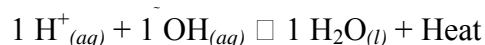




## Which Hydrogens in Citric Acid Are Acidic?

### INTRODUCTION

A neutralization reaction occurs in aqueous solution when protons,  $\text{H}^+_{(aq)}$ , react with hydroxide ions,  $\text{OH}^-_{(aq)}$ , to produce water as shown below:



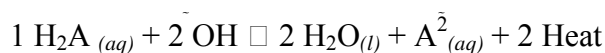
These reactions are the combination of one proton with one hydroxide ion to produce one molecule of water and a discrete amount of heat energy. Compounds that can break apart to produce protons are called acids. Acids will also react with hydroxide ions in water, in a neutralization reaction to produce water and heat.



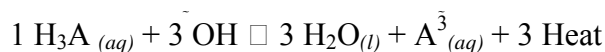
and



Some acids, polyprotic acids, may lose more than one proton and produce more heat in proportion to the number of protons lost in the neutralization reactions. Each of these polyprotic acids loses a specific number of protons, which is prescribed by their structure.

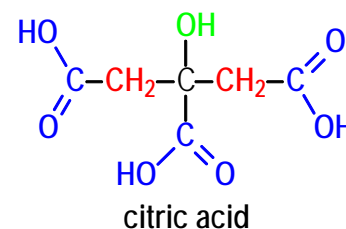


and



The other information essential to this investigation is that the heat released in the neutralization reaction is essentially proportional to the temperature change of the reaction mixture if the total amount of aqueous liquids used in each trial of the investigation is kept constant.

The described principles can be used to investigate citric to determine which types of hydrogens in citric acid act as acids and dissociate to produce protons. When the structure of citric acid is examined, there are three possibilities for the number of protons that can react with hydroxide ion, as shown by the different colored hydrogens. If the one OH hydrogen, shown in green, reacts with the hydroxide ion, then one mole of citric acid will react optimally with one mole of hydroxide ions. If the three  $\text{CO}_2\text{H}$ , shown in blue, react with hydroxide ions, then one mole of citric acid will optimally react with three moles of hydroxide ions. If the four  $\text{CH}_2$  hydrogens, shown in red, react with hydroxide ions, then one mole of citric acid will optimally react with four moles of hydroxide ions.



In this investigation, 1.00 M aqueous solutions of sodium hydroxide and citric

acid will be used to ensure sufficient temperature change in the neutralization reaction. All reactions will be performed in polystyrene cups (figure 1), calorimeters, to minimize heat losses to the environment, and the temperature changes will be measured with the LabQuest. The solutions should be measured in separate, labeled graduated cylinders, as shown in Table 1. A drop of thymol blue indicator may be added to each solution to give them different colors, making each visually distinct from the other.

## REAGENTS AND EQUIPMENT

LabQuest  
LabQuest App  
Temperature Probe  
2 – 10 mL graduated cylinder  
2 – 100 mL graduated cylinder  
250 mL baker

Styrofoam cup  
1.00 M aqueous citric acid solution  
1.00 M sodium hydroxide  
Thymol blue indicator  
Deionized water

**Table 1.**

Reagent	Volume of Reagents (mL) to be Combined										
1.00 M citric acid	5	10	15	20	25	30	35	40	45	50	55
1.00 M sodium hydroxide	55	50	45	40	35	30	25	20	15	10	5

Each group will be assigned one or more reaction ratio from Table 1 and three trials should be performed by the group on each reaction ratio.

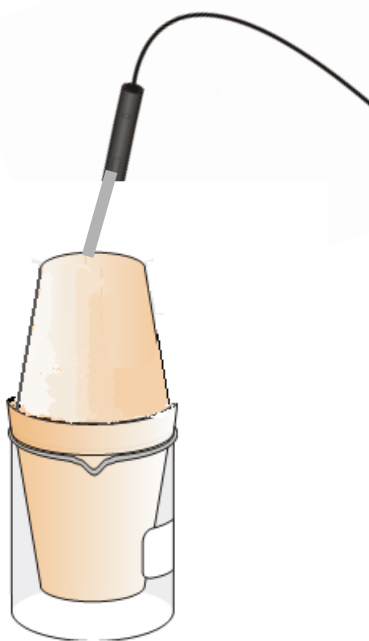


Figure 1

## **PROCEDURE**

1. Obtain and wear goggles.
2. Connect the Temperature Probe to LabQuest, press the power button to turn it on, and choose New from the File menu.
3. On the Meter screen, tap Rate. Change the data-collection length to 2 minutes and the data-collection rate to 10 minute. (Note - the mode remains on Time Based)
4. Place a Styrofoam cup into a 250 mL beaker as shown in Figure 1. Measure out the assigned volume of citric acid solution into the Styrofoam cup. Place the Temperature Probe through a second cup and into the citric acid solution.
5. You are now ready to begin collecting data.
  - a. Start data collection.
  - b. After about 5 seconds have elapsed, slide the Styrofoam lid up and add the sodium hydroxide to the citric acid solution. Gently stir the solution slowly rotating the 250 ml beaker to ensure good mixing.
  - c. A real-time graph of temperature *vs.* time will be displayed on the screen during data collection.
  - d. Temperature readings (in °C) can also be monitored in a display box to the right of the graph.
6. Dispose of the reaction products as directed by your instructor.
7. When data collection is complete, a graph of temperature *vs.* time will be displayed. To examine the data pairs on the displayed graph, tap any data point. As you tap each data point, its temperature and time values are displayed in the display box to the right of the graph. Determine the initial temperature,  $t_1$  and final (or minimum) temperature,  $t_2$ . Record the temperature values in your data table. Record the initial temperature, the highest temperature, and the temperature change on your Data Table.
8. Before starting your next trial, rinse the calorimeter with deionized water and dry with a paper towel.
9. Three trials should be by the group on each reaction ratio. The temperature changes for each set of three trials should be averaged and entered into a data spreadsheet for analysis and class discussion.
10. Repeat steps 4 through 7 for each remaining trial.

## **POST-LAB QUESTIONS**

1. What ratio of sodium hydroxide to citric acid yielded the largest temperature change?
2. How many moles of sodium hydroxide and how many moles of citric acid were in the optimal reaction?

3. How many moles of sodium hydroxide are necessary to neutralize 1.00 moles of citric acid?
4. How many hydrogens are acidic on one molecule of citric acid?
5. Which type of hydrogens ( $\text{OH}$ ,  $\text{CO}_2\text{H}$ , and/or  $\text{CH}_2$ ) are acidic in citric acid?

Adapted from Hayes, S. E. *J. Chem. Ed.* **1995**, 72, 1029.