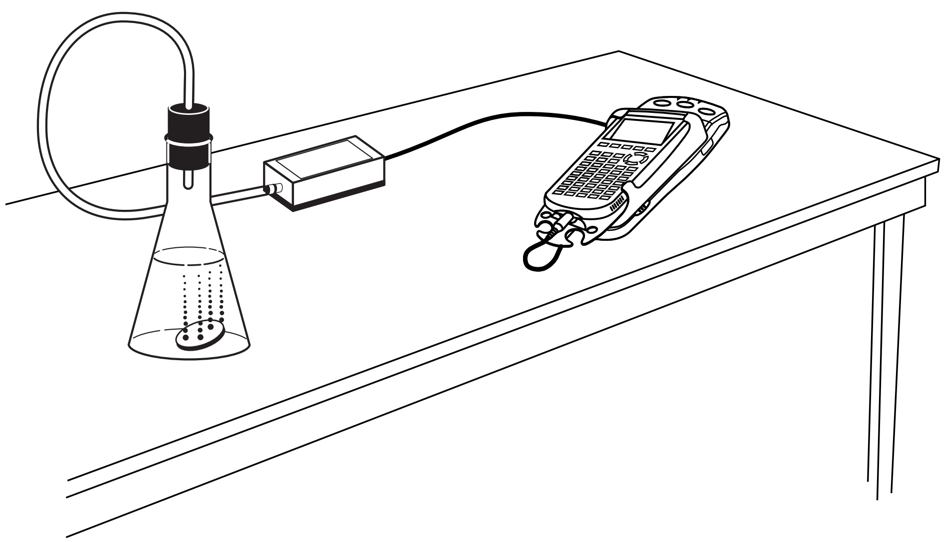
Activity
**5**

# Keep It Bottled Up:
# Linear Rates of Pressure Increase

When two or more chemicals react, other substances such as gases may be produced. The rate at which the reaction takes place can be affected by a number of different factors including temperature. In this activity, you will see how temperature affects the rate at which an effervescent antacid tablet reacts with water and releases a gas. The rate at which the reaction occurs is measured by the rate of gas production.

You will measure this rate by recording the pressure variation in a closed container as the reaction proceeds using a pressure sensor. Then you can use a mathematical model relating pressure and time to describe how water temperature affects chemical reaction rates.



## OBJECTIVES

- Record pressure versus time data as a chemical reaction proceeds.
- Model pressure data using a linear function.
- Use the concept of slope to describe the effect of temperature on chemical reaction rates.

## MATERIALS

TI-83 Plus or TI-84 Plus graphing calculator
EasyData application
data-collection interface
Vernier Gas Pressure Sensor with plastic tubing
empty 500 mL container
one-hole rubber stopper
water, room-temperature and warmed
effervescent antacid tablets
safety goggles

## PROCEDURE

1. Obtain and wear safety goggles.

2. Turn on the calculator. Connect the Pressure Sensor, data-collection interface, and calculator.

3. Attach the tubing directly to the white stem of the Pressure Sensor with a gentle half-turn. Attach the other end of the tubing to a rubber stopper that tightly fits the container.

4. Set up EasyData for data collection.

   a. Start the EasyData application, if it is not already running.
   b. Select File from the Main screen, and then select New to reset the application.
   c. Select Setup from the Main screen, and then select Time Graph…
   d. Select Edit from the Time Graph Settings screen.
   e. Enter **0.2** as the time between samples in seconds.
   f. Select Next.
   g. Enter **100** as the number of samples and select Next.
   h. Select OK to return to the Main screen.

5. You are now ready to collect pressure as a function of time data.

   a. Put 200 mL of room-temperature water in the container. In rapid sequence, put the tablet in the container, seal the container with the stopper, and select Start to begin data collection in order to capture the start of the pressure change. Data collection will run for 20 seconds.
   b. After data collection is complete, point the container away from all people and carefully remove the stopper. Discard the water and any remains of the tablet.

6. Examine the displayed graph. If you achieved a good seal between the container and stopper, you should see a uniformly increasing pressure graph.

   If you need to repeat data collection, select Main and repeat Step 6. If the run was good, select Main to return to the Main screen. To store the data, select File, select **Store Run**, and then select OK.

7. Now prepare to repeat the experiment with warm water.

   a. Put 200 mL of warm water in the container. In rapid sequence, put the tablet in the container, seal the container with the stopper, and select Start to begin data collection in order to capture the start of the pressure change.
   b. After data collection is complete, point the container away from all people and carefully remove the stopper. Discard the water and any remains of the tablet.

8. Examine the displayed graph. If you achieved a good seal between the container and stopper, you should see a uniformly increasing pressure graph. If you need to repeat data collection, select Main and repeat Step 7.

9. Once you are satisfied with the graph, select Main to return to the Main screen. Exit EasyData by selecting Quit from the Main screen and then selecting OK.

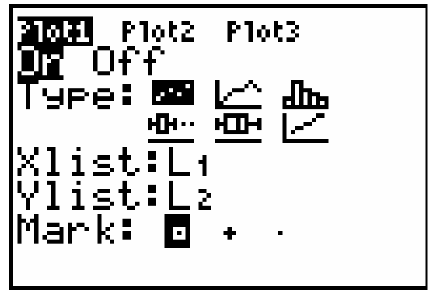
  

10. Next you can view both runs together.

   a. Press 2nd [STAT PLOT] and press ENTER to select Plot 1.

   b. Change the Plot1 settings to match the screen shown here. Press ENTER to select any of the settings you change.

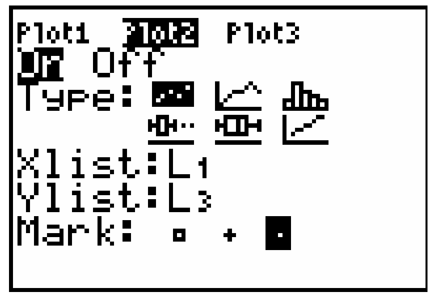
   This means that the warm-water data will be plotted with the box ▫ symbol.




   c. Use the cursor keys to position the cursor back up at the top of the screen, highlighting the Plot2 icon. Press ENTER to switch the screen to Plot2.

   d. Change the Plot2 settings to match the screen shown here. Press ENTER to select any of the settings you change.

   The room-temperature water data will then be plotted with the dot · symbol.




   e. Press ZOOM and then select ZoomStat (use cursor keys to scroll to ZoomStat) to draw a graph with the *x* and *y* ranges set to fill the screen with data.

   f. Press TRACE to read values off of the plots. Press ▶ and ◀ to trace along each plot. Switch between plots by pressing ▲ and ▼.

## ANALYSIS

1. Position the cursor at the beginning of the room-temperature water plot and find the *y*-intercept. Repeat for the warm-water plot. Round all values to three significant digits and record both *y*-intercepts in the Data Table on the *Data Collection and Analysis* sheet.

⇒ Answer Question 1 on the *Data Collection and Analysis* sheet.

2. Position the cursor on the room-temperature water plot. Use the cursor keys to identify two points ($x_1$, $y_1$) and ($x_2$, $y_2$) separated by at least five seconds. Record the coordinates in the Data Table on the *Data Collection and Analysis* sheet.

3. Switch to the warm water plot and identify two points from this line. Record the coordinates in the Data Table on the *Data Collection and Analysis* sheet.

4. When the coordinates of two points on a line are known, the slope of the line can be computed by finding the difference in *y* values divided by the difference in *x* values:

$$slope = \frac{y_2 - y_1}{x_2 - x_1}$$

⇒ Answer Questions 2 and 3 on the *Data Collection and Analysis* sheet.

   Use this formula to compute the slope for each plot. Record your answers in the Data Table.

5. Now, have the calculator plot these two lines with the data.

   a. Press Y=.
   b. Press CLEAR to remove any existing equation.
   c. Enter the equation for the warm-water plot. For example, if the slope and intercept were 4 and 5 respectively, enter 4*x+5.
   d. Press ENTER to move to the Y2 field, press CLEAR, and enter the equation for the room-temperature plot.
   e. Press GRAPH to see the data with the model graphs superimposed.

⇒ Answer Questions 4–8 on the *Data Collection and Analysis* sheet.

## DATA COLLECTION AND ANALYSIS

Name ______________________________

Date ______________________________

## DATA TABLE

| | $x_1$ | $y_1$ | $x_2$ | $y_2$ | *y-intercept* | *slope* |
|---|---|---|---|---|---|---|
| **Room temp water** | | | | | | |
| **Warm water** | | | | | | |

## QUESTIONS

1. What is the physical meaning of the *y*-intercept? Why is this value nearly the same for both plots?

2. What is the physical meaning of the slopes of the pressure versus time plots?

3. The slope-intercept form of a linear equation is $y = mx + b$, where $m$ is the slope of the line and $b$ is the *y*-intercept. Use the information you found above to write linear equations to model the pressure versus time data:

   Equation for room-temperature water data ______________________________

   Equation for warm water data ______________________________

4. How well do the equations fit the data? You may wish to adjust the slope and/or intercept values slightly if you are not satisfied with the way the lines fit the data. If you adjust these values, rewrite the modeling equations below.

5. What do you think the pressure versus time plot would look like after several minutes, if the stopper were left in the container?

   Would pressure continue to increase at a steady rate? Explain why or why not.

6. What would the pressure versus time graph look like if the stopper popped off in the middle of the data collection?

7. For a given water temperature, how do you think the plot would be affected if you used half a tablet?

   What if you used two tablets?

8. Which plot indicates a faster rate of reaction? How can you tell?