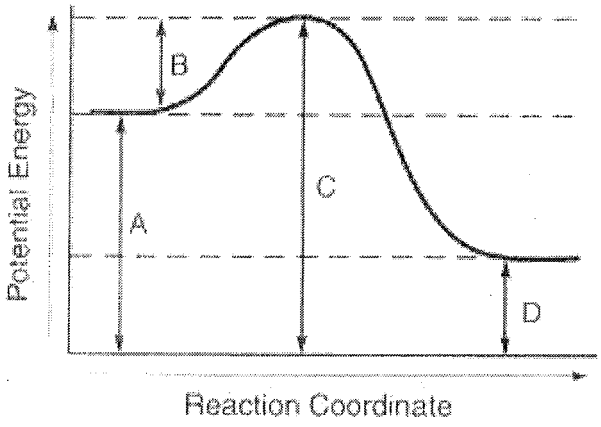
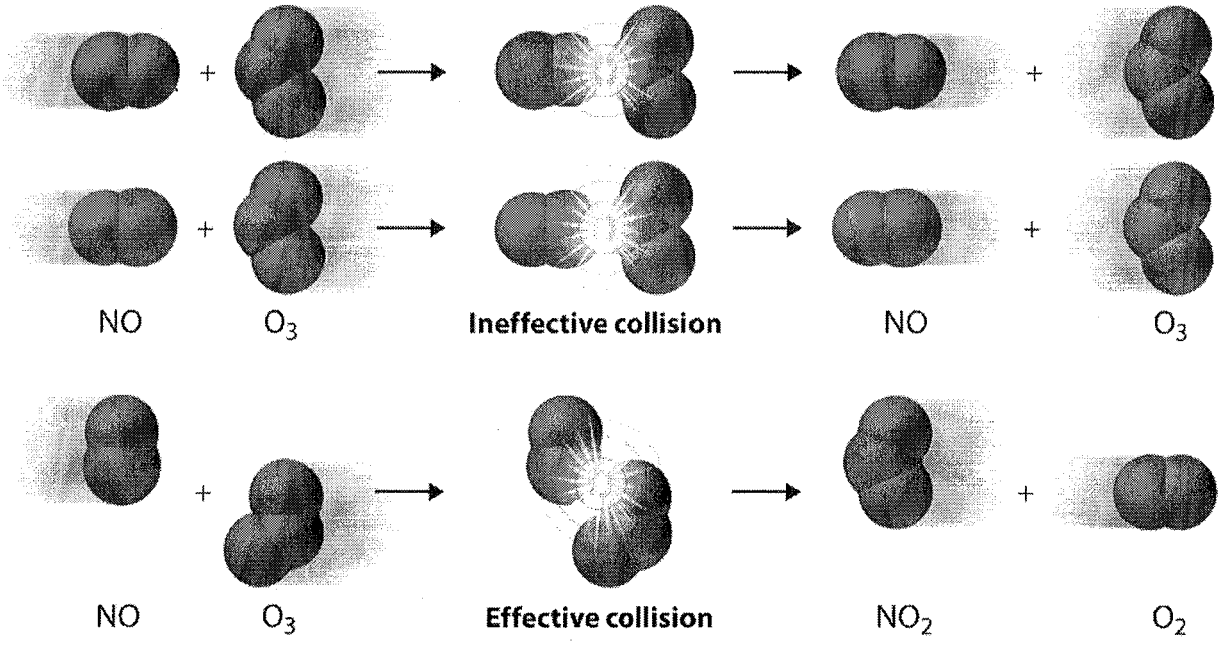
Name_____ Mr. GARDNER

Unit #7: Kinetics





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Kinetics-Equilibrium Vocabulary:

activated complex the temporary, intermediate product in a chemical reaction

activation energy the amount of energy needed to form an activated complex from reactants

catalyst a substance that alters the speed of a chemical reaction without being permanently changed

endothermic a chemical reaction that absorbs heat, producing products with more potential energy than the reactants

entropy a measure of the disorder or randomness of a system

equilibrium a condition in which the rates of opposing reactions are equal

equilibrium expression a mathematical expression that shows the relationship of reactants and products of a system at equilibrium

exothermic a chemical reaction that releases heat, producing products with less potential energy than the reactants

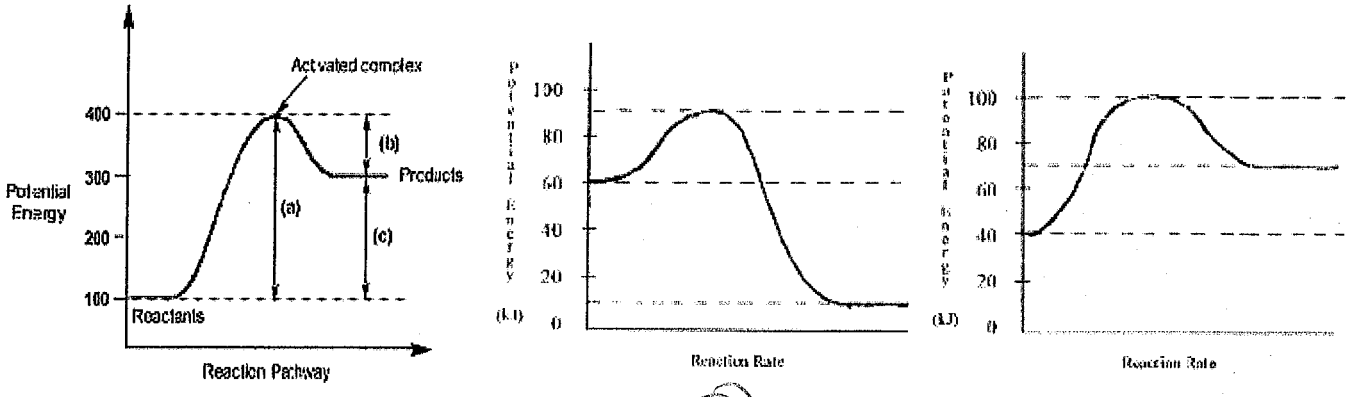
Le Chatelier's principle a system at equilibrium reacts to reduce a stress

potential energy diagram a diagram showing the changes in potential energy as a reaction proceeds

stress any change in concentration, pressure, or temperature on an equilibrium system

Kinetics-Equilibrium Objectives: You should be able to…

- Use the collision theory to explain how temperature, surface area and concentration influence the rate of reaction
- Explain the effect of a catalyst or inhibitor on a systems equilibrium
- Identify examples of physical equilibrium as phase or solution equilibrium including the concept that a saturated solution is at equilibrium
- Describe the concentration of particles and rates of opposing reactions in an equilibrium system (reactants and products)
- Qualitatively describe the effect of stress on equilibrium using LeChatelier's Principle
- Read and interpret potential energy diagrams, including PE of reactants and products, activation energy(with and without catalysts), heat of reaction and PE of the activated complex
- Compare the entropy of phases of matter and relate how systems tend to head towards high entropy and low enthalpy



1 **Kinetics/Equilibrium/Thermochemistry**

2 **Kinetics**

- study of the rates of chemical reactions
- Collision theory: in order for a reaction to occur, particles must collide with proper orientation and energy

3 **Factors affecting rate of reaction**

- Type of reactant (covalent vs. ionic)
  - Covalent
    - Hard to break bond
    - More energy required
    - More bonds to break
    - Reacts slower
  - Ionic
    - Easier to break bond
    - Less energy needed
    - Fewer bonds to break
    - Reacts quicker

4 **Factors affecting rate of reaction**

- Concentration: ↑ in amount of reactants will ↑ rate of rxn (more collisions occurring when more is present)

5 **Factors affecting rate of reaction**

- Surface Area: ↑ in surface area will ↑ rate of rxn
  - Ex. clump of sugar; inner portions are not making contact with water (the other reactant)
  - Rxn is slower than if material was crushed
-

6 **Factors affecting rate of reaction**

- Pressure: Specifically affects gases
  - ↑ in pressure will ↑ amount of collisions
  - In a closed system a volume ↓ will lead to a pressure ↑ and rxn rate ↑
- Temperature: ↑ in temp will ↑ KE of particles which will result in more energy and more effective collisions
  - As collisions ↑, rxn rate also ↑

7 **Factors affecting rate of reaction**

- Catalyst: Provides an alternate pathway for a reaction
  - ↑ rate of rxn
  - Causes activation(starting) energy to be lowered, so rxn may start easier
  - remains unchanged when rxn is complete

8 **Equilibrium**

- when both forward and reverse reactions occur at the same rate (in a closed system)
- Ex. $H_2O(l) \Leftrightarrow H_2O(g)$ (represented by double arrow)
- Quantities of reactants and products do not have to be equal, but there rates of forming or breaking up are equal
  - Ex. rate of water evaporating is the same is water vapor condensing back to liquid
  - Boiling water → steam rises and condenses back into the pot

9 **Equilibrium**

10 **Physical Equilibrium**

- Changing of state occurs
- Phase equilibrium: between solid/liquid or melting/freezing
  - Water will melt and freeze at the same rate at O°C ($H_2O(s) \Leftrightarrow H_2O(l)$)
- Solution Equilibrium: solids in liquids
  - When dissolving = recrystallizing (at a constant temperature)

11 **Physical Equilibrium**

  - Ex. sugar in a saturated tea solution→ some may dissolve, but other molecules will recrystallize ($C_{12}H_{22}O_{11}(s) \Leftrightarrow C_{12}H_{22}O_{11}(aq)$)
- Can also occur with a gas in a liquid
  - CO_2 in soda ($CO_2(g) \Leftrightarrow CO_2(aq)$)
  - If temperature ↑, more gas will escape then will be converted/dissolved to aqueous form

12 **Chemical Equilibrium**

-
- When reactants are 1st mixed, only the forward reaction will occur
- When reactant amount ↓ and product ↑ the reverse reaction will be favored
- When forward = reverse, equilibrium is achieved

13 **Le Chatelier's Principle**

-
- Systems will change their equilibriums due to changes in temperature, concentration or pressure so as to relieve stress on the system
  - May shift forward (to the right)
  - May shift reverse (to the left)

14 **Le Chatelier's Principle**

- Changes in Temperature: ex. $N_2 + 3H_2 \Leftrightarrow 2NH_3 + Heat$
  - If Heat ↑, reverse rxn favored
    - Easier to break apart larger molecules into smaller ones with the addition of heat
    - Typically takes place with endothermic reactions (heat in)
  - If Heat ↓, forward rxn favored

- Easier for smaller reactants to collide and form a larger product
- Typically takes place with exothermic reactions (heat out)

15 **Le Chatelier's Principle**

- Changes in Concentration:
  - Addition of a reactant will shift equilibrium to the right
    - More product is formed
    - Forward rxn favored over reverse
    - Equilibrium will eventually be met
  - Deletion or reduction of a reactant will shift equilibrium to the left
    - Less product can be formed
    - Reverse rxn favored over forward
    - Equilibrium is eventually met

16 **Concentration Shift**

- Ex. $4NH_3(g)+5O_2(g) \Leftrightarrow 4NO(g) + 6H_2O(g)$ + Heat
- If $O_2(g)$ is removed from the reactants, $NO(g)$ and $H_2O(g)$ would be impossible to generate

17 **Le Chatelier's Principle**

- Changes in Pressure: (typically with gases)
  - When only 1 gas present on both sides of a reaction; $CO_2(g) \Leftrightarrow CO_2(aq)$
    - Pressure ↑ will favor the forward rxn
    - More $CO_2(g)$ going into solution→ becoming CO_2 (aq)
    - Pressure ↓ will favor the reverse rxn
    - $CO_2(g)$ will come out of solution (when you open a soda can

18 **When # of gas molecules/moles is different on both sides of the reaction**

- ex. $N_2(g) + 3H_2(g) \Leftrightarrow 2NH_3(g)$
  - 4 moles of reactants⇔2 moles of products
- An ↑in pressure will ↑ concentration of reactants and products on both sides of equation
  - Molecules move closer together so reactants collide to make more product
  - Will favor the forward rxn towards the side with the fewer gas moles ($2NH_3(g)$ above)
- A ↓ in pressure will favor the reverse direction.
  - Less product made as molecules are farther apart and will not collide as successful as under high pressure

19 **Le Chatlier's Priciple: Pressure continued**

- When # of gas molecules/moles is the same on both sides, a pressure change will have NO affect on the system reaction rate
  - $H_2(g) + Cl_2(g) \Leftrightarrow 2HCl(g)$
  - 2 molecules⇔ 2 molecules in above example

20 **Le Chatelier's Principle**

- Catalyst: Introduction of a catalyst will change the rate of reaction in both directions
  - may cause equilibrium to be met quicker
  - has no affect on concentrations

21 **Potential Energy Diagrams (PED's)**

- Used to illustrate the Potential Energy changes that occur during a chemical reaction
- A= Potential Energy of Reactants
- B= Activation Energy
- C= Potential Energy of Activated Complex
- D= Potential Energy of Products

22 **Activated Complex**

- For a reaction to occur, reactants need an effective collision with proper energy and orientation
- As they collide/bond, their kinetic energy is converted to stored potential energy
-
-
-
-
-
- Reactants → Activated Complex → Products

23 **Activated Complex**

- Occurs when colliding particles form a temporary intermediate product that may break apart and reform the reactants or make a new product

24 **Activation Energy**

- To form the activated complex, the reactants must collide with enough activation energy
  - Measured as the distance between PE of reactants and the peak of the activated complex (sometimes listed as E_a)
  -
  -
  -
  -
  -
  - May be measured in both directions

25 **Heat of Reaction: (ΔH)**

- = Difference between PE of Reactants and PE of Products
  - ΔH is the quantity of heat gained or released in a chemical Rxn
  - $\Delta H = H_{products} - H_{reactants}$
    - (-) values indicate a loss of heat and therefore an exothermic reaction

- See Table I for common reactions

26 **Exothermic Reactions**

- when PE of product is lower than PE of reactant
  - A+B→ C+D + Energy
  - Heat given off
  - ΔH is negative
  -
  -
  - The greater the (-) value for ΔH, the more stable the material

27 **Endothermic Reactions**

- when PE of reactant is lower than PE of product
  - A+B+ Energy → C+D
  - Heat gained/absorbed
  - ΔH is positive
  -
  -
  - If a rxn is Exothermic in the forward direction, it will be endothermic in the reverse (and vice versa)

28 **Catalysts**

- cause a reaction to reach equilibrium quicker as they lower activation energy
  - Reactant and product values remain unchanged
  - Catalyst remains unchanged and can be reused

29 **Inhibitor**

- causes a Rxn to slow down (opposite of catalyst) or take longer to reach equilibrium
  - Reactant and product values remain unchanged
  - Activation energy increases
  -
  -
  - Activation Energy with Inhibitor

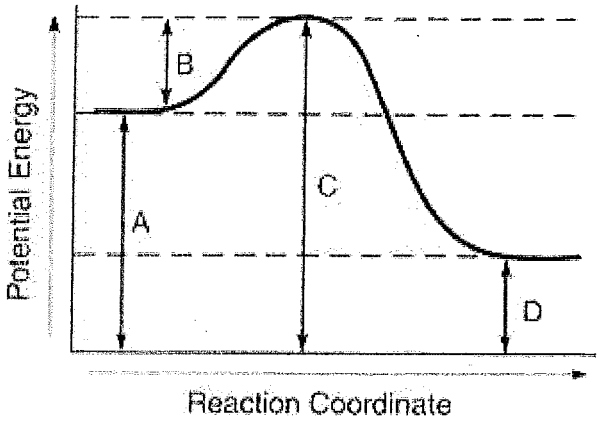
30 **Entropy**

- going to a state of randomness
  - disorder or chaos/lack of regularity
  - Systems will tend to go from low entropy (great order) to high entropy (great disorder)
    - Due to particle collisions
  - Ex. Solid → Liquid→ Gas would be the trend in entropy for molecular arrangement

31 **Enthalpy**

- Tendency to change to a lower energy

- Associated with Heat of Reaction (ΔH)
- Exothermic Rxn's→give off energy, thus products will have less PE than the reactants
- Systems tend to move towards lower energy (enthalpy) and greater disorder (entropy)

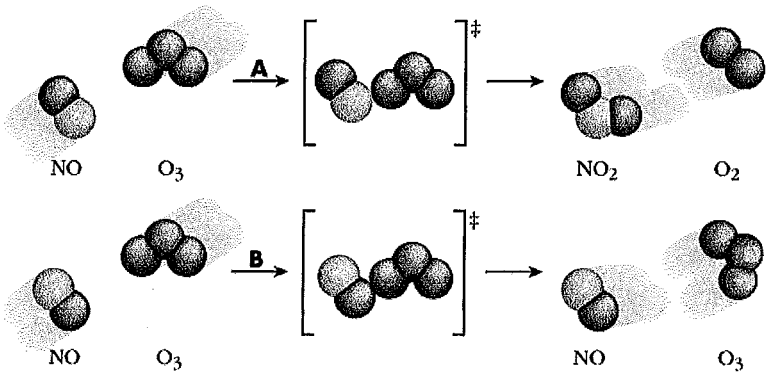


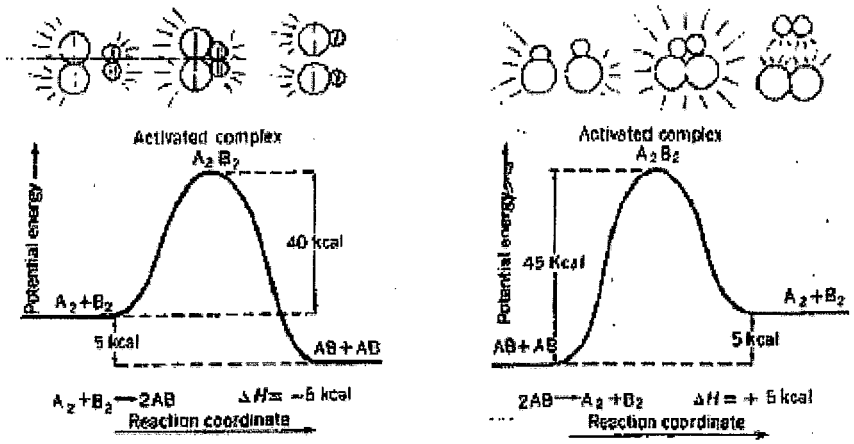
A= Potential Energy of Reactants

B= Activation Energy

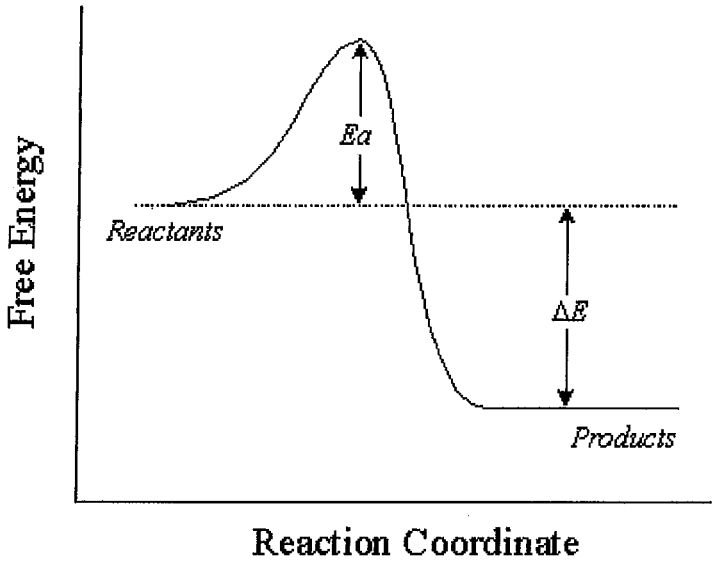
C= Potential Energy of Activated Complex

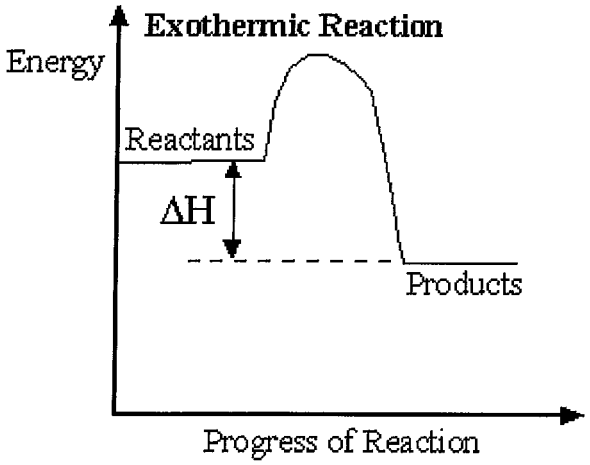
D= Potential Energy of Products

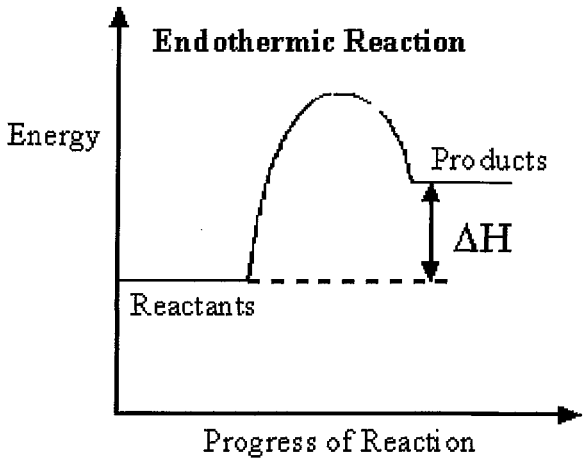


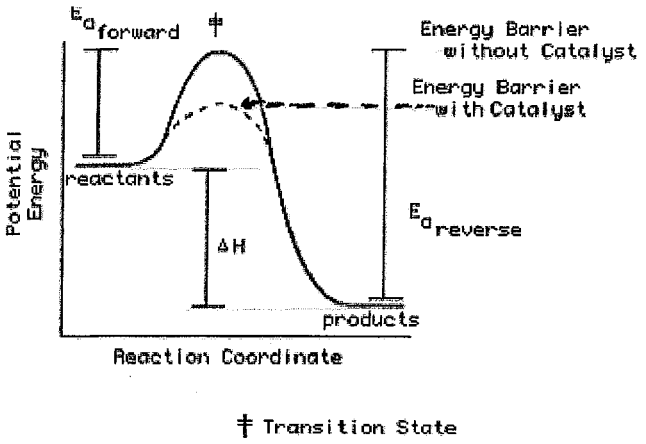


On the left is a potential energy diagram for the changes occurring in a chemical system during an exothermic reaction. On the right is the same type of diagram for an system undergoing an endothermic reaction.



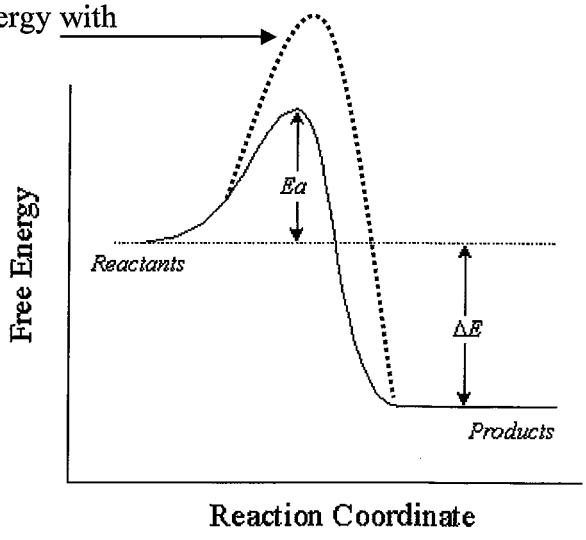






‡ Transition State

Activation Energy with Inhibitor



Name: _____

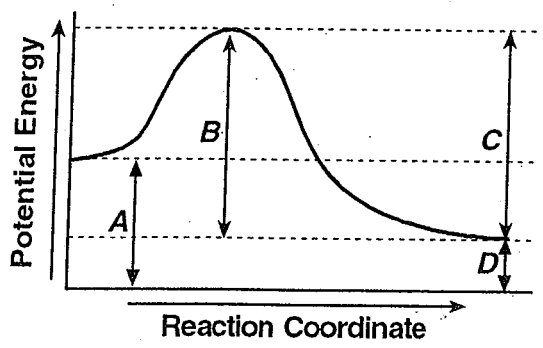
1) Beaker *A* contains a 1-gram piece of zinc and beaker *B* contains 1 gram of powdered zinc. If 100 milliliters of 0.1 M HCl is added to each of the beakers, how does the rate of reaction in beaker *A* compare to the rate of reaction in beaker *B*?

A) The rate in *A* is greater due to the smaller surface area of the zinc.
B) The rate in *B* is greater due to the smaller surface area of the zinc.
C) The rate in *B* is greater due to the larger surface area of the zinc.
D) The rate in *A* is greater due to the larger surface area of the zinc.

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

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

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



Which arrow represents the part of the reaction most likely to be affected by the addition of a catalyst?

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

4) Given the reaction:

$$2Na(s) + Cl_2(g) \longrightarrow 2NaCl(s)$$

As the reactants form products, the stability of the chemical system will

A) remain the same
B) increase
C) decrease

5) Given the reaction:

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

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

A) remains the same
B) increases
C) decreases

6) Given the reaction:

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

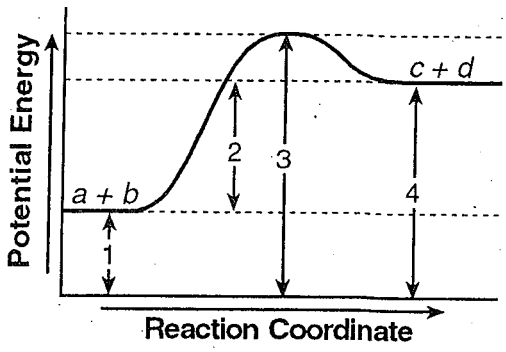
Which change would increase the rate of this reaction?

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

7) The minimum amount of energy required to start a chemical reaction is called

A) free energy
B) enthalpy
C) activation energy
D) entropy

8) Which interval on the potential energy diagram shown below represents the ΔH of the reaction $a + b \longrightarrow c + d$?



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

9) When a catalyst is added to a system at equilibrium, a decrease occurs in the

A) potential energy of the products
B) heat of the reaction
C) activation energy
D) potential energy of the reactants

10

10) Given the reaction at equilibrium:

$$AgI(s) \rightleftharpoons Ag^+(aq) + I^-(aq)$$

What happens as KI(s) is added to the solution?

A) The concentration of $Ag^+(aq)$ increases and the concentration of $I^-(aq)$ remains the same.
B) The concentration of $Ag^+(aq)$ decreases and the concentration of $I^-(aq)$ remains the same.
C) The concentration of $Ag^+(aq)$ decreases and the concentration of $I^-(aq)$ increases.
D) The concentration of $Ag^+(aq)$ increases and the concentration of $I^-(aq)$ increases.

11) Given the reaction at equilibrium:

$$C(s) + O_2(g) \rightleftharpoons CO_2(g) + \text{heat}$$

Which stress on the system will increase the concentration of $CO_2(g)$?

A) decreasing the amount of C(s)
B) increasing the temperature of the reaction
C) decreasing the pressure on the reaction
D) increasing the concentration of $O_2(g)$

12) Given the reaction at equilibrium:

$$BaCrO_4(s) \rightleftharpoons Ba^{2+}(aq) + CrO_4^{2-}(aq)$$

Which substance, when added to the mixture will cause an increase in the amount of $BaCrO_4(s)$?

A) $CaCO_3$ C) K_2CO_3
B) $BaCl_2$ D) $CaCl_2$

13) Which factors must be equal when a reversible chemical process reaches equilibrium?

A) mass of the reactants and mass of the products
B) rate of the forward reaction and rate of the reverse reaction
C) concentration of the reactants and concentration of the products
D) activation energy of the forward reaction and activation energy of the reverse reaction

14) According to *Solubility Curves* chemistry reference table, how many grams of NH_4Cl must be dissolved in 100 grams of H_2O at 70°C to reach solution equilibrium?

A) 61 g C) 52 g
B) 86 g D) 56 g

15) Given the reaction at equilibrium:

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

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

A) remains the same
B) decreases
C) increases

16) Given the reaction at equilibrium:

$$4HCl(g) + O_2(g) \rightleftharpoons 2Cl_2(g) + 2H_2O(g)$$

If the pressure on the system is increased, the concentration of $Cl_2(g)$ will

A) remain the same
B) decrease
C) increase

17) According to *Solubility Curves* chemistry reference table, which saturated solution would be the *most* dilute at 10°C?

A) NH_4Cl C) KNO_3
B) NaCl D) $KClO_3$

18) Based on the *Solubility Curves* chemistry reference table, 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 80°C
B) 40 g KCl at 60°C
C) 40 g KNO_3 at 25°C
D) 60 g $NaNO_3$ at 40°C

19) Given the reaction at equilibrium:

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) + 22 \text{ kcal}$$

Which stress would cause the equilibrium to shift to the left?

A) adding $H_2(g)$ to the system
B) increasing the pressure
C) increasing the temperature
D) adding $N_2(g)$ to the system

20) According to the *Solubility Curves* chemistry reference table, which of the following substances is *least* soluble in 100 grams of water at 50°C?

A) NH_4Cl C) NaCl
B) HCl D) KCl

Entropy

Identify each of the following as an example of an increase or decrease in entropy.

1. Water becoming ice.

2. Paper being shredded.

3. Warming a cup of tea.

4. Heating water to a vapor.

5. Hardening liquid wax.

6. Sugar dissolving in coffee.

7. Frost forming on a window pane.

8. Air pumped into a tire.

9. Acetone evaporating from nail polish remover.

10. $CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$

11. $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$

12. $NH_4Cl(s) \rightarrow NH_4^+{}_{(aq)} + Cl^-(aq)$

13. $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$

14. $NaCl(s) \rightarrow Na^+(aq) + Cl^-(aq)$

15. $H_2O(l) \rightarrow H_2O(s)$

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

17. $C_2H_5OH(g) \rightarrow C_2H_5OH(l)$

18. $2CO(g) + O_2(g) \rightarrow 2CO_2(g)$

19. $CO_2(s)$ **cooled from** $-80^\circ C$ **to** $-100^\circ C$

20. Water at $84^\circ C$ **is cooled to** $26^\circ C$

21. $C_6H_{12}O_6(s) \rightarrow C_6H_{12}O_6(aq)$

Review Sheet for Thermodynamics and Kinetics Unit Name_____

1. Define Entropy

2. Does Entropy increase or decrease for the following?

   a. Increasing temperature
   b. Solid -> Liquid
   c. Liquid -> Gas
   d. Solid -> Gas
   e. Gas -> Solid
   f. Gas -> Liquid
   g. Liquid -> Solid
   h. Reaction takes place that gives fewer products than reactants

3. Define Equilibrium

4. Solution Equilibrium
   For a closed system with a saturated solution, the rate of _____ equals the rate of _____. The _____remains the same.

5. Phase Equilibrium
   a. In a closed system at equilibrium at the melting point, the rate of the _____ equals the rate of _____.

   b. In a closed system at equilibrium at the boiling point, the rate of the _____ equals the rate of _____.

6. Reaction Equilibrium
   For a reversible reaction in a closed system at equilibrium, the rate of _____ equals the rate of _____. The concentration of _____ and _____ does not change.

7. Define Activation Energy.

8. Describe the Collision Theory.

9. Describe the effect of the following on the reaction rate and give the reason why it affects the reaction rate.
   a. Addition of a Catalyst

   b. Nature of Reactants

   For c – e, explain the effect of the following using the Collision Theory.

   c. Surface area /Particle Size

   d. Temperature

   e. Concentration (and pressure for gases)

17. Systems in nature tend to undergo changes toward _____(lower, higher) energy and _____(higher, lower) entropy.

10. State LeChatelier's Principle.

11. Describe how the following stresses shift the equilibrium of a reaction and change the concentration of the reactants and products.
    a. Addition of a Catalyst

    b. Change in Pressure

    c. Change of Temperature

    d. Adding more of a reactant or product

12. Define Heat of Reaction and give its equation.

13. For exothermic and endothermic reactions, give the following:

    a. Sign of the Heat of Reaction

    b. Is the energy absorbed or given off?

    c. The side of the equation energy is on.

    d. Stability of products vs. reactants.

    e. How the reaction changes the temperature of the environment.

14. Give the heat of the reaction for the creation of 2.5 moles of ethane.

15. A reaction will go to completion if one of the products is a _____ or _____.

16. For the following Potential Energy Diagrams

    a. Classify the forward and reverse reactions as either exothermic or endothermic.

    b. Label each diagram with
        1. Potential Energy of the Reactants
        2. Potential Energy of the Products
        3. Potential Energy of the Activated Complex
        4. Heat of Reaction
        5. Activation Energy for the Forward Reaction
        6. Activation Energy for the Reverse Reaction

    c. Draw a dashed line to show how the Potential Energy of the reaction pathway would change with the addition of a catalyst. Would the Heat of Reaction Change?

Name _____ Class _____ Date _____

Le Chatelier's Principle

According to Le Chatelier's Principle, when a system at equilibrium is subjected to a stress (a change in concentration, temperature, or pressure), the equilibrium will shift in the direction that tends to counteract the effect of the stress.

For each of the following systems at equilibrium, predict the effect of the given change on the concentration of the specific substances. Write I if the concentration increases, D if the concentration decreases, or R if the concentration remains the same.

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

1. Change: increase in $[N_2]$ — **1a.** _____
What is the effect on the concentration of:
a. $[NH_3]$ **b.** $[H_2]$ — **b.** _____

2. Change: increase in temperature — **2a.** _____
What is the effect on the concentration of:
a. $[N_2]$ **b.** $[NH_3]$ — **b.** _____

3. Change: increase in pressure — **3a.** _____
What is the effect on the:
a. number of moles of N_2 — **b.** _____
b. number of moles of NH_3

$2NO(g) \rightleftharpoons N_2(g) + O_2(g) + \text{heat}$

4. Change: decrease in $[O_2]$ — **4a.** _____
What is the effect on the concentration of:
a. $[N_2]$ **b.** $[NO]$ — **b.** _____

5. Change: decrease in temperature — **5a.** _____
What is the effect on the concentration of:
a. $[O_2]$ **b.** $[NO]$ — **b.** _____

6. Change: increase in pressure — **6a.** _____
What is the effect on the:
a. number of moles of O_2 — **b.** _____
b. number of moles of NO

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

7. Change: increase in $[SO_2]$ — **7a.** _____
What is the effect on the concentration of:
a. $[O_2]$ **b.** $[SO_3]$ — **b.** _____

8. Change: increase in temperature — **8a.** _____
What is the effect on the concentration of:
a. $[SO_2]$ **b.** $[SO_3]$ — **b.** _____

9. Change: decrease in pressure — **9a.** _____
What is the effect on the:
a. number of moles of O_2 — **b.** _____
b. number of moles of SO_3

17

LeChatelier's Principle: Complete the following table by describing the effect of the stresses put on this system at equilibrium. Show resulting concentrations with the appropriate symbol from the key below.

$C_3H_{8(g)} + 5O_{2(g)} \Leftrightarrow 3CO_{2(g)} + 4H_2O_{(g)}$ + energy

Stress	Equilibrium shift	$[C_3H_{8(g)}]$	$[O_{2(g)}]$	$[CO_{2(g)}]$	$[H_2O_{(g)}]$
Pressure Increase					
Pressure Decrease					
Temperature Increase					
Temperature Decrease					
$[C_3H_{8(g)}]$ Increase					
$[O_{2(g)}]$ Increase					
$[CO_{2(g)}]$ Decrease					
$[H_2O_{(g)}]$ Decrease					

Key:
Equilibrium Shift forward/right →
Equilibrium Shift reverse/left ←

Concentration increase ↑
Concentration decrease ↓

No Change -----

Le Chatelier Practice Problems

1 Given this reaction at equilibrium:

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

At constant temperature and pressure, an increase in the concentration of $A(g)$ will cause
(1) an increase in the concentration of $B(g)$
(2) a decrease in the concentration of $B(g)$
(3) a decrease in the concentration of $C(g)$
(4) a decrease in the concentration of $D(g)$

2 Given the Haber reaction at equilibrium:

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

Which stress on the system at equilibrium favors the production of $NH_3(g)$?
(1) decreasing the concentration of $N_2(g)$
(2) decreasing the concentration of $H_2(g)$
(3) increasing the pressure on the system
(4) increasing the temperature of the system

3 Given this reaction at equilibrium:

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

The equilibrium will shift to the right if there is an increase in
(1) temperature
(2) pressure
(3) concentration of $HI(g)$
(4) volume of the reaction container

4 Given this reaction at equilibrium:

$$H_2(g) + Cl_2(g) \leftrightarrows 2HCl(g) + \text{heat}$$

The equilibrium will shift to the right when there is an increase in
(1) temperature
(2) pressure
(3) concentration of $H_2(g)$
(4) concentration of $HCl(g)$

5 Which system at equilibrium will shift to the right when the pressure is increased?
(1) $NaCl(s) \overset{H_2O}{\rightleftarrows} Na^+(aq) + Cl^-(aq)$
(2) $C_2H_5OH(\ell) \overset{H_2O}{\rightleftarrows} C_2H_5OH(aq)$
(3) $NH_3(g) \overset{H_2O}{\rightleftarrows} NH_3(aq)$
(4) $C_6H_{12}O_6(s) \overset{H_2O}{\rightleftarrows} C_6H_{12}O_6(aq)$

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Le Chatelier Practice Problems (2)

5 Which change takes place when a catalyst is added to a reaction at equilibrium?
(1) The point of equilibrium is shifted to the right.
(2) The point of equilibrium is shifted to the left.
(3) The rates of the forward and reverse reactions are increased unequally.
(4) The rates of the forward and reverse reactions are increased equally.

6 Given the reaction

$$2Na(s) + 2H_2O(\ell) \rightarrow 2Na^+(aq) + 2OH^-(aq) + H_2(g)$$

This reaction goes to completion because one of the products formed is
(1) an insoluble base (2) a soluble base
(3) a precipitate (4) a gas

7 Given this reaction at equilibrium:

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

As the temperature increases, the rate of the forward reaction
(1) decreases (2) increases (3) remains the same

8 Given this reaction at equilibrium:

$$A(g) + B(g) = C(g) + D(g) + \text{heat}$$

As additional $A(g)$ is added to the system at constant temperature, the concentration of $B(g)$
(1) decreases (2) increases (3) remains the same

9 Given this reaction at equilibrium:

$$BaSO_4(s) \leftrightarrows Ba^{2+}(aq) + SO_4^{2-}(aq)$$

As the concentration of the SO_4^{2-} ions is increased, at constant temperature the concentration of Ba^{2+} ions
(1) decreases (2) increases (3) remains the same

10 Given the system

$$CO_2(aq) \leftrightarrows CO_2(g) \text{ at equilibrium}$$

As the pressure increases at constant temperature, the amount of $CO_2(g)$ will
(1) decrease (2) increase (3) remain the same

11 Given this reaction at equilibrium:

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

Which concentration changes occur when the temperature of the system is increased?
(1) The $[H_2]$ decreases and the $[O_2]$ decreases.
(2) The $[H_2]$ increases and the $[O_2]$ decreases.
(3) The $[H_2]$ decreases and the $[O_2]$ increases.
(4) The $[H_2]$ increases and the $[O_2]$ increases.

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12. Consider the following system at equilibrium:

$$2NO_2(g) \rightleftharpoons N_2(g) + 2O_2(g) + \text{heat energy}$$

A vessel contains $NO_2(g)$, $N_2(g)$, and $O_2(g)$ at equilibrium. How will each of the following stresses affect the equilibrium position?

(a) More $NO_2(g)$ is added to the vessel.
(b) Some $N_2(g)$ is removed from the vessel.
(c) The volume of the vessel is reduced to one-half its original value.
(d) Some He(g) is added to the vessel.
(e) The temperature of the system is increased.

13. Given this reaction at equilibrium:

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) + 197 \text{ kJ}$$

The amount of SO_3 will increase if there is

(1) an increase in temperature
(2) a decrease in pressure (an increase in volume)
(3) an increase in the concentration of SO_2
(4) a decrease in the concentration of O_2

14. Given this equilibrium system:

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

When a catalyst is added to this system, the rate of the forward reaction

(1) decreases and the rate of the reverse reaction decreases
(2) decreases and the rate of the reverse reaction increases
(3) increases and the rate of the reverse reaction decreases
(4) increases and the rate of the reverse reaction increases

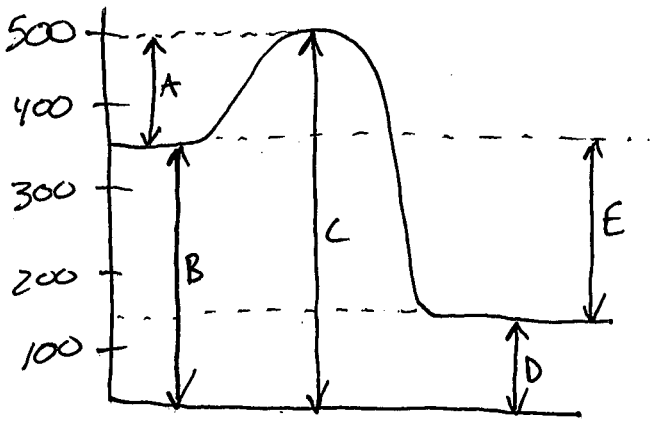
15. Given this equilibrium reaction:

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

If the volume of the reaction vessel is decreased at constant temperature, there will be an increase in the number of moles of

(1) N_2, only
(2) H_2, only
(3) NH_3, only
(4) N_2, H_2 and NH_3

(1)



	NAME	Amount
A =		
B =		
C =		
D =		
E =		

(2) Draw a PED for the production of H_2O from its components (Hint = Table I)

(3) Draw the change assoccated w/ the use of a Catalyst

(4) A) $H_2 + I_2 + Heat \leftrightarrow 2HI$

IF I Cool the System How will the equilibrium shift

B) $N_2 + 3H_2 \leftrightarrow 2NH_3 + Heat$

IF pressure is increased, which direction will be Favored

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

IF I add more B, what happens to A?

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Keeping the fizz in your soft drink

Question: Recently a co-worker was opening a 2-liter bottle of soda slowly to keep it from foaming because the air inside was whooshing out. She was scolded for doing it slowly because it would make the soda flat. Does that make sense?

Answer: Experts say the biggest factor on losing fizz is not whether you open the bottle fast or slow. It's whether the soda is warm or cold. If the soda is warm, it doesn't matter how you open it, you're gonna lose a lot of fizz.

Soda makers force carbon dioxide into drinks to make them carbonated. (The bubbles form carbonic acid, which actually changes the taste of the drink. Flat soda tastes too sweet, because that carbonic acid has been lost.)

Gas dissolves easier in cold soda; the fizz is in. That's because the carbon dioxide molecules are a lot more active when warm. So when a bottle of soda is warm, there's a lot of built-up pressure from those active carbon dioxide molecules. You open the bottle, and there's suddenly a great pressure differential between what's inside and outside the bottle. That telltale soda-opening hiss is the pressure equalizing itself. And then, with no pressure holding the carbon dioxide in the soda, it slowly leaks out through bubbles.

So if you want to keep your soda fizzy, keep it cold and recap it fast.

Name_____ Kinetics Quiz #1

1) List five factors that can affect the rate of a reaction.
   a.
   b.
   c.
   d.
   e.

2) Describe the collision theory:

3) Is it necessary for the quantities of a reactant and product to be equal in order for a system to be in equilibrium?

4) What occurs during phase equilibrium?

5) $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) + heat$ Using the equation to the left, determine what will occur to the equilibrium, if the following were to occur. (Hint! describe the shift that occurs)
   a. heat was added: Result →_____
   b. Oxygen was added in to the system: Result →_____

Bonus: 1) Give the name of and reasons why the purple catalyst from the movie was worth $350,000?

2) Explain how you would make a glow stick last longer and why this process works in terms of kinetics;

3) Why was the 'OC' on for 2 hours last night?

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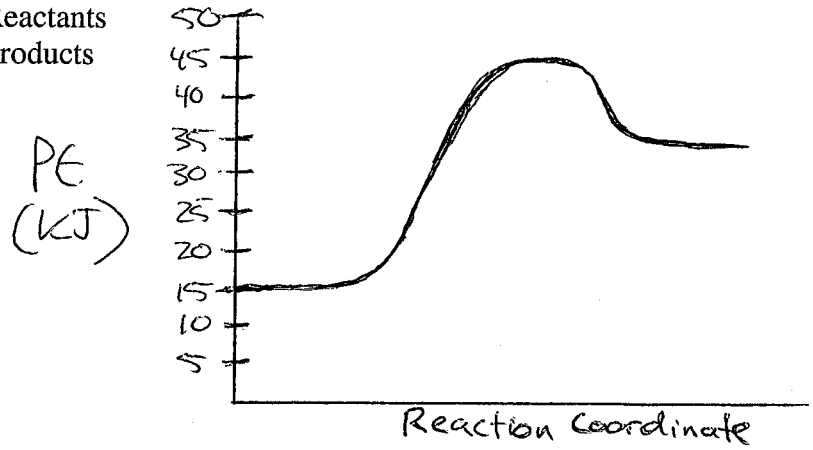
Name_____

Kinetics Quiz #2

1) Label the following parts of the potential energy diagram below with double arrows:
   a. Potential Energy of the Reactants
   b. Potential Energy of the Products
   c. Activated complex
   d. Heat of reaction



2) Using the above diagram, what is the potential energy value for Heat of Reaction?

3) In same diagram above, is this exothermic or endothermic?

4) List four factors that can affect the rate of a reaction:

5) In the following equation→ $CO_2(g) \leftrightarrow CO_2(aq)$
   a. If I were to add heat to this system, would it cause the equilibrium to shift to the left or right?

   b. If I increased the pressure on the system, would it cause the equilibrium to shift in the forward or reverse direction?

6) Describe the two main details of the collision theory and how a reaction may occur:

7) When a catalyst or inhibitor is added into a system, which part of the reaction will be modified?

Name: _____ Class: _____ Date: _____ ID: A

Kinetics-Equilibrium

Multiple Choice
Identify the letter of the choice that best completes the statement or answers the question.

____ 1. In a concentrated solution there is ____.
a. no solvent b. a large amount of solute c. a small amount of solute d. no solute

____ 2. What is the molarity of a solution that contains 6 moles of solute in 2 liters of solution?
a. 6*M* b. 12*M* c. 7*M* d. 3*M*

____ 3. What is the number of moles of solute in 250 mL of a 0.4*M* solution?
a. 0.1 mol b. 0.16 mol c. 0.62 mol d. 1.6 mol

____ 4. If the percent by volume is 2.0% and the volume of solution is 250 mL, what is the volume of solute in solution?
a. 0.5 mL b. 1.25 mL c. 5.0 mL d. 12.5 mL

____ 5. What is the term for the dissolving medium in a solution?
a. solvent b. solute c. solvator d. emulsifier

____ 6. A solution is a mixture ____.
a. from which the solute can be filtered b. that has the same properties throughout c. that is heterogeneous
d. in which a solid solute is always dissolved in a liquid solvent

____ 7. An electric current can be conducted by ____.
a. methane gas b. a sugar solution c. a salt solution d. rubbing alcohol

____ 8. Which of the following mixture types is characterized by the settling of particles?
a. solution b. suspension c. colloid d. hydrate

____ 9. Why does a higher temperature cause a reaction to go faster?
a. There are more collisions per second only. b. Collisions occur with greater energy only. c. There are more collisions per second and the collisions are of greater energy. d. There are more collisions per second or the collisions are of greater energy.

____ 10. What happens to a catalyst in a reaction?
a. It is unchanged. b. It is incorporated into the products. c. It is incorporated into the reactants. d. It evaporates away.

____ 11. A catalyst works by ____.
a. lowering the activation energy barrier b. shifting the equilibrium position toward the products
c. changing the temperature of the reactants d. changing the particle size of the reactants

____ 12. The rate of a chemical reaction normally ____.
a. decreases as temperature increases b. is slowed down by a catalyst c. increases as reactant concentration increases d. decreases as reactant concentration increases

____ 13. Which of the following substances act as catalysts in the body?
a. carbohydrates b. nucleic acids c. lipids d. enzymes

____ 14. At equilibrium, what is the rate of production of reactants compared with the rate of production of products?
a. much higher b. higher c. the same d. lower

(25)

____ 15. If sulfur dioxide and oxygen can be made into sulfur trioxide, what is the reverse reaction?
a. $2SO_3 \rightarrow 2SO_2 + O_2$ b. $SO_3 + O_2 \rightarrow SO_5$ c. $2SO_2 + O_2 \rightarrow 2SO_3$ d. $SO_2 + 2SO_3 \rightarrow 3S + 4O_2$

____ 16. Consider the reaction $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$. What is the effect of decreasing the volume on the contained gases?
a. The reaction shifts toward the product gas. b. The system reacts by increasing the number of gas molecules. c. The pressure on the gases decreases momentarily. d. Ammonia is consumed in the reaction.

____ 17. What happens to a reaction at equilibrium when more reactant is added to the system?
a. The reaction makes more products. b. The reaction makes more reactants. c. The reaction is unchanged. d. The answer cannot be determined.

____ 18. In an endothermic reaction at equilibrium, what is the effect of raising the temperature?
a. The reaction makes more products. b. The reaction makes more reactants. c. The reaction is unchanged. d. The answer cannot be determined.

____ 19. Which of the changes listed below would shift the following reaction to the right?
$4HCl(g) + O_2(g) \rightleftharpoons 2Cl_2(g) + 2H_2O(g)$
a. addition of Cl_2 b. removal of O_2 c. increase of pressure d. decrease of pressure

____ 20. What is the effect of adding more water to the following equilibrium reaction?
$CO_2 + H_2O \rightleftharpoons H_2CO_3$
a. More H_2CO_3 is produced. b. CO_2 concentration increases. c. The equilibrium is pushed in the direction of reactants. d. There is no effect.

____ 21. Entropy measures ____.
a. energy b. heat transferred c. disorder d. force

____ 22. If a system is left to change spontaneously, in what state will it end?
a. the same state in which it began b. the state with lowest possible energy c. the state with the maximum disorder d. the state with the lowest possible energy consistent with the state of maximum disorder

____ 23. Which reaction results in the greatest increase in entropy?
a. $A \rightarrow B$ b. $A \rightarrow 2B$ c. $2A \rightarrow B$ d. $3A \rightarrow B$

____ 24. This symbol ($\rightleftharpoons$) indicates that ____.
a. heat must be applied b. an incomplete combustion reaction has occurred c. a gas is formed by the reaction d. the reaction is reversible

____ 25. What are the coefficients that will balance the skeleton equation below?
$AlCl_3 + NaOH \rightarrow Al(OH)_3 + NaCl$
a. 1, 3, 1, 3 b. 3, 1, 3, 1 c. 1, 1, 1, 3 d. 1, 3, 3, 1

____ 26. Which of the following statements is NOT true about what happens in all chemical reactions?
a. The ways in which atoms are joined together are changed. b. New atoms are formed as products. c. The starting substances are called reactants. d. The bonds of the reactants are broken and new bonds of the products are formed.

____ 27. Chemical equations must be balanced to satisfy ____.
a. the law of definite proportions b. the law of multiple proportions c. the law of conservation of mass
d. Avogadro's principle

____ 28. When potassium hydroxide and barium chloride react, potassium chloride and barium hydroxide are formed. The balanced equation for this reaction is ____.
a. $KH + BaCl \rightarrow KCl + BaH$ b. $KOH + BaCl \rightarrow KCl + BaOH$ c. $2KOH + BaCl_2 \rightarrow 2KCl + Ba(OH)_2$
d. $KOH + BaCl_2 \rightarrow KCl_2 + BaOH$

____ 29. In order for the reaction $2Al + 6HCl \rightarrow 2AlCl_3 + 3H_2$ to occur, which of the following must be true?
a. Al must be above Cl on the activity series. b. Al must be above H on the activity series. c. Heat must be supplied for the reaction. d. A precipitate must be formed.

____ 30. In a combustion reaction, one of the reactants is ____.
a. hydrogen b. nitrogen c. oxygen d. a metal

____ 31. In a double-replacement reaction, the ____.
a. products are always molecular b. reactants are two ionic compounds c. reactants are two elements
d. products are a new element and a new compound

____ 32. Which of the following is a balanced equation representing the decomposition of lead(IV) oxide?
a. $PbO_2 \rightarrow Pb + 2O$ b. $PbO_2 \rightarrow Pb + O_2$ c. $Pb_2O \rightarrow 2Pb + O$ d. $PbO \rightarrow Pb + O_2$

____ 33. In the activity series of metals, which metal(s) will displace hydrogen from an acid?
a. only metals above hydrogen b. only metals below hydrogen c. any metal d. only metals from Li to Na

____ 34. Use the activity series of metals to complete a balanced chemical equation for the following single replacement reaction.
$Ag(s) + KNO_3(aq) \rightarrow$
a. $AgNO_3 + K$ b. $AgK + NO_3$ c. $AgKNO_3$ d. No reaction takes place because silver is less reactive than potassium.

____ 35. The reaction $2Fe + 3Cl_2 \rightarrow 2FeCl_3$ is an example of which type of reaction?
a. combustion reaction b. single-replacement reaction c. synthesis reaction d. decomposition reaction

____ 36. How many hydrogen atoms are in 5 molecules of isopropyl alcohol, C_3H_7O?
a. $5 \times (6.02 \times 10^{23})$ b. 5 c. 35 d. $35 \times (6.02 \times 10^{23})$

____ 37. Avogadro's number of representative particles is equal to one ____.
a. kilogram b. gram c. kelvin d. mole

____ 38. The volume of one mole of a substance is 22.4 L at STP for all ____.
a. gases b. liquids c. solids d. compounds

____ 39. Which combination of temperature and pressure correctly describes standard temperature and pressure, STP?
a. 0°C and 101 kPa b. 1°C and 0 kPa c. 0°C and 22.4 kPa d. 100°C and 100 kPa

____ 40. Which of the following is NOT true about empirical and molecular formulas?
a. The molecular formula of a compound can be the same as its empirical formula. b. The molecular formula of a compound can be some whole-number multiple of its empirical formula. c. Several compounds can have the same empirical formula, but have different molecular formulas. d. The empirical formula of a compound can be triple its molecular formula.

Short Answer

41. What is the percentage of water in the hydrate $CoCl_2 \cdot 6H_2O$?

42. Balance the following equation.
$Mg + H_3PO_4 \rightarrow Mg_3(PO_4)_2 + H_2$

43. Balance the following equation.
$Au_2O_3 \rightarrow Au + O_2$

44. Find the mass, in grams, of 1.40×10^{23} molecules of N_2.

Essay

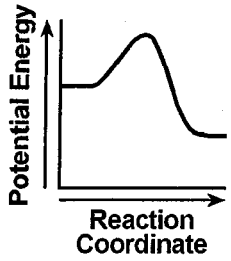
45. Discuss the different factors that can affect the solubility of a substance. Include specific examples in your discussion.

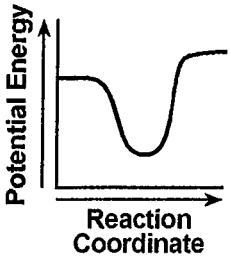
Name: _____

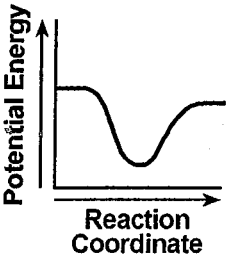
1) Which statement correctly describes an endothermic chemical reaction?

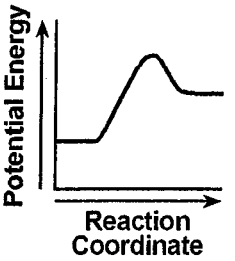
A) The products have lower potential energy than the reactants, and the DH is positive.
B) The products have lower potential energy than the reactants, and the DH is negative.
C) The products have higher potential energy than the reactants, and the DH is positive.
D) The products have higher potential energy than the reactants, and the DH is negative.

2) According to the *Heats of Reaction at 101.3 kPa and 298 K* chemistry reference table, which potential energy diagram *best* represents the reaction that forms $H_2O(l)$ from its elements?

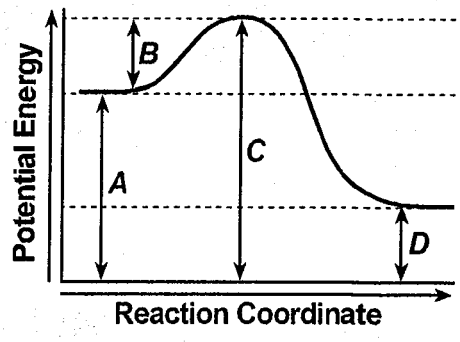
A)


B)


C)


D)


3) 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*

4) Which event must *always* occur for a chemical reaction to take place?

A) addition of a catalyst to the reaction system
B) formation of a gas
C) effective collisions between reacting particles
D) formation of a precipitate

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

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

6) Which statement *best* explains the role of a catalyst in a chemical reaction?

A) A catalyst is added as an additional reactant and is consumed but not regenerated.
B) A catalyst changes the kinds of products produced.
C) A catalyst provides an alternate reaction pathway that requires less activation energy.
D) A catalyst limits the amount of reactants used.

7) Which process is accompanied by a decrease in entropy?

A) subliming of iodine
B) melting of ice
C) boiling of water
D) condensing of water vapor

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8) Given the equation:

$$KNO_3(s) \xrightarrow{H_2O(\ell)} KNO_3(aq)$$

As $H_2O(l)$ is added to $KNO_3(s)$ to form $KNO_3(aq)$, the entropy of the system

A) remains the same
B) increases
C) decreases

9) Which type or types of change, if any, can reach equilibrium?

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

10) Which statement about a system at equilibrium is true?

A) The forward reaction rate is equal to the reverse reaction rate.
B) The forward reaction rate stops and the reverse reaction rate continues.
C) The forward reaction rate is less than the reverse reaction rate.
D) The forward reaction rate is greater than the reverse reaction rate.

11) Given the equilibrium at 101.3 kPa:

$$H_2O(s) \text{ âää } H_2O(l)$$

At what temperature does this equilibrium occur?

A) 273 K
B) 373 K
C) 298 K
D) 100 K

12) Given the reaction at equilibrium:

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

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

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

13) Given the reaction:

$$N_2(g) + O_2(g) + 182.6 \text{ kJ } \text{âää } 2NO(g)$$

Which change would cause an immediate increase in the rate of the forward reaction?

A) decreasing the reaction pressure
B) increasing the concentration of NO(g)
C) increasing the concentration of $N_2(g)$
D) decreasing the reaction temperature

14) Given the equilibrium reaction in a closed system:

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

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

15) Given the reaction at equilibrium:

$$C_2(g) + D_2(g) \text{ âää } 2CD(g) + \text{energy}$$

Which change will cause the equilibrium to shift?

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

16) Given the reaction at 25DC:

$$Zn(s) + 2HCl(aq) \text{ ÅÇ } ZnCl_2(aq) + H_2(g)$$

The rate of this reaction can be increased by using 5.0 grams of powdered zinc instead of a 5.0-gram strip of zinc because the powdered zinc has

A) more zinc atoms
B) lower concentration
C) lower kinetic energy
D) more surface area

17) Which sample has the *lowest* entropy?

A) 1 mole of $KNO_3(s)$
B) 1 mole of $KNO_3(l)$
C) 1 mole of $H_2O(g)$
D) 1 mole of $H_2O(l)$

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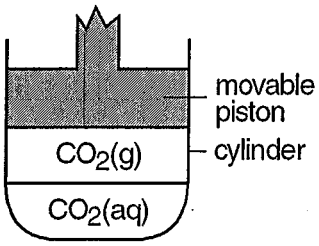
18) Which statement correctly describes a chemical reaction at equilibrium?

A) The concentrations of the products and reactants are constant.
B) The concentrations of the products and reactants are equal.
C) The rate of the forward reaction is greater than the rate of the reverse reaction.
D) The rate of the forward reaction is less than the rate of the reverse reaction.

19) A solution that is at equilibrium must be

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

20) Given the diagram below that shows carbon dioxide in an equilibrium system at a temperature of 298 K and a pressure of 1 atm:



Which changes must increase the solubility of the carbon dioxide?

A) decrease pressure and increase temperature
B) decrease pressure and decrease temperature
C) increase pressure and decrease temperature
D) increase pressure and increase temperature

21) A student wishes to determine how the rate of reaction of magnesium strips with hydrochloric acid, HCl(aq), varies as a function of temperature of the HCl(aq). Give *two* additional factors, other than the temperature, that could affect the rate of reaction and must be held constant during the experiment.

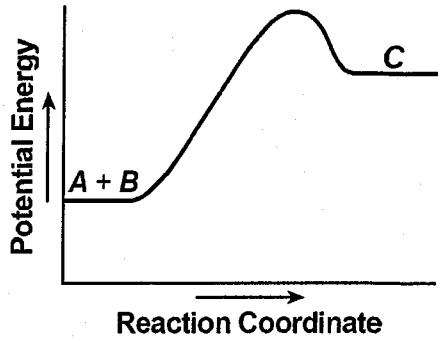
22) Given the equation for the dissolving of sodium chloride in water:

$$NaCl(s) \xrightarrow{H_2O} Na^+(aq) + Cl^-(aq)$$

When NaCl(s) is added to water in a 250-milliliter beaker, the temperature of the mixture is lower than the original temperature of the water. Describe this observation in terms of heat flow.

Questions 23 and 24 refer to the following:

The diagram below represents the changes in potential energy that occur during the given reaction: $A + B \rightarrow C$.

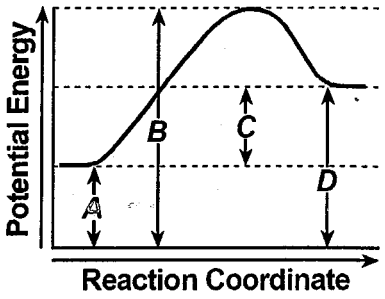


23) Does the diagram illustrate an exothermic or an endothermic reaction? [*State one reason, in terms of energy, to support your answer.*]

24) On the given above, draw a dashed line to indicate a potential energy curve for the reaction if a catalyst is added.

Questions 25 and 26 refer to the following:

Chemical cold packs are often used to reduce swelling after an athletic injury. The diagram below represents the potential energy changes when a cold pack is activated.



25) Which lettered interval on the given diagram represents the heat of reaction?

26) Which lettered interval on the given diagram represents the potential energy of the products?

27) Given the reaction at equilibrium:

$N_2(g) + 3H_2(g)$ âäã $2NH_3(g) + 92.05$ kJ

(a) State the effect on the number of moles of $N_2(g)$ if the temperature of the system is increased.

(b) State the effect on the number of moles of $H_2(g)$ if the pressure on the system is increased.

(c) State the effect on the number of moles of $NH_3(g)$ if a catalyst is introduced into the reaction system. [*Explain why this occurs.*]

NOTE: Be sure you actually do study this year...Each night, put some time in and you will see the exponential growth of your knowledge that will help you on upcoming exams in this class.

Kinetics

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