Berkeley Engineers and Mentors

Bubble, Fizzle, Pop!

Target Grade: Elementary/Middle School
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Brief Overview

This lesson teaches mentees about chemical reactions and explores the more colorful and tasty aspects of chemistry. Students will learn about acids and bases, the concept of pH, how chemical reactions can cause color changes through indicators, and how acids and bases can create fun effects in food.

Main Teaching Goals

After this lesson, students should understand the main differences between acids and bases, be familiar with the relative pH of common substances, why indicator solutions change color depending on the presence of an acid or a base, and the chemistry behind the classic baking soda and vinegar reaction.

- **Acid:** substance with pH < 7
    - Often sour, perhaps corrosive
- **Base:** substance with pH > 7
    - Often bitter or slippery
- **pH:** a measure of hydrogen ion concentration, usually on a scale of 1 (most acidic) to 14 (most basic)
        - Put simply, pH labels the acidity/basicity of a substance.
    - It is possible to have a pH or below 1 or above 14 on certain occasions, but the general pH scale is only from 1 to 14.
- **Indicators:** substances that change color at certain pH levels
    - Some indicators can change colors multiple times and have a spectrum of colors, while others only change colors once.
- Baking soda and vinegar reaction (an acid/base reaction):
    - $NaHCO_3 + HCH_3COO \rightarrow NaHCH_3COO + CO_2 + H_2O$
    - **Baking soda:** $NaHCO_3$ (sodium bicarbonate), a base
    - **Vinegar:** HCH_3COO (acetic acid), an acid
        - These are the components of a general acid/base reaction (acid & base).

    - This reaction releases carbon dioxide gas, CO_2, which is the source of the bubbles and fizzing when baking soda and vinegar are combined.

Careers and Applications

Acid/base reactions are ubiquitous in everyday life! They take place in our bodies, in food preparation, and in so many more aspects. Chemists (and chem students) perform countless acid/base reactions while synthesizing new compounds and isolating substances from mixed solutions.

Agenda

- Module 0: Introduction & Acid or Base? (10-15 min)
- Module 1: Cabbage Chemistry (10-15 min)
- Module 2: Exploding Bag (10-15 min)
- Module 3: Fizzy Lemonade (15-20 min)
- Conclusion (5-10 min)

Module 0: Introduction & Acid or Base? Activity

Introduction

In this module, the students will classify items as acids or bases. They can have some time to talk to each other about their choices and compare their thought processes.

Teaching Goals

The aim of this short activity is to have the kids become more familiar with acids and bases in daily life through group discussion and decision-making. They can talk with their peers and provide their own opinions and logic behind their choices. (e.g. This is an acid since it's sour and I know a lot of acids are sour!)

- **Acid:** pH < 7
    - Turns pH paper red/orange
    - Commonly sour
        - Lemon juice, stomach acid, black coffee
- **Base:** pH > 7
    - Turns pH paper green/blue
    - Commonly bitter, slippery
        - Bleach, ammonia, baking powder

Background for Mentors

An **acid** has a high concentration of hydronium ions (H_3O^+) and a pH of less than 7, while a **base** has a high concentration of hydroxide ions (HO^-) and a pH of over 7. Using the Brønsted–Lowry definitions of acids and bases, acids can donate proton(s) and bases can accept proton(s). We rank them with the pH scale, which measures the acidity and basicity of many different substances. To find the pH, we use the formula $pH = -\log [H_3O^+]$, so it depends on the concentration of hydronium ions in solution. The greater the concentration of H^+ ions, the more acidic a substance is. There is a difference of a factor of 10 between any two consecutive pH values! Interestingly, acids and bases can neutralize each other, since mixing them changes the relative amount of positive and negative ions.

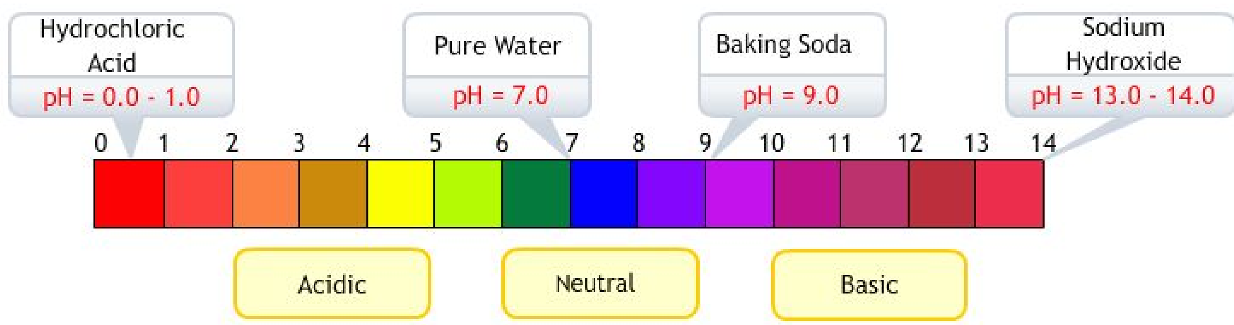
Common foods and items have pH values, and these can be measured with indicators (or pH probes for higher accuracy). Our bodies use acids to digest food, while many cleaning products contain bases. Some examples of acids are orange juice, tomatoes, and battery acid. Some examples of bases are soap and ammonia. Strong acids and bases, such as battery acid and ammonia, can be dangerous. Acids are commonly sour and perhaps corrosive, and bases are often bitter and slippery.

Activity

The lesson should start with a discussion on acids and bases and applications in everyday life. To begin: What is an acid? What is a base? Have the kids discuss their thoughts.

Acids are substances that have more positive charge and bases have more negative charge. (For more advanced sites, discuss the relative concentrations of hydrogen ions and hydroxide ions in solution, but the definition can be left as that for elementary sites.)

Let's go over an important concept: pH. pH is a measurement of the relative amount of hydrogen ions (positive) in solution. Acids have low pH (<7) and are commonly sour. Bases have high pH (>7) and are commonly bitter.



Now that the kids have an idea of what acids and bases are, let's play a fun game! Find an open area and have the kids all stand up. Designate the right side as acid and the left as base (or vice versa). Call out a substance in the ITEM column, and have the kids discuss if it's an acid or a base (or neither?). If the student thinks it's an acid, have him/her go to the acid side; if base, then to the base side. Give the students a minute or so to make their decisions for each round, but they can try to convince each other until time is up!

ITEM	ACID/BASE
Fruit punch	Acid
Seawater	Base
Bleach	Base

Coffee	Acid
Soda	Acid
Water	Neither! (let's please not go into water's properties as both an acid and a base *triggered*)

Fun Information for Mentors

Why is pure water neutral but seawater basic? In the ocean, CO_2 becomes carbonic acid, which then forms bicarbonate and carbonate ions. Basic salts contain the conjugate base of a weak acid, so when dissolved in water, they react and form a basic solution. Mineral carbonates dissociate and can accept protons to form bicarbonate, keeping the pH of seawater above 7.

Bleach is a very strong base. For example, chlorine base is made by dissolving chlorine gas in concentrated sodium hydroxide. The products sodium hypochlorite and sodium chloride are highly basic. If acid is added to chlorine base, chlorine gas will form, so it's advised to avoid that scenario.

Why is soda acidic? Many sodas contain acids such as phosphoric acid and citric acid, and carbon dioxide is inherently acidic as well, so soda is acidic even if it doesn't taste sour. The bubbles are from carbonic acid as well. High consumption of soda and similarly acidic drinks can lead to tooth decay and possibly trigger acid reflux.

Fruit juices, like the fruits themselves are acidic. They are sometimes sour, which is a characteristic shared by certain acids. Interestingly, coffee is also acidic. The pH depends on how light or dark the coffee is and how it is brewed. Black coffee has a pH of around 5.

Module 1: Cabbage Chemistry

Introduction

In this module, the kids will learn about the functions of indicators and see the differences in pH of various foods and household items.

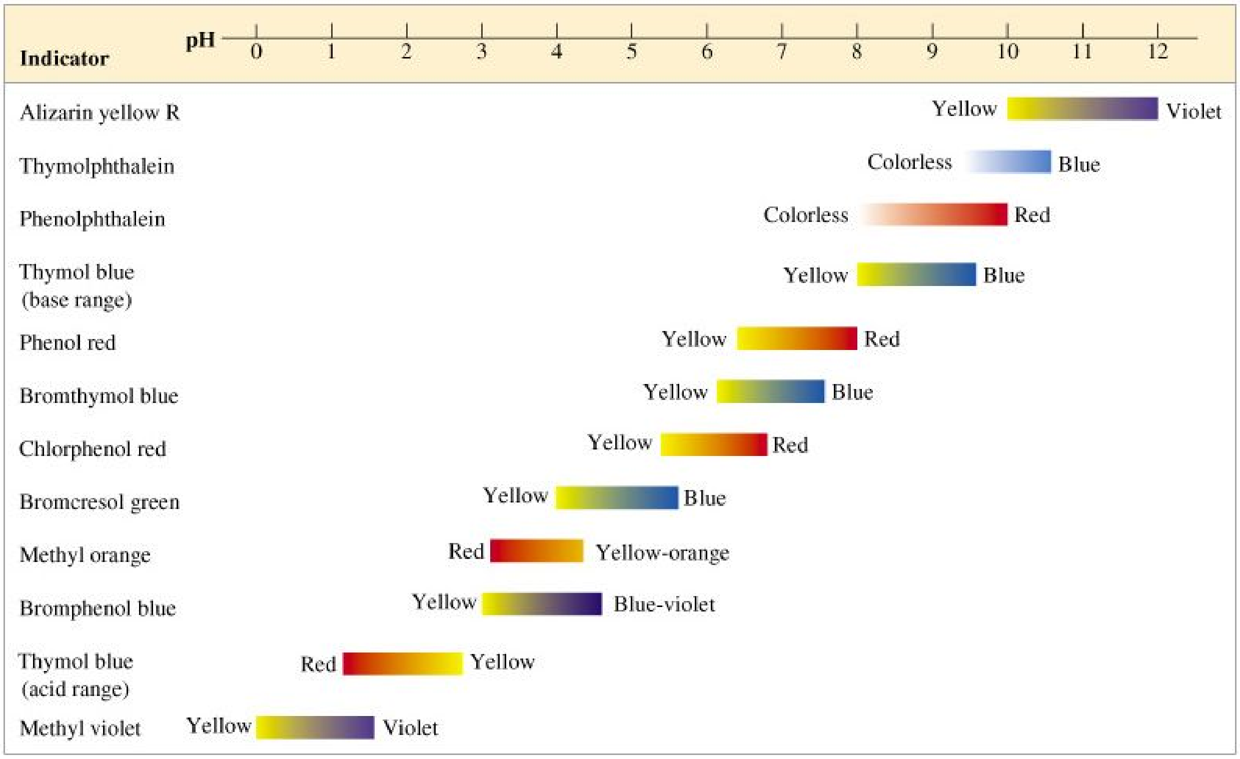
Teaching Goals

The goal of this module is to teach the kids about indicators and what they do (change color) in solutions of different pH.

Background for Mentors

To begin, a solution consists of a substance dissolved in a solvent. One can predict the pH of a solution with indicators.

An **indicator** is a substance that changes color at certain thresholds of hydronium concentration, or pH values. They show different hues when exposed to acids or bases, and each indicator is different. Some change colors once, while others have a wide range of colors.



Red cabbage juice is a fairly common and easily prepared indicator. It is usually made by straining out the purple water from red cabbage. It turns red in highly acidic and yellow in highly basic conditions. We can use this to estimate the pH of different substances and rank their relative acidity or basicity.

Materials

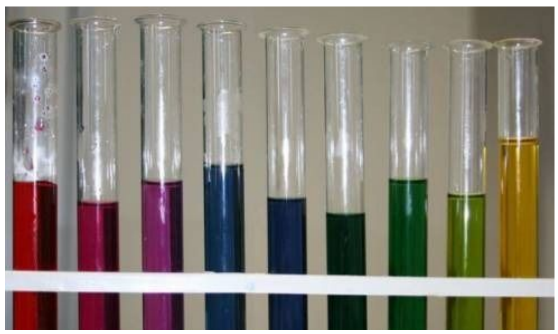
- Red cabbage indicator
  - Red cabbage
  - Water
- 5 small jars/clear cups
- Liquid soap
- Baking powder
- Water
- Soda
- Lemon juice

Procedure

1. Place the cups in a line on the table. Fill the cups with an equal amount, around ⅓ to ½ full, of purple indicator solution.
2. Prepare the different test liquids: liquid soap and water, baking powder solution (one to

two tablespoons in water), water, clear soda, and lemon juice with water.

3. Each cup should be filled with approximately ¼ cup of liquid and generally clear.
4. Ask the kids what they think will be more acidic or basic and what changes they'd expect to happen once cabbage juice is added.
    a. If kids have seen this experiment before, have them try to explain why they think the solutions will change color.
5. Slowly pour a similar amount of test liquid into each cup of indicator, and watch as the liquids change color!
6. Red/pink indicates acid, violet/blue indicates neutral, and green/yellow indicates basic.
7. Ask the kids which substances they expected to be more acidic/basic and if the results agree with their hypotheses.



pH scale with appropriate colors

Solutions after red cabbage indicator added
(acidic → basic)

Additional Notes for Mentors

The cabbage water is prepared beforehand for the sake of time, but we can tell the kids how easy it is to make it themselves if they're curious. There's so much more than the substances tested here that the cabbage indicator can test.

<u>Module 2: Exploding Bag</u>

Introduction

In this module, students will be exploring a classic acid/base reaction: the baking soda and vinegar reaction. Additionally, students will learn how the products of this reaction can be used to inflate a plastic bag and make it explode.

Teaching Goals
We're using a basic acid and base reaction and confirming the products of the reactions by letting the reaction run in a closed environment. The kids can see the resulting powder (mostly dissolved), water, and most importantly, carbon dioxide, which causes the bag to inflate.

Background for Mentors

(1) $NaHCO_3 + HCH_3COO \rightarrow NaHCH_3COO + CO_2 + H_2O$

This chemical reaction (1) is an acid/base reaction between baking soda and vinegar. Baking soda, also known as sodium bicarbonate, is a weak base with a pH around 9. The basic nature of sodium bicarbonate allows people to use baking soda for many purposes, such as for cleaning or baking. Vinegar, or acetic acid, is a weak acid with a pH around 3 used mainly as a cooking ingredient. When baking soda and vinegar are combined, it results in the formation of carbon dioxide gas that can be used in the leavening that takes place during baking (adding an agent that lightens and softens a mixture). Additionally, the carbon dioxide released can be captured and used for other purposes, such as for inflating a plastic bag in this module. As the reaction proceeds, more and more carbon dioxide is formed, and the bag begins to inflate until it cannot hold any more carbon dioxide, and then the bag explodes.

Materials

- 1 sandwich size Ziploc bag per group of 3-4 students
- ¼ cup of warm water per group
- ½ cup vinegar per group
- 3 teaspoons of baking soda per group
- 1 piece of tissue per group

Procedure

1. Split up into groups of 3-4 students, and give each group one zip-lock bag. Go outside (this module can get messy!) if possible, or find an open area inside (but be prepared to clean up after the module finishes).
2. Have mentors put ¼ cup of warm water and ½ cup of vinegar into each bag.
3. Put 3 teaspoons of baking soda into the middle of the tissue, and fold the tissue around the baking soda so it does not spill out of the tissue.
4. This part might be a bit tricky -- have students **partially** close the bag, leaving a small opening to add the tissue with baking soda.
5. Tell the students to step back, then put the tissue with baking soda into the bag. Quickly zip the bag closed, shake the bag slightly to mix the baking soda and vinegar, then put the bag on the ground and watch as it expands and explodes!

Plastic bag inflating!

Additional Notes for Mentors

It might be easier to have the students put the baking soda packet into the bag and have the mentors close the bag to avoid any accidents. Also, using the smallest and thinnest piece of tissue to wrap up the baking soda will make the reaction work better.

Module 3: Fizzing Lemonade

Introduction

In this module, students will be making fizzy lemonade, examining how acid/base reactions can play a role in our food and drinks.

Teaching Goals

This module encompasses all of the topics discussed in the previous modules, giving an opportunity for the kids to review the main concepts of the lesson. Additionally, it is a nice way to spend time with your mentees while making lemonade!

Background for Mentors

The chemical reaction to create fizzing lemonade is very similar to the baking soda and vinegar reaction; in both reactions, an acid and a base are combined and carbon dioxide gas is formed as a product. However, the carbon dioxide produced is utilized for different purposes in each module. For this module, citric acid from lemon juice and baking soda are mixed to form carbon dioxide that creates the bubbles and the fizziness in the fizzing lemonade. This process of creating the fizzy nature of soda, sparkling water, and other beverages is called carbonation, in which pressurized carbon dioxide gas is dissolved into liquid to create a bubbly drink. In this module, we are creating our own carbonated drink by using an acid/base reaction that releases carbon dioxide, which we can use to mimic the fizzy nature of carbonated drinks.

Materials

- ½ lemon per group of 2-3 students
- ⅓ teaspoon of baking soda per group
- 1-2 tablespoons of sugar per group
- ½-1 cup water per group
- 1 cup per group

- 2-3 spoons per group

Procedure

1. Split students into groups of 2-3, and give each group one cup and enough spoons for each student.
2. Squeeze the juice of ½ of a lemon into the cup.
3. Add ⅓ teaspoon of baking soda. Students can take turns adding some of the baking soda to see multiple reactions and fizzing.
4. Stir the mixture to get the reaction going.
5. Remind students about the **Engineering Design Process**, and let them know how they can use those ideas to continually modify and create their lemonade.
6. Add sugar and water to the mixture to get lemonade. Students can experiment with the amount of sugar and water they want to add to their lemonade.
    a. Keep the amount of baking soda fixed at ⅓ teaspoon. Baking soda can be harmful if ingested in large quantities and will make the drink bitter.
7. Taste the lemonade, and adjust the amount of each ingredient if needed!

Fizzing lemonade!

Additional Notes for Mentors

When sugar and water are added to the lemon-baking soda mixture, there may be some fizzing. Make sure not to give the kids too much baking soda, because it can give the lemonade a slightly bitter taste.

Conclusion

At the end of the lesson, ask students to distinguish between an acid and a base, why the plastic bag inflated, and what caused the bubbling in the fizzing lemonade to see if they were able to understand some of the concepts in the lesson. Have them discuss common acids and bases and what colors the indicator turned to reflect pH and what they remember about properties of acids and bases. What qualifies something as acidic/basic? What are some properties they remember of acids/bases?

Thank them for coming! :D

References

- The Exploding Lunch Bag, Science Bob: https://sciencebob.com/the-exploding-lunch-bag/
- How to Make Fizzing Lemonade, Learn with Play at Home: http://www.learnwithplayathome.com/2014/09/how-to-make-fizzing-lemonade-edible.html
- Red Cabbage Lab: Acids and Bases, Stanford: https://web.stanford.edu/~ajspakow/downloads/outreach/ph-student-9-30-09.pdf
- Chemistry for Kids: Acids and bases, Ducksters: https://www.ducksters.com/science/acids_and_bases.php
- Magic Cabbage Juice, Jen's Library Tales: http://jenslibrarytales.blogspot.com/2016/07/magic-cabbage-juice-steam-program.html

Summary Materials Table

Material	Amount per Group	Expected $$	Vendor (or online link)
Sandwich size zip-lock bag	1 per 3-4 students	$7.78 for 125 bags	Amazon
Baking Soda	4 teaspoons per 3-4 students, 2 tablespoons for demonstration	$0.79 for 1 lb.	Target (or any grocery store)
Vinegar	¼ cup per 3-4 students	$1.99 for 64oz.	Target (or any grocery store)
Tissues/Paper towels	1 per 3-4 students	$15 for 12 paper towel rolls	Target
Lemon	½ per 2-3 students, ½ for demonstration	$0.50 per lemon	Trader Joe's (or any grocery store)
Sugar	1-2 tablespoons per 2-3 students	$3 for 64oz	Any grocery store
Cups	1 per 2-3 students, 5 for demonstration	$6.49 for 100 cups	Amazon
Spoons	1 per student	$7.57 for 100	Amazon
Bleach	2-3 tablespoons for demonstration	$3.97 for 56 oz	Walmart
Soda (clear)	2-3 tablespoons for demonstration	~$5 for 12 cans	Any grocery store