Analyzing the Relationship Between the Concentration of KIO_3 and the Speed of the $NaHSO_3$-based Iodine Clock Reaction

Tarik Onalan

31 March 2015

1 Introduction

1.1 Purpose

1.2 Hypothesis

Reaction speed will decrease (increasing the time taken to react) as KIO_3 concentration decreases, as there will be fewer KIO_3 molecules available to react at any one time.

1.3 Variables

Independent Variable

- KIO_3 concentration [M]

Dependent Variable

- Reaction speed [s]

Controlled Variables

- Molarity of $NaHSO_3$ solution [0.020 M]
- Volume of KIO_3 solution [10.000 mL]
- Volume of $NaHSO_3$ solution [10.000 mL]
- Temperature of solutions [25.200 °C]
- Distilled Water

2 Materials

- 75 mL 0.020 M KIO_3
- 100 mL 0.020 M $NaHSO_3$
- 9 · test tubes

- 2 · 100 mL beaker
- 2 · 10 mL graduated cylinder
- 1 · 2 mL pipette
- 1 · timer
- 1 · thermometer

3 Procedure

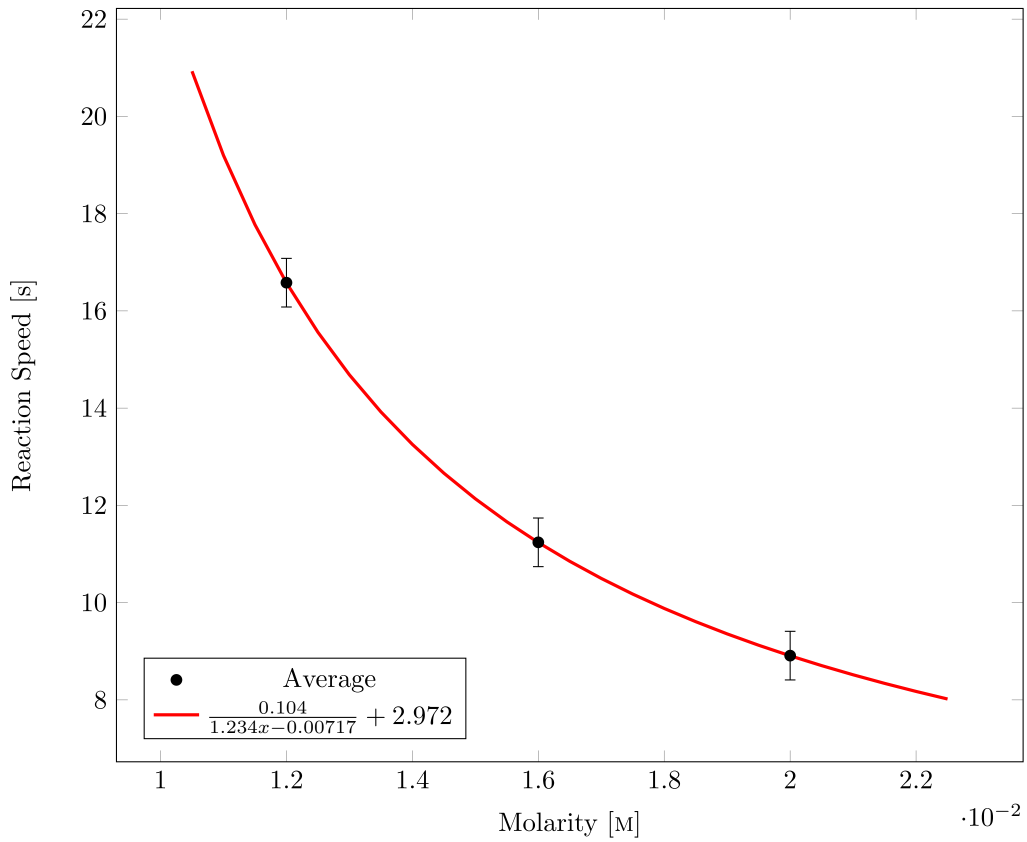
1. Pour KIO_3 and $NaHSO_3$ solutions into beakers
2. Measure 10 mL KIO_3 solution in graduated cylinder
3. Measure 10 mL $NaHSO_3$ solution in graduated cylinder
4. If KIO_3 solution is not 10 mL, fill up to 10 mL with distilled water
5. Pour both solutions into test tube
6. Start timer
7. Wait until solution turns blue/black
8. Stop timer
9. Record time taken to react
10. Repeat steps $2-9$ 2 times with 8 mL and 6 mL KIO_3 solution, respectively
11. Repeat steps $1-10$ as necessary for data collection

4 Data

Table 1: Data

Molarity	Trial 1 s	Trial 2 s	Trial 3 s	avg
0.020±0.50	8.030±0.50	9.180±0.50	9.510±0.50	8.91±0.50
0.016±0.50	11.000±0.50	11.120±0.50	11.590±0.50	11.24±0.50
0.012±0.50	18.460±0.50	15.820±0.50	15.450±0.50	16.58±0.50

Reaction Speed Relative to the Molarity of KIO_3 Solution



5 Calculations

5.1 Average

$$\langle \mathrm{s}(\mathrm{M}) \rangle \tag{1}$$

$$\frac{\sum_i \mathrm{s}(\mathrm{M})}{i} \tag{2}$$

$$\frac{\mathrm{s}(\mathrm{M}_1) + \mathrm{s}(\mathrm{M}_2) + \ldots + \mathrm{s}(\mathrm{M}_{i-1}) + \mathrm{s}(\mathrm{M}_i)}{i} \tag{3}$$

5.2 Error and Minimization

Error was calculated using sum squared error, which is defined as follows:

$$E = \sum_{i=1}^{n} (y_i - f(x_i))^2 \tag{4}$$

A program carried out the minimization of the above function, which entails tracing the derivative of the function with respect to a given parameter —defined here as k—to the local minima of the function

$$E' = \frac{\partial}{\partial k}(\sum_{i=1}^{n} (y_i - f(x_i))^2) \tag{5}$$

5.3 Line of Best Fit

When choosing my line of best fit, I first tried to piece together all of the information that I could gather without data. First I knew that my function $?(x)$ had to satisfy the following conditions for the following scenarios:

$$?(x) = \begin{cases} \text{Zero Order:} & [A] = -kt + [A]_0 \\ \text{First Order:} & \ln [A] = -kt + \ln [A]_0 \\ \text{Second Order:} & \frac{1}{[A]} = kt + \frac{1}{[A]_0} \\ \text{nth Order:} & \frac{1}{[A]^{n-1}} = (n-1)kt + \frac{1}{[A]_0^{n-1}} \end{cases} \tag{6}$$

which I simplified to

$$?(x) = \begin{cases} f(x) = a(bx + c) + d \\ g(x) = a \ln(bx + c) + d \\ h(x) = \frac{a}{bx+c} + d \end{cases} \tag{7}$$

I ended up having to assume that the rate of reaction was less than or equal to 2 primarily due to the fact that ternary (third-order or more) reactions are extremely rare, and testing for one would subsequently be impractical. Judging by the appearance of the graphed data—steep slope for smaller x, small slope for larger x—I had an intuition that the best model would be the second order reaction:

$$h(x) = \frac{a}{bx + c} + d \tag{8}$$

Testing my prediction proved me correct, as the error was much lower for the function $h(x)$—representing a second order reaction—than for $g(x)$ or $f(x)$—representing first and zeroeth order reactions, respectively. These results are shown in the table below.

Error

$f(x)$	$g(x)$	$h(x)$
1.510 02	13.954 68	$6.513\,84 \cdot 10^{-8}$