KINETICS

1. For the equation
   
   \[ 2 \text{H}_2(g) + \text{O}_2(g) \rightarrow 2 \text{H}_2\text{O}(g) \]

   How is the rate of formation of H\textsubscript{2}O mathematically related to the rate of disappearance of O\textsubscript{2}?

2. Determine the relative reaction rates of the four substances involved in the following chemical reaction. Place the appropriate numbers in the boxes.

   \[
   2 \text{C}_2\text{H}_2(g) + 5 \text{O}_2(g) \rightarrow 4 \text{CO}_2(g) + 2 \text{H}_2\text{O}(l)
   \]

   \[
   \frac{1}{\text{_______}} \left( \frac{-\Delta[\text{C}_2\text{H}_2]}{\Delta t} \right) = \frac{1}{\text{_______}} \left( \frac{-\Delta[\text{O}_2]}{\Delta t} \right) = \frac{1}{\text{_______}} \left( \frac{-\Delta[\text{CO}_2]}{\Delta t} \right) = \frac{1}{\text{_______}} \left( \frac{\Delta[\text{H}_2\text{O}]}{\Delta t} \right)
   \]

3. For the following reaction, the rate of disappearance of A is equal to -0.084 M/s at the start of the reaction. What are the rates of change for B, C, and D at this time?

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

   Rate of Change of B = _________ M/s
   
   Rate of Change of C = _________ M/s
   
   Rate of Change of D = _________ M/s

4. Based on the graph below, determine the instantaneous rate of change of [x] at 10 seconds.

   \[
   \text{Instantaneous Rate of Change of X} = \text{_______}
   \]
5. Based on the data below, what are the average rates of change of \([O_2]\) and \([NO_2]\) over the interval 0 to 660 seconds?

<table>
<thead>
<tr>
<th>Time (s)</th>
<th>([NO]) M</th>
<th>([O_2]) M</th>
<th>([NO_2]) M</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.1000</td>
<td>0.01000</td>
<td>0.0000</td>
</tr>
<tr>
<td>285</td>
<td>0.0090</td>
<td>0.0095</td>
<td>0.0010</td>
</tr>
<tr>
<td>660</td>
<td>0.0080</td>
<td>0.0090</td>
<td>0.0020</td>
</tr>
<tr>
<td>1175</td>
<td>0.00070</td>
<td>0.0085</td>
<td>0.0030</td>
</tr>
</tbody>
</table>

Average Rate of Change of \(O_2\) = ______________

Average Rate of Change of \(NO_2\) = ______________

6. If the rate constant, \(k=350\) s\(^{-1}\) for a certain reaction, what is the overall order for that reaction? ______________

8. The following reaction occurs in the gaseous state.

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

The following rate data were obtained.

<table>
<thead>
<tr>
<th>Trial</th>
<th>Initial ([NO])</th>
<th>Initial ([H_2])</th>
<th>Initial rate(M/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.20 M</td>
<td>0.20 M</td>
<td>0.060</td>
</tr>
<tr>
<td>2</td>
<td>0.20 M</td>
<td>0.30 M</td>
<td>0.090</td>
</tr>
<tr>
<td>3</td>
<td>0.40 M</td>
<td>0.20 M</td>
<td>0.240</td>
</tr>
</tbody>
</table>

(a) Determine the rate law for this reaction (including all exponents & rate constant).

Rate Law: ____________________________

(b) What is the order or the reaction with respect to:

\(\text{NO}\)? _____ \(\text{H}_2\)? _____ Overall? _____

(c) What would the initial rate of the reaction be if the initial concentrations were:

\([\text{NO}] = 0.10\text{M} \quad [\text{H}_2] = 0.30\text{ M}\)
9. Determine the rate constant of the following reaction at 298K, where
A (the Arrhenius pre-exponent factor) = 1.2 \times 10^{12}, and Ea = 11.6 \text{kJ/mol}

\[ \text{NO}(g) + \text{O}_3(g) \rightarrow \text{NO}_2(g) + \text{O}_2(g) \]

\[ k = A e^{-\frac{E_a}{RT}} \]

\[ k = (1.2 \times 10^{12}) e^{-\frac{(11600 \text{J})}{(8.314 \text{J/K mol})(298 \text{K})}} = 1.1 \times 10^{10} \]

10. Complete the data table below for the reaction \( A + B \rightarrow C \). Then calculate the slope of the plot of \( \ln k \) vs \( 1/T \) (Arrhenius Plot) and the activation energy of the reaction. Be sure to use unrounded values in your calculations.

<table>
<thead>
<tr>
<th>K (M(^{-1})s(^{-1}))</th>
<th>T (K)</th>
<th>Ln k</th>
<th>1/T (K(^{-1}))</th>
<th>Slope =</th>
</tr>
</thead>
<tbody>
<tr>
<td>6255</td>
<td>288</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8831</td>
<td>323</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Ea =

11. From the following graph, determine the activation energy and the enthalpy of the reaction.

\[ \text{Ea} = \text{_______} \]

\[ \Delta H = \text{_______} \]

12. According to the graph below, about what percentage of the collisions will have sufficient kinetic energy to form products?

\[ \% \]

13. In order for a reaction to occur reactant molecules must:
   A) ______________________________
   B) ______________________________
   C) ______________________________
14. The mechanism for the reaction $3 \text{ClO}^- \rightarrow \text{ClO}_3^- + 2 \text{Cl}^-$ is

\[
\begin{align*}
\text{ClO}^- + \text{ClO}^- & \rightarrow \text{ClO}_2^- + \text{Cl}^- \quad \text{(slow)} \\
\text{ClO}^- + \text{ClO}_2^- & \rightarrow \text{ClO}_3^- + \text{Cl}^- \quad \text{(fast)}
\end{align*}
\]

Derive the rate law for this reaction:

15. Identify the catalyst(s) and/or reaction intermediate(s) in the following reaction mechanism.

<table>
<thead>
<tr>
<th>Step 1:</th>
<th>O_3(g) + NO(g) → O_2(g) + NO_2(g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 2:</td>
<td>NO_2(g) → NO(g) + O(g)</td>
</tr>
<tr>
<td>Step 3:</td>
<td>O(g) + O_3(g) → 2 O_2(g)</td>
</tr>
</tbody>
</table>

catalyst(s): _______________________________________________________________________
reaction intermediate(s): ______________________________________________________________________

16. At a certain temperature, the reaction $2\text{B} \rightarrow \text{C} + \text{D}$ obeys the rate law:

\[
\text{rate} = 1.14 \times 10^{-3} \text{M}^{-1} \text{s}^{-1} [\text{B}]^2
\]

If 5.00 mol of B is initially present in a 1.00 L container at that temperature, how much B is left after 117 seconds?

17. Write a rate equation for the following elementary step:

\[
\text{BeO}_3^- + 2 \text{H}^+ \rightarrow \text{H}_2\text{BrO}_3^+
\]

18. For a given reaction, the concentration of reactant “A” was doubled and the rate of reaction remained the same. We can conclude that the reaction is what order with respect to “A”? 

____________________
THERMODYNAMICS

1. Predict the sign for the following reaction and then calculate the value of $\Delta S^\circ$ using the information below and compare to your prediction for $\Delta S^\circ$.

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

Predicted sign: 

<table>
<thead>
<tr>
<th>compound</th>
<th>$S^\circ$ J/mol K</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\text{O}_2(\text{g})$</td>
<td>205.0</td>
</tr>
<tr>
<td>$\text{H}_2(\text{g})$</td>
<td>130.6</td>
</tr>
<tr>
<td>$\text{H}_2\text{O}(\text{g})$</td>
<td>188.7</td>
</tr>
</tbody>
</table>

2. Predict the value of $\Delta G$ under the following conditions:
   
   A) $\Delta H$ negative and $\Delta S$ positive
   - $\square \Delta G < 0$
   - $\square \Delta G > 0$
   - $\square$ Cannot predict the sign of $\Delta G$
   
   B) $\Delta H$ positive and $\Delta S$ positive
   - $\square \Delta G < 0$
   - $\square \Delta G > 0$
   - $\square$ Cannot predict the sign of $\Delta G$
   
   C) $\Delta H$ positive and $\Delta S$ negative
   - $\square \Delta G < 0$
   - $\square \Delta G > 0$
   - $\square$ Cannot predict the sign of $\Delta G$
   
   D) $\Delta H$ negative and $\Delta S$ negative
   - $\square \Delta G < 0$
   - $\square \Delta G > 0$
   - $\square$ Cannot predict the sign of $\Delta G$

3. Determine the value of $\Delta G$ in kJ at 25°C for the following reaction given that $\Delta S^\circ=326.4$ J/K and $\Delta H^\circ=571.6$ kJ.

\[ 2 \text{H}_2\text{O}(\text{l}) \rightarrow 2 \text{H}_2(\text{g}) + \text{O}_2(\text{g}) \]

4. Calculate the change in entropy for the following reaction. (Hint use your appendix data / green sheet.)

\[ \text{Ca}^{2+}(\text{aq}) + 2 \text{OH}^- (\text{aq}) \rightarrow \text{Ca(OH)}_2(\text{s}) \]
5. Will the decomposition of potassium chlorate be spontaneous at low temperatures, high temperatures, or all temperatures? Use values from your appendix/handout.

6. True or False

______ A) Gases have less entropy than liquids.
______ B) When solids dissolve they tend to increase in entropy.
______ C) The greater the moles of solid, the greater the entropy.
______ D) CH₄(g) has greater entropy than CH₃-CH₂-CH₂-CH₃(g).
______ E) An endergonic reaction is always non-spontaneous.