1. The rate constant for a particular reaction is $1.3 \times 10^{-4} \text{M}^{-1}\text{sec}^{-1}$ at 100°C, and $1.1 \times 10^{-3}\text{M}^{-1}\text{sec}^{-1}$ at 150°C. What is the overall order of the reaction?
   a) 1
   b) 2
   c) 3
   d) 4
   e) 5

Which one of the following statements is false?

a) In order for a reaction to occur, reactant molecules must collide with each other.
b) A catalyst alters the rate of a reaction and is neither a product nor a reactant in the overall equation.
c) According to collision theory, a three-body collision is less likely than a two-body collision.
d) In reactions that are second order in one reactant and first order in another, the slowest step generally involves a three-body collision of these reactants.
e) The transition state is a short-lived, high energy state, intermediate between reactants and products.

2. Evaluate the specific rate constant at the temperature at which the data were collected. The rate-law expression is Rate = $\text{rate constant} \times \left[\text{NO}_2\right]^x \times \left[H_2\right]^y$.

\[
H_2(g) + NO_2(g) \rightarrow NO_2(g) + H_2O(g)
\]

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Initial $\text{NO}_2$ (M)</th>
<th>Initial $\text{H}_2$ (M)</th>
<th>Initial Rate (M sec$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.30</td>
<td>0.35</td>
<td>$2.635 \times 10^{-2}$</td>
</tr>
<tr>
<td>2</td>
<td>0.60</td>
<td>0.35</td>
<td>$1.134 \times 10^{-2}$</td>
</tr>
<tr>
<td>3</td>
<td>0.60</td>
<td>0.70</td>
<td>$2.268 \times 10^{-2}$</td>
</tr>
</tbody>
</table>

\[
\text{rate} = \frac{\left[\text{NO}_2\right]^x \times \left[H_2\right]^y}{M \text{sec}^{-1}}
\]

3. Given the following data for the $\text{NH}_4^+ + \text{NO}_2^- \rightarrow \text{N}_2 + 2\text{H}_2\text{O}$ reaction.

\[
\begin{array}{ccc}
\text{[NH}_4^+\text{]} & \text{[NO}_2^\text{-}] & \text{Rate} \\
0.010 & 0.020 & 0.030 \\
0.015 & 0.020 & 0.030 \\
0.010 & 0.010 & 0.005 \\
\end{array}
\]

The rate law for the reaction is

\[\text{Rate} = \frac{f_{\text{NH}_4^+} \times [\text{NH}_4^+]^x \times [\text{NO}_2^-]^y}{M \text{sec}^{-1}}\]

a) $R = [\text{NH}_4^+]^{-1}$
b) $R = [\text{NH}_4^+]^{-2}$
c) $R = [\text{NH}_4^+]^{-1} [\text{NO}_2^-]$  
d) None of the above

e) Choose the correct value for the first-order rate constant for the reaction $\text{NO}_2^- \rightarrow \text{N}_2 + 2\text{H}_2\text{O}$.

\[
\begin{align*}
\text{rate} & = \frac{k}{[\text{NO}_2^-]} \\
0.020 & = \frac{0.010}{0.015} \\
0.030 & = \frac{(0.010)^x}{(0.015)^y} \\
\text{ln}(0.020) & = x \text{ln}(0.010) \\
\text{ln}(0.030) & = y \text{ln}(0.015)
\end{align*}
\]

\[x = 1, \quad y = 2\]
5. The gas phase reaction \( 3C + 2D \rightarrow E + F \) obeys the rate-law expression:

\[ \text{Rate} = k[C]^3 \text{ and has a half-life of } 0.680 \text{ s}. \]

If 2.00 mole of \( D \) is injected into a 1.00 L container with excess \( C \), what concentration of \( D \) remains after 1.50 seconds?

\[ \frac{1}{2} \ln \left( \frac{[D]}{[D]_0} \right) = \frac{-kt + 2n[A]}{C} \]

\[ \ln \left( \frac{[D]}{[D]_0} \right) = \ln \left( \frac{0.735}{5.50} \right) = 0.305 \frac{1}{s} \]

\[ \frac{1}{2} \ln \left( \frac{[D]}{[D]_0} \right) = \frac{-0.305(1.50) + 2n[A]}{C} \]

\[ [D] = e^{-0.515} = 0.597 \text{ M} \]

6. Consider the following proposed mechanism. If this mechanism for the overall reaction were correct, and if \( k_1 \) were much less than \( k_2 \), then the observed rate law would be:

\[ \text{Rate} = k_3 \text{[A] [C]} \]

\[ \text{Rate} = k_4 \text{[I] [B]} \]

\[ \text{Rate} = k_5 \text{[I]}^2 \text{[B]} \]

\[ \text{Rate} = k_6 \text{[I] [B]} \]

7. One of the reactions that is used to produce gaseous hydrogen commercially follows. A proper expression for the rate of this reaction could be:

\[ H_2(g) + CO(g) \rightarrow H_2(g) + CO_2(g) \]

\[ \text{Rate} = -\frac{\Delta [CO]}{\Delta t} \]

\[ \text{Rate} = -\frac{\Delta [H_2]}{\Delta t} \]

\[ \text{Rate} = k \]

\[ \text{Rate} = \frac{\Delta [CO]}{\Delta t} \]

\[ \text{Rate} = -\frac{\Delta [H_2]}{\Delta t} \]
8. Which one of the following graphs shows the correct relationship between concentration and time for a reaction that is second order in A?

a) \( \ln[A] \) vs. time
b) \([A]\) vs. time
c) \(1/[A]\) vs. time
d) \([A]\) vs. time
e) \([A]\) vs. time

9. A reaction has an activation energy of 40 kJ and an overall energy change of reaction \( \Delta E \) of 100 kJ. In each of the following potential energy diagrams, the horizontal axis is the reaction coordinate and the vertical axis is potential energy in kJ. Which potential energy diagram best describes this reaction?

(a) [Diagram A]
(b) [Diagram B]
(c) [Diagram C]
(d) [Diagram D]
(e) [Diagram E]

10. A catalyst

a) is used up in a chemical reaction
b) changes the value of \( \Delta E^0 \) of the reaction
c) is always a solid
d) does not influence the reaction in any way
(e) changes the activation energy of the reaction
11. The gas phase reaction \( A + B \rightarrow C \) has a reaction rate which is experimentally observed to follow the relationship \( \text{Rate} = k[A][B] \). Which one of the following would affect the value of the specific rate constant, \( k \)?
   a) decreasing the temperature
   b) changing the concentration of \( A \)
   c) changing the concentration of \( B \)
   d) changing the concentration of \( C \)
   e) letting the reaction go on for a long time

12. The oxidation of NO by \( O_2 \) is first order in each of the reactants, and its rate constant is \( 1.5 \times 10^7 \text{ L}^2 \text{ mol}^{-2} \text{ s}^{-1} \). If the concentrations of NO and \( O_2 \) are each \( 5.0 \times 10^{-7} \text{ mol L}^{-1} \), what is the rate of oxidation of NO in \( \text{mol L}^{-1} \text{ s}^{-1} \)?
   a) \( 3.8 \times 10^{-4} \)
   b) \( 2.5 \times 10^{-14} \)
   c) \( 7.5 \times 10^{-7} \)
   d) 15
   e) 7.5

13. The mechanism for formation of the product \( X \) is:
   \[ A + B \rightarrow C + D \]
   \[ B + D \rightarrow X \]
   The intermediate reactant in the reaction is _________.
   a) \( A \)
   b) \( B \)
   c) \( C \)
   d) \( D \)
   e) \( X \)

14. The reaction \( A + B \rightarrow C + D \), obeys the rate law expression \( \text{Rate} = k[A][B] \). Which response lists all the proposed mechanisms below that are consistent with this information and none that are inconsistent?
   \[ 1. \ A + B \rightarrow C + D \text{ One step} \]
   \[ 2. \ A + B \rightarrow E \text{ fast, equilibrium} \]
   \[ 3. \ E \rightarrow C + D \text{ slow} \]
   \[ 4. \ A + B \rightarrow E \text{ fast, equilibrium} \]
   \[ 5. \ A + E \rightarrow C + B \text{ slow} \]
   a) 1 and 2
   b) 2
   c) 3
   d) 2 and 3
   e) 1, 2, and 3
15. Consider the hypothetical reaction shown below.

\[ \text{A} + 2 \text{B} \rightarrow \text{AB}_2 \]

Assume that the following proposed mechanism is consistent with the rate data.

- \( \text{B} + \text{B} \rightarrow \text{B}_2 \) slow
- \( \text{B}_2 + \text{A} \rightarrow \text{AB} + \text{B} \) fast
- \( \text{B} + \text{AB} \rightarrow \text{AB}_2 \) fast
- \( \text{A} + 2 \text{B} \rightarrow \text{AB}_2 \) overall

Which one of the following statements must be true? The reaction is

a) first order in A, second order in B, and third order overall
b) second order in B and second order overall
c) first order in A and first order overall
d) second order in B, zero order in A, and third order overall
e) second order in A and second order overall

16. One difference between first and second-order reactions is that

a) the half-life of a first-order reaction does not depend on \([\text{A}]\); the half-life of a second-order reaction does depend on \([\text{A}]\).
b) the rate of a first-order reaction does not depend on reactant concentrations; the rate of a second-order reaction does depend on reactant concentrations.
c) the rate of a first-order reaction depends on reactant concentrations; the rate of a second-order reaction does not depend on reactant concentrations.
d) a first-order reaction can be catalyzed; a second-order reaction cannot be catalyzed.
e) the half-life of a first-order reaction depends on \([\text{A}]\); the half-life of a second-order reaction does not depend on \([\text{A}]\).

17. For a first order reaction, a plot of \[ \int \frac{1}{[\text{A}]} \] versus \( t \) is linear.

a) \( \int \frac{1}{[\text{A}]} \) versus \( t \)
b) \( \int [\text{A}] \) versus \( t \)
c) \( \frac{1}{[\text{A}]} \) versus \( t \)
d) \( [\text{A}] \) versus \( t \)
e) \( t \) versus \( \frac{1}{[\text{A}]} \)

18. The units of the rate constant for a second order reaction can be

\[ k = \text{M}^{-1} \text{s}^{-1} \]

a) M\(^{-1}\) s\(^{-1}\)
b) \( \frac{\text{M}^2}{\text{s}} \)
c) M\(^{-1}\) s\(^{-1}\)
d) s\(^{-1}\)
e) M\(^2\) s\(^{-1}\)
19. Given the following potential energy diagram for the one-step reaction
\[ X + Y \rightarrow Z + A \]
The arrow "\( \rightarrow \)" represents the ________.

- a) energy content of products
- b) activation energy for the forward reaction
- c) energy content of reactants
- d) activation energy for the reverse reaction
- e) net change in energy for the reaction

20. The disproportionation (auto-oxidation-reduction) of the hypochlorite ion to chlorate and chloride ions occurs in aqueous solution. The rate expression is found to be Rate = \( k [ClO^-]^2 \). Which one of the following (possible) mechanisms is consistent with this information?

\[
3ClO^- \rightarrow ClO_3^- + 2Cl^- \\
\text{a) } ClO^- + Cl^- \rightarrow ClO_2^- + Cl^- \quad \text{(slow)} \\
\text{ClO}^- + ClO_2^- \rightarrow ClO_3^- + 2Cl^- \quad \text{(fast)}
\]

\[
\text{b) } ClO^- \rightarrow Cl + O^- \\
\text{ClO}^- \rightarrow Cl^- + O_2 \quad \text{(fast)} \\
O_2 + ClO^- \rightarrow Cl^- + O_2 \quad \text{(fast)} \\
O_2 + ClO^- \rightarrow ClO_2^- \quad \text{(fast)}
\]

\[
\text{c) } 3ClO^- \rightarrow ClO_3^- + 2Cl^- \quad \text{(one step)}
\]

\[
\text{d) } ClO^- \rightarrow Cl^- + O \\
ClO^- + O_2 \rightarrow ClO_2^- \quad \text{(fast)} \\
O + ClO^- \rightarrow Cl^- + O_2 \quad \text{(fast)}
\]

\[
\text{e) } 3ClO^- \rightarrow ClO_2^- + ClO_2^- \\
ClO_2^- \rightarrow Cl^- + Cl^- \quad \text{(fast)} \\
ClO^- + ClO_2^- \rightarrow Cl^- + ClO_2^- \quad \text{(fast)}
\]

21. The decomposition of dimethyl ether at 50°C is first order with a half-life of 1570 seconds. What fraction of an initial amount of dimethyl ether remains after 4710 seconds?

\[ \ln \left( \frac{[A]_t}{[A]_0} \right) = -kt \]

- a) 1/3
- b) 1/6
- c) 1/16
- d) 1/32
- e) 0.679

\[ k = \frac{0.693}{t_\frac{1}{2}} \]

\[ k = 4.414 \times 10^{-4} \text{ s}^{-1} \]
22. The gas phase reaction \( A + B \rightarrow C \) has a reaction rate which is experimentally observed to follow the relationship \( r = k[A]^2[B] \). The overall order of the reaction 

a) is first.  
b) is second. 
c) is third.  
d) is zero.  
e) cannot be answered without a detailed knowledge of the reaction mechanism.

23. A reaction mechanism will usually be 

a) the only possible explanation for the reaction.  
b) difficult to verify experimentally. 
c) proven experimentally to be the balanced chemical equation.  
d) obvious from a consideration of the balanced chemical equation.  
e) obvious from a consideration of the reaction rate data.

24. The reaction \( A + B \rightarrow C \) is first order in \([A]\). The concentration of \( A(0) \) is ______ M after 40.0 s.

<table>
<thead>
<tr>
<th>Time(s)</th>
<th><a href="M">A</a></th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>0.20</td>
</tr>
<tr>
<td>5.0</td>
<td>0.14</td>
</tr>
<tr>
<td>10.0</td>
<td>0.10</td>
</tr>
<tr>
<td>15.0</td>
<td>0.071</td>
</tr>
<tr>
<td>20.0</td>
<td>0.050</td>
</tr>
</tbody>
</table>

\( \frac{0.20}{0.14} = 0.0125 \)

25. Calculate the activation energy of a reaction if the rate constant is 0.75 s\(^{-1}\) at 25°C and 11.5 s\(^{-1}\) at 75°C.

\[ \ln \left( \frac{R_2}{R_1} \right) = \frac{E_a}{R} \left( \frac{1}{T_2} - \frac{1}{T_1} \right) \]

\[ \ln 0.75 = \frac{E_a}{8.314 \times 273.15} \left( \frac{1}{273.15} - \frac{1}{727.15} \right) \]

26. A first-order reaction has a rate constant of 0.33 min\(^{-1}\). It takes ______ min for the reactant concentration to decrease from 0.13 M to 0.088 M.

\[ \ln [A]_t = -kt + \ln [A]_0 \]

\[ \ln [0.088] = -0.33t + \ln [0.13] \]

\[ t = 1.18 \text{ min} \]
27. Suppose a reaction \( A + B \rightarrow C \) occurs at some initial rate at 25°C. Which response includes all of the changes below that could increase the rate of this reaction?

I. lowering the temperature
II. adding a catalyst
III. increasing the initial concentration of B

a) I
b) II
c) III
d) I and II

\( \text{III and III} \)

28. Which of the following does not play a part in determining the rate of a reaction?

a) temperature
b) the concentrations of reactants
c) the presence of a catalyst
d) the surface area of solid or liquid reactants
e) the equilibrium constant

29. The half-life of a first-order reaction

a) is the time necessary for the reactant concentration to drop to half its original value
b) is constant
c) can be calculated from the reaction rate constant
d) does not depend on the initial reactant concentration

all of these are correct

30. The gas phase reaction \( A + B \rightarrow C \) has a reaction rate which is experimentally observed to follow the relationship \( \text{Rate} = k[A]^2[B] \). If the concentration of \( A \) is tripled and the concentration of \( B \) is doubled, the reaction rate would be increased by a factor of

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

a) 6
b) 9
c) 12
\[ \text{(c)} \]
d) 18
\[ \text{(d)} \]
e) 36

31. Consider the following rate data for the reaction below at a particular temperature.

\[ 2A + 3B \rightarrow \text{Products} \]

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Initial ([A])</th>
<th>Initial ([B])</th>
<th>Initial Rate of Loss of A</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.10 M</td>
<td>0.30 M</td>
<td>(7.20 \times 10^{-5} \text{ M s}^{-1})</td>
</tr>
<tr>
<td>2</td>
<td>0.20 M</td>
<td>0.60 M</td>
<td>(1.44 \times 10^{-4} \text{ M s}^{-1})</td>
</tr>
<tr>
<td>3</td>
<td>0.20 M</td>
<td>0.90 M</td>
<td>(8.64 \times 10^{-4} \text{ M s}^{-1})</td>
</tr>
</tbody>
</table>

The reaction is _______ order in \( A \) and _______ order in \( B \).

a) first, first
b) second, first
c) first, second
d) second, second
e) third, first

32. As the temperature of a reaction is increased, the rate of the reaction increases because the _______.

\( \text{a) reactant molecules collide less frequently} \)
\( \text{b) reactant molecules collide with greater energy per collision} \)
\( \text{c) activation energy is lowered} \)
\( \text{d) reactant molecules collide less frequently and with greater energy per collision} \)
\( \text{e) reactant molecules collide more frequently with less energy per collision} \)
33. Suppose the reaction

\[ 2AB + C_2 \rightarrow A_2C + B_2C \]

occurs by the following mechanism:

Step 1: \( AB + C_2 \rightarrow A_2C + B \) (slow)

Step 2: \( B + AB \rightarrow AB_2 \) (fast)

Step 3: \( AC_2 + AB_2 \rightarrow A_2C_2 + B_2 \) (fast)

Step 4: \( AB_2C_2 + B_2 \rightarrow A_2C + B_2C \) (fast)

Overall: \( 2AB + C_2 \rightarrow A_2C + B_2C \)

The rate law expression must be \( \text{Rate} = \) _______.

a) \( k[AB][C_2] \)

b) \( k[AB][C_2] \)

c) \( k[AB]^2 \)

d) \( k[AB] \)

e) \( k[C_2] \)