1. Which of the following units could be used to express reaction rate?

   A. mL/s
   B. mL/g
   C. g/mL
   D. mL/mol

2. Consider the reaction:

$$Zn_{(s)} + 2HCl_{(aq)} \rightarrow ZnCl_{2(aq)} + H_{2(g)}$$

   The rate of production of $ZnCl_2$, can be increased by

   A. decreasing the $[HCl]$.

   B. increasing the temperature.

   C. increasing the volume of H_2.

   D. decreasing the surface area of Zn.

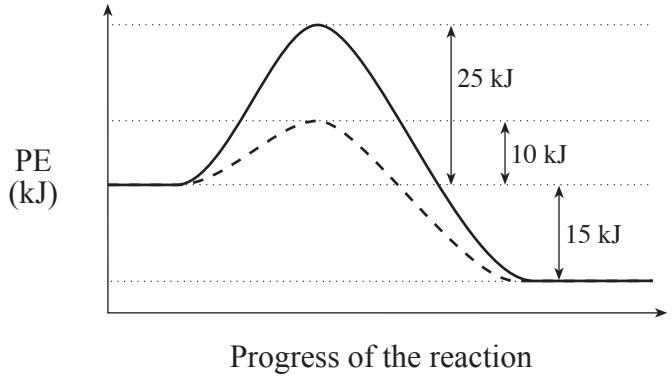
3. The statement, *the minimum energy needed to achieve a successful collision,* defines

   A. entropy.
   B. activation energy.
   C. the ΔH of reaction.
   D. the activated complex.

4. As an activated complex changes to products,

   A. potential energy changes to kinetic energy.
   B. kinetic energy changes to potential energy.
   C. kinetic energy changes to activation energy.
   D. potential energy changes to activation energy.

5. Consider the following PE diagram for an uncatalysed and a catalyzed reaction:



Which of the following describes the forward catalyzed reaction?

	Activation Energy (kJ)	ΔH (kJ)
A.	10	−15
B.	10	15
C.	25	−15
D.	25	15

6. A substance that increases the rate of a reaction without appearing in the equation for the overall reaction is a(n)

A. product.
B. catalyst.
C. reactant.
D. intermediate.

7. Which of the following reactions occurs most rapidly at standard conditions?

A. $2Fe_{(s)} + O_{2(g)} \rightarrow 2FeO_{(s)}$
B. $CaO_{(s)} + 3C_{(s)} \rightarrow CaC_{2(s)} + CO_{(g)}$
C. $SnO_{2(s)} + 2CO_{(g)} \rightarrow Sn_{(s)} + 2CO_{2(g)}$
D. $2AgNO_{3(aq)} + Na_2CrO_{4(aq)} \rightarrow Ag_2CrO_{4(s)} + 2NaNO_{3(aq)}$

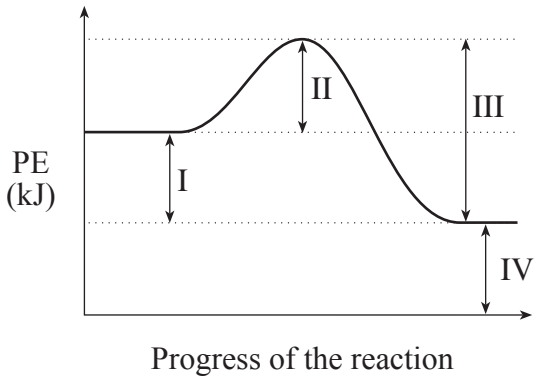
8. Which of the following reactions occurs most rapidly at standard conditions?

A. $2Fe_{(s)} + O_{2(g)} \rightarrow 2FeO_{(s)}$
B. $CaO_{(s)} + 3C_{(s)} \rightarrow CaC_{2(s)} + CO_{(g)}$
C. $SnO_{2(s)} + 2CO_{(g)} \rightarrow Sn_{(s)} + 2CO_{2(g)}$
D. $2AgNO_{3(aq)} + Na_2CrO_{4(aq)} \rightarrow Ag_2CrO_{4(s)} + 2NaNO_{3(aq)}$

9. In order for a collision between reactant particles to be successful

A. a ΔH must be positive.
B. the system must be closed.
C. there must be sufficient KE.
D. the change in KE must be less than the change in PE.

10. Consider the following PE diagram:



The activation energy for the forward reaction is represented by

A. I
B. II
C. III
D. IV

11. What is the relationship between the activation energy and the rate of a reaction?

A. When the activation energy is high, the rate of reaction is fast.
B. When the activation energy is low, the rate of reaction is slow.
C. When the activation energy is high, the rate of reaction is slow.
D. There is no relationship between activation energy and rate of reaction.

12. Consider the following reaction mechanism:

Step 1	$OCl^- + H_2O \rightarrow HOCl + OH^-$
Step 2	$I^- + HOCl \rightarrow HOI + Cl^-$
Step 3	$HOI + OH^- \rightarrow H_2O + OI^-$

Which of the following is correct for the overall reaction?

A. HOI is a product.
B. H_2O is a reactant.
C. HOCl is a catalyst.
D. OH^- is a reaction intermediate.

13. Which of the following reactions is slowest at room temperature?

A. $NH_{3(g)} + HCl_{(g)} \rightarrow NH_4Cl_{(s)}$

B. $MgCl_{2(s)} + Ca_{(s)} \rightarrow Mg_{(s)} + CaCl_{2(s)}$

C. $HCl_{(aq)} + NaOH_{(aq)} \rightarrow NaCl_{(aq)} + H_2O_{(\ell)}$

D. $Ba(NO_3)_{2(aq)} + Na_2SO_{4(aq)} \rightarrow BaSO_{4(s)} + 2NaNO_{3(aq)}$

14. Consider the following reaction:

$$COCl_{2(g)} \rightarrow CO_{(g)} + Cl_{2(g)}$$

Which of the following could be used to determine reaction rate in a closed system?

A. a decrease in gas pressure
B. an increase in gas pressure
C. a decrease in the mass of the system
D. an increase in the mass of the system

15. *Activation energy* is defined as the

A. ΔH.
B. average kinetic energy.
C. energy of a particle's motion.
D. minimum energy needed for a successful collision.

16. Which of the following reactions is endothermic?

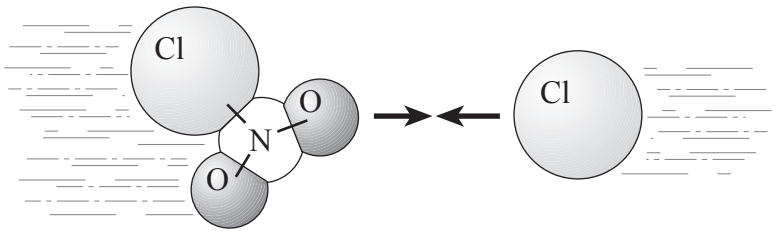
A. $CH_{4(g)} + 2O_{2(g)} \rightarrow CO_{2(g)} + 2H_2O_{(\ell)} + 890.3\,kJ$

B. $2Na_2O_{2(s)} + 2H_2O_{(\ell)} - 287.0\,kJ \rightarrow 4NaOH_{(aq)} + O_{2(g)}$

C. $CaO_{(s)} + H_2O_{(\ell)} \rightarrow Ca(OH)_{2(aq)} \qquad \Delta H = -65.2\,kJ$

D. $CaO_{(s)} + 3C_{(s)} \rightarrow CaC_{2(s)} + CO_{(g)} \qquad \Delta H = +464.8\,kJ$

17. The following diagram shows reactant molecules approaching one another:



What is happening to the kinetic energy and the potential energy?

	Kinetic Energy	Potential Energy
A.	decreasing	decreasing
B.	decreasing	increasing
C.	increasing	increasing
D.	increasing	decreasing

18. A proposed mechanism for a reaction is:

Step 1	$H_3O^+ + I^- \rightarrow HI + H_2O$
Step 2	$H_2O_2 + HI \rightarrow H_2O + HOI$
Step 3	$HOI + H_3O^+ + I^- \rightarrow 2H_2O + I_2$
Step 4	$I_2 + I^- \rightarrow I_3^-$

In the above mechanism, which of the following is true for the overall reaction?

A. HI is a catalyst
B. H_3O^+ is a product
C. H_2O_2 is a reactant
D. H_2O is an intermediate

19. Consider the following reaction:

$$N_2H_{4(\ell)} + 2H_2O_{2(\ell)} \rightarrow N_{2(g)} + 4H_2O_{(\ell)}$$

In 5.0 seconds, 0.015 mol of H_2O_2 is consumed. The rate of production of N_2 is

A. 1.5×10^{-3} mol/s
B. 3.0×10^{-3} mol/s
C. 6.0×10^{-3} mol/s
D. 1.5×10^{-2} mol/s

20. Consider the following reaction:

$$3Fe_2O_{3(s)} + CO_{(g)} \rightarrow 2Fe_3O_{4(s)} + CO_{2(g)} + 46\,kJ$$

Which of the following would cause the rate of the reaction to increase?

A. removing the Fe_3O_4
B. decreasing the temperature
C. increasing the surface area of Fe_2O_3
D. increasing the volume of the reaction vessel

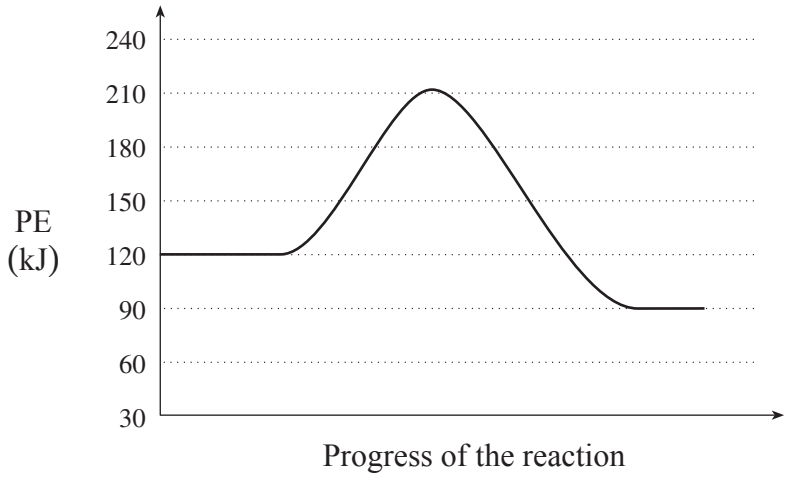
21. *Activation energy* is described as

A. the energy of the activated complex.
B. a point on the PE diagram where KE = PE.
C. the unstable high PE structural arrangement of atoms.
D. the minimum PE difference between the activated complex and the reactants.

22. What happens to the activation energy and ΔH when a catalyst is added to a reaction?

	Activation Energy	ΔH
A.	increases	remains the same
B.	increases	increases
C.	decreases	remains the same
D.	decreases	decreases

23. Consider the following potential energy diagram for a reaction:



What is the value of ΔH for this reaction?

A. −120 kJ
B. −30 kJ
C. +30 kJ
D. +120 kJ

24. A substance that is produced in one step in a reaction mechanism and consumed in a subsequent step, without appearing in the overall reaction, is a(n)

A. catalyst.
B. product.
C. reactant.
D. intermediate.

25. Which of the following has the greatest reaction rate?

A. $C_{(s)} + O_{2(g)} \rightarrow CO_{2(g)}$
B. $2H_2O_{2(\ell)} \rightarrow 2H_2O_{(\ell)} + O_{2(g)}$
C. $2Al_{(s)} + 3CuCl_{2(aq)} \rightarrow 2AlCl_{3(aq)} + 3Cu_{(s)}$
D. $NaCl_{(aq)} + AgNO_{3(aq)} \rightarrow AgCl_{(s)} + NaNO_{3(aq)}$

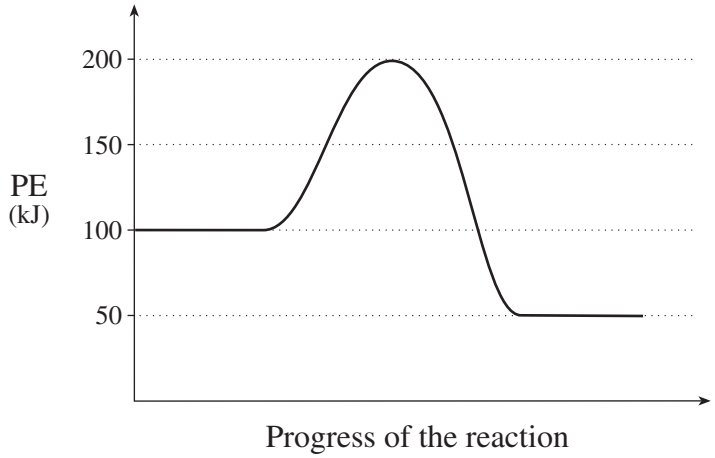
26. Which factor explains why potassium generally reacts faster than sodium?

A. surface area
B. temperature
C. concentration
D. nature of reactants

27. What happens to the PE and KE of the reactant particles as the activated complex is formed?

	PE	KE
A.	increases	decreases
B.	increases	increases
C.	decreases	decreases
D.	decreases	increases

28. Consider the following PE diagram:



What are the values of ΔH and activation energy (E_a) for the forward reaction?

	ΔH (kJ)	E_a (kJ)
A.	−50	100
B.	−50	200
C.	+50	100
D.	+50	200

29. Consider the following reaction mechanism:

Step 1	$Cl_2 \rightarrow 2Cl$
Step 2	$CHCl_3 + Cl \rightarrow HCl + CCl_3$
Step 3	$CCl_3 + Cl \rightarrow CCl_4$

Which of the following is a reactant in the overall reaction?

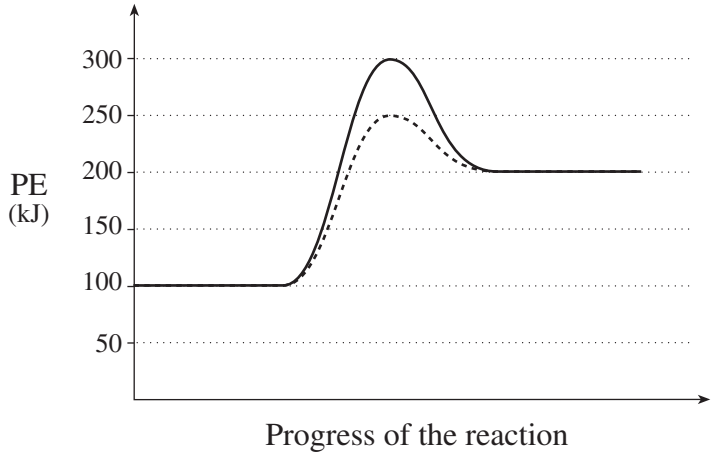
A. Cl

B. HCl

C. CCl_3

D. $CHCl_3$

30. Consider the following PE diagram for a catalyzed and uncatalyzed reaction:



Which of the following describes the **reverse** reaction?

	Reverse Reaction	Activation Energy (kJ)	ΔH (kJ)
A.	catalyzed	50	−100
B.	uncatalyzed	50	−100
C.	catalyzed	50	+100
D.	uncatalyzed	50	+100

31. Which of the following could be used to describe the rate of a reaction?

A. $\frac{\text{change in time}}{\text{change in mass}}$

B. $\frac{\text{change in mass}}{\text{change in volume}}$

C. $\frac{\text{change in volume}}{\text{change in time}}$

D. $\frac{\text{change in volume}}{\text{change in mass}}$

32. Consider the following reaction:

$$2H_2O_{2(aq)} \rightarrow 2H_2O_{(\ell)} + O_{2(g)}$$

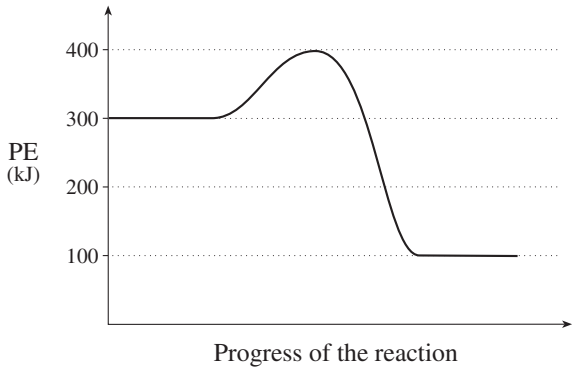
Which factor explains why the above reaction speeds up in the presence of $MnO_{2(s)}$?

A. temperature
B. concentration
C. nature of reactants
D. presence of catalyst

33. What happens to the potential energy and the total energy as an activated complex changes into products?

	PE	Total Energy
A.	increases	increases
B.	decreases	decreases
C.	increases	remains constant
D.	decreases	remains constant

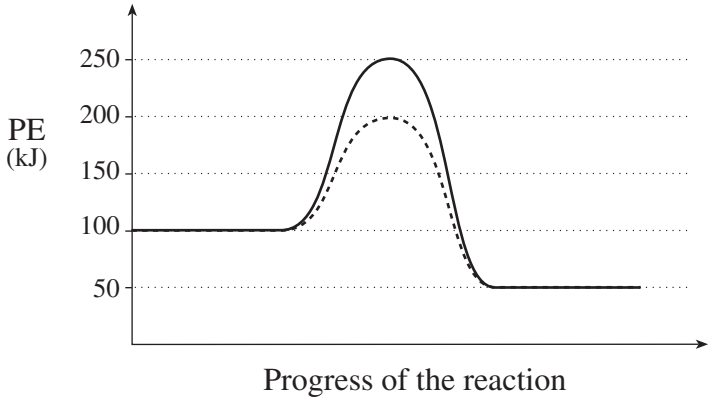
34. Consider the following PE diagram:



Which of the following describes the type of reaction and ΔH for the **reverse** reaction?

	Type of Reaction	ΔH (kJ)
A.	exothermic	positive
B.	endothermic	positive
C.	exothermic	negative
D.	endothermic	negative

35. Consider the following diagram for a catalyzed and uncatalyzed reaction:



Which of the following describes the **forward** reaction?

	Reaction	Activation Energy (kJ)	ΔH (kJ)
A.	catalyzed	100	−50
B.	uncatalyzed	100	−50
C.	catalyzed	150	+50
D.	uncatalyzed	150	+50

36. Consider the following reaction mechanism:

Step 1	$NO_2 + SO_2 \rightarrow SO_3 + NO$
Step 2	$NO + \frac{1}{2}O_2 \rightarrow NO_2$

Identify the catalyst.

A. O_2
B. NO
C. SO_2
D. NO_2

37. Which of the following has the lowest rate of reaction?

A. $Pb_{(s)} + CuCl_{2(aq)} \rightarrow Cu_{(s)} + PbCl_{2(aq)}$
B. $HCl_{(aq)} + NaOH_{(aq)} \rightarrow H_2O_{(\ell)} + NaCl_{(aq)}$
C. $H_2SO_{4(aq)} + Ba(OH)_{2(aq)} \rightarrow 2H_2O_{(\ell)} + BaSO_{4(s)}$
D. $Pb(NO_3)_{2(aq)} + 2NaI_{(aq)} \rightarrow PbI_{2(s)} + 2NaNO_{3(aq)}$

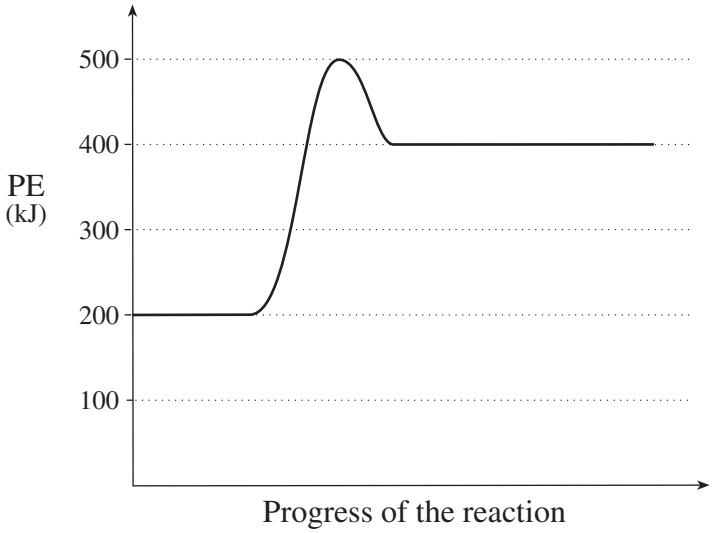
38. Which of the following affects the rate of heterogeneous reactions, but does not affect the rate of homogeneous reactions?

A. catalyst
B. temperature
C. surface area
D. concentration

39. As reactant particles approach each other, what changes occur in KE and PE?

	KE	PE
A.	increases	increases
B.	increases	decreases
C.	decreases	increases
D.	decreases	decreases

40. Consider the following PE diagram:



What is the minimum potential energy required to change reactants to the activated complex?

A. 200 kJ
B. 300 kJ
C. 400 kJ
D. 500 kJ

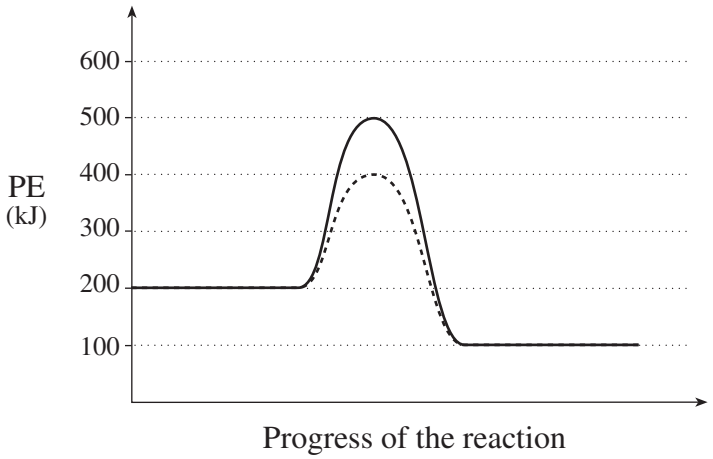
41. Consider the following reaction mechanism:

Step 1	$2NO_2 \rightarrow NO_3 + NO$
Step 2	$NO_3 + CO \rightarrow NO_2 + CO_2$

Identify a product in the overall reaction.

A. CO
B. CO_2
C. NO_2
D. NO_3

42. Consider the following PE diagram for a catalyzed and uncatalyzed reaction:



Which of the following describes the **reverse** reaction?

	Reverse Reaction	Activation Energy (kJ)	ΔH (kJ)
A.	uncatalyzed	300	−100
B.	catalyzed	300	−100
C.	uncatalyzed	400	+100
D.	catalyzed	400	+100

43. Which of the following could be used to describe the rate of a reaction?

A. $\frac{\text{change in time}}{\text{change in concentration}}$

B. $\frac{\text{change in mass}}{\text{change in concentration}}$

C. $\frac{\text{change in concentration}}{\text{change in time}}$

D. $\frac{\text{change in concentration}}{\text{change in mass}}$

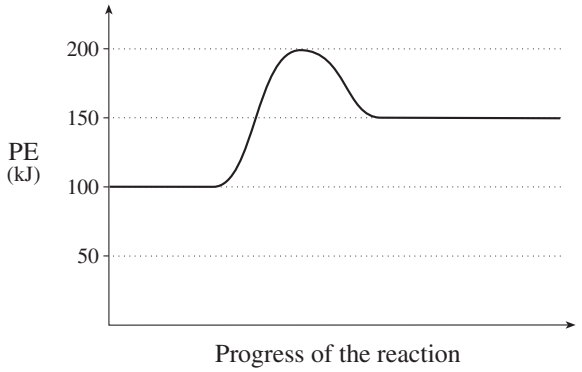
44. Which factor explains why coal dust is explosive?

A. temperature
B. surface area
C. concentration
D. addition of catalyst

45. As an activated complex changes into products, what changes occur in the chemical bonds of the activated complex and the PE of the system?

	Bonds	PE
A.	form	increases
B.	form	decreases
C.	break	increases
D.	break	decreases

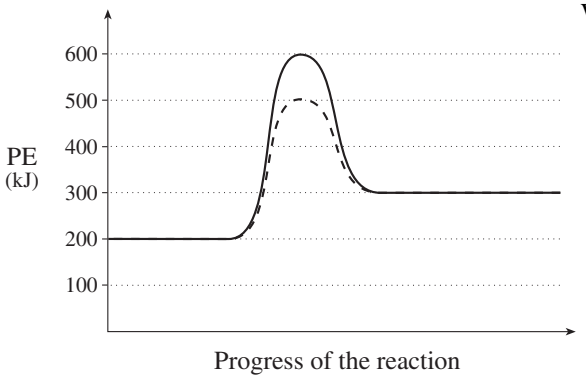
46. Consider the following PE diagram:



Which of the following describes ΔH and the type of reaction in the forward direction?

	ΔH (kJ)	Type of Reaction
A.	–50	exothermic
B.	–50	endothermic
C.	+50	exothermic
D.	+50	endothermic

47. Consider the following PE diagram for a catalyzed and uncatalyzed reaction:



Which of the following describes the forward reaction?

	Reaction	Activation Energy (kJ)	ΔH (kJ)
A.	catalyzed	300	−100
B.	uncatalyzed	300	−100
C.	catalyzed	400	+100
D.	uncatalyzed	400	+100

Consider the following reaction mechanism:

48.

Step 1	$NOCl \rightarrow NO + Cl$
Step 2	$NOCl + Cl \rightarrow NO + Cl_2$

Identify the reaction intermediate.

A. Cl
B. Cl_2
C. NO
D. NOCl

49. Given the reaction:

$$CaCO_{3(s)} + 2HCl_{(aq)} \rightarrow CaCl_{2(aq)} + H_2O_{(\ell)} + CO_{2(g)} + \text{heat}$$

Which of the following will cause the reaction rate to increase?

A. increasing pressure
B. decreasing pressure
C. increasing temperature
D. decreasing temperature

50. Consider the following reaction:

$$Fe_2O_{3(s)} + 2Al_{(s)} \rightarrow Al_2O_{3(s)} + 2Fe_{(\ell)}$$

If 0.50 mol of Fe is produced in 10.0 sec, what is the rate of consumption of Fe_2O_3 in mol/s ?

A. 5.0×10^{-2} mol/s
B. 2.5×10^{-2} mol/s
C. 1.0×10^{-1} mol/s
D. 5.0 mol/s

51. Which of the following would result in a successful collision between reactant particles?

A. particles have sufficient KE
B. particles convert all their PE into KE
C. particles are in an excited state and are catalyzed
D. particles have sufficient KE and proper molecular orientation

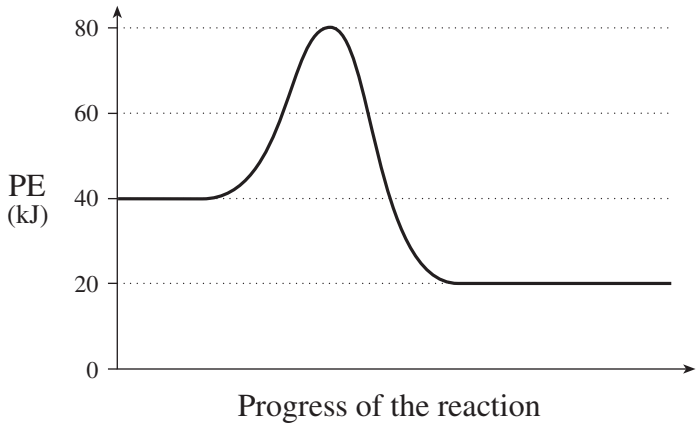
52. Which of the following best describes the E_a of a fast reaction and the stability of its activated complex?

	E_a	Activated Complex
A.	small	unstable
B.	small	stable
C.	large	unstable
D.	large	stable

53. How does the addition of a catalyst increase the reaction rate of an endothermic reaction?

A. It reduces the ΔH of the reaction.
B. It increases the ΔH of the reaction.
C. It reduces the required activation energy.
D. It causes the reaction to become exothermic.

54. Consider the following PE diagram:



What is the activation energy for the **reverse** reaction?

A. −60 kJ
B. −20 kJ
C. +40 kJ
D. +60 kJ

55. Consider the following reaction occurring in an open container:

$$CaCO_{3(s)} + 2HCl_{(aq)} \rightarrow CaCl_{2(aq)} + H_2O_{(\ell)} + CO_{2(g)}$$

The reaction rate could be calculated by using which of the following?

A. a change in $\left[Cl^-\right]$
B. a decrease in pH value
C. a change in gas pressure
D. a decrease in the mass of the system

56. Which of the following does **not** affect both homogeneous and heterogeneous reaction rates?

A. addition of a catalyst
B. change in temperature
C. change in surface area
D. change in concentration

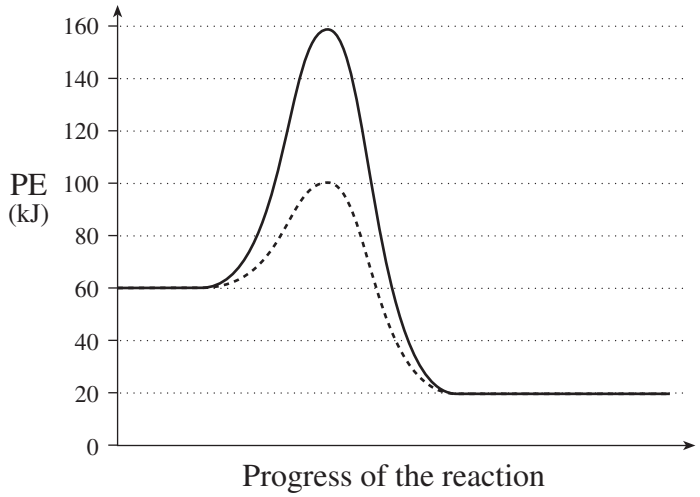
57. How do KE and PE change as reactant particles collide with each other?

	KE	PE
A.	increases	increases
B.	increases	decreases
C.	decreases	increases
D.	decreases	decreases

58. Under which of the following conditions will the reaction rate decrease for a reaction which goes to completion?

A. A catalyst is removed.
B. Products are removed.
C. Temperature is increased.
D. Solid reactants are ground into powders.

59. Consider the following potential energy diagram for a reaction:



Which of the following represents the correct activation energies?

	Forward Catalyzed E_a	Reverse Uncatalyzed E_a
A.	40 kJ	140 kJ
B.	80 kJ	40 kJ
C.	100 kJ	80 kJ
D.	100 kJ	160 kJ

60. What is an important function of the catalyst found in an automobile exhaust system?

A. increase fuel economy
B. decrease the rate of CO_2 production
C. increase the conversion rate of NO_2 to N_2
D. increase the conversion rate of heat into work

61. Which of the following reactions would have the greatest reaction rate at room temperature?

A. $C_3H_{8(g)} + 5O_{2(g)} \rightarrow 3CO_{2(g)} + 4H_2O_{(g)}$
B. $Ca_{(s)} + 2H_2O_{(\ell)} \rightarrow Ca(OH)_{2(aq)} + H_{2(g)}$
C. $AgNO_{3(aq)} + NaCl_{(aq)} \rightarrow AgCl_{(s)} + NaNO_{3(aq)}$
D. $Na_2CO_{3(s)} + 2HCl_{(aq)} \rightarrow 2NaCl_{(aq)} + H_2O_{(\ell)} + CO_{2(g)}$

62. Consider the following reaction:

$$2NO_{(g)} + O_{2(g)} \rightarrow 2NO_{2(g)} \qquad \Delta H = -114\,kJ$$

How could the rate of this reaction be increased?

A. Reduce the pressure.
B. Increase the volume.
C. Remove some $NO_{2(g)}$.
D. Increase the temperature.

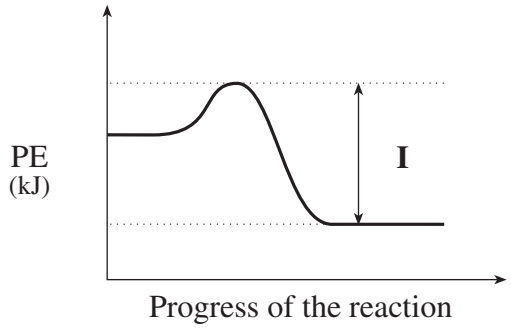
63. An activated complex can be described as

A. a particle of maximum KE and minimum PE.
B. a stable particle found in a reaction mechanism.
C. an unstable particle that is neither reactant nor product.
D. a particle which is first used then regenerated in a reaction mechanism.

64. Which of the following could result in an increase in reaction rate?

A. an increase in the activation energy
B. an increase in the reaction enthalpy
C. an increase in the frequency of collisions
D. an increase in the potential energy of the activated complex

65. Consider the following PE diagram:



Which of the following describes the energy value indicated by **I**?

A. heat of reaction
B. activation energy for the reverse reaction
C. activation energy for the forward reaction
D. potential energy of the reaction intermediate

66. Consider the following reaction mechanism and overall reaction:

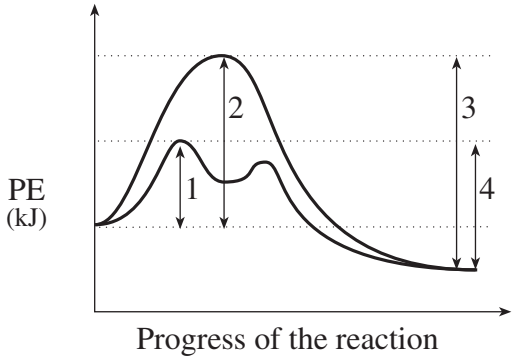
$$\begin{array}{lllll} \frac{1}{2}O_{2(g)} + NO_{(g)} & \rightarrow & NO_{2(g)} & & \\ NO_{2(g)} & \xrightarrow{\text{sunlight}} & NO_{(g)} + O_{(g)} & & \\ O_{(g)} + O_{2(g)} & \rightarrow & O_{3(g)} & & \\ \hline \frac{3}{2}O_{2(g)} & \rightarrow & O_{3(g)} & & \end{array}$$

What is the catalyst in this mechanism?

A. $O_{(g)}$
B. $NO_{(g)}$
C. $NO_{2(g)}$
D. sunlight

67. Consider the following PE diagram:

Identify the activation energy for the forward uncatalysed reaction.



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

68. Which of the following reactions would be slowest at room temperature?

A. $Zn_{(s)} + S_{(s)} \rightarrow ZnS_{(s)}$

B. $Cu_{(s)} + 2AgNO_{3(aq)} \rightarrow Cu(NO_3)_{2(aq)} + 2Ag_{(s)}$

C. $Pb(NO_3)_{2(aq)} + 2KI_{(aq)} \rightarrow PbI_{2(s)} + 2KNO_{3(aq)}$

D. $HC_2H_3O_{2(aq)} + KOH_{(aq)} \rightarrow KC_2H_3O_{2(aq)} + H_2O_{(\ell)}$

69. Consider the following reaction:

$$\underset{\text{(yellow)}}{2BaCrO_{4(s)}} + 2H^+_{(aq)} \rightarrow 2Ba^{2+}_{(aq)} + H_2O_{(\ell)} + \underset{\text{(orange)}}{Cr_2O_7{}^{2-}_{(aq)}}$$

The progress of the reaction could be followed by observing the rate of

A. mass loss.
B. decrease in pH.
C. precipitate formation.
D. formation of orange colour in the solution.

70. What happens to the activation energy as the temperature in a reacting system increases?

A. the activation energy increases
B. the activation energy decreases
C. the activation energy stays the same
D. the activation energy is converted to kinetic energy

71. Consider the following information for a reversible chemical reaction:

1	forward activation energy = 20kJ
2	reverse activation energy = 30kJ

Which of the following describes the reaction type and enthalpy change for the forward reaction?

	Reaction Type	ΔH Value
A.	exothermic	−10 kJ
B.	exothermic	+10 kJ
C.	endothermic	−10 kJ
D.	endothermic	+10 kJ