

- Explains how a system in equilibrium will respond to STRESS
  - STRESS is any change in:
    - Concentration
    - Pressure
    - Temperature

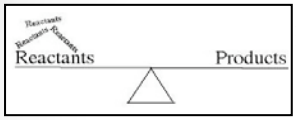
- When a stress is applied, the system or reaction will shift in order to relieve that stress and reach a new equilibrium
- SHIFT: an increase in the RATE of EITHER the forward or reverse reaction.
- Shift to right (towards the products)

  Reactants → Products
- Shift to left (towards the reverse reaction)

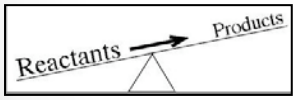
  Reactants ← Products



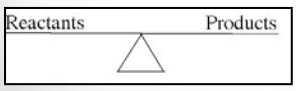
Equilibrium
Rate Forward = Rate Reverse



Add more reactant
Increase concentration of reactants



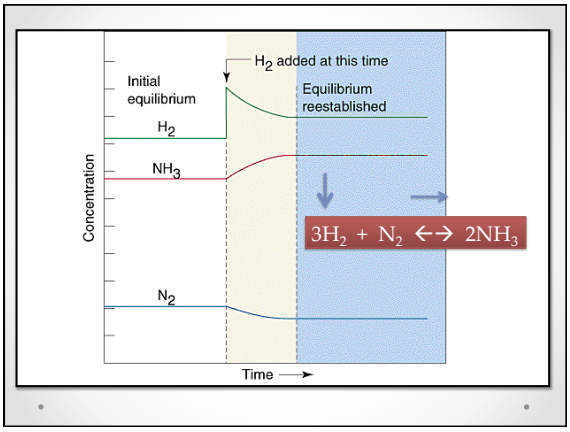
Produce more products
Rate of forward reaction increases
Shift left



Return to equilibrium
Rate of forward =rate of reverse

Concentration

- Concentration
  - When the concentration of a reactant or product is increased: the reactions shifts away from the increase
  - When the concentration of a reactant or product is decreased the reaction will shift toward the side that has experienced the decrease
    - Replaces what was taken!



Temperature

- Temperature
  - Involves increasing or decreasing "Heat"

NOTE: HEAT/ENERGY/J/KJ will either be a reactant or a product

A + B ⇆ C + D + HEAT

A + B + energy ⇆ C + D

- When temp is increased reaction shifts away from the side containing heat
- When temp is decreased the reaction shifts towards the side containing heat

Shift Right Or reverse

Add heat

$4NH_3(g) + 5O_2(g) \leftrightarrows 4NO(g) + 6H_2O(g) + HEAT$

If we added heat, which concentrations will decrease?

NO and H_2O

If we added heat, which concentrations will increase?

NH_3 and O_2

Pressure

- Pressure: Affects GASES ONLY!
  - Increase in Pressure
    - Reaction shifts to the side with the LEAST # of gas molecules (moles)
  - Decrease in Pressure
    - Reaction shifts to the side with the GREATEST # of gas molecules (moles)

★Note: if rxn contains no gas molecule or the rxn has same # of mols on reactant and product sides NO SHIFT★

$CO_{2\ (g)} \leftrightarrows CO_{2\ (aq)}$

If we increase the pressure, the concentration of which species will increase?

$CO_{2\ (aq)}$

If we decrease the pressure, the concentration of which species will increase?

$CO_{2\ (g)}$

Sketch Notes

Video 12.1: Collision Theory

1. Indicate whether each of the following would increase or decrease the rate of reaction.
    1. adding heat
    2. adding a catalyst
    3. diluting a solution
    4. removing an enzyme
    5. lowering the temperature
    6. decreasing the surface area
    7. increasing the concentration of a solution
    8. breaking a reactant down into smaller pieces

2. Identify which situation would have a higher reaction rate. Then state the factor that affected the rate of reaction in each situation.

	Situation X	**Situation Y**	**Higher reaction rate (X or Y)**	**Factor affecting the rate of reaction**
A	1 g of sugar cubes	1 g of sugar granules		
B	H_2O at 50°C	H_2O at 0°C		
C	1M $NaCl_{(aq)}$	5M $NaCl_{(aq)}$		
D	Protein synthesis w/ enzymes	Protein synthesis w/o enzymes		
E	3M $CO_{2(aq)}$ @ 1atm	3M $CO_{2(aq)}$ @ 2atm		

3. _____ Which of the following are true about how temperature affects the rate of reaction?
    I. heating causes the particles of the reactants to move quickly
    II. lowering the temperature will raise the energy of the particles
    III. increasing the temperature results in more collisions between the particles

    1. I and II only
    2. I and III only
    3. II and III only
    4. I, II and III

4. _____ Increasing which of the following will increase the frequency of collisions?
    I. temperature
    II. surface area
    III. concentration

    1. I and II only
    2. I and III only
    3. II and III only
    4. I, II and III

5. _____ Which of the following will lower the rate of reaction?
    1. adding an enzyme to the reaction
    2. decreasing the temperature from 40°C to 10°C
    3. breaking a chunk of calcium up into smaller pieces
    4. increasing the amount of solute dissolved in a solution

12.1 Collision Theory & Reaction Rate

1. As the temperature of a chemical reaction in the gas phase is increased, the rate of the reaction increases because

   1) fewer particle collisions occur
   2) more effective particle collisions occur
   3) the required activation energy increases
   4) the concentration of the reactants increases

2. A chemical reaction between iron atoms and oxygen molecules can only occur if

   1) the particles are heated
   2) the atmospheric pressure decreases
   3) there is a catalyst present
   4) there are effective collisions between the particle

3. Why can an increase in temperature lead to more effective collisions between reactant particles and an increase in the rate of a chemical reaction?

   1) The activation energy of the reaction increases.
   2) The activation energy of the reaction decreases.
   3) The number of molecules with sufficient energy to react increases.
   4) The number of molecules with sufficient energy to react decreases.

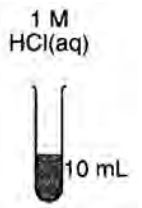
4. A reaction is most likely to occur when reactant particles collide with

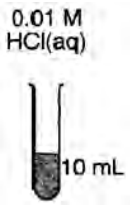
   1) proper energy, only
   2) proper orientation, only
   3) both proper energy and proper orientation
   4) neither proper energy nor proper orientation

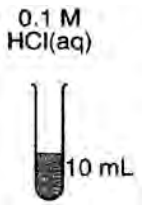
5. Increasing the temperature increases the rate of a reaction by

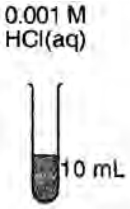
   1) lowering the activation energy
   2) increasing the activation energy
   3) lowering the frequency of effective collisions between reacting molecules
   4) increasing the frequency of effective collisions between reacting molecules

6. Each of four test tubes contains a different concentration of HCl(aq) at 25°C. A 1-gram cube of Zn is added to each test tube. In which test tube is the reaction occurring at the fastest rate?

   1) 

   3) 

   2) 

   4) 

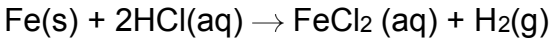
7. A 5.0-gram sample of zinc and a 50.-milliliter sample of hydrochloric acid are used in a chemical reaction. Which combination of these samples has the fastest reaction rate?

   1) a zinc strip and 1.0 M HCl(aq)
   2) a zinc strip and 3.0 M HCl(aq)
   3) zinc powder and 1.0 M HCl(aq)
   4) zinc powder and 3.0 M HCl(aq)

8. For a given chemical reaction, the addition of a catalyst provides a different reaction pathway that

   1) decreases the reaction rate and has a higher activation energy
   2) decreases the reaction rate and has a lower activation energy
   3) increases the reaction rate and has a higher activation energy
   4) increases the reaction rate and has a lower activation energy

9. Given the balanced equation representing a reaction:



$$Fe(s) + 2HCl(aq) \rightarrow FeCl_2(aq) + H_2(g)$$

This reaction occurs more quickly when powdered iron is used instead of a single piece of iron of the same mass because the powdered iron

1) acts as a better catalyst than the single piece of iron
2) absorbs less energy than the single piece of iron
3) has a greater surface area than the single piece of iron
4) is more metallic than the single piece of iron

10. The activation energy of a chemical reaction can be *decreased* by the addition of

1) a catalyst
2) an indicator
3) electrical energy
4) thermal energy

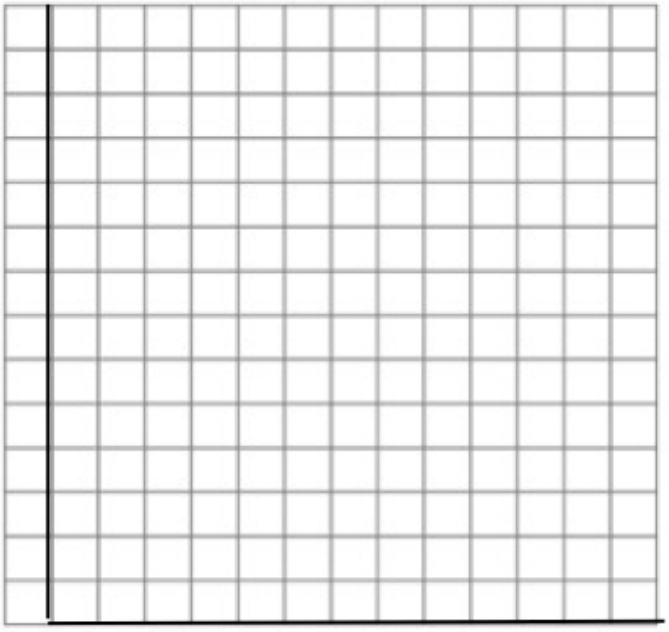
Video 12.2: Potential Energy Diagrams

Potential Energy Diagram #1

1. Construct a potential energy diagram for the reversible reaction below, given the following information:

$$A + B + \text{Energy} \leftrightarrows C + D$$

1. Potential Energy of Reactants = 20 kJ
2. Potential Energy of the Activated Complex = 90 kJ
3. Potential Energy of the Products = 60 kJ



2. Label the Reactants and Products on the diagram
3. Label the following using the numbers listed:
   1. Potential Energy of Reactants
   2. Potential Energy of the Products
   3. Potential Energy of the Activated Complex
   4. Heat of Reaction (H) for the forward reaction Value = _____
   5. Activation energy for the forward reaction Value = _____
   6. Activation Energy of the Reverse reaction Value = _____

4. Is this reaction an Endothermic or Exothermic Reaction? How do you know?

5. Use a dotted line to show the addition of a Catalyst affects the potential energy diagram above.

1. How does the addition of a catalyst affect the following energy values (decreases, increase or remains the same)?

1. Activation Energy of the reverse reaction:

2. Potential Energy of the products:

3. Potential Energy of the activated complex:

2. How do the following factors affect the rate of a chemical reaction (decreases, increase or remains the same)?

1. Temperature:

2. Concentration:

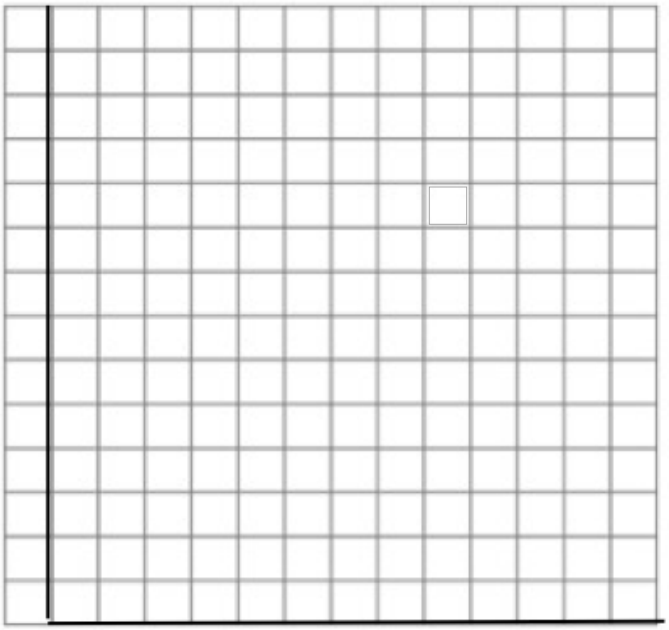
3. Surface Area:

Potential Energy Diagram #2

1. Construct a potential energy diagram for the reversible reaction below, given the following information:

$$A + B \leftrightarrows C + D + \text{energy}$$

1. Potential Energy of Reactants = 50 kJ
2. Potential Energy of the Activated Complex = 80 kJ
3. Potential Energy of the Products = 30 kJ



2. Label the Reactants and Products on the diagram
3. Label the following using the numbers listed:
   1. Potential Energy of Reactants
   2. Potential Energy of the Products
   3. Potential Energy of the Activated Complex
   4. Heat of Reaction (H) for the forward reaction Value = _____
   5. Activation energy for the forward reaction Value = _____
   6. Activation Energy of the Reverse reaction Value = _____

4. Is this reaction an Endothermic or Exothermic Reaction? How do you know?

5. Use a dotted line to show the addition of a Catalyst affects the potential energy diagram above.

1. How does the addition of a catalyst affect the following energy values (decreases, increase or remains the same)?

1. Activation Energy of the reverse reaction:

2. Potential Energy of the products:

3. Potential Energy of the activated complex:

2. How do the following factors affect the rate of a chemical reaction (decreases, increase or remains the same)?

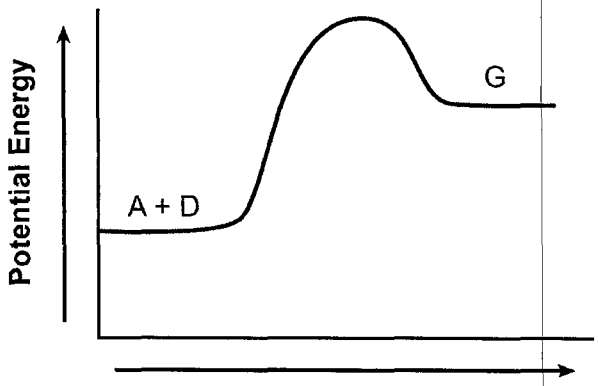
1. Temperature:

2. Concentration:

3. Surface Area:

Name: **Potential Energy Diagram Practice**

1. Given the potential energy diagram and equation representing the reaction between substances *A* and *D*:



$A + D \longrightarrow G$

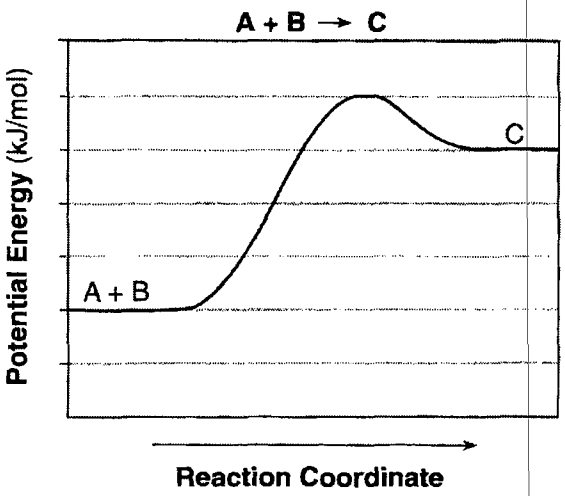
According to Table *I*, substance *G* could be

A) HI(g) B) $H_2O(g)$
C) $CO_2(g)$ D) $C_2H_6(g)$

2. In a chemical reaction, the difference between the potential energy of the products and the potential energy of the reactants is equal to the

A) activation energy
B) entropy of the system
C) heat of fusion
D) heat of reaction

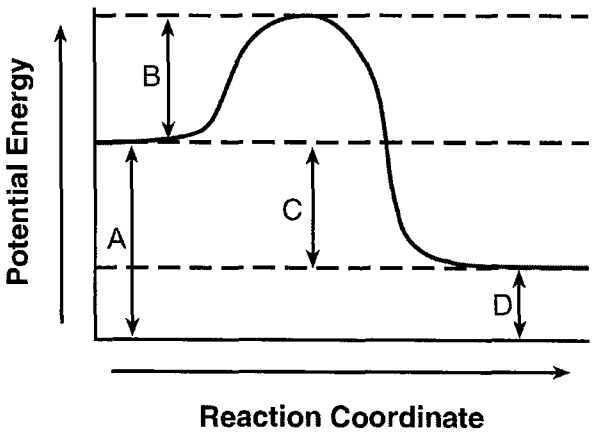
3. Given the equation and potential energy diagram representing a reaction:



If each interval on the axis labeled "Potential Energy (kJ/mol)" represents 10. kJ/mol, what is the heat of reaction?

A) +60. kJ/mol B) +20. kJ/mol
C) +30. kJ/mol D) +40. kJ/mol

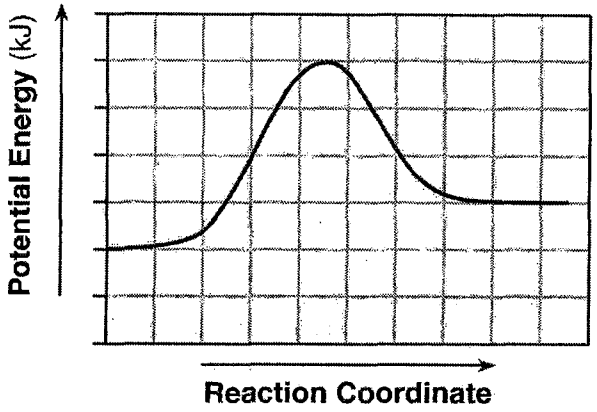
4. Given the potential energy diagram representing a reversible reaction:



The activation energy for the reverse reaction is represented by

A) $A + B$ B) $B + C$ C) $B + D$ D) $C + D$

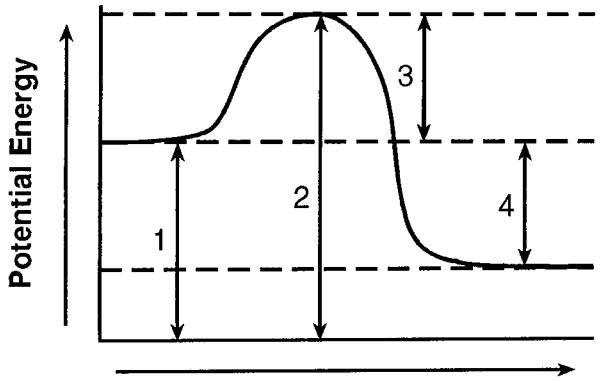
5. The potential energy diagram for a chemical reaction is shown below.



Each interval on the axis labeled "Potential Energy (kJ)" represents 40 kilojoules. What is the heat of reaction?

A) –120kJ B) –40kJ
C) +40kJ D) +160kJ

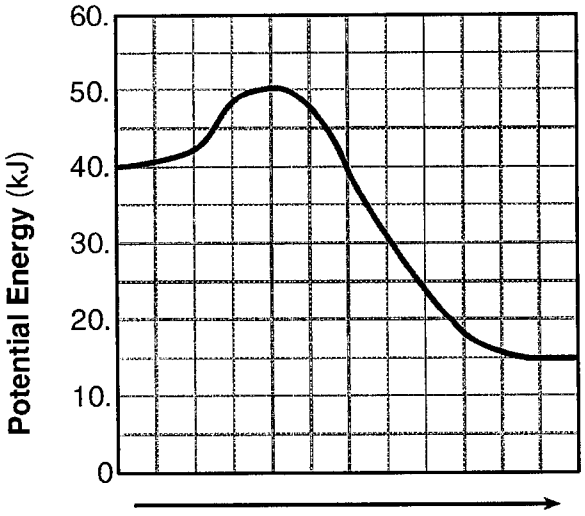
6. Given the potential energy diagram for a reaction:



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

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

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



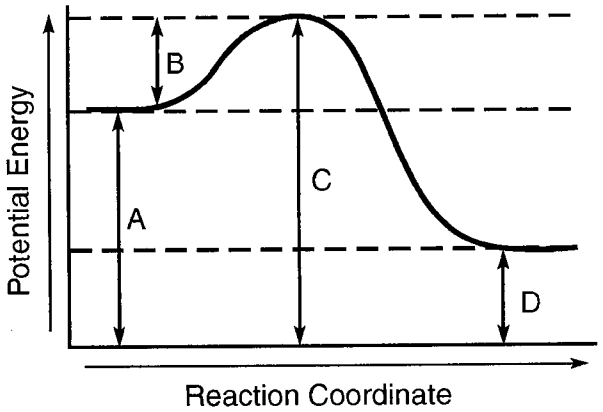
Which statement correctly describes the energy changes that occur in the forward reaction?

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

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

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

9. The potential energy diagram below represents a reaction.



Which arrow represents the activation energy of the forward reaction?

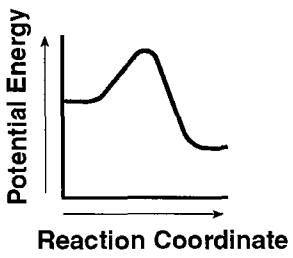
A) *A* B) *B* C) *C* D) *D*

10. Given the reaction:

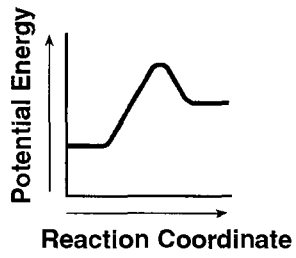
$S(s) + O_2(g) \rightarrow SO_2(g) + \text{energy}$

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

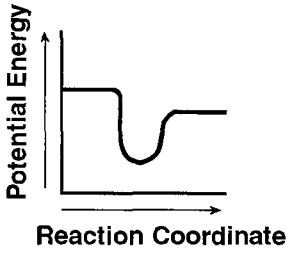
A)



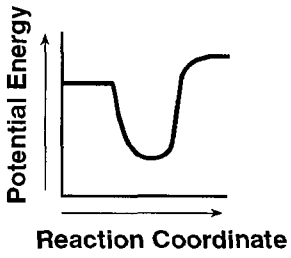
B)



C)

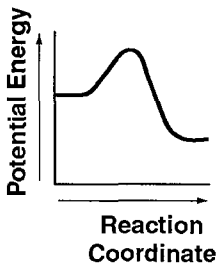


D)

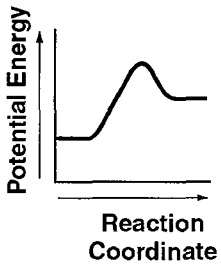


11. According to Table *I*, which potential energy diagram best represents the reaction that forms $H_2O(\ell)$ from its elements?

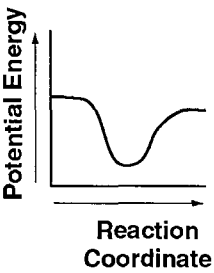
A)



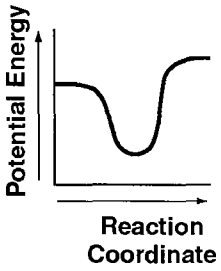
B)



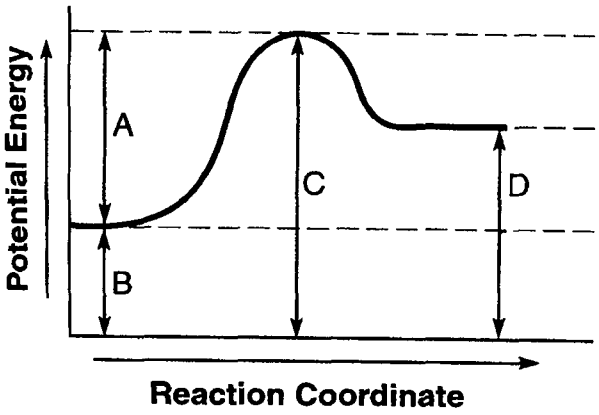
C)



D)



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



Which arrow represents the potential energy of the reactants?

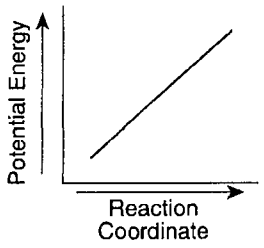
A) *A* B) *B* C) *C* D) *D*

13. The activation energy required for a chemical reaction can be *decreased* by

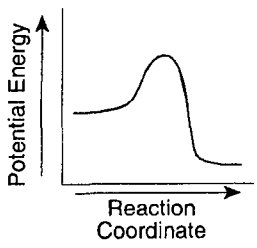
A) increasing the surface area of the reactant
B) increasing the temperature of the reactant
C) adding a catalyst to the reaction
D) adding more reactant

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

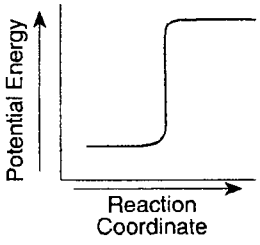
A)



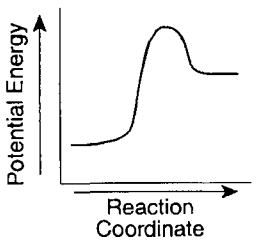
B)



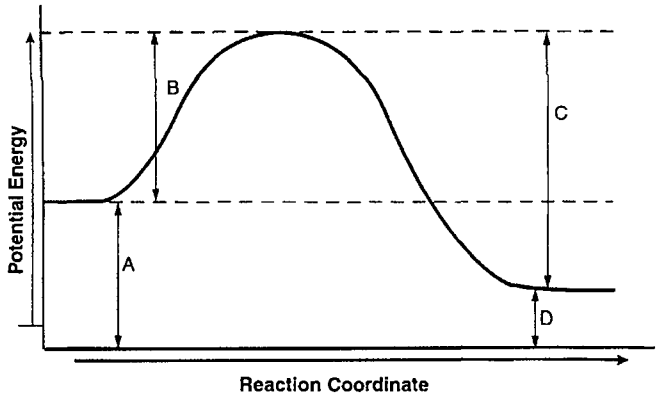
C)



D)



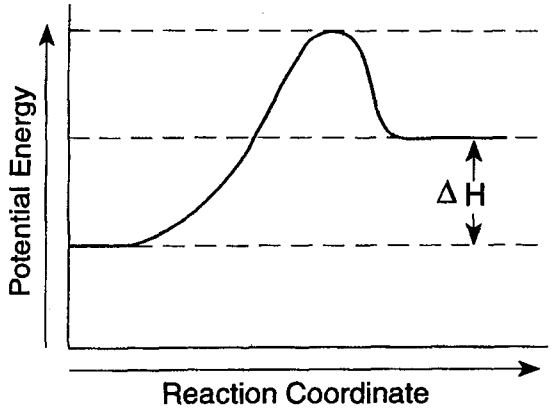
15. A potential energy diagram is shown below.



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*

16. The diagram below represents the energy changes that occur during the formation of a certain compound under standard conditions.

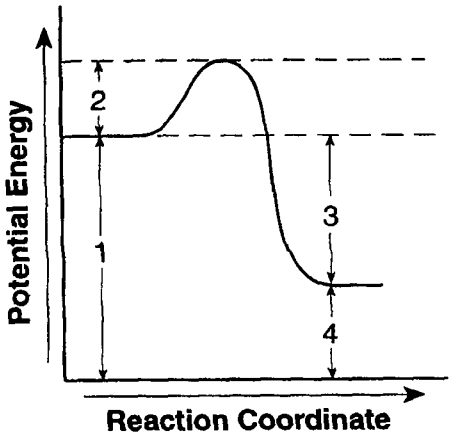


According to Reference Table I, the compound could be

A) $C_2H_6(g)$
B) $CO_2(g)$
C) $HI(g)$
D) $NH_3(g)$

Base your answers to questions **17** and **18** on the potential energy diagram below, which represents the reaction:

$A + B \rightarrow C +$ energy.



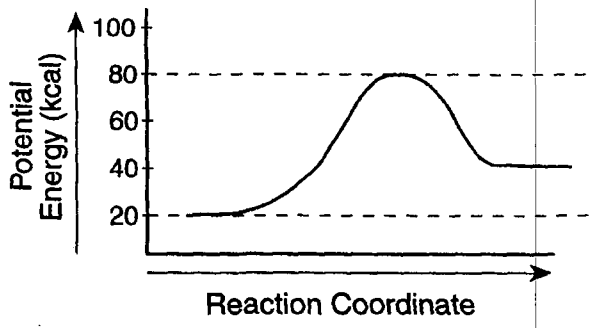
17. Which numbered interval will change with the addition of a catalyst to the system?

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

18. Which statement correctly describes this reaction?

A) It is endothermic and energy is absorbed.
B) It is endothermic and energy is released.
C) It is exothermic and energy is absorbed.
D) It is exothermic and energy is released.

19. A potential energy diagram of a chemical reaction is shown below.



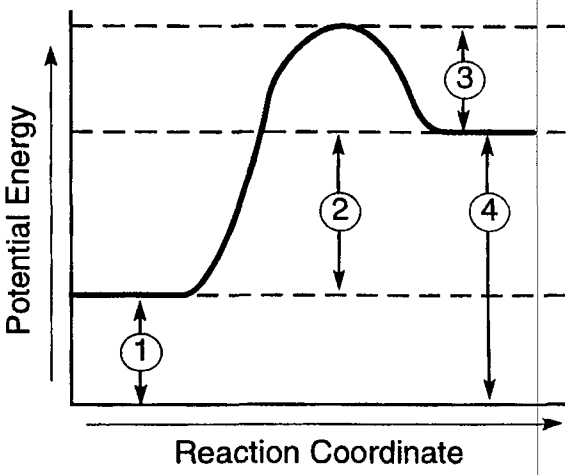
What is the difference between the potential energy of the reactants and the potential energy of the products?

A) 20. kcal B) 40. kcal
C) 60. kcal D) 80. kcal

20. Given the reaction:

$N_2(g) + 2\ O_2(g) \leftrightarrow 2\ NO_2(g)$
$\Delta H = +7.9$ kcal/mole

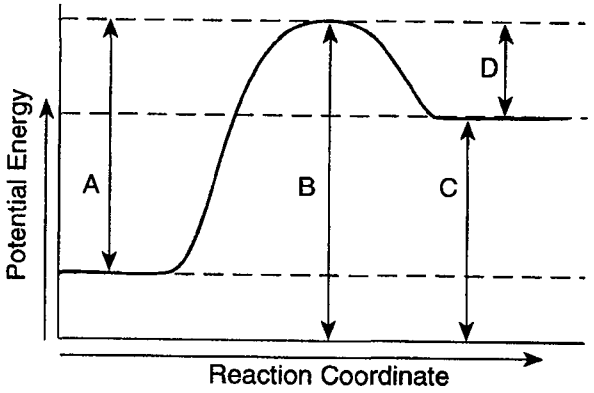
The potential energy diagram of the reaction is shown below.



Which arrow represents the heat of reaction (ΔH) for the reverse reaction?

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

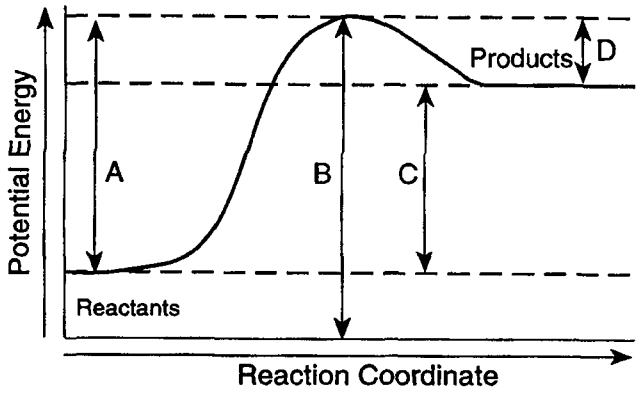
21. Base your answer to the following question on the potential energy diagram of a chemical reaction shown below.



The forward reaction is best described as an

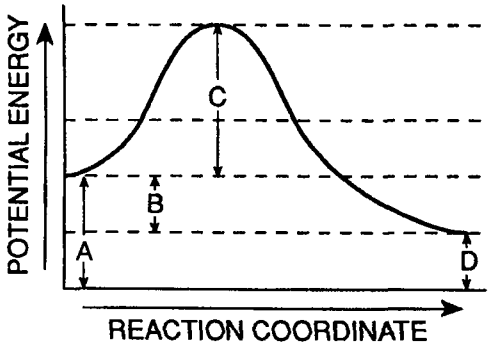
A) exothermic reaction in which energy is released
B) exothermic reaction in which energy is absorbed
C) endothermic reaction in which energy is released
D) endothermic reaction in which energy is absorbed

22. In the diagram below, which letter represents the activation energy for the reverse reaction?



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

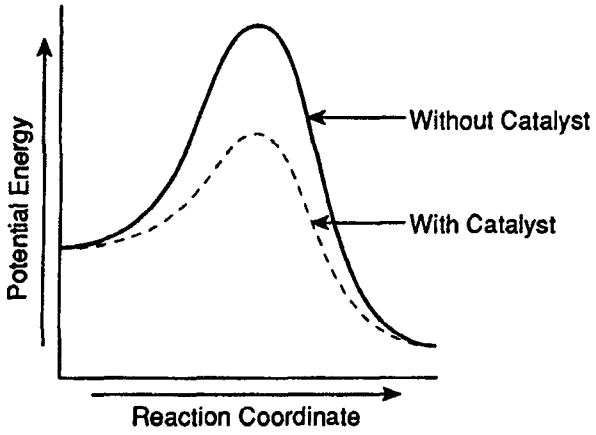
23. The potential energy diagram of a chemical reaction is shown below.



Which letter in the diagram represents the heat of reaction (ΔH)?

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

24. A potential energy diagram is shown below.

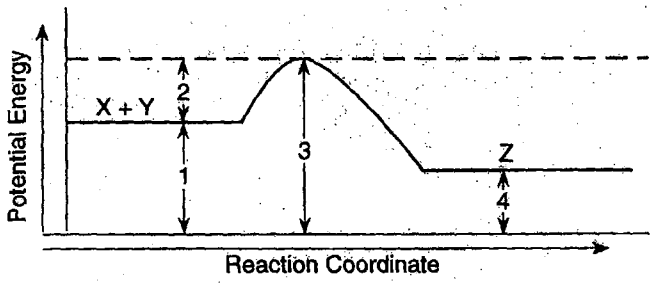


Which reaction would have the lowest activation energy?

A) the forward catalyzed reaction
B) the forward uncatalyzed reaction
C) the reverse catalyzed reaction
D) the reverse uncatalyzed reaction

25. The potential energy diagram below shows the reaction

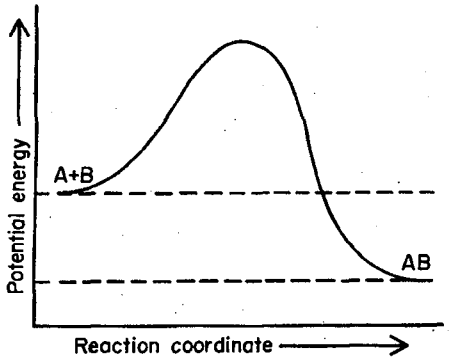
$X + Y \rightarrow Z$.



When a catalyst is added to the reaction, it will change the value of

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

26. Given the potential energy diagram:

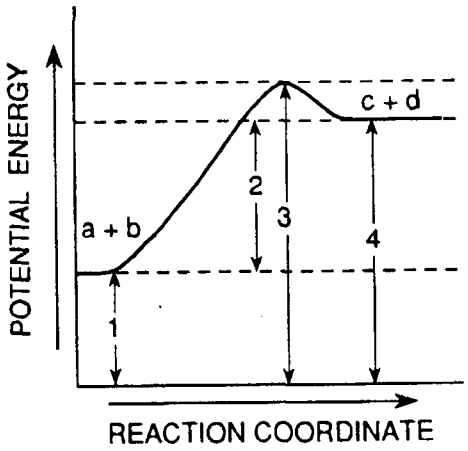


With reference to energy, the reaction $A + B \rightarrow AB$ can best be described as

A) endothermic, having a $+\Delta H$
B) endothermic, having a $-\Delta H$
C) exothermic, having a $+\Delta H$
D) exothermic, having a $-\Delta H$

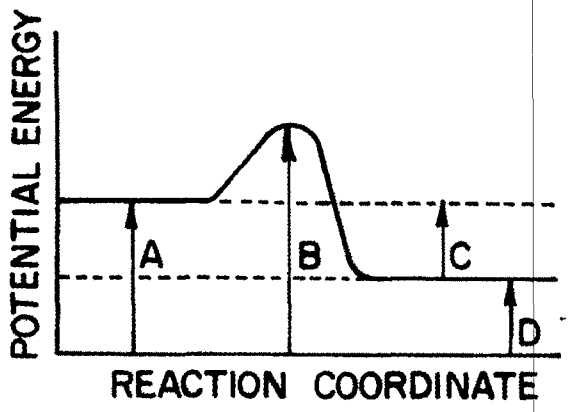
27. Which interval on the potential energy diagram shown below represents the ΔH of the reaction

$a + b \rightarrow c + d$?



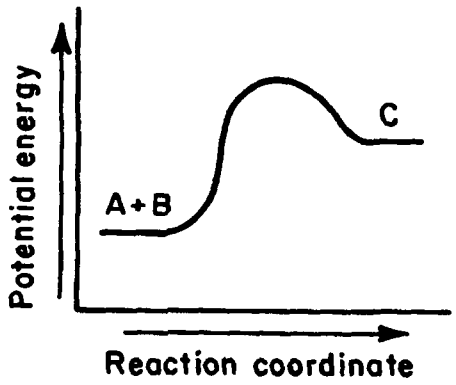
A) 1 B) 2 C) 3 D) 4

28. In the potential energy diagram below, which letter represents the potential energy of the activated complex?



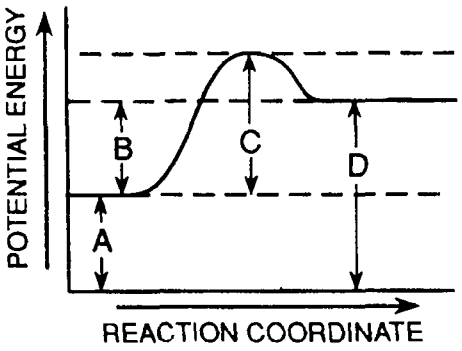
A) *A* B) *B* C) *C* D) *D*

29. According to the potential energy diagram below, what is the reaction $A + B \rightarrow C$?



A) endothermic and ΔH *is positive*
B) endothermic and ΔH *is negative*
C) exothermic and ΔH *is positive*
D) exothermic and ΔH *is negative*

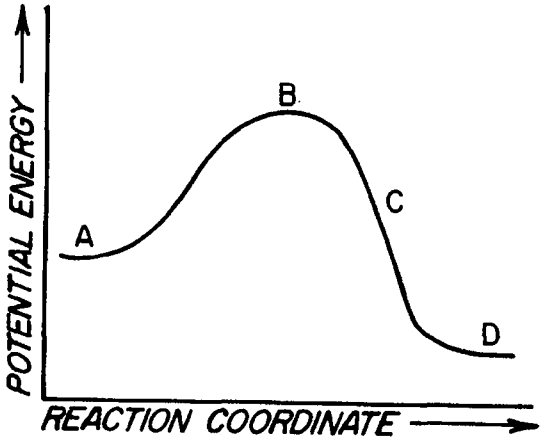
30. Base your answer to the following question on the reaction coordinate shown below:



Which interval represents the heat of reaction?

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

31. The graph below represents the potential energy changes that occur in a chemical reaction. Which letter represents the activated complex?

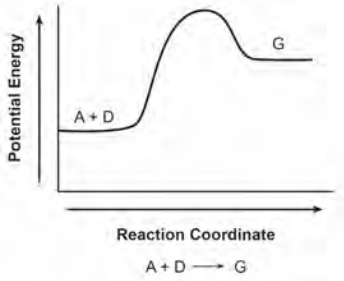


A) *A* B) *B* C) *C* D) *D*

Video 12.3: Enthalpy vs. Entropy
Enthalpy (ΔH) is also known as the heat of reaction.

1. _____ According to Table *I*, which equation represents a change resulting in the greatest quantity of energy released?
   1. $2C_{(s)} + 3H_{2(g)} \rightarrow C_2H_{6(g)}$
   2. $2C_{(s)} + 2H_{2(g)} \rightarrow C_2H_{4(g)}$
   3. $N_{2(g)} + 3H_{2(g)} \rightarrow 2NH_{3(g)}$
   4. $N_{2(g)} + O_{2(g)} \rightarrow 2NO_{(g)}$

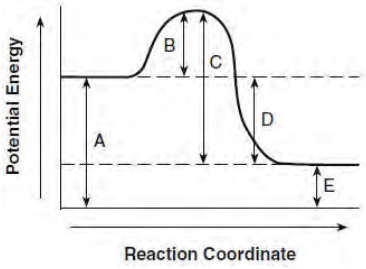
2. _____ Given the potential energy diagram and equation representing the reaction between substances *A* and *D*: According to Table I, substance G can be:
   1. $HI_{(g)}$
   2. $H_2O_{(g)}$
   3. $CO_{2(g)}$
   4. $C_2H_{6(g)}$



3. _____ In a chemical reaction, the difference between the potential energy of the products and the potential energy of the reactants is equal to the
   1. activation energy
   2. entropy of the system
   3. heat of fusion
   4. heat of reaction

Base your answers to question 4-5 on the P.E. diagram

4. _____ Which letter on represents the heat of reaction
   1. A
   2. B
   3. C
   4. D



5. This diagram represents an (endothermic/exothermic) reaction.

6. Answer the following questions using Table I and the reactions below. Determine the heat of reaction and state whether the reaction is endothermic or exothermic.
   1. $2NH_4NO_{3(s)} \rightarrow 2NH_4^+{}_{(aq)} + 2NO_3^-{}_{(aq)}$
   2. $2NH_{3(g)} \rightarrow N_{2(g)} + 3H_{2(g)}$
   3. The synthesis of $H_2O_{(l)}$ from its elements.
   4. The decomposition of 1 mole of aluminum oxide.

7. _____ According to Table I, the dissolving when 2.00 moles of $NaOH_{(s)}$ dissolves in water
   1. 44.5 kJ of energy is released and the temperature of the water increases
   2. 44.5 kJ of energy is absorbed and the temperature of the water decreases
   3. 89 kJ of energy is released and the temperature of the water increases
   4. 89 kJ of energy is absorbed and the temperature of the water decreases

Entropy (ΔS) is the degree of randomness in a substance. Determine whether the following reactions show on 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. $KCI(s) \rightarrow KCI(I)$ _____
6. $CO_2(s) \rightarrow CO_2(g)$ _____
7. $C(s) + O_2(g) \rightarrow CO_2(g)$ _____

8. _____ Given the balanced equation: **$I_2(s)$ + energy → $I_2(g)$**
   As a sample of $I_2(s)$ sublimes to $I_2(g)$, the entropy of the sample
   1. increases because the particles are less randomly arranged
   2. increases because the particles are more randomly arranged
   3. decreases because the particles are less randomly arranged
   4. decreases because the particles are more randomly arranged

9. _____ Which of these changes produces the greatest increase in entropy?
   1. $CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$
   2. $2\ Mg(s) + O_2(g) \rightarrow 2\ MgO(s)$
   3. $H_2O(g) \rightarrow H_2O(l)$
   4. $CO_2(g) \rightarrow CO_2(s)$

10. _____ Which process is accompanied by a *decrease* in entropy?
    1. boiling of water
    2. condensing of water vapor
    3. subliming of iodine
    4. melting of ice

11. _____ Given the balanced equation:

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

Which statement best describes this process?

1. It is endothermic and entropy increases.
2. It is endothermic and entropy decreases.
3. It is exothermic and entropy increases.
4. It is exothermic and entropy decreases

12. _____ A thermometer is in a beaker of water. Which statement best explains why the thermometer reading initially increases when LiBr(s) is dissolved in the water?

1. The entropy of the LiBr(aq) is greater than the entropy of the water.
2. The entropy of the LiBr(aq) is less than the entropy of the water.
3. The dissolving of the LiBr(s) in water is an endothermic process.
4. The dissolving of the LiBr(s) in water is an exothermic process.

Video 12.4 Physical & Chemical Equilibrium

1. Which balanced equation represents a phase equilibrium?

   A) $H_{2(g)} + I_{2(g)} \leftrightarrow 2HI_{(g)}$
   B) $2NO_{2(g)} \leftrightarrow N_2O_{4(g)}$
   C) $Cl_{2(g)} \leftrightarrow Cl_{2(l)}$
   D) $3O_{2(g)} \leftrightarrow 2O_{3(g)}$

2. Which type of equilibrium exists in a sealed flask containing $Br_2(\ell)$ and $Br_2(g)$ at 298 K and 1.0 atm?

   A) static phase equilibrium
   B) static solution equilibrium
   C) dynamic phase equilibrium
   D) dynamic solution equilibrium

3. The temperature at which the solid and liquid phases of matter exist in equilibrium is called its

   A) freezing point
   B) boiling point
   C) heat of fusion
   D) heat of vaporization

4. Which statement describes a reversible reaction at equilibrium?

   A) The activation energy of the forward reaction must equal the activation energy of the reverse reaction.
   B) The rate of the forward reaction must equal the rate of the reverse reaction.
   C) The concentration of the reactants must equal the concentration of the products.
   D) The potential energy of the reactants must equal the potential energy of the products.

5. Which balanced equation represents a phase equilibrium?

   A) $H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$
   B) $2NO_2(g) \rightleftharpoons N_2O_4(g)$ C) $Cl_2(g) \rightleftharpoons Cl_2(\ell)$
   D) $3O_2(g) \rightleftharpoons 2O_3(g)$

6. Some solid KNO_3 remains at the bottom of a stoppered flask containing a saturated $KNO_3(aq)$ solution at 22°C. Which statement explains why the contents of the flask are at equilibrium?

   A) The rate of dissolving is equal to the rate of crystallization.
   B) The rate of dissolving is greater than the rate of crystallization.
   C) The concentration of the solid is equal to the concentration of the solution.
   D) The concentration of the solid is greater than the concentration of the solution.

7. A solution that is at equilibrium must be

   A) concentrated B) dilute
   C) saturated D) unsaturated

8. Based on Reference Table G, which amount of a compound dissolved in 100 grams of water at the stated temperature represents a system at equilibrium?

   A) 20 g $KClO_3$ at 80ºC
   B) 40 g KNO_3 at 25ºC
   C) 40 g KCl at 60ºC
   D) 60 g $NaNO_3$ at 40ºC

Spontaneous Reactions

Use Table I & your knowledge of enthalpy & entropy to determine if the following reactions are always, sometimes or never spontaneous.

Chemical Reactions	ΔH	ΔS	Spontaneous?
$4Al_{(s)} + 3O_{2(g)} \rightarrow 2Al_2O_{3(s)}$			
$NaOH_{(s)} \rightarrow Na^{+1}_{(aq)} + OH^{-1}_{(aq)}$			
$3CO_{2(g)} + 4H_2O_{(l)} \rightarrow 5O_{2(g)} + C_3H_{8(g)}$			
$2NO_{2(g)} \rightarrow N_{2(g)} + 2O_{2(g)}$			
$Li^{+1}_{(aq)} + Br^{-1}_{(aq)} \rightarrow LiBr_{(s)}$			

Video 12.5. Le Chatelier's Principle

For each of the following, indicate the direction the equilibrium would shift **and** what would happen to the concentrations of each substance in equilibrium.

1. The following equilibrium maybe established with carbon dioxide and steam.

$$CO(g) + H_2O\ (g) \text{ <---> } CO_2\ (g) + H_2\ (g) + \text{heat}$$

What would be the effect of each of the following on the equilibrium and concentrations?

	Shift	***Concentrations***
a) The addition of more H_2O?	_____	_____
b) The removal of some H_2?	_____	_____
c) Raising the temperature?	_____	_____
d) Increasing the pressure?	_____	_____
e) Addition of a catalyst?	_____	_____

Name _____

Equilibrium – Le Chatelier's Principle

Guiding Question: How does the addition or removal of an acid (H+) affect the equilibrium of black tea?

Figure 1.

$$Tea_{(aq)} + H^{+}_{(aq)} \leftrightarrow TeaH^{+}_{(aq)}$$

dark light color

Demonstration/ Phenomenon: Record your observations as vinegar and ammonia are added to the tea.

Stress	Color Prediction	Resulting Color
Control		
Vinegar addition (add H+)		
Ammonia addition (removal of H+)		

Questions:

1. In this activity, how could you determine whether or not a change occurred in equilibrium? Explain.

2. For each reaction performed, explain how each change occurred in terms of Le Chatelier's Principle. Indicate the ***stress*** on each of the reactions below and the direction of the ***shift*** that had an impact on the Tea Equilibrium.

Vinegar (Acetic acid, $HC_2H_3O_2$): $Tea_{(aq)} + H^{+}_{(aq)} \Leftrightarrow TeaH^{+}_{(aq)}$

Ammonia (NH_3): $Tea_{(aq)} + H^{+}_{(aq)} \Leftrightarrow TeaH^{+}_{(aq)}$

3. What other "stresses" do you wonder would affect our tea equilibrium? How could we test it?

2. What would be the effect of each of the following on the equilibrium involving the synthesis of methanol?

$$CO(g) + 2H_2\ (g) \text{ <---> } CH_3OH\ (g)$$

	Shift	***Concentration***
a. The removal of CH_3OH?	_____	_____
b. An increase in pressure	_____	_____
c. Lowering the concentration of H_2?	_____	_____
d. The addition of a catalyst?	_____	_____

3. A small percentage of nitrogen gas and oxygen gas in the air combine at high temperatures found in automobile engines to produce NO(g), which is an air pollutant.

$$N_2(g) + O_2(g) + \text{heat} \text{ <---> } 2NO(g)$$

   a. Higher engine temperatures are used to minimize carbon monoxide production. What effect does higher engine temperatures have on the production of NO(g)? Why?

   b. What effect would high pressures have on the production of NO(g)? Why?

12. 5 Le Chatelier' s Principle

1. Given the equation representing a reaction at equilibrium:

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

Which change causes the equilibrium to shift to the right?

A) adding a catalyst
B) adding more $O_2(g)$
C) decreasing the pressure
D) increasing the temperature

2. 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

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

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

5. Given the system at equilibrium:

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

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

A) The equilibrium shifts to the right and the concentration of $PCl_3(g)$ increases.
B) The equilibrium shifts to the right and the concentration of $PCl_3(g)$ decreases.
C) The equilibrium shifts to the left and the concentration of $PCl_3(g)$ increases.
D) The equilibrium shifts to the left and the concentration of $PCl_3(g)$ decreases.

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

7. 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) adding a catalyst
C) increasing the temperature
D) increasing the pressure

8. 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

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

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

11. Given the system at equilibrium:

$N_2O_4(g) + 58.1\ \text{kJ} \leftrightarrow 2\ NO_2(g)$
What will be the result of an increase in temperature at constant pressure?

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

12. Given the equilibrium reaction in a closed system:

$H_2(g) + I_2(g) + \text{heat} \leftrightarrow 2\ HI(g)$
What will be the result of an increase in temperature?

A) The equilibrium will shift to the left and $[H_2]$ will increase.
B) The equilibrium will shift to the left and $[H_2]$ will decrease.
C) The equilibrium will shift to the right and [HI] will increase.
D) The equilibrium will shift to the right and [HI] will decrease.

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

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

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

16. 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

17. 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

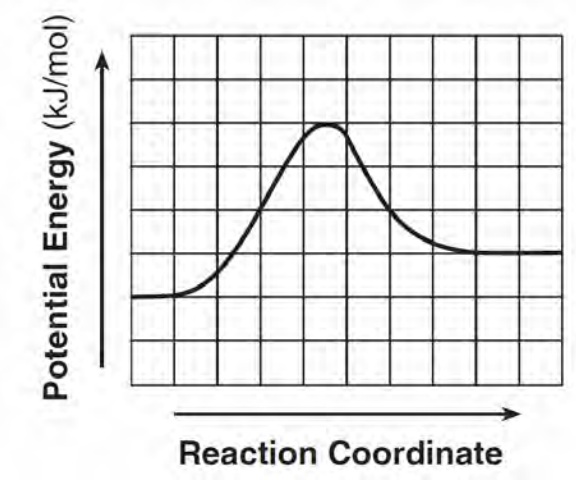
A) decrease B) increase
C) remain the same

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

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

Name: **Kinetics & Equilibrium Review**

1. Given the potential energy diagram for a reversible chemical reaction:



Each interval on the axis labeled "Potential Energy (kJ/mol)" represents 10. kilojoules per mole. What is the activation energy of the forward reaction?

1) 10. kJ/mol
2) 30. kJ/mol
3) 40. kJ/mol
4) 60. kJ/mol

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

1) standard temperature and pressure
2) a catalyst added to the reaction system
3) effective collisions between reactant particles
4) an equal number of moles of reactants and products

3. Why can an increase in temperature lead to more effective collisions between reactant particles and an increase in the rate of a chemical reaction?

1) The activation energy of the reaction increases.
2) The activation energy of the reaction decreases.
3) The number of molecules with sufficient energy to react increases.
4) The number of molecules with sufficient energy to react decreases.

4. 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 effective collisions between reacting molecules
4) increasing the frequency of effective collisions between reacting molecules

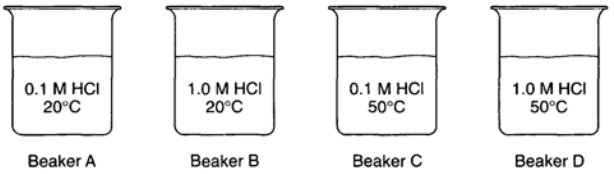
5. Given the reaction:

$$Mg + 2\ H_2O \rightarrow Mg(OH)_2 + H_2$$

At which temperature will the reaction occur at the greatest rate?

1) 25ºC
2) 50ºC
3) 75ºC
4) 100ºC

6. In each of the four beakers shown below, a 2.0-centimeter strip of magnesium ribbon reacts with 100 milliliters of HCl(aq) under the conditions shown.



In which beaker will the reaction occur at the fastest rate?

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

7. Given the reaction:

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

If the concentration of HCl(aq) is increased, the frequency of reacting collisions will

1) decrease, producing a decrease in the reaction rate
2) decrease, producing an increase in the reaction rate
3) increase, producing a decrease in the reaction rate
4) increase, producing an increase in the reaction rate

8. Given the balanced equation representing a reaction:

$$Fe(s) + 2HCl(aq) \longrightarrow FeCl_2(aq) + H_2(g)$$

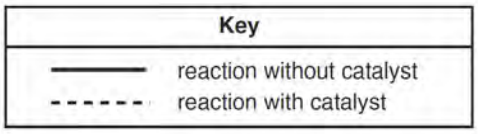
This reaction occurs more quickly when powdered iron is used instead of a single piece of iron of the same mass because the powdered iron

1) acts as a better catalyst than the single piece of iron
2) absorbs less energy than the single piece of iron
3) has a greater surface area than the single piece of iron
4) is more metallic than the single piece of iron

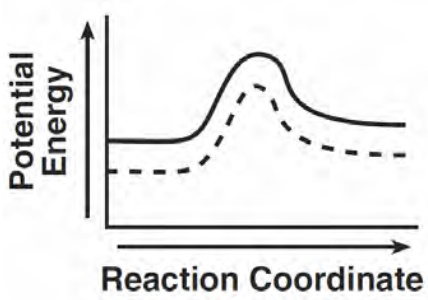
9. At STP, which 4.0-gram zinc sample will react fastest with dilute hydrochloric acid?

1) lump
2) bar
3) powdered
4) sheet metal

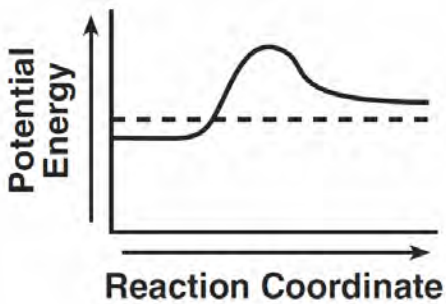
10. Which potential energy diagram represents the change in potential energy that occurs when a catalyst is added to a chemical reaction?



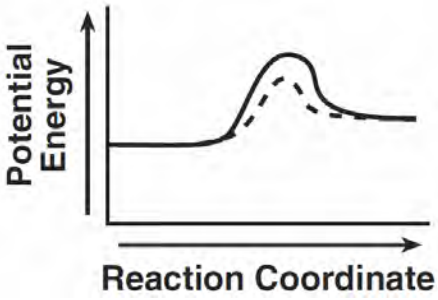
1)



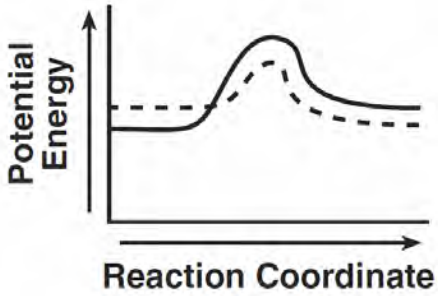
3)



2)



4)



11. The activation energy of a chemical reaction can be *decreased* by the addition of

1) a catalyst
2) an indicator
3) electrical energy
4) thermal energy

12. For a given reaction, adding a catalyst increases the rate of the reaction by

1) providing an alternate reaction pathway that has a higher activation energy
2) providing an alternate reaction pathway that has a lower activation energy
3) using the same reaction pathway and increasing the activation energy
4) using the same reaction pathway and decreasing the activation energy

13. A thermometer is in a beaker of water. Which statement best explains why the thermometer reading initially increases when LiBr(s) is dissolved in the water?

1) The entropy of the LiBr(aq) is greater than the entropy of the water.
2) The entropy of the LiBr(aq) is less than the entropy of the water.
3) The dissolving of the LiBr(s) in water is an endothermic process.
4) The dissolving of the LiBr(s) in water is an exothermic process.

14. Which balanced equation represents an endothermic reaction?

1) $C(s) + O_2(g) \rightarrow CO_2(g)$
2) $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(\ell)$
3) $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$
4) $N_2(g) + O_2(g) \rightarrow 2NO(g)$

15. For a chemical reaction, the difference between the potential energy of the products and the potential energy of the reactants is equal to the

1) heat of fusion
2) heat of reaction
3) activation energy of the forward reaction
4) activation energy of the reverse reaction

16. Given the balanced equation representing a reaction at 101.3 kPa and 298 K:

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

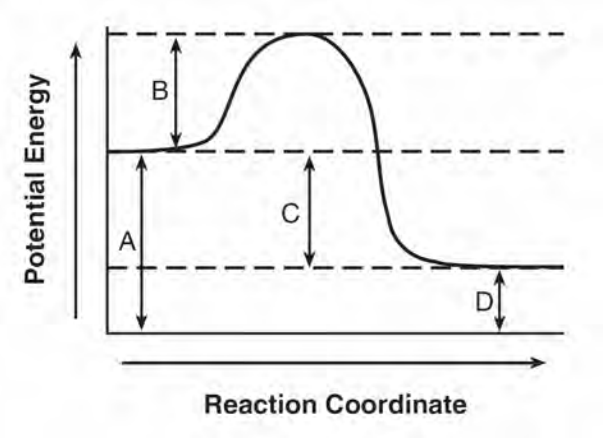
Which statement is true about this reaction?

1) It is exothermic and ΔH *equals –91.8 kJ.*
2) It is exothermic and ΔH *equals +91.8 kJ.*
3) It is endothermic and ΔH *equals –91.8 kJ.*
4) It is endothermic and ΔH *equals +91.8 kJ.*

17. According to Table *I*, which equation representsa change resulting in the greatest quantity of energy released?

1) $2C(s) + 3H_2(g) \rightarrow C_2H_6(g)$
2) $2C(s) + 2H_2(g) \rightarrow C_2H_4(g)$
3) $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$
4) $N_2(g_+O_2(g) \rightarrow 2NO(g)$

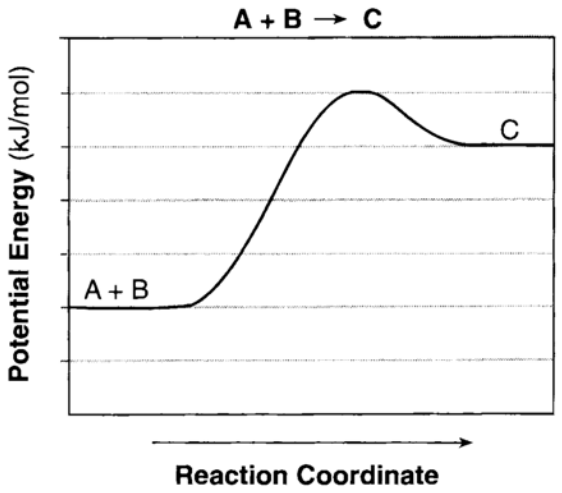
18. Given the potential energy diagram representing a reversible reaction:



The activation energy for the reverse reaction is represented by

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

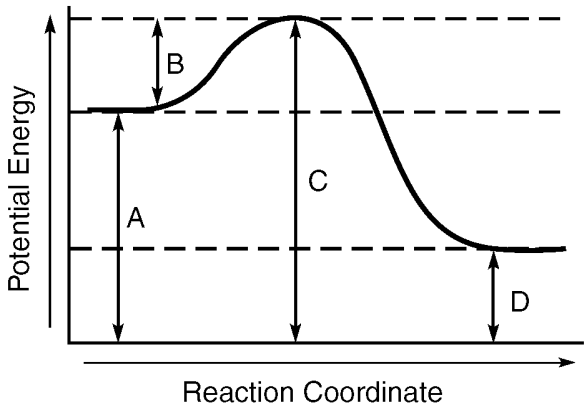
19. Given the equation and potential energy diagram representing a reaction:



If each interval on the axis labeled "Potential Energy (kJ/mol)" represents 10. kJ/mol, what is the heat of reaction?

1) +60. kJ/mol
2) +20. kJ/mol
3) +30. kJ/mol
4) +40. kJ/mol

20. The potential energy diagram below represents a reaction.



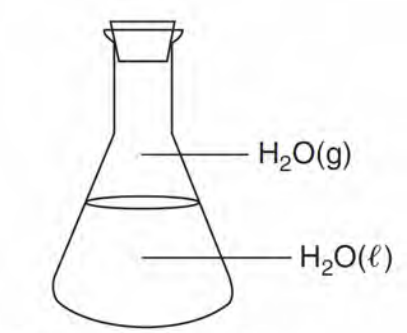
Which arrow represents the activation energy of the forward reaction?

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

21. Which statement describes a chemical reaction at equilibrium?

1) The products are completely consumed in the reaction.
2) The reactants are completely consumed in the reaction.
3) The concentrations of the products and reactants are equal.
4) The concentrations of the products and reactants are constant.

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



Stoppered Flask

Which statement describes this system at equilibrium?

1) The mass of $H_2O(\ell)$ equals the mass of $H_2O(g)$.
2) The volume of $H_2O(\ell)$ equals the volume of $H_2O(g)$.
3) The number of moles of $H_2O(\ell)$ equals the number of moles of $H_2O(g)$.
4) The rate of evaporation of $H_2O(\ell)$ equals the rate of condensation of $H_2O(g)$.

23. Which two factors must be equal when a chemical reaction reaches equilibrium?

1) the concentration of the reactants and the concentration of the products
2) the number of reactant particles and the number of product particles
3) the rate of the forward reaction and the rate of the reverse reaction
4) the mass of the reactants and the mass of the products

24. Some solid KNO_3 remains at the bottom of a stoppered flask containing a saturated $KNO_3(aq)$ solution at 22°C. Which statement explains why the contents of the flask are at equilibrium?

1) The rate of dissolving is equal to the rate of crystallization.
2) The rate of dissolving is greater than the rate of crystallization.
3) The concentration of the solid is equal to the concentration of the solution.
4) The concentration of the solid is greater than the concentration of the solution.

25. Given the equation representing a system at equilibrium:

H_2O (s) $\leftrightarrow$ H_20 (l)
At which temperature does this equilibrium exist at 101.3 kilopascals?

1) 0 K
2) 0°C
3) 32 K
4) 273°C

26. 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?

1) increasing the temperature
2) increasing the pressure
3) decreasing the amount of $SO_2(g)$
4) decreasing the amount of $O_2(g)$

27. 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 $A_2B_3(g)$?

1) adding more $A(g)$
2) adding a catalyst
3) increasing the temperature
4) increasing the pressure

28. Given the equation representing a reaction at equilibrium:

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

Which change causes the equilibrium to shift to the right?

1) adding a catalyst
2) adding more $O_2(g)$
3) decreasing the pressure
4) increasing the temperature

29. 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*?

1) The concentration of $H_2(g)$ increases and the concentration of $N_2(g)$ increases.
2) The concentration of $H_2(g)$ decreases and the concentration of $N_2(g)$ increases.
3) The concentration of $H_2(g)$ decreases and the concentration of $NH_3(g)$ decreases.
4) The concentration of $H_2(g)$ decreases and the concentration of $NH_3(g)$ increases.

30. In terms of entropy and energy, systems in nature tend to undergo changes toward

1) lower entropy and lower energy
2) lower entropy and higher energy
3) higher entropy and lower energy
4) higher entropy and higher energy

31. Which equation represents a change that results in an increase in disorder?

1) $I_2(s) \rightarrow I_2(g)$
2) $CO_2(g) \rightarrow CO_2(s)$
3) $2Na(s) + Cl_2(g) \rightarrow 2NaCl(s)$
4) $2H_2(g) + O_2(g) \rightarrow 2H_2O(\ell)$

Base your answers to questions **32** through **34** on the information below and on your knowledge of chemistry.

Common household bleach is an aqueous solution containing hypochlorite ions. A closed container of bleach is an equilibrium system represented by the equation below.

$$\mathrm{Cl_2(g) + 2OH^-(aq) \rightleftharpoons ClO^-(aq) + Cl^-(aq) + H_2O(\ell)}$$

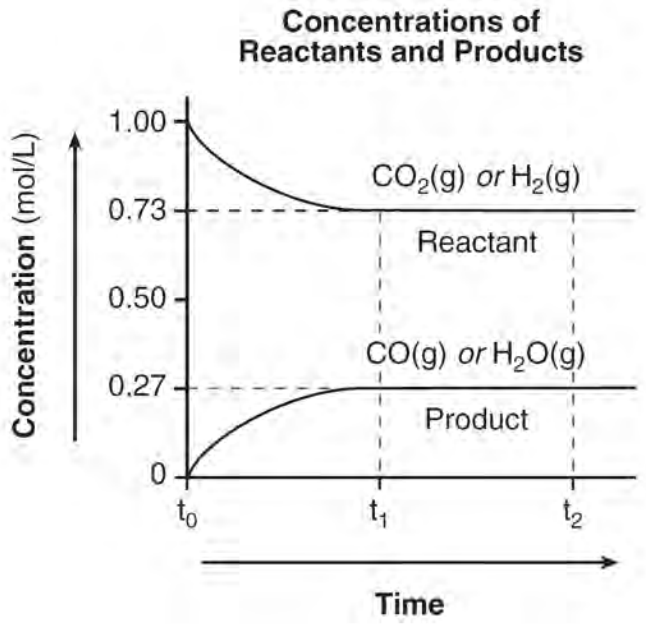
32. State the effect on the concentration of the $\mathrm{ClO^-}$ ion when there is a *decrease* in the concentration of the $\mathrm{OH^-}$ ion.

33. Explain why the container must be closed to maintain equilibrium.

34. Compare the rate of the forward reaction to the rate of the reverse reaction for this system.

Base your answers to questions **35** and **36** 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.

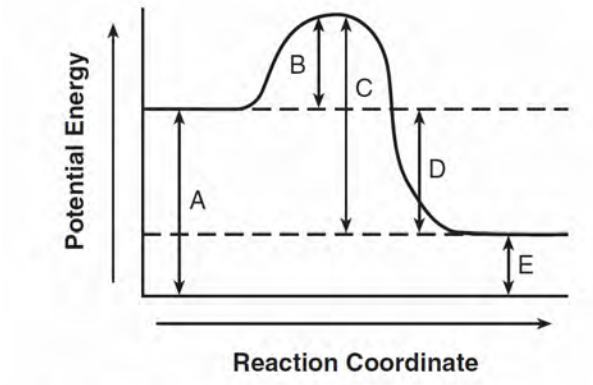


35. What can be concluded from the graph about the concentrations of the reactants and the concentrations of the products between time t_1 and time t_2?

36. Determine the change in the concentration of $CO_2(g)$ between time t_0 and time t_1.

Base your answers to questions **37** and **38** on the information below.

The chemical reaction between methane and oxygen is represented by the potential energy diagram and balanced equation below.



$$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(\ell) + 890.4\ kJ$$

37. Explain, in terms of collision theory, why a lower concentration of oxygen gas *decreases* the rate of this reaction.

38. Which potential energy interval in the diagram represents the activation energy of the foward reaction?

Base your answers to questions **39** and **40** on the information below.

At room temperature, a reaction occurs when $KIO_3(aq)$ is mixed with $NaHSO_3(aq)$ that contains a small amount of starch. The colorless reaction mixture turns dark blue after a period of time that depends on the concentration of the reactants.

In a laboratory, 12 drops of a 0.02 M $NaHSO_3(aq)$ solution containing starch were placed in each of six test tubes. A different number of drops of 0.02 M $KIO_3(aq)$ and enough water to maintain a constant volume were added to each test tube and the time for the dark-blue color to appear was measured. The data were recorded in the table below.

Data Table

Test Tube	A	B	C	D	E	F
Number of Drops of 0.02 M KIO_3(aq)	2	4	6	8	10	12
Time for Dark-Blue Color to Appear (s)	210.	88	49	39	33	27

39. Identify *one* factor, other than the concentration of the reactants, that would affect the rate of this reaction.

40. State how increasing the number of drops of 0.02 M $KIO_3(aq)$ used in the reaction affects the rate of reaction.