More Rate Law Practice

Write the rate law (format only; no values for orders and \( k \)) for the following:

1) \( 2 \text{HI}(g) \rightarrow \text{H}_2(g) + \text{I}_2(g) \)

Rate Law: \( R = k[\text{HI}]^m \)

2) \( 2 \text{C}_2\text{H}_4(g) + \text{O}_3(g) \rightarrow 2 \text{CH}_2\text{O}(g) + \frac{1}{2} \text{O}_2(g) \)

Rate Law: \( R = k[\text{C}_2\text{H}_4]^m[\text{O}_3]^n \)

3) \( 2 \text{NO}(g) + 2 \text{H}_2(g) \rightarrow \text{N}_2(g) + 2 \text{H}_2\text{O}(g) \)

Rate Law: \( R = k[\text{NO}]^m[\text{H}_2]^n \)

Work in a group of 2-3 people on this problem:

\[
2 \text{Fe}^{2+}(\text{aq}) + \text{Cl}_2(\text{aq}) + \text{H}^+(\text{aq}) \rightarrow 2 \text{Fe}^{3+}(\text{aq}) + 2 \text{Cl}^-(\text{aq})
\]

<table>
<thead>
<tr>
<th>[Fe(^{2+})] (M)</th>
<th>[Cl(_2)] (M)</th>
<th>[H(^+)] (M)</th>
<th>Initial Rate (M/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exp 1 0.0020</td>
<td>0.0020</td>
<td>1.0</td>
<td>1.0 \times 10^{-5}</td>
</tr>
<tr>
<td>Exp 2 0.0040</td>
<td>0.0020</td>
<td>1.0</td>
<td>2.0 \times 10^{-5}</td>
</tr>
<tr>
<td>Exp 3 0.0020</td>
<td>0.0040</td>
<td>1.0</td>
<td>2.0 \times 10^{-5}</td>
</tr>
<tr>
<td>Exp 4 0.0040</td>
<td>0.0040</td>
<td>1.0</td>
<td>4.0 \times 10^{-5}</td>
</tr>
<tr>
<td>Exp 5 0.0020</td>
<td>0.0020</td>
<td>0.5</td>
<td>2.0 \times 10^{-5}</td>
</tr>
<tr>
<td>Exp 6 0.0020</td>
<td>0.0020</td>
<td>0.1</td>
<td>1.0 \times 10^{-4}</td>
</tr>
</tbody>
</table>

What is the reaction order with respect to Fe\(^{2+}\), Cl\(_2\), and H\(^+\)?

**Answers:** order of Fe\(^{2+}\) is 1; order of Cl\(_2\) is 1; order of H\(^+\) is -1

**Work/Reasoning:**

Verbal: Going from Exp 1 to Exp 2, [Fe\(^{2+}\)] doubles while the concentrations of Cl\(_2\) and H\(^+\) remain the same. The rate also doubles. As such, the order of Fe\(^{2+}\) must be 1. Going from Exp 1 to Exp 3, [Cl\(_2\)] doubles while the concentrations of Fe\(^{2+}\) and H\(^+\) remain the same. The rate also doubles. As such, the order of Cl\(_2\) must be 1. Going from Exp 6 to Exp 1, [H\(^+\)] increases by a factor of 10 while the concentrations of the other two reactants remain the same. The rate becomes one-tenth its original value. This means the order must be -1. I will show the last relationship via the “brute force” method below:

\[
\text{Exp 6: } 1.0 \times 10^{-4} \text{ M} \cdot \text{s}^{-1} = k(0.0020 \text{ M})^m(0.0020 \text{ M})^n(0.10 \text{ M})^p \\
\text{Exp 1: } 1.0 \times 10^{-5} \text{ M} \cdot \text{s}^{-1} = k(0.0020 \text{ M})^m(0.0020 \text{ M})^n(1.0 \text{ M})^p
\]

Dividing Exp 6’s equation by Exp 1’s, you get:
More Rate Law Practice

\[ \frac{R_a}{R_i} = \frac{1.0 \times 10^{-4} \text{ M/s}}{1.0 \times 10^{-5} \text{ M/s}} = \frac{k(0.0020 \text{ M})^m(0.0020 \text{ M})^n(0.10 \text{ M})^p}{k(0.0020 \text{ M})^m(0.0020 \text{ M})^n(1.0 \text{ M})^p} = 1(1)^m(1)^n\left(\frac{0.10}{1.0}\right)^p \]

\[ \Rightarrow 10 = (0.10)^p = \left(\frac{1}{10}\right)^p = (10^{-1})^p \Rightarrow p = -1 \]

OR (taking \(\ln\) of both sides to solve for \(p\)):

\[ \ln(10) = \ln(0.10)^p = p\ln(0.10) \]

\[ \Rightarrow 2.30\ldots = p(-2.30\ldots) \Rightarrow p = -1 \]

What is the rate law and the rate constant?

**Answers:** \( R = k[\text{Fe}^{2+}][\text{Cl}_2][\text{H}^+]^{-1}; \ k = 2.5 \text{ s}^{-1} \)

Substituting values from Exp 6 (you could use any Exp) into the rate law:

\[ 1.0 \times 10^{-4} \text{ M/s} = k(0.0020 \text{ M})(0.0020 \text{ M})(0.10 \text{ M})^{-1} = k(0.000040 \text{ M}^2\text{M}^{-1}) = k(0.000040 \text{ M}) \]

\[ \Rightarrow k = \frac{1.0 \times 10^{-4} \text{ M/s}}{(0.00040 \text{ M})} = 2.5 \text{ s}^{-1} \]