

Name: Amy Khounmany
Lab Partner Khairul Islam

Quiz Section: AF
Student ID #: 1723263

Chem 152 Experiment #1: Kinetics II, Method of Initial Rates

Goals of this lab:

- Evaluate initial rate versus concentration measurements to determine the order of a reaction with respect to each reactant and the overall rate constant
- Apply the use of a pseudo rate laws to finding the order of reaction with respect to individual reactants in a mixture
- Analyze data collected at multiple temperature to calculate the activation energy
- Analyze data collected with and without the use of a catalyst to demonstrate the effect of a catalyst on the activation energy
- Use Excel to graphically represent and interpret experimental data
- Assemble a complete kinetic description of the reaction from data gathered

Your lab report will be grade on the following criteria using a poor/good/excellent rating system:

- Calculations are accurate and complete based on data gathered; proper significant figures and units are used
- Data evaluated is class data provided by TA; outliers are identified and possible explanations are reasonable
- Interpretations of graphs and data are reasonable
- Reaction orders and activation energies are determined accurately from data gathered; reasonable conclusions are reached
- All graphs and tables are clearly and accurately labeled

By signing below, you certify that you have not falsified data, that you have not plagiarized any part of this lab report, and that all calculations and responses other than the reporting of raw data are your own independent work. Failure to sign this declaration will result in 5 points being deducted from your lab score.

Signature: Amy Khounmany

This lab is worth 60 points: 10 points for notebook pages, 50 points for the lab report

NAME: Amy KhounmanyQUIZ SECTION: AF**Note: All sections of this report must be typed****Data, Calculations and Graphs****Table 1. Reagent Stock Concentrations**

| Stock Solutions | | |
|-----------------------------|--------|-------|
| Solution | Conc. | Units |
| $\text{S}_2\text{O}_3^{2-}$ | 0.0005 | M |
| I^- | 0.010 | M |
| BrO_3^- | 0.040 | M |
| HCl | 0.100 | M |

Table 2. Initial Concentration for Run #2

| After all reagents are mixed | | |
|------------------------------|----------|-------|
| Solution | Conc. | Units |
| $\text{S}_2\text{O}_3^{2-}$ | 1.00E-04 | M |
| I^- | 3.00E-03 | M |
| BrO_3^- | 8.00E-03 | M |
| HCl | 2.00E-02 | M |

Table 3. Class Data for Temperature and Time with Student-Calculated Rates

| Run # | Temperature °C | Temperature K | Δ Time sec. |
|-------|----------------|---------------|-------------|
| 1 | 25.2 | 298.35 | 31.5 |
| 2 | 24.7 | 297.85 | 49 |
| 3 | 25.7 | 298.85 | 79 |
| 4 | 24.8 | 297.95 | 145 |
| 5 | 24.9 | 298.05 | 35.5 |
| 6 | 25 | 298.15 | 57.8 |
| 7 | 25.3 | 298.45 | 110.5 |
| 8 | 25.3 | 298.45 | 187 |
| 9 | 24.7 | 297.85 | 17.8 |
| 10 | 24.8 | 297.95 | 36.3 |
| 11 | 24.8 | 297.95 | 101.3 |
| 12 | 24.4 | 297.55 | 351.5 |
| 13 | 0.7 | 273.85 | 280.8 |
| 14 | 23.7 | 296.85 | 34.9 |
| 15 | 0.7 | 273.85 | 74.9 |

Show your calculation for the "Working Concentration" of $\text{S}_2\text{O}_3^{2-}$ in **Run #2** (see Table 2) :

$$\begin{aligned}
 (M_1)(V_1) &= (M_2)(V_2) \\
 (0.0005 \text{ mol/L})(0.0005 \text{ L}) &= (M_2)(0.0025 \text{ L}) \\
 (M_2) &= 1.00\text{E-}04 \text{ mol/L} \\
 &= \mathbf{1.00\text{E-}04 \text{ M}}
 \end{aligned}$$

Show your calculation for the "Rate" using data for **Run #2**:

$$\begin{aligned}
 \text{Rate} &= (-1/6) \times (0 - 1.00\text{E-}04 \text{ M}) / \Delta t \\
 &= (-1/6) \times (-1.00\text{E-}04 \text{ M}) / 49 \text{ s} \\
 &= \mathbf{3.4\text{E-}07 \text{ M/s}}
 \end{aligned}$$

NAME: Amy KhounmanyQUIZ SECTION: AF

Reaction Order Determination for I⁻

READ THIS BEFORE PROCEEDING:

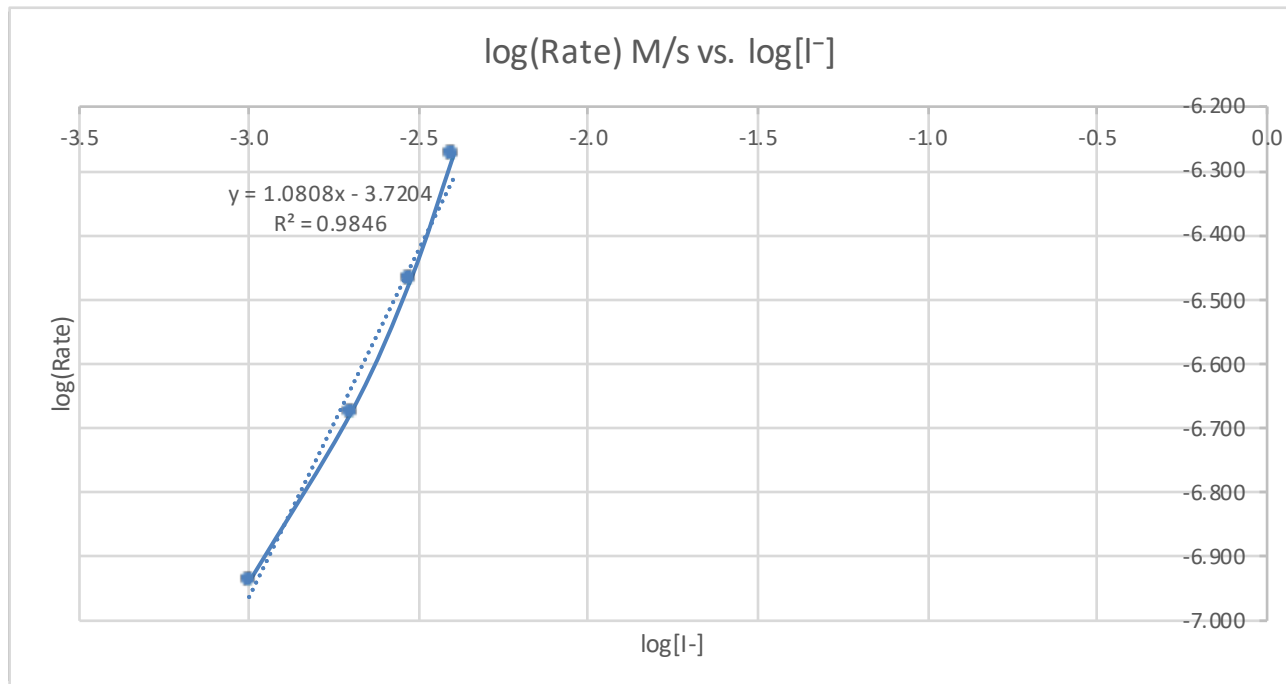
Recall that since BrO₃⁻ and H⁺ are held constant, the rate law takes on the following form:

$$\text{Rate} = B[\text{I}^-]^i$$

where "B" is the pseudo rate constant that includes k, [H⁺], and [BrO₃⁻]. Therefore, a plot of log(Rate) vs. log([I⁻]) (y-axis axis) will yield a straight line with a slope equal to i, the order of the reaction with respect to I⁻. This use of the pseudo rate law will be used evaluating the order for each of the other reactants as well.

Table 4. Data for the Runs 1-4, Where the Concentration of Iodide Changes

| Experiment | [I ⁻] M | Rate M/sec | X-axis log(I ⁻) | Y-axis log(Rate) | (Rate data Auto Fill from Table 3 on Pg 1.) |
|------------|------------------------|---------------|--------------------------------|---------------------|---|
| Run 1 | 4.00E-03 | 5.3E-07 | -2.4 | -6.276 | |
| Run 2 | 3.00E-03 | 3.4E-07 | -2.5 | -6.468 | |
| Run 3 | 2.00E-03 | 2.1E-07 | -2.7 | -6.676 | |
| Run 4 | 1.00E-03 | 1.1E-07 | -3.0 | -6.940 | |



What is the order with respect to I⁻ as determined from your data?

1

A trendline equation is required on the plot in order to earn credit for the order.

When determining the order, round to the nearest whole number.

NAME: Amy Khounmany

QUIZ SECTION: AF

Reaction Order Determination for BrO_3^-

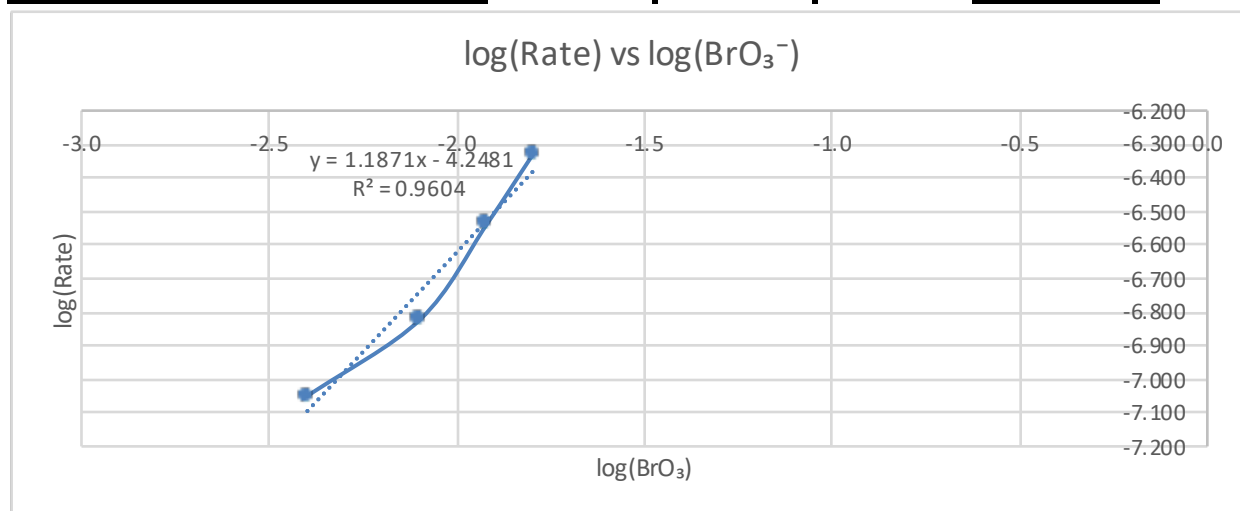
Table 5. Data for the Runs 6-8, Where the Concentration of Bromate Changes

| Experiment | $[\text{BrO}_3^-]$ M | Rate M/sec | X-axis $\log(\text{BrO}_3^-)$ | Y-axis $\log(\text{Rate})$ |
|------------|-------------------------|---------------|----------------------------------|-------------------------------|
| Run 5 | 1.60E-02 | 4.7E-07 | -1.8 | -6.328 |
| Run 6 | 1.20E-02 | 2.9E-07 | -1.9 | -6.540 |
| Run 7 | 8.00E-03 | 1.5E-07 | -2.1 | -6.822 |
| Run 8 | 4.00E-03 | 8.9E-08 | -2.4 | -7.050 |

(Rate data Auto Fill from Table 3 on Pg 1.)

What is the order with respect to BrO_3^- as determined from your data?

1



Reaction Order Determination for H^+

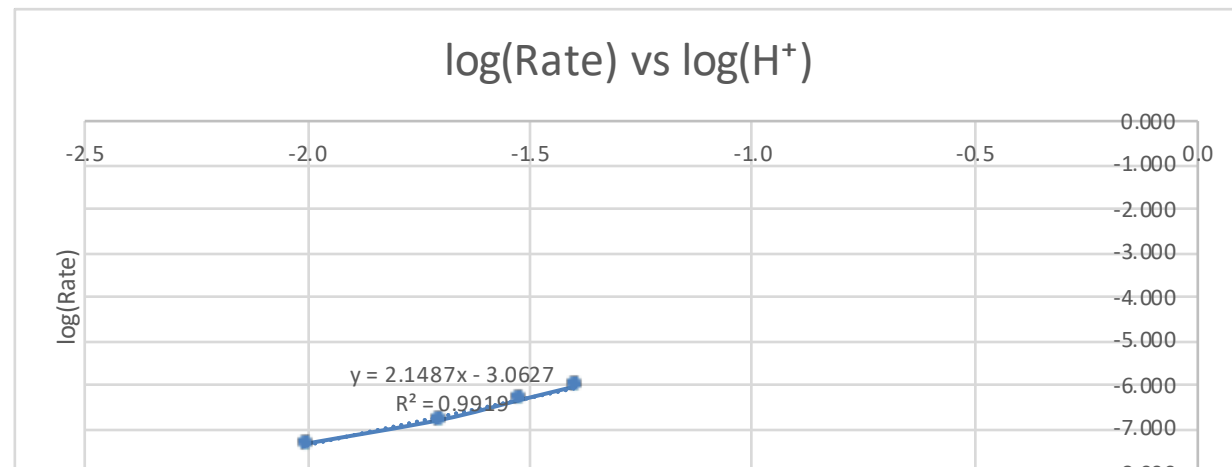
Table 6. Data for the Runs 9-12, Where the Concentration of Hydronium Ion Changes

| Experiment | $[\text{H}^+]$ M | Rate M/sec | X-axis $\log(\text{H}^+)$ | Y-axis $\log(\text{Rate})$ |
|------------|---------------------|---------------|------------------------------|-------------------------------|
| Run 9 | 4.00E-02 | 9.4E-07 | -1.4 | -6.029 |
| Run 10 | 3.00E-02 | 4.6E-07 | -1.5 | -6.338 |
| Run 11 | 2.00E-02 | 1.6E-07 | -1.7 | -6.784 |
| Run 12 | 1.00E-02 | 4.7E-08 | -2.0 | -7.324 |

(Rate data Auto Fill from Table 3 on Pg 1.)

What is the order with respect to H^+ as determined from your data?

2



log(H⁺)

-8.000

NAME: Amy Khounmany

QUIZ SECTION: AF

Calculations of Rate Constant, k, and Activation Energy, Ea

(Several cells for order, rate, concentration, and temp. values will auto-fill from previous entries in the report.)

Summary of orders from pages 3 and 4:

| | | | | | |
|---------------------------------|---|------------------|---|------------------|---|
| BrO ₃ ⁻ : | 1 | I ⁻ : | 1 | H ⁺ : | 2 |
|---------------------------------|---|------------------|---|------------------|---|

Show your calculation of the overall rate constant, k, using data from **Run 3**:

$$\begin{aligned}\text{Rate} &= k[\text{BrO}_3^-]^b[\text{I}^-]^c[\text{H}_3\text{O}^+]^h \\ 2.1\text{E-}07 &= k[0.0080][0.0020][0.0200]^2 \\ k &= (2.1\text{E-}07)/[0.0080][0.0020][0.0200]^2 \\ &= \mathbf{32.81}\end{aligned}$$

Table 7. Data from Runs 3, 7, and 11 for Calculating the Average Rate Constant

| Experiment | Rate M/sec | [I ⁻] M | [BrO ₃ ⁻] M | [H ⁺] M | k |
|------------|---------------|------------------------|---------------------------------------|------------------------|-------|
| Run 3 | 2.1E-07 | | | | 32.81 |
| Run 7 | 1.5E-07 | 0.0020 | 0.0080 | 0.0200 | 23.44 |
| Run 11 | 1.6E-07 | | | | 25.00 |

Average k = 27.08

Units for k = M⁻³s⁻¹

Show the calculation of E_a uncatalyzed using the average rate constant from the room temp. data along with the rate constant you calculate for the 0°C data in Run 13:

$$\begin{aligned}\ln(k_2/k_1) &= -E_a/R(1/T_2 - 1/T_1) \\ E_a &= (-R) \ln(k_2/k_1) / (1/T_2 - 1/T_1) \\ &= (-8.314 \text{ J K}^{-1} \text{ mol}^{-1})(\ln 9.22/27.08) / (1/273.85 - 1/298.42) \\ &= 29794 \text{ J/mol} \\ &= \mathbf{29.8}\end{aligned}$$

Table 8. Data from runs 3, 7, 11, and 13 for Calculating the Uncatalyzed Activation Energy

| Experiment | Rate M/sec | Temp Kelvin | k M ⁻³ s ⁻¹ |
|------------|---------------|----------------|--------------------------------------|
| Ave * | 1.8E-07 | 298.42 | 27.1 |
| Run 13 | 5.9E-08 | 273.85 | 9.2 |

* Average value from runs # 3, 7, & 11

E_a of the uncatalyzed reaction:

E_a (uncatalyzed) = 29.8 kJ/mol

Table 9. Data from runs 14 and 15 for Calculating the Catalyzed Activation Energy

| Experiment | Rate M/sec | Temp Kelvin | k 0.00 |
|------------|---------------|----------------|-----------|
| Run 14 | 4.8E-07 | 296.85 | 75.0 |
| Run 15 | 2.2E-07 | 273.85 | 34.4 |

E_a of the catalyzed reaction:E_a (catalyzed) = 22.9 kJ/mol

NAME: Amy Khounmany

QUIZ SECTION: AF

Results from earlier in the report autofill here:

Orders from pages 3 & 4:

| | | | | | |
|------------------|---|---------------------------------|---|------------------|--|
| I ⁻ : | 1 | BrO ₃ ⁻ : | 1 | H ⁺ : | |
|------------------|---|---------------------------------|---|------------------|--|

Average rate constant from pg 5:

| | | | |
|--------|------|--------|---------------------------------|
| value: | 27.1 | units: | M ⁻³ s ⁻¹ |
|--------|------|--------|---------------------------------|

Activation energies (kJ/mol) from pg 5:

| | | | |
|------------|------|--------------|--|
| Catalyzed: | 29.8 | Uncatalyzed: | |
|------------|------|--------------|--|

Results and Discussion

1. Based on your data and the average value for the rate constant at room temperature for the uncatalyzed, write the complete rate law, including the value and units for the rate constant.

$$\text{Rate} = 27.1 \text{ M}^{-3}\text{s}^{-1} [\text{BrO}_3^-][\text{I}^-][\text{H}_3\text{O}^+]^2$$

2. The literature values for the reaction orders are 1 for BrO₃⁻ and I⁻ and 2 for H⁺. Calculate the % error for the experimental value for the order with respect to [I⁻].

$$[\text{I}^-] \% \text{ error} = \frac{|\# \text{ experimental} - \# \text{ theoretical}|}{\# \text{ theoretical}} \times (100)$$

$$[\text{I}^-] \% \text{ error} = \frac{|(1.08 - 1.00)|}{1.00} \times (100) = 8\%$$

3. Discuss your most likely sources of error.

Likely sources of error include not cleaning and drying the test tubes thoroughly, not mixing solutions enough, wrong measurements or some that were off by a little, and the method we decided to record our data when to start and stop the timer. All of these instances would result in inaccurate data.

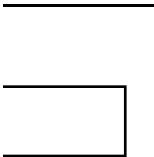
4. How do the activation energies for the catalyzed and uncatalyzed reaction compare to each other? Is this in line with what is expected? Explain.

The activation energy for the catalyzed reaction (22.9) is slightly lower than the activation energy of the uncatalyzed reaction (29.8). This is in line with what is expected because the main role of a catalyst is to lower a reaction's activation energy in order to speed up a chemical reaction.

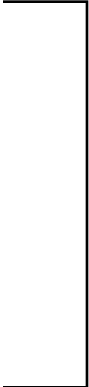
Laboratory Waste Evaluation Laboratory waste is considered *anything* generated during an experiment that is not poured down the sewer drain, thrown in the garbage, collected in a container for disposal by the UW Environmental Health & Safety department, or released into the environment. Based on the written lab procedure and your actions during the lab, list the type and approximate amount (mass or volume) of waste that you generated while performing this experiment.

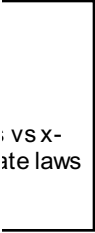
and approximate amount (mass or volume) of waste that you generated while performing this experiment.

Throughout the experiment, we have generated 9mL of $\text{Na}_2\text{S}_2\text{O}_3$, 9 mL of KBrO_3 , 9mL of HCl , ~ 8 drops of 1% starch in drops of ammonium molybdate, and ~50 mL of H_2O and ice. There were also kim wipes, pH strips, and pipet tips disposed



| Rate |
|---------|
| M/s |
| 5.3E-07 |
| 3.4E-07 |
| 2.1E-07 |
| 1.1E-07 |
| 4.7E-07 |
| 2.9E-07 |
| 1.5E-07 |
| 8.9E-08 |
| 9.4E-07 |
| 4.6E-07 |
| 1.6E-07 |
| 4.7E-08 |
| 5.9E-08 |
| 4.8E-07 |
| 2.2E-07 |





]

]

]

2

22.9

write the

3

, taking
eciding to

1 line with

alyzed
3

is disposed
afety
3 identity

icator, 2
l of.