Cream of Tartar/Baking Soda Titration Lab

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Learning Objectives

1. Correctly prepare saturated solutions and provide evidence that the solution has reached equilibrium
2. Describe how a single compound can have multiple types of aqueous behavior
3. Explain the limitations and assumptions present in electrochemical measurements of aqueous equilibrium
4. Explain the connection between equilibrium calculations of pH and observed experimental results.

5. Describe why similar experimental tools can be used in multiple contexts and list the strengths and limitations for the approach.

Research Questions

1. How much baking soda and/or cream of tartar will dissolve in a saturated solution?
2. How can we insure that the solution has reached equilibrium?
3. How can the acid base properties of a salt be used to measure its solubility?

Experimental Context

Food Deserts and the Right to Cook

Have you ever lived in an area where you've had to travel far to find food that is actually good for you? Are vegetables and fruits hard to find in your neighborhood uncanned? Do you have access to many corner stores, bodegas and fast food places but nowhere to find something healthy and inexpensive like the other food you can find easily? This is all too common in many areas in the United States. The term "food desert" is used to describe a geographic area where residents do not have sufficient access to healthy food options, mainly fresh produce, due to the lack of grocery stores within reasonable travelling distance.[1] Food deserts disproportionately affect urban areas in minority and low-income communities. Watch this short video for a brief, but deeper **explanation.**

Figure 1. Produce Consisting of Vegetables and Fruits

There are about triple the amount of supermarkets in wealthy districts than in low socioeconomic areas.[1] Those living in food deserts are often unable to afford the transportation required to shop at supermarkets. Therefore the food choices of residents in food deserts are egregiously limited to only the affordable options available. These options lack healthy options

like fresh produce, limiting residents to convenient stores, liquor stores, and either fast food restaurants or processed foods that contain high amounts of sodium, fat, and sugar.[1]

The Food Empowerment Project suggests that it may be easy to overlook food desert communities when the US government relies on data from the North American Industry Classification System (NAICS).[1] The NAICS classifies small corner grocery stores together with large supermarkets even though these small convenience stores may be extremely limited in terms of food options and what healthy food options are available are often overpriced. In the US, as healthy foods become more expensive, unhealthy food becomes cheaper: "For instance, while the overall price of fruits and vegetables in the US increased by nearly 75 percent between 1989 and 2005, the price of fatty foods dropped by more than 26 percent during the same period."[1]

Where Are Food Deserts Found?

In all but very dense urban areas, the higher the percentage of minority population, the more likely the area is to be a food desert. From a study conducted by the USDA, areas with higher levels of poverty are more likely to be food deserts. Except for other factors, such as vehicle availability and use of public transportation, the association with food desert status varies across very dense urban areas, less dense urban areas, and rural areas. Places with higher poverty rates are more likely to be food deserts regardless of rural or urban designation.[2]

Figure 2. View of a Neighborhood Via Sidewalk

The Overarching Problem and What You Can Do!

Residents of food deserts therefore lack the access to affordable nutritious foods within their communities. However, the overarching issue is not residents having a lack of nutrition (though they often do), but rather having a deficiency in personal freedoms to buy the foods they want, that many others have full access to. Instead of having the option to bake desserts or cook meals with quality ingredients of their choice, people living within food deserts are often left only with the option of processed, prepackaged foods.

If you would like to take action to combat the issues of food deserts listed above consider supporting any of the following organizations linked below:

1. Produce for Better Health Foundation
2. Community Food Lab
3. Wholesome Wave
4. Soul Fire Farm
5. Food Empowerment Project
6. Thrive Market
7. Food Revolution Network

At a more local scale, consider donating to community food banks or by starting or contributing to a community garden. These actions increase accessibility to foods within your community. If you live in a food desert, the Food Empowerment Project recommends to start helping out your community by growing your own food, communicating with local retailers, and bringing up these issues to local representatives and government officials.[1] On social media, supporting the #GiveHealthy movement which aims to enable people to donate healthy foods and raise public awareness.

Baking Soda

Baking soda or sodium bicarbonate ($NaHCO_3$) is added to recipes as a leavening agent. This means that it reacts in a recipe to produce gas and this gas is trapped in the dough and causes the cake or cookie to "rise" or puff up. Baking soda is used in doughs or mixes that are acidic (due to vinegar, lemon juice, buttermilk or the like). The following reaction details how baking soda (sodium bicarbonate) reacts with acid to produce carbon dioxide gas (CO_2)

1. $H^+(aq) + NaHCO_3\,(aq) \rightarrow Na^+\,(aq) + H_2CO_3\,(aq)$
2. $H_2CO_3\,(aq) \rightarrow H_2O(l) + CO_2\,(g)$

Sodium bicarbonate is acting here as a base and accepting the proton from the acid. As you will see in your experiment, it can also act like an acid and donate a proton. This makes baking soda an amphoteric compound just like cream of tartar.

Cream of Tartar

Figure 3. Box of Folger's Cream of Tartar

So what do we do for leavening in batters that aren't already acidic? In those cases, we need to add an acid into the batter react with the baking soda. Cream of tartar is an acid commonly used with baking soda in many cookie, pie and cake recipes. As shown in the following reaction, baking soda and cream of tartar react together to produce carbon dioxide gas.

3. $KHC_4H_4O_6(aq) + NaHCO_3\,(aq) \rightarrow NaKC_4H_4O_6\,(aq) + H_2CO_3\,(aq)$
4. $H_2CO_3\,(aq) \rightarrow H_2O(l) + CO_2\,(g)$[4]

In the case of cooking, we are interested in using cream of tartar's acidic properties. The combination of the two is actually what baking powder consists of. Between the acidity of cream of tartar and the basicity of baking soda, a neutralization reaction occurs, and with the addition of heat, leavening can occur.[4]

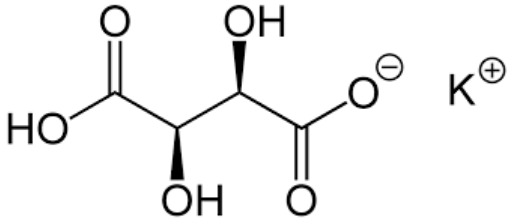


Figure 4. Skeletal structure of cream of tartar

Methods

In this lab, you will prepare a saturated solution of your amphoteric salt in order to experimentally measure the aqueous concentration of either bicarbonate or bitartrate.. The supernatant liquid will be titrated using a microfluidic chip that works based on surface tension. Each spot has deposited on it 5 µL of the indicated molarity of sodium hydroxide.

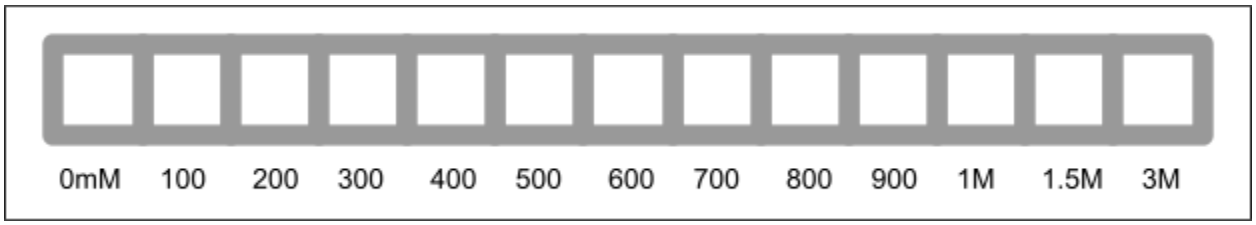


Figure 1. Titration µPad device loaded with NaOH

Each square will also get a small piece of indicator paper. The colors of the indicator paper at various pHs are shown in the diagram below.

Figure 2. pH Indicator Paper Scale

Helpful Tutorial Videos

1. **How to Use Bubble Titrator Chips**
2. **How to do Math with Microfluidics**

Pre-Lab Questions

1. Write the dissolution reaction for each compound (sodium bitartrate and sodium bicarbonate) and its associated Ksp expression.
2. How would determining the concentration of bicarbonate or bitartrate help you determine the Ksp?
3. What is the structure of each resulting anion and what are their reactions with sodium hydroxide?
4. Using your chosen solid, what color should the pH indicator paper be at the endpoint? What information do you need to determine the answer? Explain your reasoning.

5. Look at the concentrations on your chip. Your goal is to measure the endpoint as accurately as possible. Which spot on the chip will allow you to see a color change most clearly? Please explain your answer.
6. What information will you need to know to determine if your solution needs to be diluted in order to be analyzed using this chip?
7. Given the materials available, develop two different ways to make any necessary dilution. Explain the strengths and weaknesses of each.

Procedure

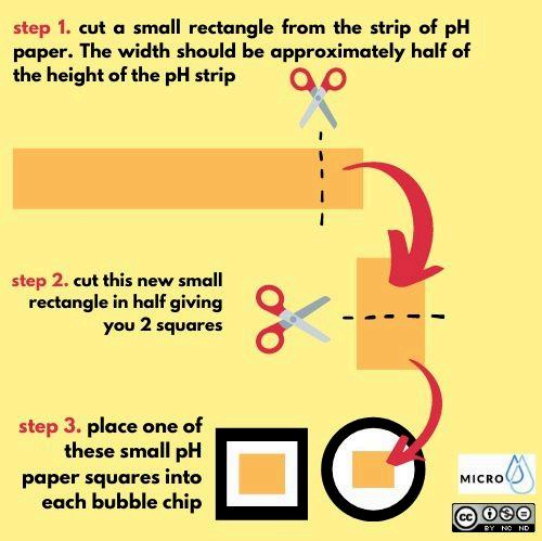
Materials:

- cards with 10 preloaded NaOH spots
- food-grade cream of tartar and/or baking soda
- 1 mL plastic pipettes
- pH paper
- weigh boats
- mass balance
- scissors
- water

Performing the Titration:

1. Make a saturated solution of either baking soda or cream of tartar. How will you know when the solution has reached equilibrium?
2. If needed, dilute the supernatant liquid. Ensure that there is enough solution for all the spots by diluting multiple drops supernatant. The total amount of solution should be no less than 1000 µL. Make sure your diluted mixture is homogeneous by mixing your diluted solution with your pipette.

3. Cut up your pH paper into pieces of approximately 2mm x 3mm as shown in the figure below. Place one piece of pH paper in the center of each circle or the card.



4. It may be helpful to view the video on how to use the titration bubble chip
5. Add up to 80 µL of your mixed solution to the center of the circle. The drops should form a dome inside the bounds of the circle. Make sure the pH paper is completely submerged in the bubble. Be careful not to jostle it too much or the surface tension bubble will pop and your solutions will escape their spots. Mix the solution using the pipette.
6. If the bubble escapes from the µPad, that data must be repeated
7. Allow the reaction to take place for a couple of minutes. Measure the color of the indicator paper in each bubble by eye or using ColorAssist. Note the pHs indicated by the colors.

Concepts to Brainstorm or Investigate During Lab

1. Experimentally verify that your salt solution is at equilibrium.
2. Compare the actual end point to where you anticipated it to be. Adjust the dilution factor and repeat as necessary in order to get the most reliable results
3. It is always optimal to make multiple measurements of the same quantity to do a statistical analysis. Because this measurement is not a continuous measurement (we can't measure any concentration as the endpoint, the endpoint will be in one of the discrete NaOH concentrations), we need to do something to vary the expected endpoint. Propose two different ways to do this and perform the experiments until you have three measurements of the end point.
4. If appropriate, repeat this procedure with the other compound.

Post-Lab Questions

1. How were you able to determine that you had prepared a saturated solution? How were you able to determine that it was at equilibrium?
2. What values did you calculate for Ksp of baking soda and/or cream of tartar? How do those values compare to those found in the literature. Please cite your sources.
3. What are three possible sources of error of this experiment? Human error is not an acceptable answer.
4. What assumptions did you make about the solubility and acid/base chemistry that may have impacted your results?
5. How would you theoretically change the experiment to ensure optimal results?
6. Comparing your experiences in the vinegar lab with those in this lab, what do you think are the strengths and limitations of this piece of analytical measurement technology? What are 2 other types of applications for this technology?

More Information

- Living in a food desert: Living in a Food Desert Documentary
- What is baking soda? Video
- What is cream of tartar? Video
- Foods baking soda and/or cream of tartar are used in: Recipes here

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