1. The rate of decomposition of HI into its diatomic elements is $5.0 \times 10^{-3}$ mole/L·s. What is the rate of formation of hydrogen in the same reaction?

2. Butene, decomposes to ethylene according to

$$C_4H_8(g) \rightarrow 2 C_2H_4(g)$$

The following data were collected as a function of time

a. Estimate the instantaneous rate of decomposition of $C_4H_8$ at 75 s.

b. Estimate the instantaneous rate of formation of $C_2H_4$ at 75 s.
3. Aspirin (I) hydrolyzes in the body to the active form, salicylic acid (II), and acetic acid (III).

\[
\text{\begin{align*}
\text{H}_2\text{O}(l) & \quad \text{\text{aspirin} (I)} \\
& \quad \text{\text{II} \quad \text{III}}
\end{align*}}
\]

The following data were collected as a function of time

\[
\begin{array}{c|c}
\text{Time (s)} & \text{[aspirin] (M)} \\
0 & 0.006 \\
100 & 0.005 \\
200 & 0.004 \\
300 & 0.003 \\
400 & 0.002 \\
500 & 0.001 \\
600 & 0.000
\end{array}
\]

a. Estimate the instantaneous rate of \textbf{hydrolysis} of aspirin at 100 s.

b. Estimate the instantaneous rate of \textbf{formation} of salicylic acid at 100 s.
4. Initial rate data for

\[ 2 \text{HgCl}_2(\text{aq}) + \text{C}_2\text{O}_4^{2-}(\text{aq}) \rightarrow 2 \text{Cl}^- (\text{aq}) + 2 \text{CO}_2(\text{g}) + \text{Hg}_2\text{Cl}_2(\text{s}) \]

are tabulated below:

<table>
<thead>
<tr>
<th>Exp#</th>
<th>[HgCl(_2)](_i), M</th>
<th>[C(_2)O(_4)(^{2-})](_i), M</th>
<th>Initial rate, M/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.105</td>
<td>0.150</td>
<td>1.8 \times 10^{-5}</td>
</tr>
<tr>
<td>2</td>
<td>0.105</td>
<td>0.300</td>
<td>7.1 \times 10^{-5}</td>
</tr>
<tr>
<td>3</td>
<td>0.052</td>
<td>0.300</td>
<td>3.5 \times 10^{-5}</td>
</tr>
<tr>
<td>4</td>
<td>0.200</td>
<td>0.100</td>
<td>?</td>
</tr>
</tbody>
</table>

a. Write the rate law for the reaction.

b. What is the order of the reaction in oxalate ion?

c. Calculate the numerical value of the rate constant.

d. Calculate the rate of experiment #4.

f. What function of [HgCl\(_2\)], when plotted versus time, would give a straight line?
5. Initial rate data for

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

are tabulated below:

<table>
<thead>
<tr>
<th>Exp#</th>
<th>[NO]_i, M</th>
<th>[Cl_2]_i, M</th>
<th>Initial rate, M/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.0125</td>
<td>0.0255</td>
<td>2.27 x 10^{-5}</td>
</tr>
<tr>
<td>2</td>
<td>0.0125</td>
<td>0.0510</td>
<td>4.55 x 10^{-5}</td>
</tr>
<tr>
<td>3</td>
<td>0.0250</td>
<td>0.0255</td>
<td>9.08 x 10^{-5}</td>
</tr>
<tr>
<td>4</td>
<td>0.0300</td>
<td>0.0300</td>
<td>?</td>
</tr>
</tbody>
</table>

a. Write the rate law for the reaction.

b. What is the overall order of the reaction?

c. Calculate the numerical value of the rate constant.

d. Calculate the rate of experiment #4.

f. What function of [NO], when plotted versus time, would give a straight line?
6. The integrated forms of the rate laws for 0th, 1st, and 2nd order reactions all contain \( k \). What would be the units for \( k \) in each expression. If necessary, use the time unit seconds (s).

7. A temperature increase from 10.0 to 20.0 °C doubles the rate of a reaction, calculate \( E_a \).

8. Given,

\[
\text{H}_2(\text{g}) + 2 \text{BF}_3(\text{g}) + \text{N}_2\text{H}_4(\text{g}) \rightarrow 2 \text{F}_3\text{BNH}_3(\text{g})
\]

Sketch the clearly labeled (approximately to scale) reaction profile if \( \Delta H = -2.71 \text{ kJ} \) and \( E_a = +510 \text{ J} \).
9. The rate constant of the following reaction was studied as a function of temperature:

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

<table>
<thead>
<tr>
<th>Exp#</th>
<th>Temperature (°C)</th>
<th>( k ) (L/mole·s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-78.2</td>
<td>( 1.08 \times 10^9 )</td>
</tr>
<tr>
<td>2</td>
<td>-43.2</td>
<td>( 2.95 \times 10^9 )</td>
</tr>
<tr>
<td>3</td>
<td>-13.2</td>
<td>( 5.42 \times 10^9 )</td>
</tr>
<tr>
<td>4</td>
<td>25.0</td>
<td>( 1.20 \times 10^{10} )</td>
</tr>
<tr>
<td>5</td>
<td>95.9</td>
<td>( 3.55 \times 10^{10} )</td>
</tr>
</tbody>
</table>

Plot the proper function of the data to determine the activation energy, \( E_a \).
10. A proposed mechanism for:

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

is

1. \[2 \text{NO}_2 \rightarrow \text{NO}_3 + \text{NO} \quad (\text{slow}) \quad k_1\]
2. \[\text{NO}_3 + \text{CO} \rightarrow \text{NO} + \text{CO}_2 \quad k_2\]

What is the testable rate law for the reaction?

11. Chlorination of hydrocarbons relies on the formation of chlorine atoms. For example, the chlorination of chloroform proceeds by the following mechanism

1. \[\text{Cl}_2 \rightarrow 2 \text{Cl} \quad k_1\]
2. \[2 \text{Cl} \rightarrow \text{Cl}_2 \quad (\text{both fast}) \quad k_{-1}\]
3. \[\text{Cl} + \text{CHCl}_3 \rightarrow \text{HCl} + \text{CCl}_3 \quad (\text{slow}) \quad k_2\]
4. \[\text{Cl} + \text{CCl}_3 \rightarrow \text{CCl}_4 \quad (\text{fast}) \quad k_3\]

Write the balanced, overall reaction. Write the testable rate law predicted by the reaction.
12. a. Write the equilibrium constant expression for the reaction,

\[
\text{CS}_2(g) + 4 \text{H}_2(g) \rightleftharpoons \text{CH}_4(g) + 2 \text{H}_2\text{S}(g)
\]

b. A flask is filled with 0.1000 M (each) of CS$_2$, CH$_4$, and H$_2$S and heated to 960 ºC. At equilibrium, the concentration of H$_2$S is **measured** to be 0.0548 M. Calculate the **value of K** for this reaction at 960 ºC.

c. Using the equilibrium constant calculated for the above reaction (in b), determine the value of K, at 960 ºC, of the following:

\[
\text{CH}_4(g) + 2 \text{H}_2\text{S}(g) \rightleftharpoons \text{CS}_2(g) + 4 \text{H}_2(g)
\]

\[
\frac{1}{2} \text{CS}_2(g) + 2 \text{H}_2(g) \rightleftharpoons \frac{1}{2} \text{CH}_4(g) + \text{H}_2\text{S}(g)
\]

\[
3 \text{CH}_4(g) + 6 \text{H}_2\text{S}(g) \rightleftharpoons 3 \text{CS}_2(g) + 12 \text{H}_2(g)
\]

d. Using the equilibrium constant calculated in b, calculate the value of K$_P$ for this reaction.
13. An analysis of the decomposition at 340 °C, 

\[
\text{PCl}_5(g) \rightleftharpoons \text{PCl}_3(g) + \text{Cl}_2(g)
\]

shows that at one instant PCl₅, PCl₃ and Cl₂ are present in equal concentrations of 0.120 M.

a. Given an equilibrium constant of 0.800 at 340 °C, is the reaction mixture moving towards products, toward reactant or is it at equilibrium?

b. If the reaction is not at equilibrium, determine the equilibrium concentration of each component at 340 °C.
14. A mixture of hydrogen, iodine and hydrogen iodide, each at a concentration of 0.200 M, is introduced into a container heated to 490 °C.

\[ \text{H}_2(\text{g}) + \text{I}_2(\text{g}) \rightleftharpoons 2 \text{HI}(\text{g}) \quad K = 46 \]

a. Predict the **direction** that the reaction goes to reach equilibrium.

b. Calculate the **equilibrium** concentrations of all three species.

15. Using Le Châtelier Principle, predict which direction (left, right, or no change) the reaction below will go if the following occurs. Explain, briefly.

\[ 4 \text{NH}_3(\text{g}) + 5 \text{O}_2(\text{g}) \rightleftharpoons 4 \text{NO}(\text{g}) + 6 \text{H}_2\text{O}(\text{g}) \quad \Delta H = -905.5 \text{ kJ} \]

a. Nitrogen monoxide is added to the vessel.

b. The pressure in the vessel is increased.

c. The reaction is cooled.

d. Xenon gas is pumped into the reaction vessel.
16. What is the hydroxide ion concentration of a solution that has a pH of 4.56?

17. Calculate the pH of the following. Show an appropriate chemical equation of each.

a. \(1.2 \times 10^{-3}\) M HI

b. \(0.010\) M Sr(OH)\(_2\)

c. \(0.10\) M HCHO\(_2\)
d. 0.20 M hydrazine

e. 0.010 M sodium perchlorate

f. 0.15 M lithium pyruvate

g. 0.10 M dimethylammonium bromide