Analyzing Rate of Decomposition of $NaBO_3$ in Changing Molarities of HCl

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1 Introduction

The objective of this lab is to understand how rate of reaction changes in varying environments. This lab will focus on the decomposition of sodium perborate ($NaBO_3$), the active ingredient in Efferdent denture cleaning tablets, in HCl solutions of varying molarity.

1.1 Question

How does the rate of decomposition of $NaBO_3$ change in HCl solutions of varying molarity?

1.2 Hypothesis

I predict that as the molarity of the HCl solution decreases, the rate of decomposition of $NaBO_3$ will decrease, as there will be less solution to react with the salt.

$$\mathrm{HCl}(aq) + \mathrm{NaBO_3}(s) \rightarrow \mathrm{HBO_3}(aq) + \mathrm{NaCl}(aq)$$

1.3 Variables

- **Manipulated Variable:** Molarity of HCl solution
  - 0.50 M
  - 0.75 M
  - 1.0 M
- **Dependent Variable:** Time of decomposition of $NaBO_3$ tablet
- **Controlled Variables:**
  - Type of tablet used (Efferdent)
  - Mass of tablet ($\sim 5.0\,\mathrm{g}$)
  - Temperature of HCl ($\sim 21.0\,°\mathrm{C}$)
  - Temperature of H_2O ($\sim 21.0\,°\mathrm{C}$)
  - Water used to dilute HCl solution (distilled water)
- **Trials:** Three trials per iteration of molarity

1.4 Materials

- 9 Efferdent tablets
- 250 mL HCl Solution
- 250 mL distilled H_2O
- 3 beakers
- 2 graduated cylinders
- 3 timers

1.5 Procedure

1. Gather materials
2. As necessary, heat H_2O and HCl solutions until 21.0 °C
3. Fill beaker with 25.0 mL of 1.0 M HCl solution
   - Later trials will require lower molarities; dilute solution as necessary to reach desired molarities (0.75 M, 0.50 M)
4. Drop tablet into beaker, start timer
   - Make sure tablet is whole (all tablets ~ 5.0 g)
5. When tablet is fully dissolved, stop timer
   - Record time taken
   - Reset timer
6. Repeat items 2-6 for trials 2-3
7. Repeat items 2-7 for 0.75 M and 0.50 M

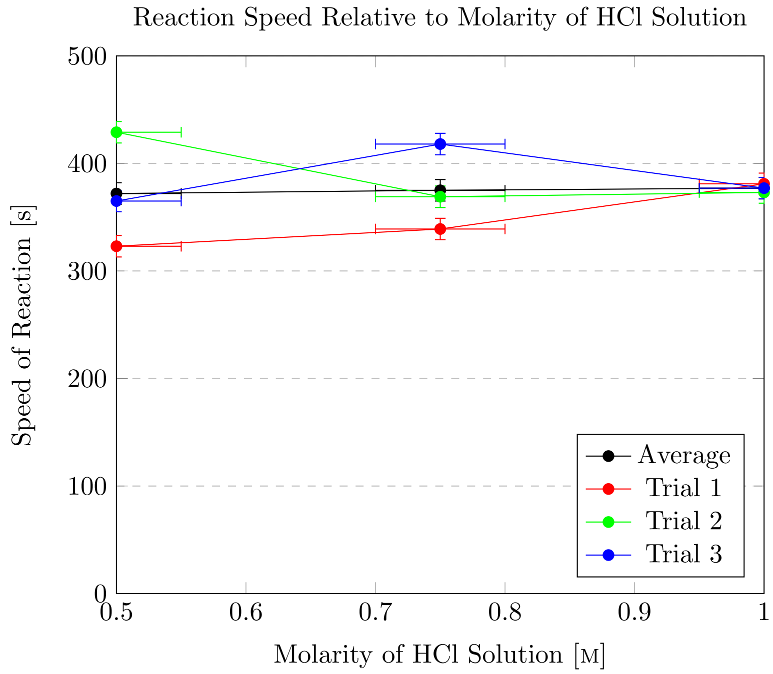
Note that trials on differing or changing molarities can be run simultaneously with the three beakers in the materials list

2 Data

2.1 Table

Molarity	Trial 1	Trial 2	Trial 3	Average
0.50 M ±0.025	323 s ±10.0 s	429 s ±10.0 s	365 s ±10.0 s	372 s ±10.0 s
0.75 M ±0.025	339 s ±10.0 s	369 s ±10.0 s	418 s ±10.0 s	375 s ±10.0 s
1.0 M ±0.025	381 s ±10.0 s	373 s ±10.0 s	377 s ±10.0 s	377 s ±10.0 s

2.2 Graph



2.3 Calculations

- Dilution:

$$M_1 \cdot V_1 = M_2 \cdot V_2$$

Example→0.75 M

$$1.0\,\text{M} \cdot 25.0\,\text{mL} = 0.75\,\text{M} \cdot x$$

$$x = \frac{1.0\,\text{M} \cdot 25.0\,\text{mL}}{0.75\,\text{M}}$$

$$x = 33.3\,\text{mL}$$

- Average:

$$t_{avg} = \langle t_i \rangle$$

$$t_{avg} = \frac{t_0 + t_1 + t_2}{3}$$

t→Trial 1

$$t_{avg} = \frac{381\,\text{s} + 373\,\text{s} + 377\,\text{s}}{3}$$

$$t_{avg} = 377\,\text{s}$$

3 Analysis

My hypothesis, that the rate of reaction would decrease as molarity of the HCl solution decreased, was invalid according to my data. There seemed to be very little correlation between the molarity of the acid and the rate of the reaction between HCl and the tablets. The averages of the data could even suggest that reaction rate increases as the molarity of HCl decreases. The rate of reaction went from an average of 377 s in 1.0 M HCl to 375 s in 0.75 M, and decreasing even further to 372 s in 0.50 M. However, it is worth noting that the range of 5 s in these values only makes up a $\sim 1.3\%$ difference, well within the margins of error–10 s– thus making it statistically insignificant. However, looking at the raw data shows an interesting *lack* of a pattern. Sometimes, the solution with the lowest molarity had the fastest reaction. In fact, the solution with the highest molarity never had the fastest reaction. In trial 1 of the three molarities, for example, the lowest molarity solution, 0.50 M HCl, had the fastest reaction at 323 s. This was followed by the 0.75 M solution, with a reaction length of 339 s. The slowest reaction was the 1.0 M solution, with a reaction length of 381 s.

I believe that the impurities in the individual tablets was the cause of the discrepancies in the data. In a lab with pure salts, our class observed that the salts would react faster in a high concentration acid as opposed to a low concentration acid. However, the tablets are not pure. They contain, among other chemicals, citric acid, food coloring and odor-releasing chemicals. One of the important assumptions that I had to make during this lab is that tablets of the same brand and "model", per se, would behave the same. However, that was not necessarily a guarantee. Production is not perfect, and different masses of chemicals can go into different tablets, possibly creating a tablet-to-tablet behavior difference. I knew, during the lab, that the HCl solution was uniform, as it had all been taken from a single source, and, of course, any aqueous impurities would most likely have spread themselves throughout the solution. Beyond the tablets, judging the end of the reaction was also a struggle. As the tablet begins to near complete dissolution, it begins to float to the surface, making it especially difficult to see, as the bubbles "hide" the tablet. This is why there is a considerable uncertainty in the time measurement, as the timer could have been stopped in a 20-second window where the tablet was extremely close to dissolving completely.

In the future, students should use more pure substances instead of tablets. In this experiment, the tablets proved to be an uncontrolled variable that skewed results. Not every tablet was the same as the other, producing contradictory results. Pure substances would remove the variables of the production processes of tablets, leaving the reaction to take place without the "interference" of extraneous chemicals. The other issue I mentioned in the previous paragraph–judging the end of a reaction–comes down to the persistence of the student, I believe. It is not impossible to see the tablet as it gets smaller; the tablet stays in the water. Looking under the beaker instead of from the side would probably allow for better spotting of the tablet as it dissolves, as that would provide a view with fewer bubbles.