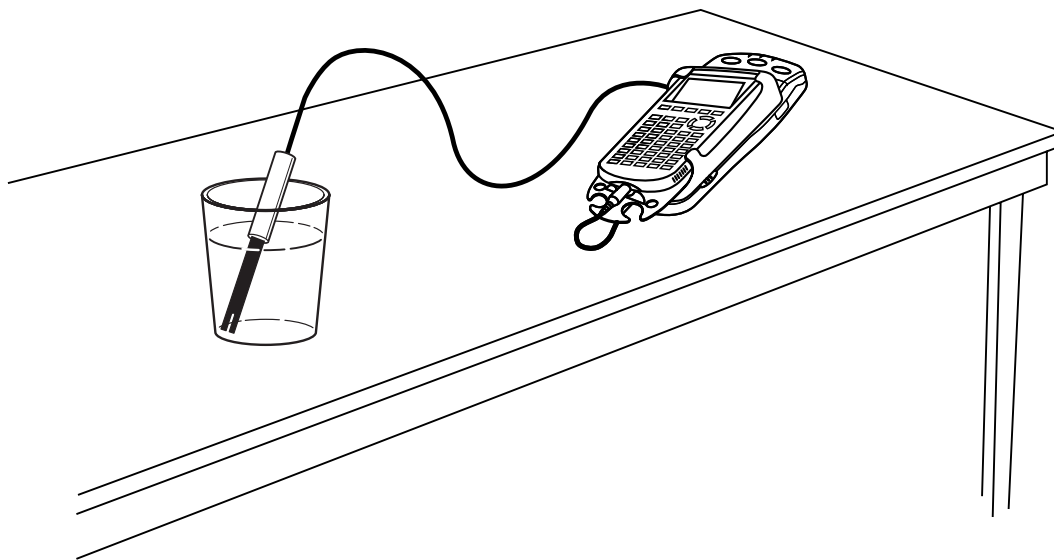


Sour Chemistry: The Exponential pH Change

Chemists quantify the acidity or alkalinity of a solution by measuring its pH on a scale ranging from 0 to 14. A neutral substance has a pH of 7. A pH lower than 7 suggests an acidic solution, while a pH higher than 7 indicates that a solution is basic.

Different pH levels must be maintained throughout the body in order for a person to remain healthy. Excessively high or low pH levels often result in discomfort or irritation. For example, common indigestion or upset stomach usually indicates the presence of excessive amounts of stomach acids. This condition can sometimes be alleviated by taking an antacid tablet, or by drinking a solution such as Alka-Seltzer® and water, designed to neutralize these acids and raise the pH level in the stomach.

In this activity, the conditions found in an acid stomach will be simulated using a solution of lemon juice and water. The effectiveness of an antacid remedy will be tested by monitoring the pH of the solution after an effervescent antacid tablet has been added to it. The resulting data will be modeled using a modified exponential function.



OBJECTIVES

- Record pH versus time data as an antacid tablet neutralizes the acid in lemon juice.
- Model the pH data with a modified exponential function.

MATERIALS

TI-83 Plus or TI-84 Plus graphing calculator
EasyData application
data-collection interface
pH Sensor
distilled water

lemon juice
eyedropper
effervescent antacid tablets
clean cup or beaker

PROCEDURE

1. Turn on the calculator. Connect the pH Sensor, data-collection interface, and calculator.
2. 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, then select **Time Graph...**
 - d. Select **(Edit)** on the Time Graph Settings screen.
 - e. Enter **0.5** 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.
3. Collect pH data.
 - a. Place about 125 mL of distilled water in a very clean cup. The cup *must* be clean to get good results.
 - b. Loosen the top of the pH storage bottle, and carefully remove the bottle. Slide the top of the bottle up the shaft of the sensor so that the bottle top is out of the way. Do not remove the top from the sensor shaft.
 - c. Rinse the tip of the pH sensor with distilled water.
 - d. Place the pH sensor in the water, and support it so the sensor does not fall.
 - e. Put 20 drops of lemon juice into the water. This will simulate an acid stomach. Stir gently with the sensor.
 - f. Get ready to drop your effervescent tablet into the water.
 - g. Select **(Start)** to begin data collection. Then, drop the tablet into the water.
 - h. Data collection will run for 50 seconds. After collection ends, a graph of pH versus time will be shown.
 - i. The graph should show pH values that increase rapidly at first and then level off. Select **(Main)** to return to the Main screen.

If you want to repeat data collection, discard the solution and thoroughly rinse the cup and pH sensor in distilled water, and repeat this step.
 - j. Once you are satisfied with the data, select **(Main)** to return to the Main screen. Exit EasyData by selecting **(Quit)**, and then selecting **(OK)**.
4. Use additional distilled water to rinse the pH sensor. Discard the solution in the cup, and rinse the cup. Replace the storage bottle on the pH sensor.

ANALYSIS

- To work with the data, redisplay the graph outside EasyData.
 - Press 2nd [STAT PLOT].
 - Press ENTER to select Plot1 and press ENTER again to select On.
 - Press ZOOM .
 - Press V until ZoomStat is highlighted; press ENTER to display a graph with the x and y ranges set to fill the screen with data.
 - Press TRACE to determine the coordinates of a point on the graph using the cursor keys.
- A modified exponential model can be used to model the data you have just collected.

$$y = A(1 - B^x) + C$$

In this expression, y represents the pH of the solution at any time x . C represents the initial pH of the solution, which is also the y -intercept. A measures the magnitude of the pH change, while B is a value between 0 and 1 which measures the rate of the change.

To fit this model to the data, first determine the y -intercept from your graph. Trace to the left edge of the graph. Round the $x = 0$ pH value to two significant digits and record it in the Data Table on the *Data Collection and Analysis* sheet.

- At the other side of the graph the pH values should approach a constant value as the curve flattens. Trace to the right edge of the graph to estimate the value the pH curve is approaching. Record this value in the Data Table.
 - The pH approach value you just determined is related to a sum of constants in the model equation. Assume that $0 < B < 1$. If x is large, the model expression approaches the sum $A + C$.
- ⇒ Answer Question 1 on the *Data Collection and Analysis* sheet.
- Use the value for the approach pH and the y -intercept to determine a value for the parameter A . Enter the result in the Data Table.
 - Enter the model expression for graphing, along with values for the parameters A and C .
 - Press Y= .
 - Press CLEAR to remove any existing equation.
 - Enter the modified exponential model as $A*(1-B^X) + C$ in the Y_1 field.
 - Press 2nd [QUIT] to return to the home screen.
 - Enter the value for the parameter A . Press $\text{STO} \blacktriangleright$ A ENTER to store the value in the variable A .
 - Enter the value for the parameter C . Press $\text{STO} \blacktriangleright$ C ENTER to store the value in the variable C .
 - Set a value for the parameter B , and then look at the resulting graph. To obtain a good fit, you will need to try several values for B . Use the steps below to store different values to the parameter B . Start with $B = 0.5$.
 - Enter a value for the parameter B . Press $\text{STO} \blacktriangleright$ B ENTER to store the value in the variable B .
 - Press GRAPH to see the data with the model graph superimposed.
 - Press 2nd [QUIT] to return to the home screen.

Activity 20

Experiment until you find a value that provides a good fit for the data and record the value in the Data Table.

⇒ Answer Questions 2-5 on the *Data Collection and Analysis* sheet.

EXTENSION

The equation used in this activity $y = A(1 - B^x) + C$ is a modified version of the exponential function $y = ab^x$. Show how $y = ab^x$ can be transformed into the model used here using reflections and shifts.

Hint: Work backwards by distributing A and regrouping.

DATA COLLECTION AND ANALYSIS

Name _____

Date _____

DATA TABLE

y-intercept C	
pH approach value	
A	
optimized B	

QUESTIONS

1. Explain why the model expression from Step 4 approaches the sum of $A + C$.

2. How does the value of B affect the shape of the modeling curve?

Activity 20

3. How would adding more drops of lemon juice to the starting solution affect the resulting plot of pH versus time? Which of the parameters A , B and C in the model expression would change? Explain the reasoning.

Hint: Adding more lemon juice would make the initial solution more acidic, yielding a lower pH value at the start of data collection.

4. How would adding two antacid tablets (instead of one) to the starting solution affect the resulting plot of pH versus time? Which of the parameters A , B and C in the model expression would change? Explain the reasoning.

5. How would you compare the effectiveness of two different brands of antacid tablets? Which of the parameters A , B and C in the model expression would give an indication of how well a tablet works?

Hints: Which variable describes the speed of relief? Which variable describes the magnitude of relief?