

## Purpose

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Students will explore the effects of variables on the rate of a chemical reaction.

## Student Guide

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A PDF of the student guide is provided to students during the instruction, the virtual experiment, and the in-laboratory (“wet”) experiment, both of which follow the same lab procedure. Either provide copies to students or enable them to print the guide themselves when they reach the instruction phase of the lab lesson.

## Background Information

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Sodium bicarbonate ( $\text{NaHCO}_3$ ), commonly known as baking soda, is the active ingredient in many over-the-counter, effervescent antacid tablets. When placed in water, the sodium bicarbonate dissolves and serves as the reactant in an acid-base reaction where  $\text{HCO}_3^-(aq) + \text{H}^+(aq) \rightarrow \text{H}_2\text{O}(l) + \text{CO}_2(g)$ . The “fizzing” of the tablet is the result of the carbon dioxide gas that is produced during the reaction. If you adjust the amount of sodium bicarbonate in the lab procedure, remember that it has a modest solubility in water of 7.8 grams per 100 mL of water at room temperature.

Chemical reactions occur at certain rates based on a number of factors, including temperature, concentration, surface area, presence of catalysts, and so forth. In particular for this laboratory activity, students should observe that reaction rate increases with higher temperatures as the number of collisions between the particles increase. Additionally, tablets that are broken up and offer more surface area to interact with the water should dissolve at a faster rate.

## Preparation/Alternatives

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- As an alternative to beakers, clear plastic cups with known volumes can be substituted for these reactions, and measurement of the water will be approximate.
- Ideally, the hot water is at a standard temperature for the experiments, available to all students from a common source on a hotplate. Alternatively, hot water from the tap can be used, provided the water is allowed to run for a while to reach a consistent temperature.
- Ideally, the cold water is at a standard temperature of  $0^\circ\text{C}$  and is retrieved from an ice water solution common to all students. Alternately, cold water from the tap can be used, provided the water is allowed to run for a while to reach a consistent temperature.
- The procedure can be modified to have students work in groups of three, completing all three trials for each data table simultaneously.
- Many name-brand and generic effervescent antacid tablets are available at a wide variety of stores. Any brand may be used, provided it has the same active ingredient, sodium bicarbonate, and is at the same concentration.

## Monitoring the Lab Procedure

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- Ensure that safety procedures are followed at all times.
- Ensure that students correctly handle hot liquids with adequate precaution and appropriate safety gear.
- Despite using over-the-counter medication, do not allow students to consume any of the sodium bicarbonate solution or tablets and remind them to treat this compound as any other laboratory chemical.

## Teacher Guide (continued)

- After the data are collected, the students will need to construct graphs. Provide the students with the Lab Report Guide so that they have a place to sketch their graphs.

### Data

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While students perform the procedure, they should record their data in the data tables provided in the student guide. Sample data shown below match the results of the virtual experiment. Student data may vary, but generally, it should show that of the three temperatures, the tablet in the hot water dissolves the fastest, and of the three surface areas, the crushed tablet dissolves the fastest. Students should explain deviations from these trends in the conclusion.

Note that actual data will vary depending on the size and thickness of the tablets that are used in your particular experiment.

**Table A: Baseline Data for Tablet in Room Temperature Water**

	Volume (mL)	Temp. (°C)	Start Time	End Time	Elapsed Time (s)
Trial #1	250	20	0	50	50
Trial #2	250	20	0	52	52
Trial #3	250	20	0	51	51
Average Time for Tablet to Dissolve					51

**Table B: Time to Dissolve Tablet in Hot Water**

	Volume (mL)	Temp. (°C)	Start Time	End Time	Elapsed Time (s)
Trial #1	250	40	0	22	22
Trial #2	250	40	0	24	24
Trial #3	250	40	0	20	20
Average Time for Tablet to Dissolve					22

**Table C: Time to Dissolve Tablet in Cold Water**

	Volume (mL)	Temp. (°C)	Start Time	End Time	Elapsed Time (s)
Trial #1	250	4	0	84	84
Trial #2	250	4	0	89	89
Trial #3	250	4	0	85	85
Average Time for Tablet to Dissolve					86

## Teacher Guide (continued)

Table D: Time to Dissolve Tablet When Quartered

	Volume (mL)	Temp. (°C)	Start Time	End Time	Elapsed Time (s)
Trial #1	250	20	0	41	41
Trial #2	250	20	0	44	44
Trial #3	250	20	0	41	41
Average Time for Tablet to Dissolve					42

Table E: Time to Dissolve Tablet When Crushed

	Volume (mL)	Temp. (°C)	Start Time	End Time	Elapsed Time (s)
Trial #1	250	20	0	18	18
Trial #2	250	20	0	18	18
Trial #3	250	20	0	15	15
Average Time for Tablet to Dissolve					17

### Summary Tables

Table F: Summary Table for the Effect of Temperature

	Volume (mL)	Temp. (°C)	Average Time (s)
Hot water	250	40	22
Room temperature	250	20	51
Cold water	250	4	86

Table G: Summary Table for the Effect of Surface Area

	Volume (mL)	Temp. (°C)	Average Time (s)
Tablet form	250	20	51
Quartered	250	20	42
Crushed	250	20	17

## Teacher Guide (continued)

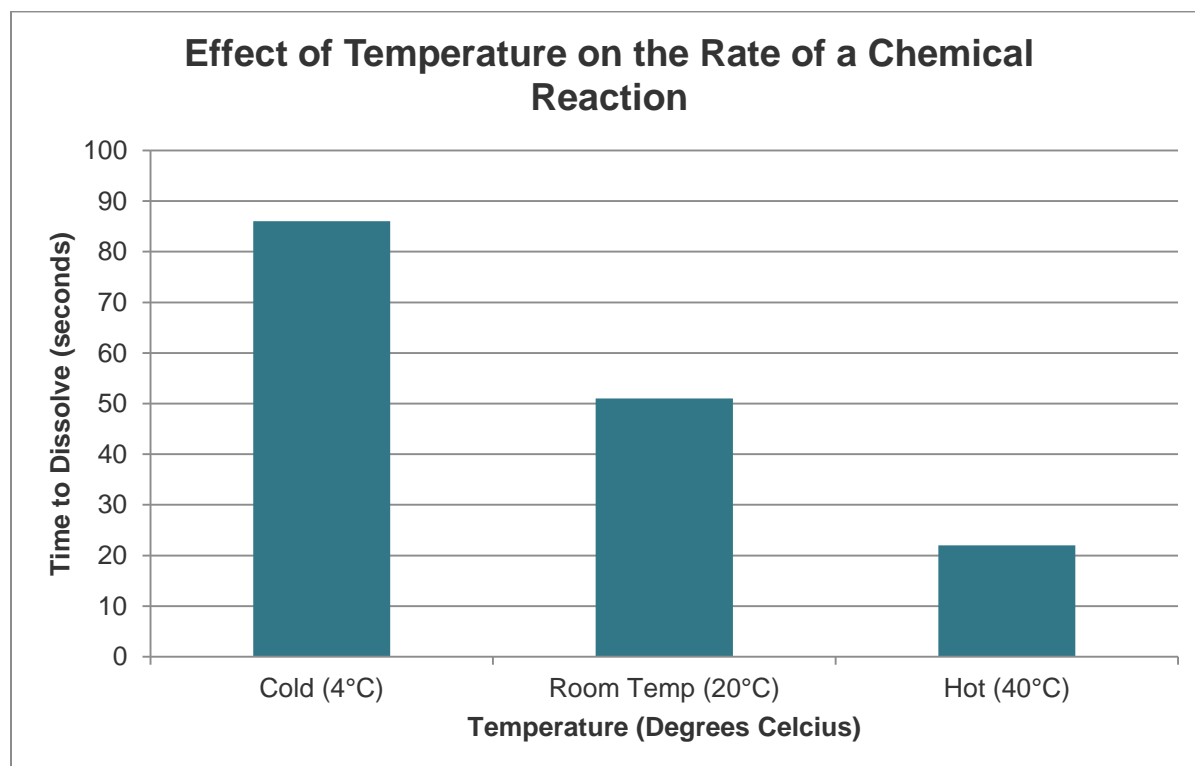
### Analysis

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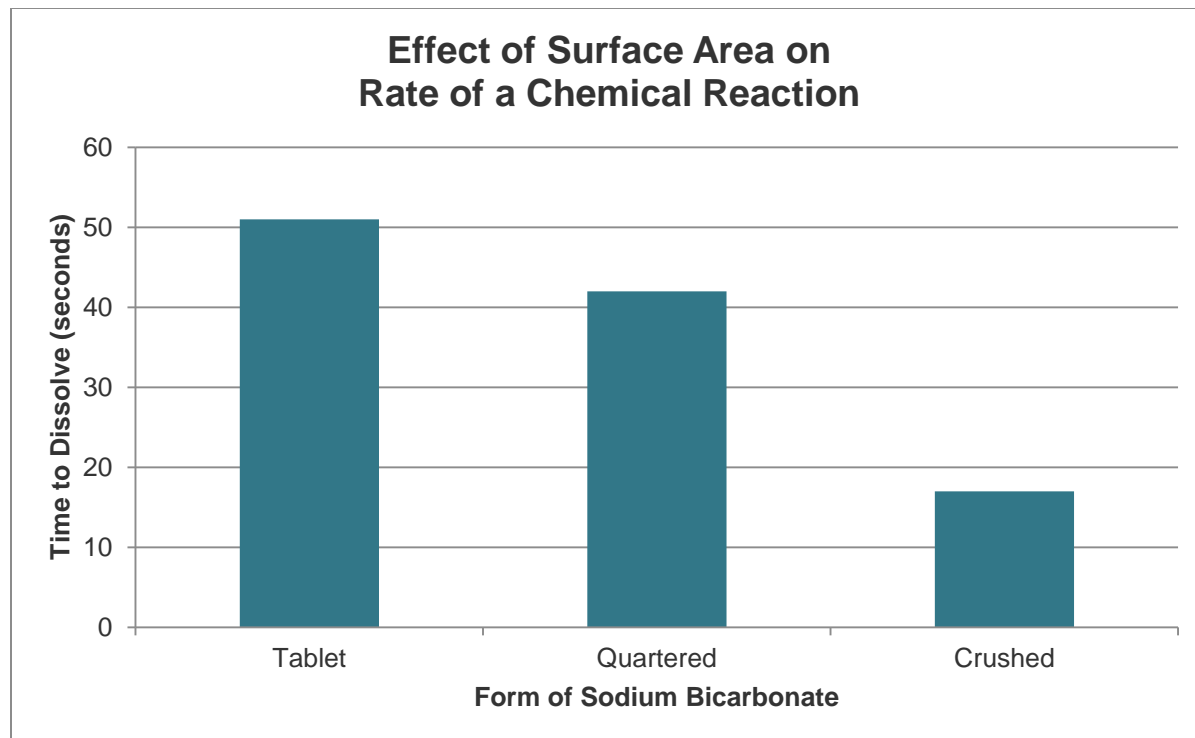
When students write their lab reports, they should provide written explanations of their results, describing how the dependent variable was affected by each independent variable.

**Sample Analysis:** The results of the experiment show that:

- when the temperature increases, so does the rate of reaction when the form of the sodium bicarbonate is constant.
- when surface area increases, so does the rate of reaction when the temperature is held constant.



## Teacher Guide (continued)



## Conclusion

When students write their lab reports, they should restate the hypothesis and explain whether it was supported or refuted by the data. They may also revise the hypothesis and propose further experiments. Students should also identify any additional questions that arose while conducting the experiment.

**Sample Conclusion:** The hypothesis was “If temperature and surface area increase, then the time it takes for sodium bicarbonate to completely dissolve will decrease, because increasing both factors increases the rate of a chemical reaction.” This hypothesis was supported by the data. As temperature increased, the time required to dissolve the sodium bicarbonate decreased. The same was true of surface area. As the amount of surface area increased, the time required to dissolve the sodium bicarbonate decreased.

Some error was associated with the measurement of time for the dissolution of the sodium bicarbonate, as can be seen in the range of measurements for each trial, but this was no more than +/- 5 seconds. If this experiment were to be conducted again, both the number of trials and the number of temperatures recorded would be increased to provide a more comprehensive dataset to demonstrate the trend.

## Teacher Guide (continued)

### Discussion Questions

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Here are some discussion questions that you can use with students once they have completed the wet lab.

- What were your results? Did other students obtain the same results? Compare your results to the results of other students in the class.
- How would you explain the results of this lab?
- What were your conclusions at the end of the lab? Discuss and compare your conclusions to those of other students in the class.
- What kinds of errors did you make while doing this lab? How did you compensate for those errors?
- What suggestions do you have for someone else who is going to do this lab now that you have completed it?

### Extension Activities

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Here are some variations that might lead to an increased understanding of and applications for which factors affect the rate of a chemical reaction.

- Perform the experiment with different volumes of solvent (water).
- Have students convert temperatures to Kelvin.
- Increase the number of times each treatment is tested.
- Increase the confidence of the experiment by increasing the number of temperatures tested.
- Attempt the experiment with antacid tablets with a different active ingredient.