1. An experiment was conducted to determine the rate law of the reaction $2 \text{A} + 2 \text{B} \rightarrow \text{C} + \text{D}$. The data collected is shown below.

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Initial $[\text{A}]$</th>
<th>Initial $[\text{B}]$</th>
<th>Initial rate of reaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.00 M</td>
<td>2.00 M</td>
<td>$4.00 \times 10^{-4}$</td>
</tr>
<tr>
<td>2</td>
<td>4.00 M</td>
<td>2.00 M</td>
<td>$1.60 \times 10^{-3}$</td>
</tr>
<tr>
<td>3</td>
<td>2.00 M</td>
<td>1.00 M</td>
<td>$1.00 \times 10^{-1}$</td>
</tr>
</tbody>
</table>

What is the rate law for this equation?

1) $k = [\text{A}][\text{B}]$
2) $k = [\text{A}]^2[\text{B}]$
3) $k = [\text{A}][\text{B}]^2$
4) $k = [\text{A}]^2[\text{B}]^2$
5) $k = [\text{A}][\text{B}]^2$

Base your answers to questions 2 through 6 on the rate law given below for the reaction $\text{A} + \text{B} + \text{C} \rightarrow \text{D}$.

$$\text{Rate} = k[\text{A}]^2[\text{B}][\text{C}]$$

2. What is the order of the reaction with respect to $\text{A}$?

1) Both $[\text{A}]$ and $[\text{C}]$ will increase.
2) Both $[\text{A}]$ and $[\text{C}]$ will decrease.
3) $[\text{A}]$ will decrease and $[\text{C}]$ will increase.
4) $[\text{A}]$ will increase and $[\text{C}]$ will decrease.
5) Both $[\text{A}]$ and $[\text{C}]$ will stay the same.

3. If the concentration of $\text{B}$ is decreased, what will happen?

1) Both $[\text{A}]$ and $[\text{C}]$ will increase.
2) Both $[\text{A}]$ and $[\text{C}]$ will decrease.
3) $[\text{A}]$ will decrease and $[\text{C}]$ will increase.
4) $[\text{A}]$ will increase and $[\text{C}]$ will decrease.
5) Both $[\text{A}]$ and $[\text{C}]$ will stay the same.

4. If the concentration of $\text{C}$ is doubled what will happen?

1) The rate of the reaction increases
2) The rate of the reaction decreases
3) The value of the equilibrium constant increases
4) The value of the equilibrium constant decreases
5) Neither the equilibrium constant nor the rate would change.

5. If $[\text{A}]$ is doubled and $[\text{B}]$ tripled, by what factor would the rate change?

1) 2 2) 3 3) 6 4) 12 5) 18

6. What is the overall order of the reaction?

1) 1 2) 2 3) 3 4) 4 5) 0

7. For which of the following rate laws would the graph of log $[\text{Z}]$ versus time be a straight line?

1) rate = $k$
2) rate = $k[Z]$
3) rate = $k[Z]^2$
4) rate = $[Z]$
5) rate = $[Z]^2$

8. When the concentrations of $[\text{A}]$ and $[\text{B}]$ are tripled, the initial rate of reaction will increase by 27 times.

1) $A$ 2) $C$ 3) $D$ 4) $E$ 5) $C$ and $D$

9. When $[\text{A}]$ is tripled and $[\text{B}]$ is constant then the initial rate of reaction remains constant.

1) $A$ 2) $B$ 3) $C$ 4) $D$ 5) $E$

10. $\text{A} + 2 \text{B} \rightarrow \text{2 C} + 4 \text{D}$

The rate law for the above reaction is

(A) $\text{Rate} = k[\text{B}]^2$  (B) $\text{Rate} = k[\text{B}][\text{A}]$
(C) $\text{Rate} = k[\text{B}]^2[\text{A}]$
(D) $\text{Rate} = k[\text{B}][\text{A}]^2$  (E) $\text{Rate} = k[\text{B}]^2[\text{A}]^2$

11. The above chart contains experimental data obtained from the following reaction:

$$\text{H}_2 + 2 \text{ICl} \rightarrow \text{I}_2 + 2 \text{HCl}$$

What is the experimental rate law for this reaction?

1) $\text{Rate} = k[\text{H}_2]/[\text{ICl}]$  2) $\text{Rate} = k[\text{H}_2][\text{ICl}]$
3) $\text{Rate} = k[\text{H}_2][\text{ICl}]^2$  4) $\text{Rate} = k[\text{H}_2]^2[\text{ICl}]^2$
5) $\text{Rate} = k[\text{H}_2]^2[\text{ICl}]$
12. \( \text{BaCO}_3(s) + 2\text{H}^+(aq) \rightarrow \text{Ba}^{2+}(aq) + \text{H}_2\text{O}(l) + \text{CO}_2(g) + \text{Heat} \)

Based on the above reaction, which will increase the rate of evolution of carbon dioxide?

1) Adding water to the system
2) Decreasing the temperature
3) Finely powdering the \( \text{BaCO}_3 \)
4) Increasing the barium ion concentration, \([\text{Ba}^{2+}]\)
5) Decreasing the volume of the system

13. Given the reaction:

\( \text{Cl}_2(l) + 2\text{Na}(s) \rightarrow 2\text{NaCl}(s) \)

The reaction rate can be significantly increased by:

1) cooling the system
2) adding more sodium, Na
3) increasing the volume of the system
4) removing sodium chloride, NaCl
5) using gaseous chlorine, Cl\(_2\)

14. The temperature of a reaction in a closed system is increased from 27.0\(^\circ\)C to 57.0\(^\circ\)C. The activation energy for this reaction 34.5 kJ. Assuming the original reaction rate was 1.00, approximately how many times faster is the reaction now proceeding?

1) 3.52 2) 5.35 3) 2.26 4) 4.61 5) 2.93

15. The temperature of a reaction in a closed system is increased from 45.0\(^\circ\)C to 75.0\(^\circ\)C, causing the reaction rate to be exactly doubled. What is the activation energy of this reaction?

1) 21.3 kJ 2) 21.3 J 3) 5.76 J 4) 5.76 kJ 5) 32.2 kJ

16. The reaction rate of a reaction is doubled. The temperature of the reaction increases from 250.0 K to 400.0 K. Which of the following equations can be used to find the activation energy (\(E_a\)) of the reaction?

1) \( \ln(2.00) = (-E_a / R)(0.0025 – 0.0040) \)
2) \( \ln(400.0 – 250.0) = (-E_a / R)(2) \)
3) \( \ln(2.00) = (-E_a / R)(250.0 – 400.0) \)
4) \( \ln(2.00) = (-E_a / R)(0.0040 – 0.0025) \)
5) \( \ln(2.00) = (-E_a) / (R)(400 – 250) \)

17. The temperature of a reaction is increased from 350 K to 400 K. The reaction rate is tripled. Which of the following equations can be used to find the activation energy of the reaction?

1) the Drake equation
2) the Clausius-Claperon Equation
3) the Arrhenius equation
4) the Nernst equation
5) Avogadro's equation

18. Base your answer to the following question on the reaction below.

\( \text{H}_2(g) + \text{I}_2(g) \leftrightarrow 2\text{HI}(g) \)

The temperature of the reaction is increased, until only the forward reaction takes place. The partial pressure of the iodine gas is doubled. What will happen to the reaction rate?

1) It will quadruple.
2) It will be quartered.
3) It will double.
4) It will halve.
5) It will stay the same.

19. \( \text{C}_3\text{H}_8(g) + 5\text{O}_2(g) \rightarrow 3\text{CO}_2(g) + 4\text{H}_2\text{O}(l) \)

For the above reaction, the reaction rate of \( \text{CO}_2(g) \) is 10.0 torr/s. What is reaction rate of oxygen during the same period?

1) –16.0 torr/s 2) 16.0 torr/s 3) –6.0 torr/s 4) 6.0 torr/s 5) –10.0 torr/s

20. \( 3\text{H}_2(g) + \text{N}_2(g) \rightarrow 2\text{NH}_3(g) \)

For the above reaction, the reaction rate of \( \text{H}_2(g) \) is –6.00 torr/s. What is reaction rate of ammonia during the same period?

1) –7.50 torr/s 2) –4.00 torr/s 3) –6.00 torr/s 4) 4.00 torr/s 5) 6.00 torr/s

21. The rate law of a certain reaction is \( k = [X]^2 \). In order to make a linear graph, you should plot which of the following?

1) \([X]^2\) versus time
2) \(1/[X]^2\) versus time
3) \(\log([X]^2)\) versus time
4) \(1/[X]\) versus time
5) \(\log([X])\) versus time
Practice Questions

Base your answers to questions 22 and 23 on the table below, for the following reaction:

\[ 2 \text{SO}_2 + \text{O}_2 \rightarrow 2 \text{SO}_3 \]

<table>
<thead>
<tr>
<th>Experiment</th>
<th>[SO(_2)]</th>
<th>[O(_2)]</th>
<th>Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.00 M</td>
<td>0.50 M</td>
<td>2.0 \times 10^{-8} M/s</td>
</tr>
<tr>
<td>2</td>
<td>1.00 M</td>
<td>0.25 M</td>
<td>1.0 \times 10^{-8} M/s</td>
</tr>
<tr>
<td>3</td>
<td>2.00 M</td>
<td>0.50 M</td>
<td>8.0 \times 10^{-8} M/s</td>
</tr>
</tbody>
</table>

22. What is the experimental rate law for the reaction above?
1) \( \text{Rate} = k[\text{SO}_2][\text{O}_2]^3 \)
2) \( \text{Rate} = k[\text{SO}_2]^3[\text{O}_2]^2 \)
3) \( \text{Rate} = k[\text{SO}_2][\text{O}_2] \)
4) \( \text{Rate} = k[\text{SO}_2]^3[\text{O}_2] \)
5) \( \text{Rate} = k[\text{SO}_2]^3 \)

23. The value of the rate constant, \( k \), for this reaction is
1) \( 4.0 \times 10^{-8} \) 2) \( 2.0 \times 10^{-8} \) 3) \( 1.0 \times 10^{-8} \) 4) \( 4.0 \times 10^{-9} \) 5) \( 2.0 \times 10^{-9} \)

Base your answers to questions 24 through 26 on the table of data for the following reaction:

\[ \text{CO}(g) + \frac{1}{2} \text{O}_2(g) \rightarrow \text{CO}_2(g) \]

<table>
<thead>
<tr>
<th>Experiment</th>
<th>[CO]</th>
<th>[O(_2)]</th>
<th>Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.50 M</td>
<td>0.50 M</td>
<td>2.0 \times 10^{-5} M/s</td>
</tr>
<tr>
<td>2</td>
<td>0.25 M</td>
<td>0.50 M</td>
<td>0.50 \times 10^{-5} M/s</td>
</tr>
<tr>
<td>3</td>
<td>0.25 M</td>
<td>1.0 M</td>
<td>1.0 \times 10^{-5} M/s</td>
</tr>
</tbody>
</table>

24. When [CO] = [O\(_2\)] = 1.0 M, the rate of reaction will be
1) \( 2.0 \times 10^{-5} \) M/s 2) \( 1.6 \times 10^{-4} \) M/s 3) \( 1.0 \times 10^{-5} \) M/s 4) \( 0.50 \times 10^{-5} \) M/s 5) \( 8.0 \times 10^{-5} \) M/s

25. What is the rate law for the reaction above?
1) \( \text{Rate} = k[\text{CO}][\text{O}_2] \)
2) \( \text{Rate} = k[\text{CO}]^2[\text{O}_2] \)
3) \( \text{Rate} = k[\text{CO}][\text{O}_2]^2 \)
4) \( \text{Rate} = k[\text{CO}]^2[\text{O}_2]^2 \)
5) \( \text{Rate} = k[\text{CO}]^3[\text{O}_2] \)

26. The value of the rate constant, \( k \), is
1) \( 1.6 \times 10^{-4} \) M/s 2) \( 8.0 \times 10^{-5} \) M/s 3) \( 4.0 \times 10^{-5} \) M/s 4) \( 1.0 \times 10^{-5} \) M/s 5) \( 3.2 \times 10^{-4} \) M/s

27. A student collected the initial-rate data in the chart below.

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Initial [XO] (mol/L)</th>
<th>Initial [O(_2)] (mol/L)</th>
<th>Initial rate of formation of XO(_2) [mol/(L·s)]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.20</td>
<td>0.20</td>
<td>0.40</td>
</tr>
<tr>
<td>2</td>
<td>0.80</td>
<td>0.20</td>
<td>6.4</td>
</tr>
<tr>
<td>3</td>
<td>0.20</td>
<td>0.40</td>
<td>0.80</td>
</tr>
</tbody>
</table>

What is the experimental rate law for this reaction?
1) \( \text{rate} = k \ [\text{XO}]^2[\text{O}_2]^{-1} \)
2) \( \text{rate} = k \ [\text{XO}][\text{O}_2]^{-1} \)
3) \( \text{rate} = k \ [\text{XO}]^2 \ [\text{O}_2] \)
4) \( \text{rate} = k \ [\text{XO}][\text{O}_2]^2 \)
5) \( \text{rate} = k \ [\text{XO}]^2 \ [\text{O}_2]^2 \)
28. The reaction \(2 \text{NO} + \text{Cl}_2 \rightarrow 2 \text{NOCl}\) is third order with respect to NO and first order with respect to \(\text{Cl}_2\). Which of the following is a correct rate law for this reaction?

1) \(\frac{-\Delta [\text{NO}]}{2\Delta t} = \frac{-\Delta [\text{Cl}_2]}{\Delta t} = k[\text{NO}]^3[\text{Cl}_2]\)
2) \(\frac{-\Delta [\text{NO}]}{2\Delta t} = -\frac{\Delta [\text{Cl}_2]}{\Delta t} = k[\text{NO}]^2[\text{Cl}_2]\)
3) \(\frac{-\Delta [\text{NO}]}{3\Delta t} = \frac{\Delta [\text{Cl}_2]}{\Delta t} = k[\text{NO}]^3[\text{Cl}_2]\)
4) \(\frac{-\Delta [\text{NO}]}{3\Delta t} = -\frac{\Delta [\text{Cl}_2]}{\Delta t} = k[\text{NO}]^2[\text{Cl}_2]\)
5) \(\frac{\Delta [\text{NO}]}{2\Delta t} = \frac{\Delta [\text{Cl}_2]}{\Delta t} = k[\text{NO}]^3[\text{Cl}_2]\)

29. \(\text{Na}(g) + 3 \text{H}_2(g) \rightarrow 2 \text{NH}_3(g)\)

The formation of ammonia is shown in the above reaction. If the rate of formation of ammonia is \(9.0 \times 10^{-4} \text{ mol/s}\), then the rate of consumption of nitrogen is

1) \(4.5 \times 10^{-4} \text{ mol/s}\)
2) \(6.0 \times 10^{-4} \text{ mol/s}\)
3) \(9.0 \times 10^{-4} \text{ mol/s}\)
4) \(1.4 \times 10^{-3} \text{ mol/s}\)
5) \(2.6 \times 10^{-2} \text{ mol/s}\)

30. Consider the following factors:

I. Reactant particles collide
II. Sufficient kinetic energy is present
III. A favorable geometry exists
IV. Catalysts are present

Which combination of the above factors is required for all successful collisions?

1) I only
2) II and III only
3) I and III only
4) I, II, III and IV
5) I, II and III only

31. In general, reaction rates double when the temperature is increased by 10°C. The temperature of a reaction is increased by 40°C. The rate of reaction will be increased by which factor?

1) 16
2) 2
3) 8
4) 4
5) 24

32. Fast rates of chemical reactions are generally associated with

1) low temperatures
2) strong bonds in reactant molecules
3) high activation energy
4) presence of a catalyst
5) exothermic reactions

33. When solid AgBr is added to saturated solution of AgBr, the reaction rates can be described as

1) rate of dissolving increases; rate of crystallization increases
2) rate of dissolving decreases; rate of crystallization increases
3) rate of dissolving increases; rate of crystallization decreases
4) rate of dissolving decreases; rate of crystallization decreases
5) rate of dissolving remains constant; rate of crystallization decreases

34. \(\text{MgCO}_3(s) + 2 \text{HCl}(aq) \rightarrow \text{CO}_2(g) + \text{H}_2\text{O}(l) + \text{MgCl}_2(aq)\)

If the above reaction occurs at a constant temperature in an open system, which of the following properties could be used to determine reaction rate?

1) Mass of the system
2) Pressure of the gas
3) Concentration of MgCO\(_3\)
4) Concentration of \(\text{H}_2\text{O}\)
5) Concentration of \(\text{CO}_2\)

35. I. \(\text{Ag}^+(aq) +\text{I}^-(aq) \rightarrow \text{AgI}(s)\)
II. \(4 \text{Fe}(s) + 3 \text{O}_2(g) \rightarrow 2 \text{Fe}_2\text{O}_3(s)\)

Which statement best describes the relative rates of the above two reactions?

1) I is faster than II
2) II is faster than I
3) I and II are both fast
4) I and II are both slow
5) The relative rates of reaction cannot be determined

36. I. \(4 \text{Al}(s) + 3 \text{O}_2(g) \rightarrow 2 \text{Al}_2\text{O}_3(s)\)
II. \(\text{Ag}^+(aq) + \text{Cl}^-(aq) \rightarrow \text{AgCl}(s)\)

Which statement best describes the relative rates of the above two reactions?

1) I is faster than II
2) II is faster than I
3) I and II are both fast
4) I and II are both slow
5) The relative rates of reaction cannot be determined
37. Base your answer to the following question on the table below which was obtained for the reaction \( A + B \rightarrow C \).

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Initial ([A] ) (mol L(^{-1}))</th>
<th>Initial ([B] ) (mol L(^{-1}))</th>
<th>Initial rate of formation of ( C ) (mol L(^{-1}) min(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.10</td>
<td>0.20</td>
<td>(6.0 \times 10^{-2})</td>
</tr>
<tr>
<td>2</td>
<td>0.20</td>
<td>0.20</td>
<td>(6.0 \times 10^{-2})</td>
</tr>
<tr>
<td>3</td>
<td>0.10</td>
<td>0.40</td>
<td>(2.4 \times 10^{-1})</td>
</tr>
</tbody>
</table>

What is the rate law for this reaction?

1) Rate = \(k[A]^2\)  
2) Rate = \(k[B]^2\)  
3) Rate = \(k[A][B]\)  
4) Rate = \(k[A]^2[B]\)  
5) Rate = \(k[A][B]^2\)

Base your answers to questions 38 and 39 on the table below, which was obtained for the reaction \( A + B \rightarrow C \).

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Initial ([A] ) (mol L(^{-1}))</th>
<th>Initial ([B] ) (mol L(^{-1}))</th>
<th>Initial rate of formation of ( C ) (mol L(^{-1}) min(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.25</td>
<td>0.30</td>
<td>(7.2 \times 10^{-3})</td>
</tr>
<tr>
<td>2</td>
<td>0.50</td>
<td>0.30</td>
<td>(14.4 \times 10^{-3})</td>
</tr>
<tr>
<td>3</td>
<td>0.50</td>
<td>0.30</td>
<td>(57.6 \times 10^{-3})</td>
</tr>
</tbody>
</table>

38. Which of the following is the rate law of the reaction?

1) Rate = \(k[A]^2\)  
2) Rate = \(k[B]^2\)  
3) Rate = \(k[A][B]\)  
4) Rate = \(k[A][B]^2\)  
5) Rate = \(k[A]^2[B]\)

39. Which concentrations would give an initial rate of \(1.8 \times 10^{-3}\) mol L\(^{-1}\) min\(^{-1}\)?

1) \([A] = 0.25\) mol L\(^{-1}\), \([B] = 0.15\) mol L\(^{-1}\)  
2) \([A] = 0.125\) mol L\(^{-1}\), \([B] = 0.15\) mol L\(^{-1}\)  
3) \([A] = 0.25\) mol L\(^{-1}\), \([B] = 0.30\) mol L\(^{-1}\)  
4) \([A] = 0.125\) mol L\(^{-1}\), \([B] = 0.30\) mol L\(^{-1}\)  
5) \([A] = 0.125\) mol L\(^{-1}\), \([B] = 0.60\) mol L\(^{-1}\)

40. Which of the following is not correlated with a fast reaction rate?

I. Catalysts  
II. High temperature  
III. High concentration of reactants  
IV. Strong bonds in the products  
V. Low level of activation energy

1) I and II only  
2) I, II, and IV only  
3) III, IV, and V only  
4) IV and V only  
5) They are all correlated with a fast reaction rate

41. Increasing the temperature increases the reaction rate. This is best explained by a(n):

1) new reaction path  
2) higher activation energy  
3) increased concentration of reactants  
4) increased number of effective collisions  
5) increased kinetic energy

42. A rise in temperature of 10 Kelvins causes the rate of some chemical reactions to double. This is best explained by the doubling of the:

1) heat of reaction, \(\Delta H\)  
2) the activation energy  
3) average kinetic energy of molecules  
4) pressure of the system  
5) number of reacting particles with the minimum activation energy

43. Generally an increase of ten degrees centigrade doubles the rate of reaction between gases. The explanation for this increase in reaction rate is the doubling of the:

1) concentration of the reactants  
2) average kinetic energy of the molecules  
3) number of intermolecular collisions per unit of time  
4) number of particles with an energy above a minimum activation energy  
5) volume of the reactants
44. Base your answer to the following question on the graph below which shows the number of molecules with a given kinetic energy plotted as a function of kinetic energy. Four catalysts are available, A, B, C and D, which have associated reaction activation energies $E_A$, $E_B$, $E_C$, and $E_D$ respectively.

Which catalyst will have an activation energy which will result in the slowest reaction rate?

1) Catalyst 'A' associated with energy $E_A$
2) Catalyst 'B' associated with energy $E_B$
3) Catalyst 'C' associated with energy $E_C$
4) Catalyst 'D' associated with energy $E_D$
5) The activation energies of catalysts A, B, C and D all result in the same reaction rate.

45. The fraction of molecules with the activation energy in a reaction will be (approximately) doubled by which of the following?

1) halving the velocity of the molecules in reaction
2) doubling the reaction rate by increasing temperature
3) halving the number of collisions
4) doubling the activation energy
5) doubling the potential energy

46. Which of the following would react most rapidly?

1) powdered Zn in 1.0 $M$ HCl at 25°C
2) powdered Zn in 2.0 $M$ HCl at 25°C
3) a lump of Zn in 2.0 $M$ HCl at 25°C
4) a lump of Zn in 1.0 $M$ HCl at 40°C
5) a lump of Zn in 1.0 $M$ HCl at 30°C

47. The temperature is changed from $T_3$ to $T_2$. Which area shows the number of additional molecules which can react?

1) Area A
2) Area C
3) Area C + B
4) Area A + B + C
5) Area A + B

48. Which is the curve for the lowest temperature?

1) Curve $T_1$
2) Curve $T_2$
3) Curve $T_3$
4) Can’t tell

49. The relative number of molecules with a given kinetic energy is plotted against kinetic energy. An uncatalyzed reaction with an activation energy, $E_a$, is being considered. In which region of the above kinetic energy distribution graph will all collisions result in a chemical reaction?

1) area I only
2) area IV only
3) areas II and III only
4) areas I, II and III only
5) areas I and IV only
Base your answers to questions 50 and 51 on the following reaction.

\[ \text{H}_2(g) + \text{I}_2(g) \leftrightarrow 2 \text{HI}(g) \]

50. The reaction above is allowed to reach equilibrium. The pressure on the system is doubled. Which of the following is true?

1) [H\(_2\)] will increase.  
2) [I\(_2\)] will increase.  
3) [HI] will decrease.  
4) 1 and 2  
5) None of these

51. NOTE: This question is about the forward reaction ONLY. At constant volume, the temperature of the system is doubled. Which of the following will occur?

1) The kinetic energy of the molecules will decrease.  
2) Nothing will change.  
3) The reaction rate will more than double.  
4) The reaction rate will double.  
5) The reaction rate will be halved.

52. Milk is refrigerated in order to slow the rate of decomposition by bacterial action. The decrease in reaction rate is due to

1) an increase in surface area  
2) a decrease in surface area  
3) a decrease in the fraction of particles possessing sufficient energy  
4) a decrease in ΔH for the reaction  
5) the introduction of an alternate pathway with greater activation energy

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

1) Zn(s) + S(s) → ZnS(s)  
2) Ba\(^{2+}\)(aq) + SO\(^{2-}\)(aq) → BaSO\(_4\)(s)  
3) NH\(_3\)(g) + HCl(g) → NH\(_4\)Cl(s)  
4) 2 Ag\(^+\)(aq) + CO\(_3^{2-}\)(aq) → Ag\(_2\)CO\(_3\)(s)  
5) NaCl(aq) → Na\(^+\)(aq) + Cl\(^-\)(aq)

54. 1. 4 CuCl\(_2\) + 4 HCl + O\(_2\) → 4 CuCl\(_2\) + 2 H\(_2\)O  
2. 4 CuCl\(_2\) → 4 CuCl + 2 Cl\(_2\)

Shown above, a two step reaction mechanism produces chlorine commercially at 450°C. Which substance is the catalyst?

1) H\(_2\)O  2) HCl  3) CuCl  4) CuCl\(_2\)  5) Cl\(_2\)

55. Which represents the activation energy for the forward reaction?

1) 1  
2) 2  
3) 3  
4) 4  
5) 6

56. A catalyst would change

1) 1 and 6  
2) 2 and 3  
3) 3 and 4  
4) 4, 5 and 6  
5) 3 and 6

57. Which represents the energy of the activated complex?

1) 6  
2) 2  
3) 3  
4) 4  
5) 5

58. The reaction mechanism for the production of ozone, O\(_3\), from automotive exhaust occurs in the three steps below.

Step 1: NO(g) + \(\frac{1}{2}\) O\(_2\)(g) → NO\(_2\)(g)  
Step 2: NO\(_2\)(g) → NO(g) + O(g)  
Step 3: O\(_2\)(g) + O(g) → O\(_3\)(g)

Overall: \(\frac{3}{2}\) O\(_2\)(g) → O\(_3\)(g)

Which species is the catalyst?

1) O(g)  
2) O\(_2\)(g)  
3) O\(_3\)(g)  
4) NO\(_2\)(g)  
5) NO(g)

59. The spark plug of an engine can best be classified (in a reaction) as

1) a catalyst  
2) a supplier of activation energy  
3) the rate determining step  
4) the activated complex  
5) the volatile reactant
60. \(2 \text{N}_2\text{O}(g) \rightarrow 2 \text{N}_2(g) + \text{O}_2(g)\)

The catalyzed reaction above occurs in three steps

1. \(\text{Cl}_2(g) \rightarrow 2 \text{Cl}(g)\)
2. \(2 \text{N}_2\text{O}(g) + 2 \text{Cl}(g) \rightarrow 2 \text{N}_2(g) + 2 \text{ClO}(g)\)
3. \(2 \text{ClO}(g) \rightarrow \text{Cl}_2(g) + \text{O}_2(g)\)

Which substance is the catalyst?

1) \(\text{Cl}(g)\)  
2) \(\text{Cl}_2(g)\)  
3) \(\text{N}_2\text{O}(g)\)  
4) \(\text{ClO}(g)\)  
5) \(\text{O}_2(g)\)

61. According to the above reaction mechanism, the distance marked "Z" represents

1) the activation energy for \(A(g) + B(g) \leftrightarrow C(g) + D(g)\)
2) the heat of reaction for \(A(g) + B(g) \leftrightarrow C(g) + D(g)\)
3) the activation energy for \(C(g) + D(g) \leftrightarrow A(g) + B(g)\)
4) the heat of reaction for \(C(g) + D(g) \leftrightarrow A(g) + B(g)\)
5) none of these

62. An exothermic chemical reaction is sped up by the addition of a catalyst. Which of the following is NOT occurring?

1) The catalyst lowers the activation energy of the reaction.
2) The catalyst makes the reaction proceed in the forward direction ONLY.
3) The addition of a catalyst lowers the activation energy of the reaction.
4) The catalyst is consumed by the reaction, and produces extra energy.
5) The catalyst slows down the speed of reaction.

63. Which of the following is the best explanation of the graph above?

1) The addition of the catalyst increases the potential energy of the reaction.
2) The catalyst makes the reaction proceed in the forward direction ONLY.
3) The addition of a catalyst lowers the activation energy of the reaction.
4) The catalyst is consumed by the reaction, and produces extra energy.
5) The catalyst slows down the speed of reaction.

64. Based on the above reaction mechanism, which of the following would not be affected by the addition of a catalyst?

1) increasing the kinetic energy
2) decreasing the heat of reaction
3) changing the concentration of the reactants
4) providing an alternate reaction mechanism
5) decreasing kinetic energy

65. A catalyst increases the rate of a chemical reaction by

1) increasing the kinetic energy
2) decreasing the heat of reaction
3) changing the concentration of the reactants
4) providing an alternate reaction mechanism
5) decreasing kinetic energy
Practice Questions

66. According to the above chart, which of the following is the correct justification for why one of the three steps is the rate determining step?

1) Step 2, because it has the lowest activation energy
2) Step 1, because it has the highest activation energy
3) Step 1, because it is neither endothermic nor exothermic
4) Step 2, because it is the most exothermic
5) Step 3, because it is the least exothermic

67. \( \frac{1}{2} \text{H}_2(g) + \frac{1}{2} \text{I}_2(g) \rightarrow \text{HI}(g) \quad \Delta H = +28 \text{ kJ} \)

The activation energy for the formation of HI, which is shown above, is 167 kJ. The activation energy for the decomposition of HI is

1) 28 kJ  2) 139 kJ  3) 167 kJ  4) 195 kJ  5) 210 kJ

68. Based on the potential energy diagram above, which of the following is true for this reaction?

1) \( \Delta H(kJ) = +20 \); Activation energy(kJ) = 60; Reaction type: Endothermic
2) \( \Delta H(kJ) = +60 \); Activation energy(kJ) = 60; Reaction type: Endothermic
3) \( \Delta H(kJ) = +40 \); Activation energy(kJ) = 60; Reaction type: Exothermic
4) \( \Delta H(kJ) = -40 \); Activation energy(kJ) = 60; Reaction type: Exothermic
5) \( \Delta H(kJ) = +40 \); Activation energy(kJ) = 60; Reaction type: Endothermic

69. An untreated sugar cube does not burn when held over a lighted match. A sugar cube coated with cigarette ash readily ignites and burns. All of the cigarette ash remains after the reaction. The factor that caused this change in rate is the

1) nature of reactants
2) increase in temperature
3) presence of a catalyst
4) increase in surface area
5) increase in concentration

70. \( \text{CO} + \text{NO}_2 \rightarrow \text{CO}_2 + \text{NO} \quad \Delta H = -234 \text{ kJ} \)

The activation energy of the forward reaction represented by the above equation is 134. kJ. What is the activation energy for the reverse reaction?

1) –134. kJ  2) –100. kJ  3) 422. kJ  4) 234. kJ  5) 368. kJ

71. If the above diagram is for the reaction \( X + Y \rightarrow Z \), which values would not change if a catalyst is added?

1) I only  2) II only  3) II and III  4) I and III  5) I, II, and III

72. Step 1: \( \text{Cu}^{2+} + \text{Sn}^{2+} \rightarrow \text{Cu}^{(s)} + \text{Sn}^{4+} \)
Step 2: \( \text{Cu}^{2+} + \text{Sn}^{(s)} \rightarrow \text{Cu}^{(s)} + \text{Sn}^{2+} \)
Step 3: \( 2\text{Be}^{(s)} + \text{Sn}^{4+} \rightarrow \text{Sn}^{(s)} + 2\text{Be}^{2+} \)

In the above proposed reaction mechanism, what would be the products of the overall catalyzed reaction?

1) \text{Sn}^{2+} \text{ and } \text{Be}^{2+}  2) \text{Sn}^{4+} \text{ and } \text{Sn}^{2+}  3) \text{Sn}(s) \text{ and } \text{Sn}^{4+}  4) \text{Cu}^{2+} \text{ and } \text{Cu}(s)  5) \text{Cu}(s) \text{ and } \text{Be}^{2+}
73. If the above energy diagram is for the reaction \( X + Y \rightarrow Z \), which value would change if a catalyst is added?

1) I only  
2) II only  
3) II and III  
4) I and III  
5) I, II, and III

74. Which is the rate–determining step in the above hypothetical reaction mechanism?

<table>
<thead>
<tr>
<th>Step</th>
<th>Species Being Produced</th>
<th>Rate of Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>(A)</td>
<td>B</td>
<td>0.0020 ( \text{mol/mol}_A )</td>
</tr>
<tr>
<td>(B)</td>
<td>C</td>
<td>0.030 ( \text{mol/mol}_B )</td>
</tr>
<tr>
<td>(C)</td>
<td>D</td>
<td>0.011 ( \text{mol/mol}_C )</td>
</tr>
<tr>
<td>(D)</td>
<td>E</td>
<td>0.42 ( \text{mol/mol}_D )</td>
</tr>
</tbody>
</table>

75. Step 1: \( \text{V}^{3+} + \text{Cu}^{2+} \rightarrow \text{V}^{4+} + \text{Cu}^{+} \) (slow)  
Step 2: \( \text{Cu}^{+} + \text{Fe}^{3+} \rightarrow \text{Cu}^{2+} + \text{Fe}^{2+} \) (fast)  
According to the above reaction mechanism, the reaction intermediate is

1) \( \text{Cu}^{+} \)  
2) \( \text{Cu}^{2+} \)  
3) \( \text{V}^{3+} \)  
4) \( \text{Fe}^{3+} \)  
5) \( \text{V}^{4+} \)

76. In a reaction mechanism, the rate determining state is the

1) fastest and has the lowest activation energy  
2) fastest and has the highest activation energy  
3) slowest and has the lowest activation energy  
4) slowest and has the highest activation energy  
5) intermediate and has the lowest activation energy

77. Which is the “rate determining step” for the above hypothetical reaction mechanism of the overall reaction \( A \rightarrow E \)?

1) step 1  
2) step 2  
3) step 3  
4) step 4  
5) the rate determining step cannot be determined

78. Step 1: \( \text{Cl}(g) + \text{O}_3(g) \rightarrow \text{ClO}(g) + \text{O}_2(g) \)  
Step 2: \( \text{O}(g) + \text{ClO}(g) \rightarrow \text{Cl}(g) + \text{O}_2(g) \)  
According to the above reaction mechanism, the reaction intermediate is

1) \( \text{Cl} \)  
2) \( \text{O}_2 \)  
3) \( \text{O}_3 \)  
4) \( \text{ClO} \)  
5) \( \text{O} \)

79. Base your answer to the following question on the reaction below.

\[ 2 \text{A}(g) + \text{B}(s) \leftrightarrow 3 \text{C}(g); \Delta H<0 \]

If the rate expression for this reaction does not depend on \( B \), what could be the cause of this?

1) \( B \) is not involved in any steps in this reaction.  
2) \( B \) is not involved in the rate determining step, but may be involved in other steps in the reaction.  
3) The coefficient of \( B \) is 1, therefore it does not affect the rate of the reaction.  
4) \( B \) is a solid, therefore does not appear in the rate expression.  
5) The order of the reaction with respect to \( B \) is 1.