

Unit 6 - Kinetics / Equilibrium

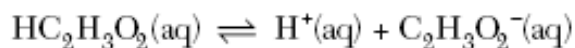
January 2008

20 Which term refers to the difference between the potential energy of the products and the potential energy of the reactants for any chemical change?

- (1) heat of deposition (3) heat of reaction
(2) heat of fusion (4) heat of vaporization

Base your answers to questions 61 through 63 on the information below.

A beaker contains 100.0 milliliters of a dilute aqueous solution of ethanoic acid at equilibrium. The equation below represents this system.



61 Compare the rate of the forward reaction to the rate of the reverse reaction for this system. [1]

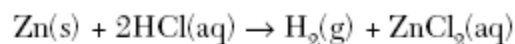
62 Describe what happens to the concentration of $\text{H}^+(\text{aq})$ when 10 drops of concentrated $\text{HC}_2\text{H}_3\text{O}_2(\text{aq})$ are added to this system. [1]

63 In the space *in your answer booklet*, draw a structural formula for ethanoic acid. [1]

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August 2007

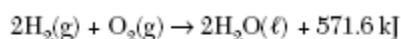
46 Given the balanced equation representing a reaction:



Which set of reaction conditions produces $\text{H}_2\text{(g)}$ at the fastest rate?

- (1) a 1.0-g lump of Zn(s) in 50. mL of 0.5 M HCl(aq) at $20.^\circ\text{C}$
- (2) a 1.0-g lump of Zn(s) in 50. mL of 0.5 M HCl(aq) at $30.^\circ\text{C}$
- (3) 1.0 g of powdered Zn(s) in 50. mL of 1.0 M HCl(aq) at $20.^\circ\text{C}$
- (4) 1.0 g of powdered Zn(s) in 50. mL of 1.0 M HCl(aq) at $30.^\circ\text{C}$

Base your answers to questions 61 through 63 on the reaction represented by the balanced equation below.



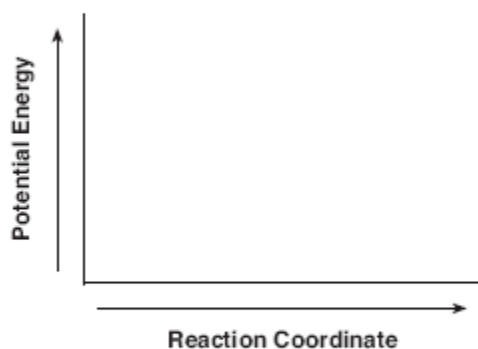
61 Identify the information in this equation that indicates the reaction is exothermic. [1]

62 On the axes *in your answer booklet*, draw a potential energy diagram for the reaction represented by this equation. [1]

63 Explain why the entropy of the system *decreases* as the reaction proceeds. [1]

61 _____

62



63 _____

Unit 6 - Kinetics / Equilibrium

June 2007

16 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)

17 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

54 Explain, in terms of collision theory, why the rate of a chemical reaction increases with an increase in temperature. [1]

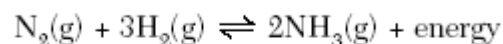
54 _____

January 2007

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

- (1) The concentration of the products is greater than the concentration of the reactants.
- (2) The concentration of the products is less than the concentration of the reactants.
- (3) The concentration of the products and the concentration of the reactants are equal.
- (4) The concentration of the products and the concentration of the reactants are constant.

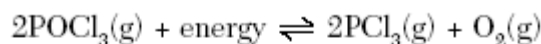
44 Given the equation representing a reaction at equilibrium:



Which change causes the equilibrium to shift to the right?

- (1) decreasing the concentration of $\text{H}_2(\text{g})$
- (2) decreasing the pressure
- (3) increasing the concentration of $\text{N}_2(\text{g})$
- (4) increasing the temperature

44 Given the system at equilibrium:



Which changes occur when $\text{O}_2(\text{g})$ is added to this system?

- (1) The equilibrium shifts to the right and the concentration of $\text{PCl}_3(\text{g})$ increases.
- (2) The equilibrium shifts to the right and the concentration of $\text{PCl}_3(\text{g})$ decreases.
- (3) The equilibrium shifts to the left and the concentration of $\text{PCl}_3(\text{g})$ increases.
- (4) The equilibrium shifts to the left and the concentration of $\text{PCl}_3(\text{g})$ decreases.

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59 Explain, in terms of collision theory, why an increase in temperature increases the rate of a chemical reaction. [1]

59

August 2006

16 Which statement best describes how a catalyst increases the rate of a reaction?

- (1) The catalyst provides an alternate reaction pathway with a higher activation energy.
- (2) The catalyst provides an alternate reaction pathway with a lower activation energy.
- (3) The catalyst provides the same reaction pathway with a higher activation energy.
- (4) The catalyst provides the same reaction pathway with a lower activation energy.

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

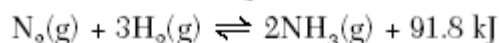
- (1) faster and more reactant is produced
- (2) faster and more product is produced
- (3) the same and the reaction has stopped
- (4) the same and the reaction continues in both directions

June 2006

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

- (1) the activation energies of the forward and reverse reactions
- (2) the rates of the forward and reverse reactions
- (3) the concentrations of the reactants and products
- (4) the potential energies of the reactants and products

45 Given the reaction at equilibrium:



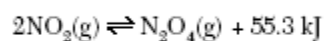
What occurs when the concentration of $\text{H}_2(\text{g})$ is increased?

- (1) The rate of the forward reaction increases and the concentration of $\text{N}_2(\text{g})$ decreases.
- (2) The rate of the forward reaction decreases and the concentration of $\text{N}_2(\text{g})$ increases.
- (3) The rate of the forward reaction and the concentration of $\text{N}_2(\text{g})$ both increase.
- (4) The rate of the forward reaction and the concentration of $\text{N}_2(\text{g})$ both decrease.

Unit 6 - Kinetics / Equilibrium

Base your answers to questions 59 and 60 on the information below.

Given the reaction at equilibrium:



- 59 Explain, in terms of energy, why the forward reaction is exothermic. [1]
- 60 Explain, in terms of Le Chatelier's principle, why the equilibrium shifts to the right to relieve the stress when the pressure on the system is increased at constant temperature. [1]

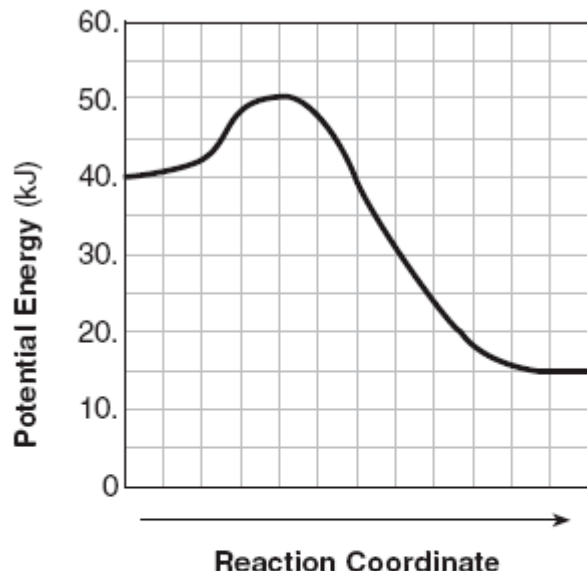
59 _____

60 _____

Unit 6 - Kinetics / Equilibrium

January 2006

43 Given the potential energy diagram for a chemical reaction:

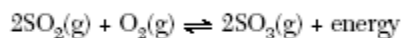


Which statement correctly describes the energy changes that occur in the forward reaction?

- (1) The activation energy is 10. kJ and the reaction is endothermic.
- (2) The activation energy is 10. kJ and the reaction is exothermic.
- (3) The activation energy is 50. kJ and the reaction is endothermic.
- (4) The activation energy is 50. kJ and the reaction is exothermic.

Base your answers to questions 59 and 60 on the information and balanced equation below.

Given the equation for a reaction at equilibrium:



- 59 Explain, in terms of LeChatelier's principle, why the concentration of $\text{SO}_2(\text{g})$ increases when the temperature is increased. [1]
- 60 Explain, in terms of collisions between molecules, why increasing the concentration of $\text{O}_2(\text{g})$ produces a *decrease* in the concentration of $\text{SO}_2(\text{g})$. [1]

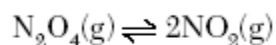
Unit 6 - Kinetics / Equilibrium

59

60

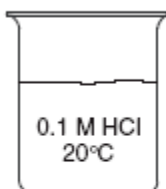
August 2005

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

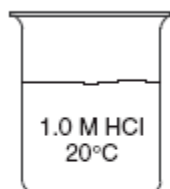


The measurable quantities of the gases at equilibrium must be

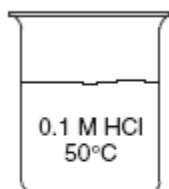
- (1) decreasing (3) equal
(2) increasing (4) constant
- 24 In each of the four beakers shown below, a 2.0-centimeter strip of magnesium ribbon reacts with 100 milliliters of HCl(aq) under the conditions shown.



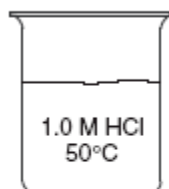
Beaker A



Beaker B



Beaker C



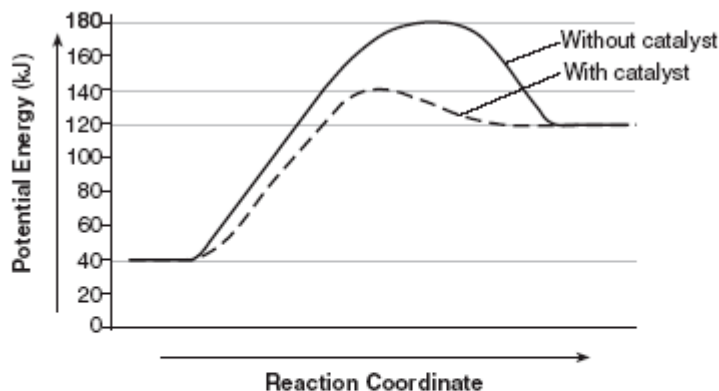
Beaker D

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

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

Unit 6 - Kinetics / Equilibrium

Base your answers to questions 53 through 55 on the potential energy diagram below.



53 What is the heat of reaction for the forward reaction? [1]

54 What is the activation energy for the forward reaction with the catalyst? [1]

55 Explain, in terms of the function of a catalyst, why the curves on the potential energy diagram for the catalyzed and uncatalyzed reactions are different. [1]

53 _____ kJ

54 _____ kJ

55 _____

June 2005

16 The kinetic molecular theory assumes that the particles of an ideal gas

- (1) are in random, constant, straight-line motion
- (2) are arranged in a regular geometric pattern
- (3) have strong attractive forces between them
- (4) have collisions that result in the system losing energy

18 Which statement must be true about a chemical system at equilibrium?

- (1) The forward and reverse reactions stop.
- (2) The concentration of reactants and products are equal.
- (3) The rate of the forward reaction is equal to the rate of the reverse reaction.
- (4) The number of moles of reactants is equal to the number of moles of product.

19 Adding a catalyst to a chemical reaction results in

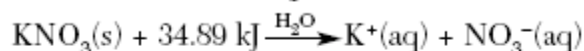
- (1) a decrease in activation energy and a decrease in the reaction rate
- (2) a decrease in activation energy and an increase in the reaction rate
- (3) an increase in activation energy and a decrease in the reaction rate
- (4) an increase in activation energy and an increase in the reaction rate

20 Systems in nature tend to undergo changes toward

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

Unit 6 - Kinetics / Equilibrium

44 Given the balanced equation:



Which statement best describes this process?

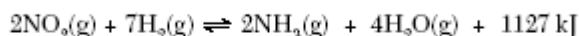
- (1) It is endothermic and entropy increases.
- (2) It is endothermic and entropy decreases.
- (3) It is exothermic and entropy increases.
- (4) It is exothermic and entropy decreases.

45 A 1.0-gram piece of zinc reacts with 5 milliliters of $\text{HCl}(\text{aq})$. Which of these conditions of concentration and temperature would produce the greatest rate of reaction?

- (1) 1.0 M $\text{HCl}(\text{aq})$ at $20.^\circ\text{C}$
- (2) 1.0 M $\text{HCl}(\text{aq})$ at $40.^\circ\text{C}$
- (3) 2.0 M $\text{HCl}(\text{aq})$ at $20.^\circ\text{C}$
- (4) 2.0 M $\text{HCl}(\text{aq})$ at $40.^\circ\text{C}$

Base your answers to questions 57 and 58 on the information below.

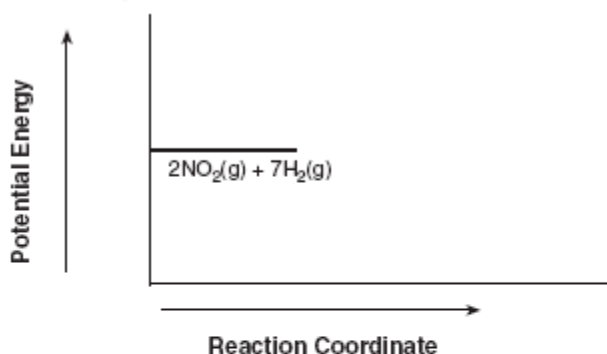
Given the reaction at equilibrium:



57 On the diagram in *your answer booklet*, complete the potential energy diagram for the forward reaction. Be sure your drawing shows the activation energy and the potential energy of the products. [2]

58 Explain, in terms of Le Chatelier's principle, why the concentration of $\text{NH}_3(\text{g})$ *decreases* when the temperature of the equilibrium system increases. [1]

57



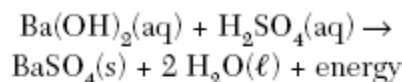
58

January 2005

43 Which of these changes produces the greatest increase in entropy?

- (1) $\text{CaCO}_3(\text{s}) \rightarrow \text{CaO}(\text{s}) + \text{CO}_2(\text{g})$
- (2) $2 \text{Mg}(\text{s}) + \text{O}_2(\text{g}) \rightarrow 2 \text{MgO}(\text{s})$
- (3) $\text{H}_2\text{O}(\text{g}) \rightarrow \text{H}_2\text{O}(\ell)$
- (4) $\text{CO}_2(\text{g}) \rightarrow \text{CO}_2(\text{s})$

46 Given the reaction:

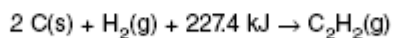
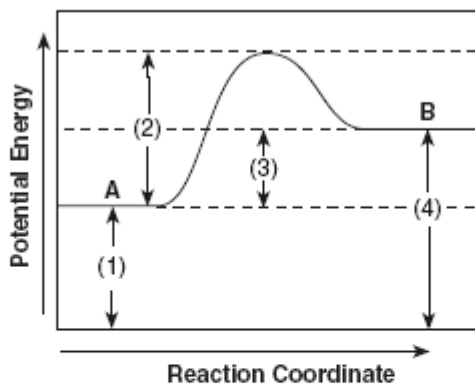


As the barium hydroxide solution is added to the solution of sulfuric acid, the electrical conductivity of the acid solution decreases because the

- (1) volume of the reaction mixture increases
- (2) temperature of the reaction mixture decreases
- (3) concentration of ions increases
- (4) concentration of ions decreases

Unit 6 - Kinetics / Equilibrium

Base your answers to questions 56 through 58 on the potential energy diagram and the equation below.



56 The letter *B* represents which chemical formula or formulas in the equation? [1]

57 If 682.2 kilojoules are absorbed, how many moles of $\text{C}_2\text{H}_2\text{(g)}$ are produced? [1]

58 Describe how the potential energy diagram will change if a catalyst is added. [1]

56 _____

57 _____ mol

58 _____

Unit 6 - Kinetics / Equilibrium

Base your answers to questions 70 through 72 on the information below.

In a laboratory experiment, 10.00 grams of an unknown solid is added to 100.0 milliliters of water and the temperature of the resulting solution is measured over several minutes, as recorded in the table below.

Data Table

Time (minutes)	Temperature (°C)
0	24.0
0.5	28.5
1.0	31.0
1.5	34.5
2.0	41.0
2.5	45.5
3.0	46.5

- 70 On the grid provided in *your answer booklet*, mark an appropriate scale on the axis labeled "Temperature (°C)." An appropriate scale is one that allows a trend to be seen. [1]
- 71 Plot the data from the data table. Circle and connect the points. [1]

Example: 

- 72 Given the statement:

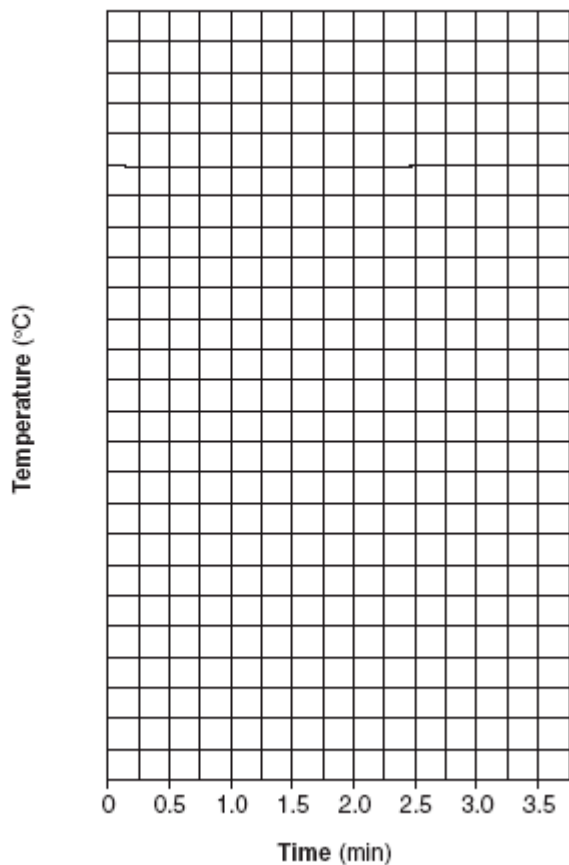
The unknown solid is either sodium hydroxide or lithium bromide, and both of these compounds dissolve in water exothermically.

- a* Explain how the experimental data support the statement. [1]
- b* State specific information from Reference Table *I* to support the statement. [1]

Unit 6 - Kinetics / Equilibrium

70 and 71

Change in Temperature During the Dissolving of a Solid



72 *a* _____

b _____

Unit 6 - Kinetics / Equilibrium

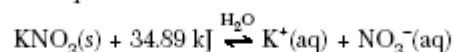
August 2004

- 14 Based on Reference Table I, which change occurs when pellets of solid NaOH are added to water and stirred?
- (1) The water temperature increases as chemical energy is converted to heat energy.
 - (2) The water temperature increases as heat energy is stored as chemical energy.
 - (3) The water temperature decreases as chemical energy is converted to heat energy.
 - (4) The water temperature decreases as heat energy is stored as chemical energy.
- 18 At STP, which 4.0-gram zinc sample will react fastest with dilute hydrochloric acid?
- | | |
|----------|-----------------|
| (1) lump | (3) powdered |
| (2) bar | (4) sheet metal |
- 19 Which information about a chemical reaction is provided by a potential energy diagram?
- (1) the oxidation states of the reactants and products
 - (2) the average kinetic energy of the reactants and products
 - (3) the change in solubility of the reacting substances
 - (4) the energy released or absorbed during the reaction
- 20 A catalyst works by
- (1) increasing the potential energy of the reactants
 - (2) increasing the energy released during a reaction
 - (3) decreasing the potential energy of the products
 - (4) decreasing the activation energy required for a reaction
- 21 Even though the process is endothermic, snow can sublime. Which tendency in nature accounts for this phase change?
- (1) a tendency toward greater entropy
 - (2) a tendency toward greater energy
 - (3) a tendency toward less entropy
 - (4) a tendency toward less energy
- 45 Given the reaction at equilibrium:
- $$\text{N}_2(\text{g}) + \text{O}_2(\text{g}) + \text{energy} \rightleftharpoons 2 \text{NO}(\text{g})$$
- Which change will result in a *decrease* in the amount of NO(g) formed?
- (1) decreasing the pressure
 - (2) decreasing the concentration of N₂(g)
 - (3) increasing the concentration of O₂(g)
 - (4) increasing the temperature

Unit 6 - Kinetics / Equilibrium

Base your answers to questions 63 and 64 on the information below.

Given the equilibrium equation at 298 K:



63 Describe, in terms of *LeChatelier's principle*, why an increase in temperature increases the solubility of KNO_3 . [1]

64 The equation indicates that KNO_3 has formed a saturated solution. Explain, in terms of *equilibrium*, why the solution is saturated. [1]

63 _____

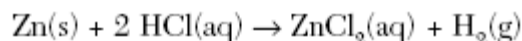
64 _____

June 2004

15 The average kinetic energy of water molecules is greatest in which of these samples?

- (1) 10 g of water at 35°C
- (2) 10 g of water at 55°C
- (3) 100 g of water at 25°C
- (4) 100 g of water at 45°C

19 Given the reaction at 25°C:



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

- (1) lower kinetic energy
- (2) lower concentration
- (3) more surface area
- (4) more zinc atoms

20 Which statement about a system at equilibrium is true?

- (1) The forward reaction rate is less than the reverse reaction rate.
- (2) The forward reaction rate is greater than the reverse reaction rate.
- (3) The forward reaction rate is equal to the reverse reaction rate.
- (4) The forward reaction rate stops and the reverse reaction rate continues.

21 A catalyst increases the rate of a chemical reaction by

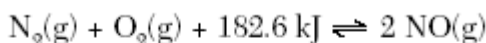
- (1) lowering the activation energy of the reaction
- (2) lowering the potential energy of the products
- (3) raising the temperature of the reactants
- (4) raising the concentration of the reactants

42 A solution that is at equilibrium must be

- (1) concentrated
- (2) dilute
- (3) saturated
- (4) unsaturated

Unit 6 - Kinetics / Equilibrium

43 Given the reaction:



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

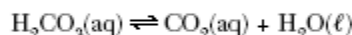
- (1) increasing the concentration of $\text{NO}(\text{g})$
- (2) increasing the concentration of $\text{N}_2(\text{g})$
- (3) decreasing the reaction temperature
- (4) decreasing the reaction pressure

44 Which 10-milliliter sample of water has the greatest degree of disorder?

- (1) $\text{H}_2\text{O}(\text{g})$ at 120°C
- (2) $\text{H}_2\text{O}(\ell)$ at 80°C
- (3) $\text{H}_2\text{O}(\ell)$ at 20°C
- (4) $\text{H}_2\text{O}(\text{s})$ at 0°C

Base your answers to questions 79 and 80 on the information and equation below.

Human blood contains dissolved carbonic acid, H_2CO_3 , in equilibrium with carbon dioxide and water. The equilibrium system is shown below.



79 Explain, using LeChatelier's principle, why decreasing the concentration of CO_2 decreases the concentration of H_2CO_3 . [1]

80 What is the oxidation number of carbon in $\text{H}_2\text{CO}_3(\text{aq})$? [1]

79 _____

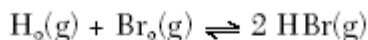
80 _____

January 2004

16 Which statement best explains the role of a catalyst in a chemical reaction?

- (1) A catalyst is added as an additional reactant and is consumed but not regenerated.
- (2) A catalyst limits the amount of reactants used.
- (3) A catalyst changes the kinds of products produced.
- (4) A catalyst provides an alternate reaction pathway that requires less activation energy.

17 Given the reaction at equilibrium:



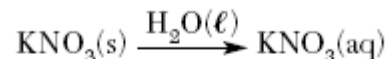
The rate of the forward reaction is

- (1) greater than the rate of the reverse reaction
- (2) less than the rate of the reverse reaction
- (3) equal to the rate of the reverse reaction
- (4) independent of the rate of the reverse reaction

30 As the temperature of a substance *decreases*, the average kinetic energy of its particles

- (1) decreases
- (2) increases
- (3) remains the same

50 Given the equation:



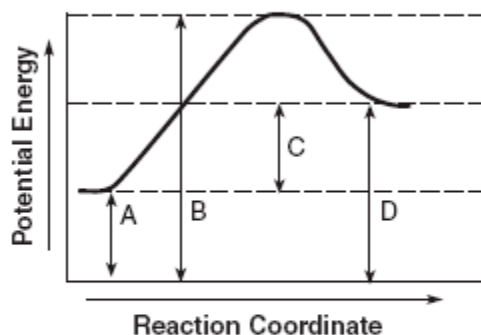
As $\text{H}_2\text{O}(\ell)$ is added to $\text{KNO}_3(\text{s})$ to form $\text{KNO}_3(\text{aq})$, the entropy of the system

- (1) decreases
- (2) increases
- (3) remains the same

Unit 6 - Kinetics / Equilibrium

Base your answers to questions 77 through 79 on the information and potential energy diagram below.

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



77 Which lettered interval on the diagram represents the potential energy of the products? [1]

78 Which lettered interval on the diagram represents the heat of reaction? [1]

79 Identify a reactant listed in Reference Table I that could be mixed with water for use in a chemical cold pack. [1]

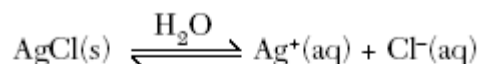
77 _____

78 _____

79 _____

August 2003

22 Given the reaction:



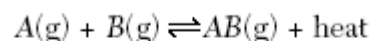
Once equilibrium is reached, which statement is accurate?

- (1) The concentration of $\text{Ag}^+(\text{aq})$ is greater than the concentration of $\text{Cl}^-(\text{aq})$.
 - (2) The $\text{AgCl}(s)$ will be completely consumed.
 - (3) The rates of the forward and reverse reactions are equal.
 - (4) The entropy of the forward reaction will continue to decrease.
- 35 In most aqueous reactions as temperature increases, the effectiveness of collisions between reacting particles
- (1) decreases
 - (2) increases
 - (3) remains the same

45 Based on the nature of the reactants in each of the equations below, which reaction at 25°C will occur at the fastest rate?

- (1) $\text{C}(s) + \text{O}_2(\text{g}) \rightarrow \text{CO}_2(\text{g})$
- (2) $\text{NaOH}(\text{aq}) + \text{HCl}(\text{aq}) \rightarrow \text{NaCl}(\text{aq}) + \text{H}_2\text{O}(\ell)$
- (3) $\text{CH}_3\text{OH}(\ell) + \text{CH}_3\text{COOH}(\ell) \rightarrow \text{CH}_3\text{COOCH}_3(\text{aq}) + \text{H}_2\text{O}(\ell)$
- (4) $\text{CaCO}_3(\text{s}) \rightarrow \text{CaO}(\text{s}) + \text{CO}_2(\text{g})$

46 Given the reaction at equilibrium:



The concentration of $\text{A}(\text{g})$ can be increased by

- (1) lowering the temperature
- (2) adding a catalyst
- (3) increasing the concentration of $\text{AB}(\text{g})$
- (4) increasing the concentration of $\text{B}(\text{g})$

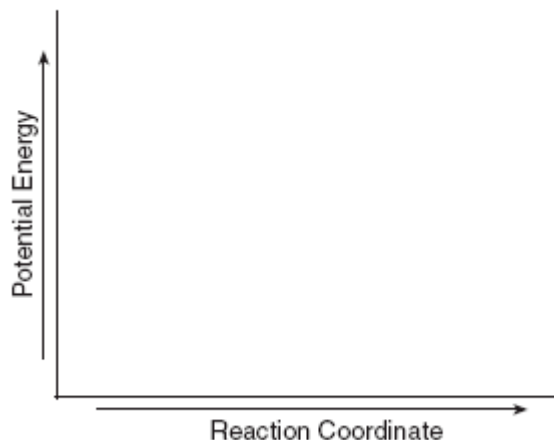
Unit 6 - Kinetics / Equilibrium

51 Explain how a catalyst may increase the rate of a chemical reaction. [1]

51

52 On the set of axes provided in *your answer booklet*, sketch the potential energy diagram for an endothermic chemical reaction that shows the activation energy and the potential energy of the reactants and the potential energy of the products. [2]

52



June 2003

17 Which change is exothermic?

- (1) freezing of water
- (2) melting of iron
- (3) vaporization of ethanol
- (4) sublimation of iodine

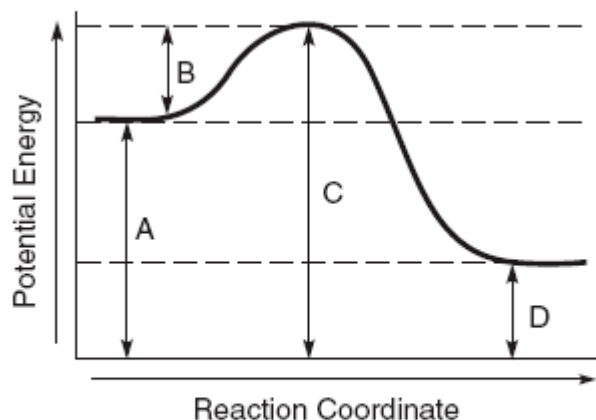
22 Which statement correctly describes an endothermic chemical reaction?

- (1) The products have higher potential energy than the reactants, and the ΔH is negative.
- (2) The products have higher potential energy than the reactants, and the ΔH is positive.
- (3) The products have lower potential energy than the reactants, and the ΔH is negative.
- (4) The products have lower potential energy than the reactants, and the ΔH is positive.

35 A catalyst is added to a system at equilibrium. If the temperature remains constant, the activation energy of the forward reaction

- (1) decreases
- (2) increases
- (3) remains the same

43 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

50 As carbon dioxide sublimes, its entropy

- (1) decreases
- (2) increases
- (3) remains the same

Unit 6 - Kinetics / Equilibrium

62 *a* In the space provided in *your answer booklet*, calculate the heat released when 25.0 grams of water freezes at 0°C. Show all work. [1]

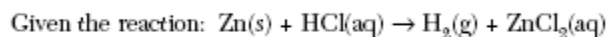
b Record your answer with an appropriate unit. [1]

62 *a*

b _____

Base your answers to questions 74 through 76 on the information below.

A student wishes to investigate how the reaction rate changes with a change in concentration of HCl(aq).



74 Identify the independent variable in this investigation. [1]

75 Identify one other variable that might affect the rate and should be held constant during this investigation. [1]

76 Describe the effect of increasing the concentration of HCl(aq) on the reaction rate and justify your response in terms of *collision theory*. [1]

74 _____

75 _____

76 _____

Unit 6 - Kinetics / Equilibrium

January 2003

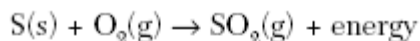
11 Which type or types of change, if any, can reach equilibrium?

- (1) a chemical change, only
- (2) a physical change, only
- (3) both a chemical and a physical change
- (4) neither a chemical nor a physical change

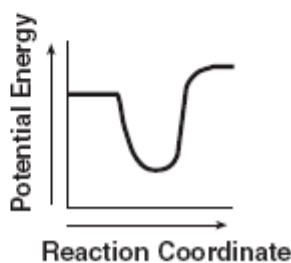
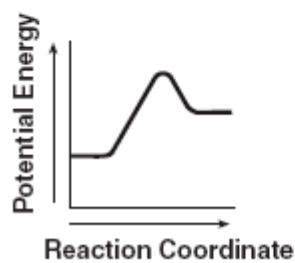
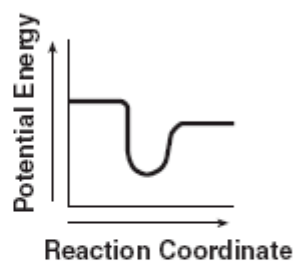
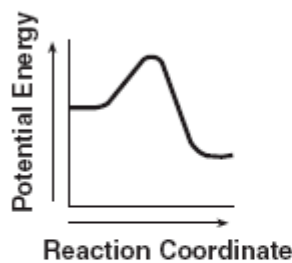
12 An increase in the average kinetic energy of a sample of copper atoms occurs with an increase in

- (1) concentration
- (2) temperature
- (3) pressure
- (4) volume

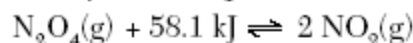
38 Given the reaction:



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



50 Given the system at equilibrium:



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

- (1) The equilibrium will shift to the left, and the concentration of $\text{NO}_2(g)$ will decrease.
- (2) The equilibrium will shift to the left, and the concentration of $\text{NO}_2(g)$ will increase.
- (3) The equilibrium will shift to the right, and the concentration of $\text{NO}_2(g)$ will decrease.
- (4) The equilibrium will shift to the right, and the concentration of $\text{NO}_2(g)$ will increase.

41 Which phase change represents a *decrease* in entropy?

- (1) solid to liquid
- (2) gas to liquid
- (3) liquid to gas
- (4) solid to gas