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LESSON

Sweet Spot Teacher Guide

Grade Level(s): 10-12
Skill level: Advanced
Focus: Chemistry, Environmental Science
Time: 45-70 minutes

+ ACTIVITY OVERVIEW

Sweet Spot Lab is an activity designed by Learning Undefeated to help students explore the acid base relationship through the lens of quality control in a sports drink manufacturing facility. In this activity students are introduced to the job of Quality Control Manager, who's responsibility it is to ensure that as product come off the line, it meets quality standards for safety and taste. Market research has found that most people find a very specific concentration of citric acid to be the best lemon flavor. It is now your job to identify whether or not we can send our product to store shelves or not by testing whether the citric acid is at the proper concentration.

+ LEARNING OUTCOMES

- Students will conduct multiple acid base titrations
- Students will calculate the concentration of citric acid present in the provided sports drink samples

ALIGNMENT TO STANDARDS

HS-PS1-2. Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties. Clarification Statement: Examples of chemical reactions could include the reaction of sodium and chlorine, of carbon and oxygen, or of carbon and hydrogen.] [*Assessment Boundary: Assessment is limited to chemical reactions involving main group elements and combustion reactions.*]

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+ BACKGROUND INFORMATION

PH SCALE

The pH scale measures the potential amount of hydrogen present in a solution. It is based on the amount of hydrogen ions, measured in moles per liter. A pH from 0-7 is considered an acid, 7 is neutral, and 7-14 is basic.

ACID/BASE TITRATION

A titration is a laboratory technique used to determine the concentration of an unknown solution by reacting it with a solution of known concentration. During the process, a titrant (the known solution) is gradually added to the analyte (the unknown solution) until the reaction reaches the equivalence point—where the amounts of acid and base are chemically balanced. An indicator is often used to signal this point through a visible color change, allowing for accurate calculation of the unknown concentration.

In this experiment, citric acid (a weak triprotic acid) is titrated with sodium hydroxide (NaOH), a strong base, to determine the molarity of the citric acid solution. The neutralization reaction occurs as NaOH donates hydroxide ions (OH^-) that react with the hydrogen ions (H^+) from citric acid. Precise measurement of the volume of NaOH required to reach the equivalence point allows for stoichiometric calculations of the acid concentration, based on the balanced chemical equation. An indicator, in this case Phenolphthalein, signals the endpoint of the titration through a visible color change. This method provides a reliable means of quantifying citric acid concentration in various solutions.

A weak acid, such as citric acid, reacting with a strong base, such as NaOH, will yield a solution with a pH greater than 7.

Equivalence point: the point at which equal amounts of the reactants have reacted.

End point: when we see a color change from the indicator solution. Ideally, this is close to the equivalence point of the reactants.

+ ACTIVITY SETUP AND MATERIALS

- 0.04 M NaOH
- 25 mL graduated cylinder
- P1000 pipette
- P1000 tips
- H_2O
- Burette (stand, base, and clamp)
- Electric Pipettor and Charger
- Plastic cups
- Sharpies
- Samples (Quality Control (QC) and Unknown (U)
- Phenolphthalein indicator

STEP 1: BURETTE PREPARATION

We use burettes to slowly and precisely add our titrant to our analyte. The metal stand screws into the black metal base. Then the clamp can be placed about ¾ of the way to the top. Secure the burette in the clamp, making sure to leave about 3 inches of space at the bottom to change out collection containers.

Next, ensure the burette stopcock is in the closed position (horizontal). You can then use the provided pipettor and serological pipettes to quickly fill the burette with the provided sodium hydroxide solution.

We recommend overfilling the burette: filling above the zero marking. We use this as a discussion point with students to help them understand how we will use the burette to measure the amount of titrant released. In addition, it works as a good moment for students to learn how to use the stopcock and practice releasing titrant in a slow, controlled manner.

STEP 2: SET UP STUDENT WORKSTATIONS

(2-3 students can work at each station)

1. 2 Pencils
2. Burette with NaOH
3. 2 Collection containers
4. Peg rack
5. Sharpie
6. Quality Control Sports Drink sample
7. Unknown Sports Drink sample
8. Phenolphthalein Indicator
9. 25mL graduated cylinder
10. P1000
11. P1000 tips
12. Waste Container

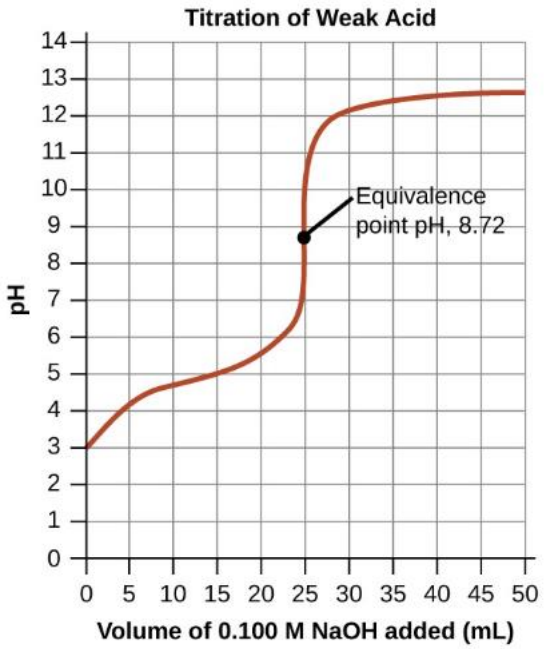
+ PROCEDURE

INTRODUCTION

Learning Undefeated is releasing a new citrus sport drink called Zest Quest, and with your background in chemistry, you have been hired to be the Quality Control Manager. As the product comes off the line, it is your team's responsibility to ensure that it meets quality standards for safety and taste. Market research has found that most people find a very specific concentration of citric acid to be the best lemon flavor. When measuring concentration of acids, we use **molarity (M)**. Molarity measures how much of a substance, or moles of a substance are in one liter of solution. We can also represent molarity as an equation:

Molarity = moles of solute/ liters of solvent

The molarity of a substance can be determined through a process called **acid-base titration.** A titration is a way of determining the concentration of a substance by adding a known concentration of a reagent. Most titrations use visual indicators, like phenolphthalein or bromophenol blue, to signal when the titration is complete.



In our lab, we will add a known concentration of a strong base, sodium hydroxide (NaOH), to a small sample of our sports drink. We will add base slowly until we see a color change. The color change is due to a change in pH, which we can observe by adding a pH indicator. When the mixture's color has been changed from clear to pink, then it has reached its **equivalence point**, and the acid has been neutralized.

$3NaOH\,(aq)$	+	$H_3C_6H_5O_7\,(aq)$	→	$Na_3C_6H_5O_7\,(aq)$	+	$3\ H_2O\,(l)$
Sodium Hydroxide		Citric Acid		Sodium Citrate		Water

QUICK CHECK: What is the equivalence point? *The equivalence point is the point at which chemically equivalent quantities of reactants have been mixed. This means that there are equal moles of acid and base according to the equation. This point is reached at a pH of about 8.*

Based upon the above reaction, what is the mol ratio of acid to base (i.e. how many mols of citric acid can be "neutralized" by only 1 mol of NaOH)?

1/3 (C)

PART I: FIRST TITRATION QUALITY CONTROL

a) After students have identified the problem that is to be solved during the lab, turn their attention to their workstations. Introduce students to the equipment they have in front of them (sports drink samples, phenolphthalein, and burette filled with NaOH, etc).

b) Have students set up their first collection cup with H2O, QC sports drink, and phenolphthalein indicator. Emphasize the importance of the indicator in this reaction. We are looking for the specific point when the acid in solution has been neutralized. We cannot see that with our eyes without an indicator like phenolphthalein. The phenolphthalein will remain clear at acidic pHs but will turn pink at basic pHs. Review how to use a pipette and the importance of slowly releasing the thumb. This will prevent the sample from splashing up into the device.

1. Label one of the two collection containers FT (rough titration).
2. Pour 10mL of H_2O into a graduated cylinder. Add the H_2O to the container.
3. Add 1000µL of the QC sports drink sample from the tube labeled QC to the container labeled FT containing the H_2O. Gently swirl the contents of the container for 10 seconds.
4. Add 100µL of the indicator solution (phenolphthalein) to the sports drink and H_2O mixture in the FT container and gently swirl the contents for 10 seconds. Note the mixture's initial color.

c) Instruct students to note the initial reading of NaOH in their burettes and record it in Table 1. Ensure students are reading from the bottom of the meniscus. Emphasize that it doesn't matter what the initial reading is- it doesn't have to be zero- as it will only be used in comparison with the final reading.

5. Record the 'initial reading of sodium hydroxide (NaOH) in the burette. Be sure to be precise in your measurement and record the data in Table 1.

d) Have students slowly turn the stopcock and add NaOH to the collection container dropwise- swirling the solution after each drop. Remind students that they are looking for the drop that gets added that causes the solution to turn pink and stay pink for 15 seconds. At that point, students can record their final reading and calculate the total amount of NaOH used.

6. Carefully position the burette directly over the FT container. Add one drop of the NaOH solution from the burette into the container by turning the handlebars. DO THIS SLOWLY and CAREFULLY. Only add ONE DROP at a time.
7. Swirl the collection container, paying attention to any prolonged color change.

8. Repeat steps 6 and 7 until the mixture turns bright pink and remains that color for at least 15 seconds.
9. Once your mixture is bright pink, record the 'final reading' of NaOH in the burette in Table 1.

QUICK CHECK: Why does the equivalence point for this titration occur at a pH >7? *The equivalence point occurs at pH >7 because this is a titration of a weak acid with a strong base. The weak acid donates its proton when base is added and create a strong conjugate base. This means that when enough NaOH has been added to neutralize the acid, there is a high presence of the conjugate base. This basic solution makes this pH higher than 7.*

QUICK CHECK: Was your titration in the expected range? What do you think went wrong or right? *It should take around 3-4mL of 0.04 M NaOH to neutralize all of the acid. Have students answer this question based on that range.*

PART II: EMERGENCY ON THE FACTORY FLOOR

e) Next, students repeat the same procedure again but with their unknown sports drink sample. We recommend having students work through this part of the procedure on their own now that they have been introduced to all of the equipment.
f) Once students have their total amount of NaOH used, they can move on to their calculations.
g) As groups finish, draw their attention to the equation at the bottom of the page. Let them know that some of these values are scattered on the page and ask them to write them down. The values for M_{base} , V_{base}, and V_{acid} are all provided throughout the procedure.
h) Then work with the class to help determine the value for C in part III. Explain what the chemical equation says, and then, note that C is the molar ratio of acids to bases. If students are familiar with ratios, this might come easily. If ratios are unfamiliar, we like to rephrase the question as "Right now, it takes three moles of NaOH to neutralize one mole of citric acid. How much citric acid would be neutralized if we only had one mol of NaOH?" You can help students further by thinking about what we would have to do to the equation to turn 3 NaOH into 1NaOH (divide by 3). As you divide all parts by 3, you should get 1/3 C.
i) Once all four numbers have been determined, ask students if they can plug their values into the equation and get something that makes sense. Ask students to pay close attention to the units. Students will have to convert the volume values to liters so that the final answer will be in moles per liter.

+ STUDENT TECHNICAL SKILLS

As the facilitator, it is the classroom educator's responsibility to demonstrate to the students how to properly use the equipment and reagents in this lab. Proper use of the equipment and reagents is necessary to obtain accurate results from the experiment. Educators should read through the following material and present this information to their students before students use the equipment to complete the laboratory activities. Teachers must supply all students with personal protective equipment, including goggles and gloves.

MICROPIPETTES

Laboratory science often involves working with very small volumes of liquid; frequently millionths of liters are used. One millionth of a liter is equal to one microliter, abbreviated 1 µl.

1 liter = 1,000 ml = 1,000,000 µl.

You can imagine that it would be very difficult to measure such small volumes without a very accurate and precise instrument. The instrument most often used to measure microliters is called a micropipette. Micropipettes differ in the volume of liquid they can accurately measure. They are expensive and must be used with care. Their accuracy is dependent upon their proper use.

Before students perform the laboratory activity, discuss with students how to use micropipettes properly. Because loading the wells of agarose gels can be difficult at first, students will be given an opportunity to practice loading dye samples into a practice agarose gel by performing the Practice Gel Loading Exercise.

Micropipettes have 2 stops as you depress the plunger to expel liquid. The first stop corresponds to the volume set in the window. The second stop gives a little puff of air to blow out any remaining liquid upon delivery. To draw liquid into the pipette tip, depress the plunger control only to the first stop. If you go to the second stop, you will draw too much liquid into the tip. The most common pipetting error is to go past the first stop to the second stop for drawing liquid into the tip (which gives an inaccurate volume). When you are letting the liquid out of the tip, then you go to the second stop. It is worthwhile to check each student for correct technique before beginning laboratory procedures requiring the use of the pipettes.

1. Select the pipette that includes the volume range you will need.
2. Adjust the pipette to the desired volume by turning the dial. Do not turn beyond the volume range for the pipette.
3. Press a new tip onto the pipette firmly (gently tap the pipette into a tip while in the box). Get a tip without touching it with your hands; this is to prevent contamination of the samples.
4. To draw liquid into the micropipette tip:
    a) Depress the plunger to the first stop to measure the desired volume and hold in that position. b) Holding the pipette vertically, immerse the tip 1-3 mm into the liquid to be transferred.
    b) Draw the fluid into the tip by slowly releasing the plunger. Wait 1-2 seconds to be sure that the full volume of the sample is drawn into the tip. If you see air bubbles, there is a problem with your volume, and you will need to repeat this step to get the correct volume (either your tip wasn't immersed far enough down into the liquid, or you perhaps raised your arm while releasing the plunger).

5. To dispense the liquid:
    a) Place the tip into the container where the liquid is to be released, near the bottom.
    b) Slowly depress the plunger to the second stop to blow out all of the liquid in the tip. Be careful not to suck liquid back into the tip by releasing the plunger while the tip is in the liquid you just dispensed.
    c) Eject the tip when done into a waste container by pressing the separate ejector plunger found on the top or side of the micropipette (depends on the brand of micropipette).