UNLOCKING SCIENCE HANDS ON!

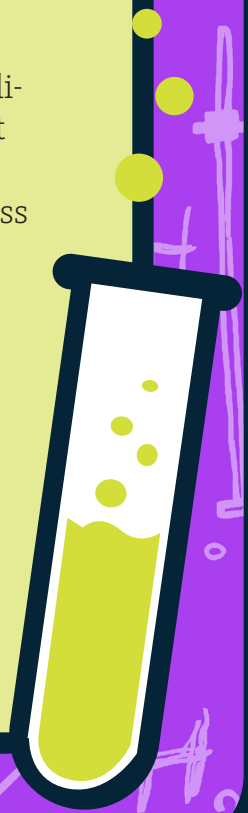
# SOUR OR BITTER?

Whether you realize it or not, you interact with acids and bases every day. You can find them in items all around your house—from batteries to cleaners to foods. We use the pH scale to measure how acidic or basic (alkaline) a substance is. Acids fall in the 0–7 range while bases go from 7–14, with 7 being a neutral pH with a balance of acid and base molecules.

There are different indicators to test for the presence of acids and bases. In these activities, you are going to make your own acid/base indicator to test various substances. You can also purchase some indicators to explore some more. If you have a pool or hot tub, you might have some test strips that tell you the pH of the water.

To test the concentration of acids and bases, chemists use a process called a titration. If you add a base to an acid, it will neutralize the acid. The more base it takes, the more concentrated the acid. Maybe you've done this before—if you have a sour stomach or heartburn, taking an antacid tablet (which is a base) will neutralize the excess stomach acid. You can test the concentration of pure lemon juice against the bottled form to see which one is more concentrated using an indicator and a simple titration process.

**Extra Family Fun:** Find some extreme sour candy and see who can eat it without changing the expression on their face when they bite into it.



# Cabbage Indicator Exploration

For this activity you will be creating an acid/base indicator from cabbage and then testing various items around the house to determine if they are acids, bases, or neutral on the pH scale.

## Supplies

- ○ Purple cabbage
- ○ Water
- ○ Cutting board and knife (with adult supervision)
- ○ Saucepan
- ○ Strainer
- ○ Bottle or jar with lid
- ○ Eyedropper or pipette
- ○ Safety glasses
- ○ Various household items to test
- ○ Optional: pH strips, litmus paper, phenolphthalein, or other indicators

## Indicator Preparation

1. Slice off about 2 cups of purple cabbage from the head.
2. Add the cabbage to about 2 cups of water and bring to a boil.
3. Let the liquid cool until you can comfortably handle the liquid. (Chop up the rest of the cabbage and make some coleslaw while you are waiting.)
4. Strain the liquid into a jar or bottle and discard the boiled cabbage.
5. Let the liquid come to room temperature before you use it. You can place it in the fridge to speed the cooling.
6. Clean up all the mess and wash all of the dishes.
7. Test your indicator solution by adding a few drops to a tablespoon of vinegar (it should turn pink) and a few drops to a tablespoon of baking soda dissolved in water or ammonia (it should turn green). Use these as the standards to compare as you test other substances.

# Acid/Base Exploration

Test various items around your house to see if they are acids or bases, making predictions before you add the indicator based on what you know about the substance. You only need to use about a tablespoon of each substance for the test so it is not wasteful. Record your results in the table. For dry substances, dissolve them in a bit of water first. If something already has a color, you will have to look carefully to see what color change happened (you can hold it up to light to see better). If you test a food substance, you can note in the observation column whether it tastes sour or bitter. Do not taste any substances you do not know are safe to eat.

### Cabbage indicator for acids and bases

| Substance | Prediction (A/B) | Color Change | Observation (A/B) (S/B) | Litmus | Phenol-phthalein | pH Strip |
|---|---|---|---|---|---|---|
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |

## Analysis Questions and Discussion

1. What substances did you determine were acids? *Answers will vary.*
2. What substances did you determine were bases? *Answers will vary.*
3. What substances did you determine were neutral or gave no color change? *Answers will vary.*
4. If you tested several cleaners, were they all acids or bases? *There is likely a mix, but most cleaners contain bases (e.g., ammonia, detergents, soaps) while a few contain acids (e.g., vinegar-based glass cleaners).*
5. If you have access to ammonia, place one drop of ammonia on your finger and rub your fingers together (use dish soap if ammonia is not available). Immediately rinse your fingers thoroughly to remove the ammonia. Describe how the ammonia made your fingers feel. *The ammonia should make your fingers feel slippery.*
6. Place one drop of vinegar or lemon juice on your finger and rub your fingers together. Immediately rinse your fingers thoroughly to remove the solution. Describe how the vinegar or lemon juice made your fingers feel. *The vinegar or lemon juice should make your fingers feel gritty as it dissolves the oils on your fingers and your friction ridges rub together.*
7. Based on your results from the exploration, how could you use the feel of a solution between your fingers to test for an acid or base? *Looking at the results of your exploration, ammonia is a base and vinegar and lemon juice are acids. So if a substance feels slippery on your fingers it is likely a base, and an acid if it feels gritty.*
8. If you tested several cleaners, were they all acids or bases? *Both acids and bases are used for cleaners.*
9. What do you think is the best way to test for an acid or base? *Answers will vary.*

# Concentration Titration Activity

Now that you know how to test whether substances are acids and bases, you are going to explore the idea of concentration. Concentration is the way chemists describe how much of a substance is mixed in a solution. If I added 15 grams (g) of sugar to a liter (L) of tea, it would be less concentrated than if I added 150 grams of sugar to a liter of tea. We could calculate the concentration in grams/liter as 15 g/L and 150 g/L and the solution with more sugar is 10 times more concentrated.

Note: In the *Sour or Bitter?* program, I mentioned that you would be using a baking soda solution, but the activity will actually work better if you use ammonia as the base. You can substitute a baking soda solution for the ammonia by mixing 3 tablespoons of baking soda in 1 cup of water to make a saturated solution. But this method will take a lot of drops to neutralize the acid.

As we learned in the "Acids & Bases" episode, when an acid and a base are mixed together in the right proportions, they will undergo a neutralization reaction so the their pH reaches 7, a neutral pH. Your task is to compare the concentration of 2 acids to see which is more concentrated. You will be using ammonia (or a baking soda solution) to neutralize the acid. The cabbage indicator solution will let you know when you reach the neutral point.

You can tell which solution is more concentrated by doing a process called a titration (ty-TRAY-shun). A simple titration can be done by counting the number of drops of a basic solution it takes to neutralize an acid. The more drops of base, the more concentrated the acid. You are going to compare the concentration of freshly squeezed lemon juice to bottled lemon juice. You will make a prediction, test that prediction, and then analyze your results. You will know that you have completed the neutralization when the color of the solution turns from pink to blue, matching the color of the cabbage indicator.

Safety Note: If using ammonia as the base, work in a well-ventilated area and avoid directly inhaling the ammonia odors. You may also want to wear safety glasses to protect your eyes from splashes.

## Supplies

- ○ Cabbage indicator solution
- ○ Ammonia (or baking soda solution)
- ○ Lemon
- ○ Lemon juice concentrate
- ○ Eyedropper or pipette
- ○ ½ teaspoon measuring spoon
- ○ 3 or 4 small glasses or beakers (preferably clear)

## Lemon Juice Titration

1. Make a prediction about which lemon juice is more concentrated and record it below.
2. Add a small amount of ammonia to a glass or beaker to use as the standard base solution. (See note above on using a baking soda solution.)
3. Carefully cut the lemon and squeeze the juice into a clean container.
4. Add ½ teaspoon (2.5 mL) of the fresh lemon juice to a small glass.
5. Add 10 drops of the cabbage indicator and swirl. Note the color carefully.
6. Using the eyedropper, add the ammonia to the lemon juice and carefully count the drops. You may want to have someone help you count and use tally marks to note every 10 drops.
7. Stop every 10 drops and swirl the solution. You may notice a brief color change where the drop enters.
8. When the neutral blue color begins to linger, you know you are getting close. You can go 1 drop at a time and swirl to get the most accurate results when the color lingers for a long time.
9. If you go too far and the solution turns green, indicating a basic solution, just make a note and remember that as you analyze the results.
10. Record the number of drops in the data table.
11. Optional: repeat the process 2 more times.
12. Using a clean glass, repeat the process of steps 4–11 using ½ teaspoon of the bottled lemon juice.

## Concentration Titration Prediction and Data

Make a prediction about which form of lemon juice is more concentrated and explain your thinking:

**Record your titration data in the table below**

| Acid | Drops of Base: Trial 1 | Drops of Base: Trial 2 | Drops of Base: Trial 3 | Drops of Base: Average | Notes |
|---|---|---|---|---|---|
| **Fresh Lemon Juice** | | | | | |
| **Bottled Lemon Juice** | | | | | |

## Analysis Questions and Discussion

1. If you did 3 trials, calculate the average by adding the three drop values together and dividing by 3. How close were the values to one another? *Answers will vary.*
2. What benefit do we get if we do several trials of an experiment or measurement? *If one of the values is very different, there was likely some mistake made in that trial and it can be thrown out as a bad result or repeated to confirm if there was an error. Doing multiple trials helps avoid errors and confirms that we have good data to make our conclusions from.*
3. Which lemon juice required more drops to neutralize? *Answers will vary, but it is most likely that the bottled juice is more concentrated.*
4. Which lemon juice is more concentrated? *Answers will vary. Whichever took the most drops of base to neutralize is the most concentrated.*
5. Which lemon juice contained more acid in the ½ teaspoon sample? *Answers will vary. Whichever took the most drops of base to neutralize has the most acid.*
6. How do these results compare to your prediction? *Answers will vary.*
7. Has anything changed about your thinking about concentration based on the results and your prediction? *Answers will vary.*

8. If you think about cooking with lemon juice, what adjustment would you need to make if a recipe called for 3 tablespoons (15 mL) of fresh lemon juice and you only had bottled lemon juice? *You would need to add less bottled lemon juice to create the same amount of sour flavor since it contains more acid per tablespoon (mL).*
9. Many products that we use every day come in a "concentrated" form that requires mixing with water or other solvents. What are the advantages of using more concentrated products? *If laundry detergent contains less water (is more concentrated), it can come in a smaller container that reduces the materials for the container and lowers shipping resources and cost because it is smaller and weighs less. Fruit juices are often concentrated and would have the same benefits. Lawn treatments and pesticides or herbicides that are concentrated allow you to only mix what you need at the time to save space. You can also consider the convenience factor—pouring juice out of a bottle is easier than having to dilute it before drinking.*
10. Construct a list of various things you use around the house that come in "concentrated" packages. How would life be different if these were not available to you? *Answers will vary.*
11. How does understanding this process and the principles help us understand God? *God has created the universe in an orderly and understandable way. This order reflects his character, which is consistent and unchanging. God is faithful to uphold the universe according to the laws he has created, and we can trust him to be faithful to all of his promises in Scripture.*

***He is the image of the invisible God, the firstborn of all creation. For by him all things were created, in heaven and on earth, visible and invisible, whether thrones or dominions or rulers or authorities—all things were created through him and for him. And he is before all things, and in him all things hold together. And he is the head of the body, the church. He is the beginning, the firstborn from the dead, that in everything he might be preeminent. For in him all the fullness of God was pleased to dwell, and through him to reconcile to himself all things, whether on earth or in heaven, making peace by the blood of his cross. Colossians 1:15–20 (ESV)***