NAME PERIOD DATE

4. HOW MUCH ACID IS IN YOUR FRUIT JUICE?

Introduction

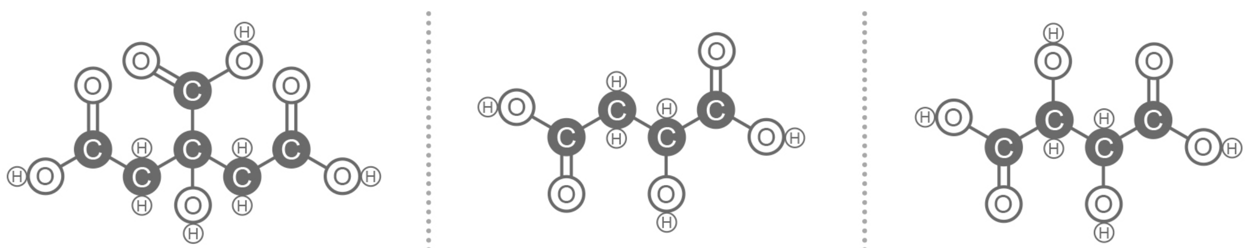
Have you ever wondered why you prefer one kind of fruit juice with your breakfast over another? Fruit juices contain organic acids and sugar in varying proportions that excite your taste buds in different ways. In this lab, the concentration of acid in common fruit juices will be determined by titration against a base, sodium hydroxide.

Concepts

- Acids and bases
- pH
- Titration
- Equivalence point
- Neutralization reaction
- End point

Background

The organic acids in food, specifically acids in fruits and vegetables, vary greatly. A handful of acids play a principal role in producing the level of tartness unique to certain fruits that enhances their desirability for consumers. However, these organic acids may also be key players in increasing the chance of developing kidney stones. Many people are aware that citric acid is found in citrus fruits such as oranges, limes and lemons, but lesser known organic acids such as malic acid in apples, and tartaric acid in grapes, occur naturally in fruit. These acids give fruits their distinctive, sharp taste and in combination with sugar, impart a unique flavor that increases the desirability of fruit juice for the consumer.



Citric Acid | Malic Acid | Tartaric Acid

These organic acids are often added to other consumer products as additives to increase tartness or enhance flavors. In addition to taste, fruit acids are also used as preservatives due to their ability to reduce the onset of bacterial degradation. High acidity slows down bacterial growth.

Excessive consumption of fruit juices may cause health challenges. Fruit acids can erode tooth enamel and increase the risk of developing dental cavities. Enamel degrades when exposed to liquids with a pH of 4 or lower. Organic acids, specifically malic acid, may also cause gastric distress in people diagnosed with conditions such as gastritis, acid reflux or interstitial cystitis and irritate gastrointestinal tissue that has already been damaged due to inflammation.

Titration is a method that uses a solution of known concentration (titrant) to determine the concentration of a component in an unknown solution (analyte). In this lab, the amount of acid in a variety of fruit juices will be determined by titration against a sodium hydroxide standard of known molarity. The neutralization reaction will be monitored by a change in pH. The volume of sodium hydroxide that must be titrated to reach the endpoint will be used to determine the concentration of acid in the juice sample.

Pre-Lab Questions

Using book or online resources, research the pH of the following fruit juices and fill in the following) table.

Fruit Juice	pH
Orange juice	
Mandarin juice	
Grapefruit juice	
Lemon juice	
Tomato juice	

Calculate the hydrogen ion concentration for each of the juices in the table.

$$pH = -\log_{10}[H+]$$

$$[H+] = 10^{-pH}$$

Fruit Juice	[H+]
Orange juice	
Mandarin juice	
Grapefruit juice	
Lemon juice	
Tomato juice	

Calculate the molar mass of citric acid, malic acid and tartaric acid from their structural formulas.

	Formula	Molar Mass (g/mol)
Citric Acid	$C_6H_8O_7$	
Malic Acid	$C_4H_6O_5$	
Tartaric Acid	$C_4H_6O_6$	

Your teacher has prepared 1 liter (L) of a citric acid solution for a class titration experiment. 25 mL of the acid are titrated with a standardized solution of 0.1 M sodium hydroxide. The volume of titrant required to reach the endpoint was determined to be 19.0 mL. The molecular equation for this reaction is:

$$\mathbf{C_3H_5O(COOH)_3 + NaOH \rightarrow Na_3C_3H_5O(COO)_3 + H_2O}$$

Balance the molecular equation for neutralization of citric acid.

How many moles of NaOH were needed to neutralize the acid in the analyte?

How many moles of citric acid were present in the 25 ml sample?

Calculate the citric acid content of the 1 L stock solution of citric acid.

Materials and Equipment

Use the following materials to complete the initial investigation. For conducting an experiment of your own design, check with your teacher to see what materials and equipment are available.

- Data collection system
- Wireless pH sensor and electrode support
- 50-mL burette
- Burette clamp
- Magnetic stirrer and stir bar
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- 250-mL beakers
- 10-mL graduated cylinders
- 0.1 M Sodium hydroxide (NaOH)
- 0.1 M Acetic acid (CH_3COOH)
- Fruit juices, variety

Safety

Follow these important safety precautions in addition to your regular classroom procedures:

- Wear safety goggles and gloves at all times.
- Solid sodium hydroxide (NaOH) causes severe burns and eye damage. Do not breathe vapors or spray solution.
- NaOH may be corrosive to some metals.
- Sodium hydroxide, 0.1 M, causes skin and eye irritation.
- Acetic acid solution causes skin and eye irritation.
- Anhydrous citric acid ($C_6H_8O_7$) causes skin and eye irritation.
- Wash hands thoroughly with soap and water before leaving laboratory.
- Dispose of solutions as directed by Material Safety Data Sheet.

Disposal

If your drain system is connected to a sanitary sewer system, the following instructions apply. Excess sodium hydroxide may be rinsed down the drain with an excess of water. Acetic acid and fruit juices may also be washed down the drain.

Initial Investigation

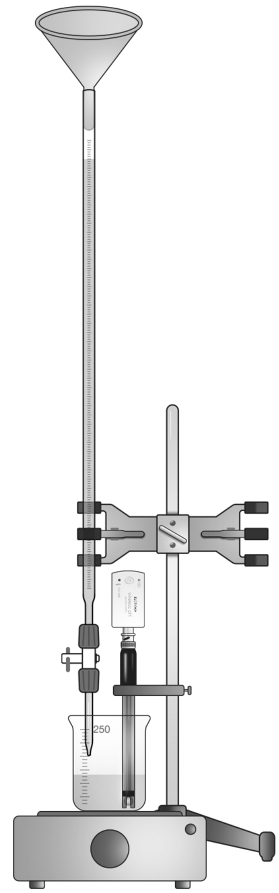
Titration of 0.1 M Acetic Acid with 0.1 M Sodium Hydroxide

1. Start a new experiment on the data collection system from your computer or mobile device.

2. Connect the pH sensor to the data collection system.

3. Open the Titration (buret) Quick Start Experiment or open lab file 04 How Much Acid is in Your Fruit Juice?.

4. Attach the electrode support and burette clamp to the ring stand. Place the burette in the clamp with a funnel still inside the burette. Place the 150-mL beaker beneath the burette so it will drain into the beaker as shown below.



5. Use the funnel to rinse the burette with 0.1 M NaOH and collect rinse into a 100-mL waste beaker. Close the stopcock.

6. Fill the burette with 0.1 M NaOH titrant to the 0.00 mL line with NaOH using the funnel. Rinse the hanging drop of NaOH, if necessary.

7. Remove waste beaker and replace with clean 250-mL beaker.

8. Use the graduated cylinder to add 10.0 mL of acetic acid to the 250-mL beaker.

9. Place the magnetic stir bar in the 250 mL beaker. Arrange the beaker, burette and pH probe on the magnetic stirrer as before and turn on the stirrer.

10 Use the electrode support to suspend the pH probe in the analyte beaker. Add enough distilled water to cover the glass bulb on the pH sensor.

11. Turn on the magnetic stirrer making sure that the pH probe stays in the solution and is out of the way of the magnetic stir bar.

12. Titrate the acetic acid with the sodium hydroxide and start collecting data. Record the initial pH at volume = 0 mL of NaOH added in the table in SPARKvue by selecting the check mark.

13. Adjust the burette to release NaOH very slowly. When 0.50 mL of NaOH has been added, close the burette. Rinse the hanging drop of NaOH if necessary. Read the burette and enter the exact volume of NaOH added in the Volume column in the SparkVue table. Use the check mark to record the pH.

    Note: When the addition of NaOH causes a change of pH that is greater than 0.5 units, slow down the addition of NaOH to 0.1 mL or drop increments.

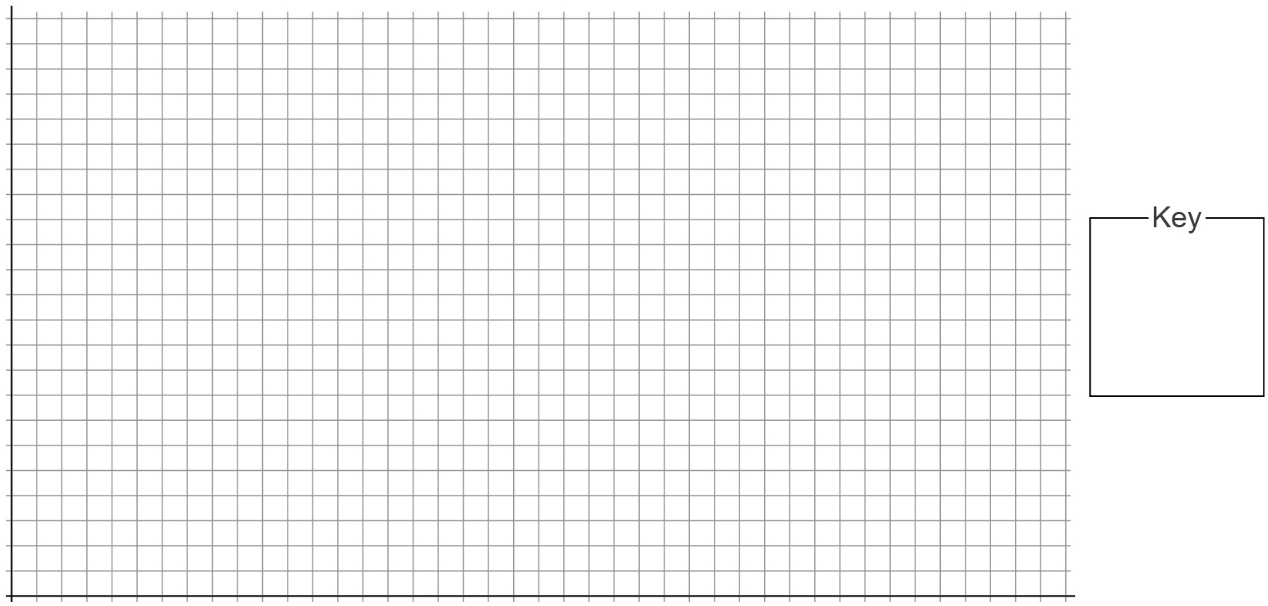
14. Continue adding the NaOH solution in 0.5 mL increments and recording the exact volume and pH in SPARKvue until the pH is greater than 11. Remember to rinse the hanging drops of NaOH.

15. Use a unique line to sketch a graph of the pH vs. volume of titrant.

16. Stop collecting data and turn off the magnetic stirrer.

17. Repeat titration procedure two more times and add data to Graph 1.

Graph 1: Titration of 0.1 M Acetic Acid with 0.1 M Sodium hydroxide



Advanced Investigation

Titration of Fruit Juices to Investigate Acid Content

1. Discuss the results of the acetic acid titration. You will be conducting similar titrations to learn more about the acid content of fruit juices.

2. As a class, choose two or three varieties of fruit juice to test, then compare your results with those of other groups.

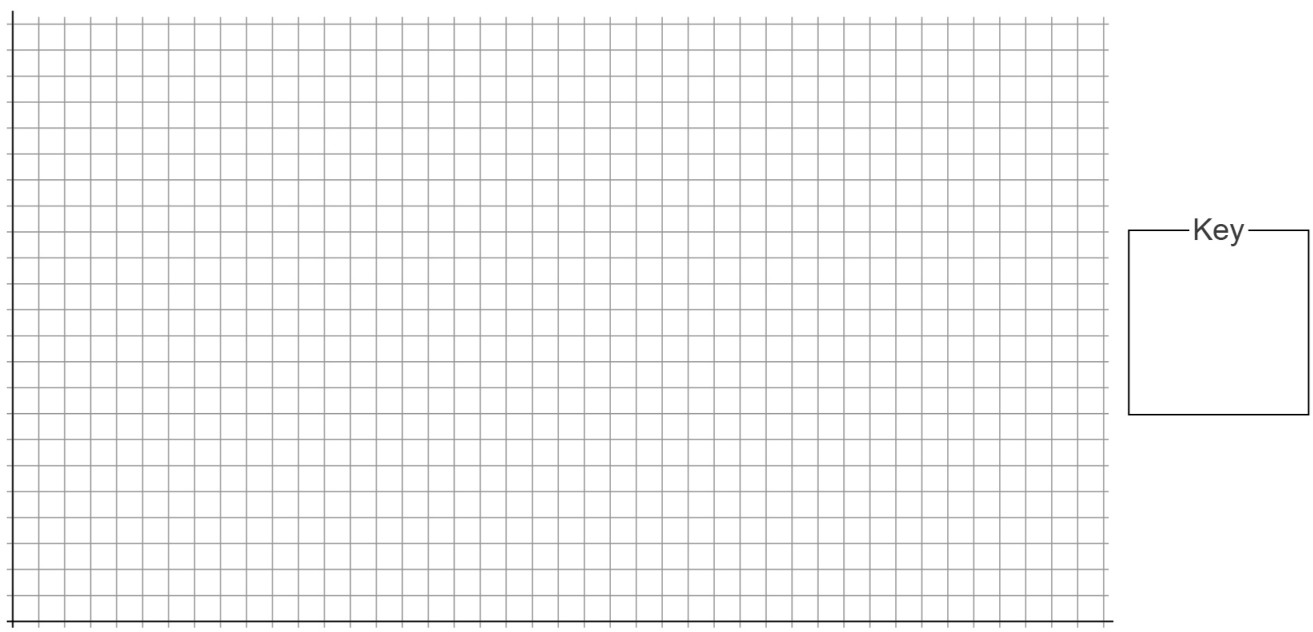
3. Considerations for fruit juice titration:

   a. Molar concentration of NaOH. Will 0.1 M NaOH be sufficient as a titrant?

   b. What acid or acids are contained in your selected fruit juice?

   c. What does it mean if your titration graph shows more than one equivalence point?

Graph 2: Titration and pH Data Collected in SPARKvue for Fruit Juices



Extended Inquiry Investigation

Compilation and Documentation

Pool class data and compare the primary acid, acid concentration, pH and titration profiles of the collective fruit juices studied in this experiment. Prepare a document that identifies trends in the collective data and a general statement that explains these trends.

Using text or online sources, research the acid content of a favorite soda drink and predict the shape of its titration curve using 0.1 M NaOH as titrant.

If you were to perform this experiment again, what changes would you make to your procedure and why?

Synthesis Questions

1. If no NaOH is available, would KOH work in place of NaOH?

2. Why did we not use diluted HCl solution to standardize the NaOH solution?

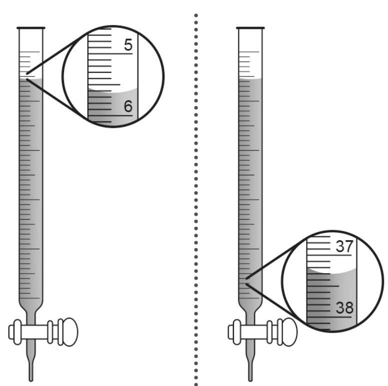
   Hint: HCl solutions are dilutions of concentrated HCl, which is about a 12 M concentration.

3. What method will allow you to use diluted HCl solution as a standardizing solution?

AP® Chemistry Review Question

1. A student is given 25 mL sample of a solution of an unknown monoprotic acid and asked to determine the concentration of the acid by titration. The student uses a standardized solution of 0.110 M NaOH, titration apparatus and an appropriate indicator.

   a. The images below show the burette before the titration begins (image on left) and at the end point (image on right). What volume must be recorded as the correct volume of NaOH titrated?



   b. Based on the given information and your answer to (a), determine the value of the concentration of the acid that should be recorded in the student's lab report.

   c. In a second trial, the student accidentally added more NaOH to the flask than was needed to reach the end point, and then recorded the final volume. Would this error increase, decrease, or have no effect on the calculated acid concentration for the second trial? Justify your answer.