General Types/Groups of problems:

<table>
<thead>
<tr>
<th>Rates of Change in Chemical Reactions</th>
<th>p1</th>
<th>First Order Rate Law Calculations</th>
<th>P9</th>
</tr>
</thead>
<tbody>
<tr>
<td>The look of concentration/time graphs</td>
<td>p2</td>
<td>Reaction Energy Diagrams, Activation Energy, Transition States…</td>
<td>P10</td>
</tr>
<tr>
<td>Rates: Average Rates, Determination of Rates from Stoichiometry and Changes of Other Chemicals</td>
<td>p3</td>
<td>Reaction Mechanisms, Intermediates…</td>
<td>P12</td>
</tr>
<tr>
<td>Reactant Order and Overall Reaction Order</td>
<td>P4</td>
<td>Mechanism Steps and Rate Laws</td>
<td>P13</td>
</tr>
<tr>
<td>Given a Rate Law, How much will rate change with change in concentration</td>
<td>P5</td>
<td>Catalysts</td>
<td>P14</td>
</tr>
<tr>
<td>Determining Reactant Orders from Actual Data</td>
<td>P6</td>
<td>Answers</td>
<td>P15</td>
</tr>
<tr>
<td>Actual Rate Law from Concentration/Rate Data</td>
<td>P7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Determining Rate Constant from Actual Data. Where you yourself need to first deduce the rate law, then plug in the values to solve for “k”.</td>
<td>P8</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Rates of Change in Chemical Reactions**

1. For the reaction \( A + 3B \rightarrow 2C \), how does the rate of disappearance of \( B \) compare to the rate of production of \( C \)?
   a. the rate of disappearance of \( B \) is 1/2 the rate of appearance of \( C \)
   b. the rate of disappearance of \( B \) is 3/2 the rate of appearance of \( C \)
   c. the rate of disappearance of \( B \) is 2/3 the rate of appearance of \( C \)
   d. the rate of disappearance of \( B \) is 1/3 the rate of appearance of \( C \)

2. For the reaction \( 2A + 3B \rightarrow 4C + 5D \), the rate of the reaction in terms of \( \Delta A \) would be written as:
   a. \(-\Delta A/\Delta t\)
   b. \(-1/2 \Delta A/\Delta t\)
   c. \(+\Delta A/\Delta t\)
   d. \(+1/2 \Delta A/\Delta t\)
   e. \(-2 \Delta A/\Delta t\)

3. For the reaction \( 2A + 3B \rightarrow 4C + 5D \), the rate of the reaction in terms of \( \Delta B \) would be written as
   a. \(-\Delta B/\Delta t\)
   b. \(+\Delta B/\Delta t\)
   c. \(-1/3 \Delta B/\Delta t\)
   d. \(+1/3 \Delta B/\Delta t\)
   e. \(-3 \Delta B/\Delta t\)

4. For the reaction \( 2A + 3B \rightarrow 4C + 5D \), the rate of the reaction in terms of \( \Delta C \) would be written as
   a. \(+\Delta C/\Delta t\)
   b. \(+4 \Delta C/\Delta t\)
   c. \(+1/4 \Delta C/\Delta t\)
   d. \(-4 \Delta C/\Delta t\)
   e. \(-1/4 \Delta C/\Delta t\)

5. In the combustion of methane, \( \text{CH}_4(g) + 2 \text{O}_2(g) \rightarrow \text{CO}_2(g) + 2 \text{H}_2\text{O} (g) \), which reactant has the greatest rate of disappearance?
   a. \( \text{CH}_4 \)
   b. \( \text{O}_2 \)
   c. \( \text{CO}_2 \)
   d. \( \text{H}_2\text{O} \)
   e. \( \text{CH}_4 \) and \( \text{O}_2 \) have the same rate of disappearance.
The look of concentration/time graphs

6. Which of the following is not a possible graph of concentration versus time for a reactant?

a. ![Graph A](image1.png)

b. ![Graph B](image2.png)

c. ![Graph C](image3.png)

d. ![Graph D](image4.png)

7. Assuming that each of the following graphs has the same concentration and time axes, which has the greatest initial rate of disappearance of reactant?

a. ![Graph A](image1.png)

b. ![Graph B](image2.png)

c. ![Graph C](image3.png)

d. ![Graph D](image4.png)

e. Any of these curves could be hydrogen

8. The following graph shows the kinetics curves for the reaction of oxygen with hydrogen to form water: \( \text{O}_2(g) + 2\text{H}_2(g) \rightarrow 2\text{H}_2\text{O}(g) \). Which curve is hydrogen?

a. the dashed curve

b. the gray curve

c. the black curve

d. either the gray or the black curve

e. Any of these curves could be hydrogen
Rates: Average Rates, Determination of Rates from Stoichiometry and Changes of Other Chemicals; Simple Rate Calculations

9. A scientist conducts an experiment to determine the rate of the following reaction:

\[ \text{N}_2(g) + \text{O}_2(g) \rightarrow 2 \text{NO}(g) \]

If the initial concentration of N\(_2\) was 0.500 \( M \) and the concentration of N\(_2\) was 0.450 \( M \) after 0.100 s, what is the rate of the reaction?

a. 0.500 \( M/s \)  
b. 1.00 \( M/s \)  
c. 5.00 \( M/s \)  
d. 10.0 \( M/s \)  
e. 0.250 \( M/s \)

10. A scientist conducts an experiment to determine the rate of NO formation in the reaction:

\[ \text{N}_2(g) + \text{O}_2(g) \rightarrow 2 \text{NO}(g) \]

If the initial concentration of N\(_2\) was 0.500 \( M \) and the concentration of N\(_2\) was 0.450 \( M \) after 0.100 s, what is the rate of NO formation?

a. 0.500 \( M/s \)  
b. 1.00 \( M/s \)  
c. 5.00 \( M/s \)  
d. 10.0 \( M/s \)  
e. 0.250 \( M/s \)

11. If the rate of appearance of O\(_2\) in the reaction:

\[ 2\text{O}_3(g) \rightarrow 3\text{O}_2(g) \]

is 0.250 \( M/s \) over the first 5.50 s, how much oxygen will form during this time?

a. 1.38 \( M \)  
b. 4.13 \( M \)  
c. 0.69 \( M \)  
d. 0.25 \( M \)  
e. 0.46 \( M \)

12. HI dissociates to form I\(_2\) and H\(_2\):

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

If the concentration of HI changes at a rate of \(-0.45\) \( M/s \), what is the rate of appearance of I\(_2\)?

a. 0.90 \( M/s \)  
b. 0.45 \( M/s \)  
c. 0.23 \( M/s \)  
d. 1.00 \( M/s \)  
e. 0.13 \( M/s \)

13. If the rate of formation of ammonia is 0.345 \( M/s \), what is the rate of disappearance of N\(_2\)?

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

a. 0.173 \( M/s \)  
b. 0.345 \( M/s \)  
c. 0.690 \( M/s \)  
d. 245 \( M/s \)  
e. 0.518 \( M/s \)

14. If the rate of formation of ammonia is 0.345 \( M/s \), what is the rate of disappearance of H\(_2\)?

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

a. 0.173 \( M/s \)  
b. 0.345 \( M/s \)  
c. 0.522 \( M/s \)  
d. 245 \( M/s \)  
e. 0.518 \( M/s \)
Reactant Order and Overall Reaction Order

15. For the reaction \(2A + B + 2C \rightarrow D + 2E\), the rate law is: \( \text{rate} = k[A]^2[B]^1[C]^1 \)
Which of the following statements is false:

a. the reaction is second order in \([A]\)
b. the reaction is first order in \([B]\)
c. the reaction is second order in \([C]\)
d. the reaction is 4th order overall

16. For the reaction \(1A + 2B + 1C \rightarrow 2D + 1E\), the rate law is: \( \text{rate} = k[B]^3[C]^1 \)
Which of the following statements is false:

a. the reaction is first order in \([A]\)
b. the reaction is second order in \([B]\)
c. the reaction is first order in \([C]\)
d. the reaction is third order overall

17. For the rate law \( \text{Rate} = k[A]^{1/2}[B] \), the partial order with respect to \(A\) is \__________, the partial order with respect to \(B\) is \__________, and the total order is \__________.

a. 1/2; 0; 1/2
b. 1/2; 1; 1
c. 1/2; 1; 3/2
d. 1/2
e. The orders cannot be determined without a chemical reaction.

18. For the rate law \( \text{Rate} = k[A][B]^{3/2} \), the order with respect to \(A\) is \__________, the order with respect to \(B\) is \__________, and the overall reaction order is \__________.

a. 0; 3/2; 3/2
b. 1; 3/2; 1
c. 1; 3/2; 5/2
d. 1; 3/2; 7/2
e. The orders cannot be determined without a chemical reaction.

19. The reaction \(A + 2B \rightarrow C\)
is first order in \(B\) and \(A\). The overall order of the reaction is \__________

a. first. d. zero.
b. second. e. fourth.
c. third.
Given a Rate Law, How much will rate change with change in concentration

20. The reaction \( \text{CHCl}_3(g) + \text{Cl}_2(g) \rightarrow \text{CCl}_4(g) + \text{HCl}(g) \) has the following rate law: \( \text{Rate} = k[\text{CHCl}_3][\text{Cl}_2] \). If the concentration of \( \text{CHCl}_3 \) is increased by a factor of five while the concentration of \( \text{Cl}_2 \) is kept the same, the rate will

- a. double.
- b. triple.
- c. stay the same.
- d. increase by a factor of five.
- e. decrease by a factor of one-fifth.

21. The reaction \( 2\text{NO}(g) + \text{O}_2(g) \rightarrow 2\text{NO}_2(g) \) has the following rate law: \( \text{Rate} = k[\text{O}_2][\text{NO}]^2 \). If the concentration of \( \text{NO} \) is reduced by a factor of two, the rate will

- a. double.
- b. quadruple.
- c. be reduced by one-quarter.
- d. be reduced by one-half.
- e. remain the same.

22. The rate of a reaction is found to double when the concentration of one reactant is quadrupled. The order of the reaction with respect to this reactant is

- a. first.
- b. second.
- c. one-quarter.
- d. one-half.
- e. third.
23. Given the following data, determine the order of the reaction with respect to Cl₂.

\[ 2\text{NO}(g) + \text{Cl}_2(g) \rightarrow 2\text{NOCl}(g) \]

<table>
<thead>
<tr>
<th>Experiment</th>
<th>[NO] (M)</th>
<th>[Cl₂] (M)</th>
<th>Rate (M/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.0300</td>
<td>0.0100</td>
<td>3.4 × 10⁻⁴</td>
</tr>
<tr>
<td>2</td>
<td>0.0150</td>
<td>0.0100</td>
<td>8.5 × 10⁻⁵</td>
</tr>
<tr>
<td>3</td>
<td>0.0150</td>
<td>0.0400</td>
<td>3.4 × 10⁻⁴</td>
</tr>
</tbody>
</table>

a. first  
d. fourth  
b. second  
e. fifth  
c. third

24. Given the following data, determine the order of the reaction with respect to H₂.

\[ \text{H}_2(g) + 2\text{ICl}(g) \rightarrow \text{I}_2(g) + 2\text{HCl}(g) \]

<table>
<thead>
<tr>
<th>Experiment</th>
<th>[H₂] (torr)</th>
<th>[ICl] (torr)</th>
<th>Rate (torr/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>250</td>
<td>325</td>
<td>1.34</td>
</tr>
<tr>
<td>2</td>
<td>250</td>
<td>81</td>
<td>0.331</td>
</tr>
<tr>
<td>3</td>
<td>50</td>
<td>325</td>
<td>0.266</td>
</tr>
</tbody>
</table>

a. one-half  
d. third  
b. second  
e. three-halves  
c. first

25. Given the following data, determine the order of the reaction with respect to NO(g).

\[ 2\text{NO}(g) + \text{Cl}_2(g) \rightarrow 2\text{NOCl}(g) \]

<table>
<thead>
<tr>
<th>Experiment</th>
<th>[NO] (M)</th>
<th>[Cl₂] (M)</th>
<th>Rate (M/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.0300</td>
<td>0.0100</td>
<td>3.4 × 10⁻⁴</td>
</tr>
<tr>
<td>2</td>
<td>0.0150</td>
<td>0.0100</td>
<td>8.5 × 10⁻⁵</td>
</tr>
<tr>
<td>3</td>
<td>0.0150</td>
<td>0.0400</td>
<td>3.4 × 10⁻⁴</td>
</tr>
</tbody>
</table>

a. first  
d. fourth  
b. second  
e. fifth  
c. third

26. Determine the overall order of the reaction: \( \text{H}_2(g) + 2\text{ICl}(g) \rightarrow \text{I}_2(g) + 2\text{HCl}(g) \) from the following data:

<table>
<thead>
<tr>
<th>Experiment</th>
<th>( P_{\text{H}} ) (torr)</th>
<th>( P_{\text{ICl}} ) (torr)</th>
<th>Rate (torr/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>250</td>
<td>325</td>
<td>1.34</td>
</tr>
<tr>
<td>2</td>
<td>250</td>
<td>81</td>
<td>0.331</td>
</tr>
<tr>
<td>3</td>
<td>50</td>
<td>325</td>
<td>0.266</td>
</tr>
</tbody>
</table>

a. first  
d. fourth  
b. second  
e. zeroth  
c. third

27. Determine the overall order of the reaction \( 2\text{NO}(g) + \text{Cl}_2(g) \rightarrow 2\text{NOCl}(g) \) from the following data:

<table>
<thead>
<tr>
<th>Experiment</th>
<th>[NO] (M)</th>
<th>[Cl₂] (M)</th>
<th>Rate (M/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.0300</td>
<td>0.0100</td>
<td>3.4 × 10⁻⁴</td>
</tr>
<tr>
<td>2</td>
<td>0.0150</td>
<td>0.0100</td>
<td>8.5 × 10⁻⁵</td>
</tr>
<tr>
<td>3</td>
<td>0.0150</td>
<td>0.0400</td>
<td>3.4 × 10⁻⁴</td>
</tr>
</tbody>
</table>

a. first  
d. fourth  
b. second  
e. fifth  
c. third
Actual Rate Law from a Table of Concentration/Rate Data

28. Given the following data, determine the rate law for the reaction

\[ \text{NH}_4^+ (aq) + \text{NO}_2^- (aq) \rightarrow \text{N}_2(g) + 2\text{H}_2\text{O}(l) \]

<table>
<thead>
<tr>
<th>Experiment</th>
<th>[\text{NH}_4^+] (M)</th>
<th>[\text{NO}_2^-] (M)</th>
<th>Rate (M/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.2500</td>
<td>0.2500</td>
<td>1.25 $\times$ 10^{-3}</td>
</tr>
<tr>
<td>2</td>
<td>0.5000</td>
<td>0.2500</td>
<td>2.50 $\times$ 10^{-3}</td>
</tr>
<tr>
<td>3</td>
<td>0.2500</td>
<td>0.1250</td>
<td>6.25 $\times$ 10^{-4}</td>
</tr>
</tbody>
</table>

a. \( k[\text{NH}_4^+][\text{NO}_2^-] \)

b. \( k[\text{NH}_4^+]^2[\text{NO}_2^-] \)

c. \( k[\text{NH}_4^+] [\text{NO}_2^-]^{1/2} \)

d. \( k[\text{NH}_4^+]^{1/2}[\text{NO}_2^-]^2 \)

e. \( k[\text{NH}_4^+]^2[\text{NO}_2^-] \)

29. Given the following data, determine the rate law for the reaction

\[ 2\text{NO}(g) + \text{Cl}_2(g) \rightarrow 2\text{NOCl}(g) \]

<table>
<thead>
<tr>
<th>Experiment</th>
<th>[\text{NO}] (M)</th>
<th>[\text{Cl}_2] (M)</th>
<th>Rate (M/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.0300</td>
<td>0.0100</td>
<td>3.4 $\times$ 10^{-4}</td>
</tr>
<tr>
<td>2</td>
<td>0.0150</td>
<td>0.0100</td>
<td>8.5 $\times$ 10^{-5}</td>
</tr>
<tr>
<td>3</td>
<td>0.0150</td>
<td>0.0400</td>
<td>3.4 $\times$ 10^{-4}</td>
</tr>
</tbody>
</table>

a. Rate = \( k[\text{NO}][\text{Cl}_2] \)

b. Rate = \( k[\text{NO}]^2[\text{Cl}_2] \)

c. Rate = \( k[\text{NO}][\text{Cl}_2] \)

d. Rate = \( k[\text{NO}][\text{Cl}_2]^{1/2} \)

e. Rate = \( k[\text{NO}]^2[\text{Cl}_2] \)

30. What is the rate law for the reaction \( 2\text{A} + 2\text{B} + 2\text{C} \rightarrow \text{products} \)

<table>
<thead>
<tr>
<th>Initial [A]</th>
<th>Initial [B]</th>
<th>Initial [C]</th>
<th>rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.273</td>
<td>0.763</td>
<td>0.400</td>
<td>3.0</td>
</tr>
<tr>
<td>0.819</td>
<td>0.763</td>
<td>0.400</td>
<td>9.0</td>
</tr>
<tr>
<td>0.273</td>
<td>1.526</td>
<td>0.400</td>
<td>12.0</td>
</tr>
<tr>
<td>0.273</td>
<td>0.763</td>
<td>0.800</td>
<td>6.0</td>
</tr>
</tbody>
</table>

a. rate = \( k[\text{A}][\text{B}][\text{C}] \)

b. rate = \( k[\text{A}]^2[\text{B}][\text{C}] \)

c. rate = \( k[\text{A}]^3[\text{B}]^2[\text{C}] \)

d. rate = \( k[\text{A}]^2[\text{B}]^2[\text{C}] \)
Determining Rate Constant from Rate Law and Actual Data. Where you yourself need to first deduce the rate law, then plug in the values to solve for “k”.

31. The initial rate data for the reaction \(2\text{N}_2\text{O}_5(g) \rightarrow 4\text{NO}_2(g) + \text{O}_2(g)\) is shown in the following table. Determine the value of the rate constant for this reaction.

<table>
<thead>
<tr>
<th>Experiment</th>
<th>(<a href="M">\text{N}_2\text{O}_5</a>)</th>
<th>Rate (M/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>(1.28 \times 10^2)</td>
<td>22.5</td>
</tr>
<tr>
<td>2</td>
<td>(2.56 \times 10^2)</td>
<td>45.0</td>
</tr>
</tbody>
</table>

a. \(4.09 \text{ s}^{-1}\)  
b. \(0.176 \text{ s}^{-1}\)  
c. \(0.0569 \text{ s}^{-1}\)  
d. \(0.225 \text{ s}^{-1}\)  
e. \(80.1 \text{ s}^{-1}\)

32. Given the following data, determine the rate constant of the reaction \(2\text{NO}(g) + \text{Cl}_2(g) \rightarrow 2\text{NOCl}(g)\)

<table>
<thead>
<tr>
<th>Experiment</th>
<th>(<a href="M">\text{NO}</a>)</th>
<th>(<a href="M">\text{Cl}_2</a>)</th>
<th>Rate (M/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.0300</td>
<td>0.0100</td>
<td>(3.4 \times 10^{-4})</td>
</tr>
<tr>
<td>2</td>
<td>0.0150</td>
<td>0.0100</td>
<td>(8.5 \times 10^{-5})</td>
</tr>
<tr>
<td>3</td>
<td>0.0150</td>
<td>0.0400</td>
<td>(3.4 \times 10^{-4})</td>
</tr>
</tbody>
</table>

a. \(1.13 \text{ M}^{-2}\text{s}^{-1}\)  
b. \(9.44 \text{ M}^{-2}\text{s}^{-1}\)  
c. \(37.8 \text{ M}^{-2}\text{s}^{-1}\)  
d. \(0.0265 \text{ M}^{-2}\text{s}^{-1}\)  
e. \(59.6 \text{ M}^{-2}\text{s}^{-1}\)
First Order Rate Law Calculations

Formulas for First Order Reactions: \( \frac{kt}{t_{1/2}} = 0.693 \)

33. The first-order reaction \( A \rightarrow B \), has \( k = 8.00 \, \text{s}^{-1} \). If \( [A]_0 = 0.500 \, \text{M} \), how long will it take \( [A] = 0.200 \, \text{M} \)?
   a. 0.115 s
e. 0.488 s
   b. 0.100 s
d. 0.244 s
   c. 8.18 s

34. The first-order reaction \( A \rightarrow B \), has \( k = 5.67 \, \text{s}^{-1} \). If \( [A]_0 = 0.500 \, \text{M} \), how long will it take \( [A] = 0.124 \, \text{M} \)?
   a. 0.122 s
e. 0.244 s
   b. 0.100 s
d. 0.488 s
   c. 8.18 s

35. A reaction is first order in A. If the rate constant of the reaction is \( 6.00 \times 10^{-3} \, \text{s}^{-1} \), what is the half-life \( (t_{1/2}) \) of the reaction?
   a. \( 4.98 \times 10^{-3} \) s
e. 1.73 \( \times 10^{-3} \) s
   b. 200 s
d. 115 s
   c. 3.45 \( \times 10^{-3} \) s

36. A reaction is first order in A. If the rate constant of the reaction is \( 3.45 \times 10^{-3} \, \text{s}^{-1} \), what is the half-life \( (t_{1/2}) \) of the reaction?
   a. \( 4.98 \times 10^{-3} \) s
d. 100 s
   b. 201 s
e. 1.73 \( \times 10^{-3} \) s
   c. 3.45 \( \times 10^{-3} \) s

37. The half-life \( (t_{1/2}) \) of a first-order reaction is 0.100 s. What is the rate constant?
   a. \( 6.93 \) s\(^{-1} \)
e. \( 0.144 \) s\(^{-1} \)
   b. \( 0.693 \) s\(^{-1} \)
d. \( 3.01 \) s\(^{-1} \)
   c. \( 0.0693 \) s\(^{-1} \)

38. The half-life \( (t_{1/2}) \) of a first-order reaction is 0.950 s. What is the rate constant?
   a. \( 6.93 \) s\(^{-1} \)
e. \( 0.144 \) s\(^{-1} \)
   b. \( 0.729 \) s\(^{-1} \)
d. \( 3.01 \) s\(^{-1} \)
   c. \( 0.0693 \) s\(^{-1} \)

39. What percentage of a material will persist after 60 minutes if it’s half life is 30 minutes?
   a. 50%
e. none of the above
   b. 33%
d. 12.5%
   c. 25%
   d. 25%
   e. 6.25%

40. What percentage of a material will persist after 80 minutes if it’s half life is 20 minutes?
   a. 50%
e. none of the above
   b. 33%
d. 12.5%
   c. 25%
   d. 6.25%
   e. 33%
Reaction Energy Diagrams, Activation Energy, Transition States...

41. Which point as labeled by an asterisk (*) on the following energy profile is the transition state?

a. 

\[ \text{Energy} \]
\[ \text{Reaction path} \]

b. 

\[ \text{Energy} \]
\[ \text{Reaction path} \]

c. 

\[ \text{Energy} \]
\[ \text{Reaction path} \]

d. 

\[ \text{Energy} \]
\[ \text{Reaction path} \]

42. The energy profiles for four different reactions are shown. Which reaction requires the most energetic collisions to reach the transition state?

a. a  

\[ \text{Energy} \]
\[ \text{Reaction path} \]

b. b  

\[ \text{Energy} \]
\[ \text{Reaction path} \]

c. c  

\[ \text{Energy} \]
\[ \text{Reaction path} \]

d. d  

\[ \text{Energy} \]
\[ \text{Reaction path} \]
43. The following energy profiles for four different reactions are shown. Which reaction is the most endothermic?

- a. a
- b. b
- c. c
- d. d

44. The following energy profiles for four different reactions are shown. Which reaction is the most exothermic?

- a. a
- b. b
- c. c
- d. d

45. Collision theory assumes that the rate of a reaction depends on __________

- a. the energy of collisions.
- b. the orientation of colliding molecules.
- c. the energy of collisions and the orientation of colliding molecules.
- d. the change in energy between the products and the reactants.
- e. the change in free energy between the reactants and products.
46. The energy needed for a reaction to proceed from reactants to products is called _________
   a. collision energy.                    d. potential energy.
   b. kinetic energy.                     e. thermodynamic energy.
   c. activation energy.

47. For the reaction diagram shown, which of the following statements is true?

   ![Diagram]

   a. Line W represents the $\Delta H$ for the forward reaction; point B represents the transition state
   b. Line W represents the activation energy for the forward reaction; point B represents the transition state
   c. Line Y represents the activation energy for the forward reaction; point C represents the transition state
   d. Line X represents the $\Delta H$ for the forward reaction; point B represents the transition state

Reaction Mechanisms, Intermediates…

48. A proposed mechanism for the photodecomposition of ozone in the atmosphere is

   Step 1: $\text{O}_3(g) + h\nu \rightarrow \text{O}_2(g) + \text{O}(g)$
   Step 2: $\text{O}_3(g) + \text{O}(g) \rightarrow 2 \text{O}_2(g)$

   Which of the following species is an intermediate?
   a. $\text{O}_3$
   b. $h\nu$
   c. $\text{O}_2$
   d. $\text{O}$
   e. This mechanism has no intermediates.

49. A proposed mechanism for the decomposition of ozone in the atmosphere is

   Step 1: $\text{Cl}(g) + \text{O}_3(g) \rightarrow \text{ClO}(g) + \text{O}_2(g)$
   Step 2: $\text{ClO}(g) + \text{O}_3(g) \rightarrow \text{Cl}(g) + 2 \text{O}_2(g)$

   Which of the following species is an intermediate?
   a. $\text{Cl}$
   b. $\text{O}_3$
   c. $\text{ClO}$
   d. $\text{O}_2$
   e. This mechanism has no intermediates.

50. The reaction $\text{NO}_3(g) + \text{CO}(g) \rightarrow \text{NO}(g) + \text{CO}_2(g)$ is thought to occur by the following mechanism:

   Step 1: $\text{NO}_3(g) + \text{NO}_2(g) \rightarrow \text{NO}_2(g) + \text{NO}(g)$
   Step 2: $\text{NO}_3(g) + \text{CO}(g) \rightarrow \text{NO}_2(g) + \text{CO}_2(g)$

   Which of the following species is an intermediate?
   a. $\text{NO}_2$
   b. $\text{NO}$
   c. $\text{NO}_3$
   d. $\text{CO}_2$
   e. This mechanism has no intermediates.
Mechanism Steps, Slow Steps, and Rate Laws

51. A proposed mechanism for the decomposition of ozone in the stratosphere is:
Step 1: Cl\((g)\) + O\(_3\)(g) → ClO\((g)\) + O\(_2\)(g)
Step 2: ClO\((g)\) + O\(_3\)(g) → Cl\((g)\) + 2O\(_2\)(g)
What is the molecularity of Step 1?
  a. zeromolecular
  b. unimolecular
  c. bimolecular
  d. termolecular
  e. More information is needed to answer this question.

52. A proposed mechanism for the reduction of nitrogen as NO by hydrogen is:
Step 1: H\(_2\)(g) + 2NO\((g)\) → N\(_2\)O\((g)\) + H\(_2\)O\((g)\)
Step 2: N\(_2\)O\((g)\) + H\(_2\)(g) → N\(_2\)(g) + H\(_2\)O\((g)\)
What is the molecularity of Step 1?
  a. unimolecular
  b. bimolecular
  c. termolecular
  d. zero molecular (spontaneous)
  e. More information is needed to answer this question.

53. The mechanism for the reaction 2H\(_2\)O\(_2\)(aq) → 2H\(_2\)O() + O\(_2\)(g) in the presence of I\(^-\)(aq) is proposed to be:
Step 1: H\(_2\)O\(_2\)(aq) + I\(^-\)(aq) → H\(_2\)O() + OI\(^-\)(aq)  
  (slow)
Step 2: H\(_2\)O\(_2\)(aq) + OI\(^-\)(aq) → H\(_2\)O() + O\(_2\)(g) + I\(^-\)(aq)  
  (fast)
What is the molecularity of the rate-determining step?
  a. zeromolecular
  b. unimolecular
  c. bimolecular
  d. termolecular
  e. More information is needed to answer this question.

54. A proposed mechanism for the reduction of nitrogen as NO by hydrogen is:
Step 1: H\(_2\)(g) + 2NO\((g)\) → N\(_2\)O\((g)\) + H\(_2\)O\((g)\)  
  (slow)
Step 2: N\(_2\)O\((g)\) + H\(_2\)(g) → N\(_2\)(g) + H\(_2\)O\((g)\)  
  (fast)
What is the rate law?
  a. Rate = \(k[H_2][NO]\)
  b. Rate = \(k[H_2]^2[NO]\)
  c. Rate = \(k[H_2][NO]^2\)
  d. Rate = \(k[H_2]^2[NO]^2\)
  e. More information is needed to answer this question.

55. The mechanism for the reaction 2H\(_2\)O\(_2\)(aq) → 2H\(_2\)O() + O\(_2\)(g) in the presence of I\(^-\)(aq) is proposed to be
Step 1: H\(_2\)O\(_2\)(aq) + I\(^-\)(aq) → H\(_2\)O() + OI\(^-\)(aq)  
  (slow)
Step 2: H\(_2\)O\(_2\)(aq) + OI\(^-\)(aq) → H\(_2\)O() + O\(_2\)(g) + I\(^-\)(aq)  
  (fast)
What is the rate law for the overall reaction?
  a. Rate = \(k[H_2O_2]\)
  b. Rate = \(k[H_2O_2]^2\)
  c. Rate = \(k[H_2O_2][I^-]\)
  d. Rate = \(k[H_2O_2][OI^-]\)
  e. Rate = \(k[H_2O_2]^2[I^-][H_2O]\)
Catalysts

56. Which of the following statements about catalysts is false:
   a. catalysts do not appear in the balanced equation
   b. catalysts reduce the activation energy for a reaction
   c. biological catalysts are called enzymes
   d. catalysts do not alter the mechanism of the reaction and never appear in the rate law
   e. since catalysts are recycled, even a small amount of catalyst can accelerate a reaction

57. Which of the following statements is false:
   a. Changing the temperature does not change the activation energy for a reaction
   b. At higher temperature a higher percentage of reactants have enough energy to get over the transition state
   c. The mechanism, rate law, and activation energy will all change when a catalyst is added.
   d. The general rate law for a reaction does not change with temperature, but the rate constant does change
   e. The rate constant “k” for a reaction does not change when the temperature increases.

58. A proposed mechanism for the following reaction is shown below. Identify the catalyst in the reaction.
   \[
   2\text{H}_2\text{O}_2(aq) \rightarrow 2\text{H}_2\text{O}(aq) + \text{O}_2 \text{ in the presence of I}^- (aq)
   \]
   Step 1: \(\text{H}_2\text{O}_2(aq) + \text{I}^- (aq) \rightarrow \text{H}_2\text{O}(aq) + \text{OI}^- (aq)\) (slow)
   Step 2: \(\text{H}_2\text{O}_2(aq) + \text{OI}^- (aq) \rightarrow \text{H}_2\text{O}(aq) + \text{O}_2(g) + \text{I}^- (aq)\) (fast)
   a. \(\text{H}_2\text{O}_2\)
   b. \(\text{OI}^-\)
   c. \(\text{I}^-\)
   d. \(\text{H}_2\text{O}\)
   e. \(\text{O}_2\)

59. The steps in a reaction mechanism are as follows. Which species is acting as a catalyst?
   Step 1: \(\text{Ag}^+(aq) + \text{Ce}^{4+}(aq) \leftrightarrow \text{Ag}^{2+}(aq) + \text{Ce}^{3+}(aq)\)
   Step 2: \(\text{Ti}^3+(aq) + \text{Ag}^{2+}(aq) \rightarrow \text{Ti}^{2+}(aq) + \text{Ag}^+(aq)\)
   Step 3: \(\text{Ti}^{2+}(aq) + \text{Ce}^{4+}(aq) \rightarrow \text{Ti}^{3+}(aq) + \text{Ce}^{3+}(aq)\)
   a. \(\text{Ag}^+\)
   b. \(\text{Ti}^3+\)
   c. \(\text{Ce}^{3+}\)
   d. \(\text{Ag}^{2+}\)
   e. \(\text{Ti}^{2+}\)
| 1. B | 31. B |
| 2. B | 32. C |
| 3. C | 33. A |
| 4. C | 34. D |
| 5. B | 35. D |
| 6. C | 36. B |
| 7. A | 37. A |
| 8. C | 38. B |
| 10. B | 40. E |
| 11. A | 41. C |
| 12. C | 42. B |
| 13. A | 43. B |
| 14. C | 44. A |
| 15. C | 45. C |
| 16. A | 46. C |
| 17. C | 47. B |
| 18. C | 48. D |
| 20. D | 50. C |
| 21. C | 51. C |
| 22. D | 52. C |
| 23. A | 53. C |
| 24. C | 54. C |
| 25. B | 55. C |
| 26. B | 56. D |
| 27. D | 57. E |
| 28. A | 58. C |
| 29. C | 59. A |
| 30. B |   |