



# Endothermic & Exothermic Reactions

Written by Chris Papadopoulos

This lesson focuses on the use of technology to collect, graph and analyze data from an exothermic and an endothermic reaction.

## Hypothesis

Chemical reactions are systems that exchange heat/energy with their surroundings.

## Primary Learning Outcomes

At the end of this lesson, students will be able to:

- Be familiarized with data collection using the Vernier LabPro and TI-84 calculator
- Collect, graph, display and make inferences from data
- Calculate the temperature change ( $\Delta t$ ) of a reaction
- Determine whether a reaction is exothermic or endothermic based on  $\Delta t$

## Assessed GPS

### Characteristics of Science:

#### Habits of Mind:

**SCSh2.** Students will use standard safety practices for all classroom laboratory and field investigations.

- a. Follow correct procedures for use of scientific apparatus.
- b. Demonstrate appropriate techniques in all laboratory situations.
- c. Follow correct protocol for identifying and reporting safety problems and violations.

**SCSh3.** Students will identify and investigate problems scientifically

- c. Collect, organize, and record appropriate data
- d. Graphically compare and analyze data points and/or summary statistics
- e. Develop reasonable conclusions based on data collected

**SCSh4.** Students will use tools and instruments for observing, measuring, and manipulating scientific equipment and materials.

- b. Use technology to produce tables and graphs

**SCSh5.** Students will demonstrate the computation and estimation skills necessary for analyzing data and developing reasonable scientific explanations.

- e. Solve scientific problems by substituting quantitative values, using dimensional analysis and/or simple algebraic formulas as appropriate.

### Content:

**SC2.** Students will relate how the Law of Conservation of Matter is used to determine chemical composition in compounds and chemical reactions.

- b. Experimentally determine indicators of a chemical reaction specifically precipitation, gas evolution, water production, and changes in energy to the system.

**SC6.** Students will understand the effects motion of atoms and molecules in chemical and physical processes.

- b. Collect data and calculate the amount of heat given off or taken in by chemical or physical processes.

**Duration**

85 minutes

**Materials and Equipment**

Styrofoam cup  
250-mL baker  
citric acid,  $\text{H}_3\text{C}_6\text{H}_5\text{O}_7$ , solution  
baking soda,  $\text{NaHCO}_3$   
hydrochloric acid,  $\text{HCl}$ , solution  
50-mL graduated cylinder

**Technology Connection**

Vernier LabPro interface  
TI Graphing Calculator  
Vernier DataMate program  
Vernier Temperature Probe

**Procedures****Step 1: Introduction/Motivation, 15 minutes**

Light a match/Bunsen burner/lighter. Question students as to what is happening. Write answers on the board. Discuss demonstration, write the chemical reaction on the board.

**(Write Equation Here)**

Lead a discussion on some common exothermic and endothermic reactions. Elicit examples from students and provide additional examples. Examples include:

Mixture of cement and water (exothermic)  
Melting and freezing of ice (endothermic and exothermic)  
Baking soda and water (exothermic)  
Hot packs and cold packs (endothermic, endothermic)

Define terms and list on board (students write in notebooks). Teacher may elaborate as desired. In an **endothermic process**, a system absorbs heat from its surroundings. Chemical reactions that absorb energy are **endothermic reactions**.

In an **exothermic process**, a system releases heat to its surroundings. Chemical reactions that release energy are **exothermic reactions**. For example, the calcium oxide in cement:  $\text{CaO}(s) + \text{H}_2\text{O}(l) \rightarrow \text{Ca}(\text{OH})_2(s) + 65.2 \text{ kJ}$ .

Show students what the set up should look like, including proper initialization of the Vernier LabPro and TI calculator.

**Step 2: Activity, 50 minutes**

Students will break up into groups and conduct activity “Endothermic and Exothermic Reactions” as outlined in student handout.

### **Step 3: Review, 20 minutes**

Gather students as a class and discuss results, answers to the review questions given at the end of the student handout, and any problems or questions with the procedure.

### **Assessment**

Completed student worksheets will be collected and graded.

Student understanding of activity components may be assessed by unit examination.

Student affect and work ethic may be assessed by affect/ethic rubric.

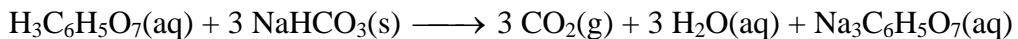
### **References**

Holmquist, D.D., Randall, J. & Volz, D. (2000). Chemistry with Calculators. pp. 1-1 – 1-T3.  
Vernier Software & Technology: Beaverton, Oregon.

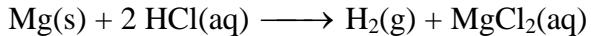
## Endothermic & Exothermic Reactions

Many chemical reactions give off energy. Chemical reactions that release energy are called *exothermic* reactions. Some chemical reactions absorb energy and are called *endothermic* reactions. You will study one exothermic and one endothermic reaction in this experiment.

In Part I, you will study the reaction between citric acid solution and baking soda. An equation for the reaction is:



In Part II, you will study the reaction between magnesium metal and hydrochloric acid. An equation for this reaction is:



Another objective of this experiment is for you to become familiar with using the DataMate data-collection program on the TI Graphing Calculator. In this experiment, you will use the program to collect and display data as a graph or list, to examine your experimental data values on a graph, and to print graphs and data lists.

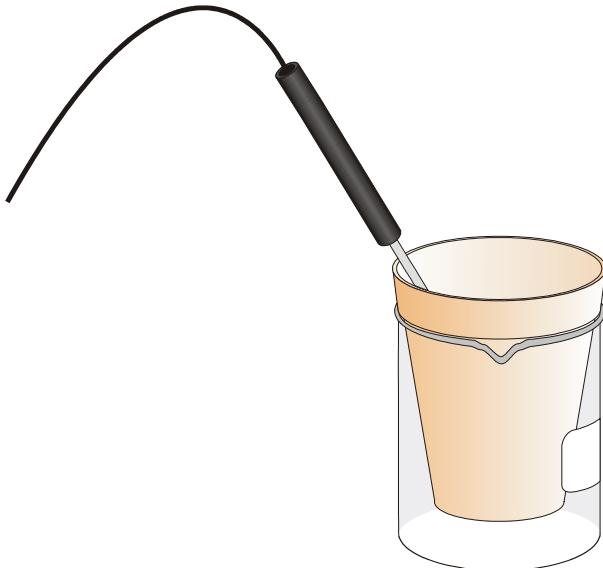


Figure 1

## MATERIALS

LabPro interface  
TI Graphing Calculator  
DataMate program  
Temperature Probe  
50-mL graduated cylinder  
balance

Styrofoam cup  
250-mL baker  
citric acid,  $\text{H}_3\text{C}_6\text{H}_5\text{O}_7$ , solution  
baking soda,  $\text{NaHCO}_3$   
hydrochloric acid,  $\text{HCl}$ , solution  
magnesium, Mg

## PROCEDURE

1. Obtain and wear goggles.

### Part I Citric Acid plus Baking Soda

2. Plug the Temperature Probe into Channel 1 of the LabPro or CBL 2 interface. Use the link cable to connect the TI Graphing Calculator to the interface. Firmly press in the cable ends.
3. Place a Styrofoam cup into a 250-mL beaker as shown in Figure 1. Measure out 30 mL of citric acid solution into the Styrofoam cup. Place the Temperature Probe into the citric acid solution.
4. Weigh out 10.0 g of solid baking soda on a piece of weighing paper.
5. Turn on the calculator and follow these steps to start the DATAMATE program.

TI-73 and TI-83 Calculators:

Press **[PRGM]**, then press the calculator key for the *number* that precedes the DATAMATE program (usually **[1]**). Press **[ENTER]**. You are now at the main screen of the program. Press **[CLEAR]** to reset the program.

TI-83 Plus Calculators:

Press **[APPS]**, then press the calculator key for the *number* that precedes the DATAMATE program. You are now at the main screen of the program. Press **[CLEAR]** to reset the program.

TI-86 Calculators:

Press **[PRGM]**, press **[F1]** to select <NAMES>, and press a menu key to select <DATAM> (usually **[F1]**). Press **[ENTER]**. You are now at the main screen of the program. Press **[CLEAR]** to reset the program.

TI-89, TI-92, and TI-92 Plus Calculators:

Press **[2nd]** **[VAR-LINK]**. Use **[▼]** or the cursor pad to scroll down to “datamate”, then press **[ENTER]**. Press **[)** to complete the open parenthesis that follows “datamate” on the entry line and press **[ENTER]**. You are now at the main screen of the program. Press **[CLEAR]** to reset the program.

6. Set up the calculator and interface for the Temperature Probe.
  - a. Select SETUP from the main screen.
  - b. If the calculator displays a Temperature Probe in CH 1, proceed directly to Step 7. If it does not, continue with this step to set up your sensor manually.
  - c. Press **[ENTER]** to select CH 1.
  - d. Select TEMPERATURE from the SELECT SENSOR menu.
  - e. Select the Temperature Probe you are using (in °C) from the TEMPERATURE menu.
7. Set up the data-collection mode.
  - a. To select MODE, press **[▲]** once and press **[ENTER]**.
  - b. Select TIME GRAPH from the SELECT MODE menu.
  - c. Select CHANGE TIME SETTINGS from the TIME GRAPH SETTINGS menu.
  - d. Enter “6” as the time between samples in seconds.

- e. Enter “50” as the number of samples. The length of the data collection will be 5 minutes.
  - f. Select OK to return to the setup screen.
  - g. Select OK again to return to the main screen.
8. You are now ready to begin collecting data.
- a. Select START on the main screen.
  - b. After about 20 seconds have elapsed, add the baking soda to the citric acid solution. Gently stir the solution with the Temperature Probe to ensure good mixing.
  - c. A real-time graph of temperature *vs.* time will be displayed on the calculator screen during data collection.
  - d. Temperature readings (in °C) can also be monitored in the upper-right corner of the graph.
  - e. Data collection will stop after 5 minutes, and a graph of temperature *vs.* time will be displayed.
9. Dispose of the reaction products as directed by your instructor.
10. Use the  $\blacktriangleright$  or  $\blacktriangleleft$  keys (or the cursor pad on the TI-92) to examine the data points along the displayed curve of temperature *vs.* time. As you move the cursor right or left, the time (X) and temperature (Y) values of each data point are displayed below the graph. Determine the initial temperature,  $t_1$ , and final (or minimum) temperature,  $t_2$ . Record the temperature values in your data table (round to the nearest 0.1°C).
11. Store the data from the first run so that it can be used later. To do this:
- a. Press **ENTER** to return to the main screen, then select TOOLS.
  - b. Select STORE LATEST RUN from the TOOLS MENU.

## Part II Hydrochloric Acid Plus Magnesium

12. Measure out 30 mL of HCl solution into the Styrofoam cup. Place the Temperature Probe into the HCl solution. Note: The Temperature Probe must be in the HCl solution for at least 30 seconds before doing Step 15.
13. Obtain a piece of magnesium metal from your instructor.
14. Choose START on the main screen to begin data collection. After about 20 seconds have elapsed, add the Mg to the HCl solution. Gently stir the solution with the Temperature Probe to ensure good mixing. **Caution:** Do not breathe the vapors. Data collection will stop after 5 minutes.
15. Dispose of the reaction products as directed by your instructor. Rinse the Temperature Probe.
16. Examine the data points along the displayed curve of temperature *vs.* time. Determine the initial temperature,  $t_1$ , and the final (or maximum) temperature,  $t_2$ . Record the temperature values in your data table (round to the nearest 0.1°C).
17. You can also examine the data by viewing the data lists directly. To do this, press **ENTER** to return to the main screen, and select QUIT. (Also press **ENTER** on a TI-83 Plus or TI-73). Then follow this procedure for your calculator:

TI-73, TI-83, and TI-83 Plus Calculators

To view the lists, press **STAT** to display the EDIT menu and then select Edit. Press  $\blacktriangledown$  to scroll down through the data lists L<sub>1</sub> (time) and L<sub>2</sub> (temperature) for Part II. **Note:** When you choose to repeat a data collection, as you did in Step 11 of this experiment, the temperature

data in L<sub>2</sub> of the first data run will be stored in L<sub>3</sub>. You can view the data for Part I of the experiment in L<sub>1</sub> and L<sub>3</sub>.

#### TI-86 Calculators

To view the lists, press [STAT] and select <EDIT> by pressing [F2]. Press [▼] to scroll down through the data lists L<sub>1</sub> (time) and L<sub>2</sub> (temperature) for Part II. **Note:** When you choose to repeat a data collection, as you did in Step 11 of this experiment, the temperature data in L<sub>2</sub> of the first data run will be stored in L<sub>3</sub>. You can view the data for Part I of the experiment in L<sub>1</sub> and L<sub>3</sub>.

#### TI-89, TI-92, and TI-92 Plus Calculators

To view the data matrix, press [APPS], select Data/Matrix Editor, then Current. Move the cursor down through the data lists c<sub>1</sub> (time) and c<sub>2</sub> (temperature) for Part II. **Note:** When you choose to repeat a data collection, as you did in Step 11 of this experiment, the temperature data of the first data run will be displayed in c<sub>3</sub>. You can view the data for Part I of the experiment in c<sub>1</sub> and c<sub>3</sub>.

18. A good way to compare the two curves is to view both sets of data on one graph.
  - a. Turn on the calculator and start the DATAMATE program.
  - b. Select GRAPH from the main screen, then press [ENTER].
  - c. Select MORE, then select L<sub>2</sub> AND L<sub>3</sub> VS L<sub>1</sub> from the MORE GRAPHS menu.
  - d. Both temperature runs should now be displayed on the same graph. Each point of Part I (citric acid and baking soda) is plotted with a box, and each point of Part II (hydrochloric acid and magnesium) is plotted with a dot.
19. (optional) Print a graph of temperature vs. time (with two curves displayed). Label each curve as “endothermic reaction” or “exothermic reaction”.

Name \_\_\_\_\_

## Data Table and Review Questions

### DATA TABLE

	Part I	Part II
Final temperature, $t_2$	°C	°C
Initial temperature, $t_1$	°C	°C
Temperature change, $\Delta t$	°C	°C

### PROCESSING THE DATA

- a. Calculate the temperature change,  $\Delta t$ , for each reaction by subtracting the initial temperature,  $t_1$ , from the final temperature,  $t_2$  ( $\Delta t = t_2 - t_1$ ).
- b. Tell which reaction is exothermic. Explain.
- c. Which reaction had a negative  $\Delta t$  value? Is the reaction endothermic or exothermic? Explain.
- d. For each reaction, describe three ways you could tell a chemical reaction was taking place.
- e. Which reaction took place at a greater rate? Explain your answer.