**Week 2 Kinetics**

**QUESTION 1**

If the following reaction is an elementary reaction, what are the *most likely* values of \( a \) and \( b \)?

\[
a \; A + b \; B \rightarrow c \; C
\]

<table>
<thead>
<tr>
<th></th>
<th>( a )</th>
<th>( b )</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>B</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>C</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>D</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>E</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

**QUESTION 2**

Nitrogen monoxide is reduced by hydrogen to give water and nitrogen by the following reaction:

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

For the following proposed mechanism, what is the role of \( \text{N}_2\text{O}_2 \)?

\[
\begin{align*}
2 \; \text{NO}(g) &= \text{N}_2\text{O}_2(g) \text{ (fast)} \\
\text{N}_2\text{O}_2(g) + \text{H}_2(g) &\rightarrow \text{N}_2(g) + \text{H}_2\text{O}(g) \text{ (slow)} \\
\text{N}_2\text{O}(g) + \text{H}_2(g) &\rightarrow \text{N}_2(g) + \text{H}_2\text{O}(g) \text{ (fast)}
\end{align*}
\]

A. \( \text{N}_2\text{O}_2 \) is a transition state.  
B. \( \text{N}_2\text{O}_2 \) is an activated complex.  
C. \( \text{N}_2\text{O}_2 \) is an intermediate.  
D. \( \text{N}_2\text{O}_2 \) is a catalyst.  
E. \( \text{N}_2\text{O}_2 \) is both a catalyst and a transition state.

**QUESTION 3**

The following two mechanism schemes have been proposed for this gas phase reaction:

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

Scheme I:

\[
\begin{align*}
2 \; \text{NO}(g) &= \text{N}_2\text{O}_2(g) \text{ fast} \\
\text{N}_2\text{O}_2(g) + \text{O}_2(g) &= 2 \; \text{NO}_2(g) \text{ slow}
\end{align*}
\]

Scheme II:

\[
\begin{align*}
\text{NO}(g) + \text{O}_2(g) &= \text{NO}_3(g) \text{ fast} \\
\text{NO}_3(g) + \text{NO}(g) &\rightarrow 2 \; \text{NO}_2(g) \text{ slow}
\end{align*}
\]

If the observed rate law is \( \text{Rate} = k[\text{NO}]^2[\text{O}_2] \), which mechanism is consistent with this observed rate law?

A. Scheme I only.  
B. Scheme II only.  
C. Neither Scheme I nor II.  
D. Both Scheme I and II.  
E. There is insufficient information to make this determination.
QUESTION 4

Dinitrogen pentoxide decomposes according to the following reaction:

\[ 2 \text{N}_2\text{O}_5(g) \rightarrow 4 \text{NO}_2(g) + \text{O}_2(g) \]

The following mechanism is proposed for this reaction:

\[ \text{N}_2\text{O}_5(g) \rightleftharpoons \text{NO}_2(g) + \text{NO}_2(g) \text{ (fast)} \]
\[ \text{NO}_2(g) + \text{NO}_2(g) \rightleftharpoons \text{NO}(g) + \text{O}_2(g) \text{ (slow)} \]
\[ \text{NO}_2(g) + \text{NO}(g) \rightarrow 2 \text{NO}_2(g) \text{ (fast)} \]

The observed rate law that is consistent with this mechanism would be:

A. first order in N\(_2\)O\(_5\).
B. first order in NO\(_2\) and first order in NO\(_3\).
C. first order in NO\(_2\) and NO\(_3\) and second order in N\(_2\)O\(_5\).
D. second order in N\(_2\)O\(_5\).
E. None of these is consistent with the mechanism.

QUESTION 5

In which one of the following situations is the reaction rate most likely to increase?

A. reactant concentration is reduced
B. product concentration is increased
C. a mixture of two solid reactants is dissolved in water
D. the total volume in which a gaseous reaction takes place is increased
E. temperature is decreased

QUESTION 6

A second order reaction is observed to be 1.31 times faster at 42.0°C than it is at 30.0°C. What is the activation energy for the reaction?

A. 236 J/mol
B. 23.6 kJ/mol
C. 178 J/mol
D. 17.9 kJ/mol
E. None of the above is within 5% of the correct answer.

QUESTION 7

Below are five statements about the temperature dependence of the reaction rate constant, k. Which statement holds true for most chemical reactions?

A. k increases with temperature, mainly because there are fewer collisions per second.
B. k increases with temperature, mainly because a higher proportion of the collisions are energetic enough to produce reaction.
C. k decreases with temperature, mainly because of the decrease in effectiveness of the attractive long-range intermolecular forces.
D. k does not change with temperature.
E. k increases or decreases with temperature, depending on whether the reaction is endothermic or exothermic.
QUESTION 8

The rate of a reaction was measured as a function of time and the data was plotted as shown in the figure below. The slope of the plot is \(-5.17 \times 10^3\) K. The y-intercept is -1.69. What is the activation energy of the reaction?

\[
\ln k = -5.17 \times 10^3 \frac{1}{T} - 1.69
\]

QUESTION 9

The following reaction is one step in the industrial manufacture of nitric acid:

\[
4 \text{NH}_3(g) + 5 \text{O}_2(g) \xrightarrow{\text{Pt catalyst}} 6 \text{H}_2\text{O}(g) + 4 \text{NO}(g) + \text{heat}
\]

What is the reason for using the Pt catalyst?

A. It changes the standard heat of reaction so as to make the process feasible.
B. It increases the standard entropy change of the reaction, which favors the forward reaction.
C. It absorbs the excess heat generated by the reaction.
D. It increases the reaction rate.
E. It eliminates the back reaction.

QUESTION 10

How do enzymes speed up chemical reactions?

I. They decrease the energy of the reaction products.
II. They increase the Arrhenius factor, A.
III. They decrease the activation energy, \(E_a\).

A. I only
B. I and II only
C. I and III only
D. II and III only
E. I, II and III
QUESTION 11

The activation energy for the un-catalyzed decomposition of acetaldehyde (CH₂CHO) is 190 kJ/mol, as shown in the following reaction:

\[
\text{CH}_2\text{CHO}(g) \rightarrow \text{CH}_4(g) + \text{CO}(g)
\]

The reaction can be catalyzed by \( \text{I}_2(g) \) according to the mechanism below, with a catalyzed activation energy of 136 kJ/mol.

\[
\begin{align*}
\text{CH}_2\text{CHO}(g) + \text{I}_2(g) & \rightarrow \text{CH}_3\text{I}(g) + \text{HI}(g) + \text{CO}(g) \\
\text{CH}_3\text{I}(g) + \text{HI}(g) & \rightarrow \text{CH}_4(g) + \text{I}_2(g)
\end{align*}
\]

Which of the provided reaction profiles is most appropriate for the catalyzed and un-catalyzed reactions? (The dotted lines are only a guide for your eye.)

NOTE: Heats of formation of the molecules are given below.

<table>
<thead>
<tr>
<th>Molecule</th>
<th>( \Delta H_f^0 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \text{CH}_2\text{CHO} ) (g)</td>
<td>(-166 \text{ kJ/mol})</td>
</tr>
<tr>
<td>( \text{CH}_4 ) (g)</td>
<td>(-74.9 \text{ kJ/mol})</td>
</tr>
<tr>
<td>( \text{CO} ) (g)</td>
<td>(-110.5 \text{ kJ/mol})</td>
</tr>
</tbody>
</table>
A plot of \([A]/[A]_0 \times 100\) vs. time, shown below, was obtained for the first order reaction of the decomposition of A to yield B.

Suppose the reaction was then carried out with the same \([A]_0\) as above, but in the presence of a heterogeneous catalyst, such that the reaction mechanism still obeyed first order kinetics. If the rate of the catalyzed decomposition was found to increase by a factor of 2 with respect to the un-catalyzed reaction, what would the resulting plot of \([A]/[A]_0\) vs. time look like for the catalyzed system with respect to the initial system?