

Acids and Bases: Cabbage Juice pH Indicator

Student Advanced Version

Acids and bases are found in a variety of everyday items, including food and drink, medicine, and cleaning products. In this lab, we will learn about what makes an acid or base “strong,” and use the juice from red cabbage to test the pH of common household liquids and perform neutralization experiments.

Key Concepts:

- The pH of a solution is determined by the concentration of specific **ions**.
- Ions are negatively or positively charged **atoms**. If a solution contains extra hydrogen ions (H^+), it is **acidic**. If a solution contains extra hydroxyl ions (OH^-), the solution is **basic**, or **alkaline**.
- **Strong** acids have a high percentage of their atoms found as ions (ie unbound), whereas **weak** acids have only a low percentage of ions in solution.
- The **pH scale** ranges from 0 to 14 in water. The closer to 0, the stronger the acid, whereas the closer to 14, the stronger the base. A pH of 7 is neutral, or neither basic nor acidic.
- When an acid and a base are mixed, the hydrogen ions from the acid bind the hydroxyl ions of the base, forming water. This is referred to as **neutralization** of the acid and base.

Part 1 – Modeling Acids and Bases

In this section, we will model what the differences are between **strong** acids or bases and **weak** acids or bases.



Model of an acetic acid



Model of a hydrochloric acid

1. Make 5 paper clip models of both acetic acid (a weak acid) and hydrochloric acid (a strong acid), using silver for the hydrogen atoms and two different colors for the rest of the molecule.
2. Now imagine that you add each of your 5 acid molecules to water by putting them in the correct column below (feel free to rip this page out to be able to answer the questions while keeping the molecules in the “water”).

STRONG

WEAK

Q1. What happens to these acids in water? Model this with your paperclip molecules. How do a weak acid and a strong acid differ?

Q2. If the acidity of a solution is based on the number of H^+ ions (more ions = more acidic), which of your two solutions would be more acidic?

Q3. Now lets compare solutions. Imagine that I put 10 “weak” acid molecules into a new glass of water. How many H^+ ions will you have in each of these solutions?

5 strong acid molecules: _____ H^+ ions 10 weak acid molecules: _____ H^+ ions

Q4. Which will be more acidic, the solution with 5 strong acids, or the one with 10 weak acids? Circle one. Why did you choose that solution?

5 strong acid molecules OR 10 weak acid molecules

Q5. What if I add 50 weak acid molecules to water? How many H^+ ions will each solution have?

5 strong acid molecules: _____ H^+ ions 50 weak acid molecules: _____ H^+ ions

Q6. Which solution will be more acidic? Why?

5 strong acid molecules OR 50 weak acid molecules

Part 2 – Determining the pH of Household Substances

Strong acids and bases are dangerous, and can really only be found in laboratories or chemical plants. Weak acids and bases, however, are incredibly useful, and can be found all around us! But how do you test whether something is acidic or basic?

You can rank how acidic or basic something is using a scale called the “**pH scale**.” As we learned in the last section, the number of hydrogen (H⁺) or hydroxyl (OH⁻) ions in a solution affects how acidic or basic it is. pH is measured using chemicals that change color when they bind to the extra hydrogen or hydroxyl ions in water. So, for example, the more acidic a solution, the more hydrogen ions there are, and the more the color will change! A solution of water, where the H⁺ and OH⁻ ions are in balance, is called **neutral**, and it has a pH of 7. As you add more acid (and therefore more hydrogen ions), the pH goes down. A pH of 0 is the strongest an acid can be in water.

Alternatively, the more of a base you put in water, the more hydroxyl ions there are (either from the base itself, or from the broken water molecules). This means that there are less H⁺ ions than there would be in a neutral (water) solution, and so you will have a pH *higher* than 7. As you get farther from neutral, the solution gets more basic (and the number of OH⁻ molecules increases). A pH of 14 is the strongest a base can be in water.

Let’s measure the pH of some things that you can find in your house.

Q7. Would you guess that the following substances are acidic, neutral, or basic? Circle your answer.

Water	Acidic	Neutral	Basic
Lemon Juice	Acidic	Neutral	Basic
Baking Soda	Acidic	Neutral	Basic
Shampoo	Acidic	Neutral	Basic
Windex (Ammonia)	Acidic	Neutral	Basic
Milk of Magnesia	Acidic	Neutral	Basic
Warhead Sour Spray/Sour Candy	Acidic	Neutral	Basic
Vinegar	Acidic	Neutral	Basic







Making the pH Indicator (this can be done in advance):

1. Put the red cabbage leaves into the blender with 800mL of water.
2. Close the top and let it blend at high power for 30 seconds.
3. Pour the mixture through a strainer into a large container. (This should provide you with 600-800 ml of cabbage juice.)

Testing pH:

4. Pour 1 Tbsp of each individual liquid into its respective cup (except for baking soda).
5. For baking soda, add 1 tsp of baking soda into 2 tsps water.
6. Pour 1Tbsp of cabbage juice into each of the cups, swirling gently.

Q8. Write down what color each solution turns the cabbage juice, based on the following pH scale.

pH	pH less than 7 = Acid			pH more than 7 = Base		
	2	4	6	8	10	12
Colour						
	Red	Purple	Violet	Blue	Blu-Grn	Grn-Yel

Liquid:	Color	Predicted pH	Actual pH
Water			
Lemon Juice			
Baking Soda			
Shampoo			
Glass Cleaner (Ammonia)			
Milk of Magnesia			
Warhead Spray / Sour Candy			
Vinegar			

Now find out from your teacher what the actual pH of each of the substances is, and see how accurate the cabbage juice indicator was!

Q9. Categorize your results below:

Very Acidic	Mildly Acidic	Neutral	Mildly Basic	Very Basic

Q10. All of the acids and bases in these solutions are “weak,” yet we get some pretty extreme pH values. How is that possible? (Think about the questions in part 1)

Part 3 - Neutralization

Since acidic hydrogen ions (H^+) have a positive charge, and basic hydroxyl ions (OH^-) have a negative charge, they like to stick to each other when mixed together. When they do, they form H_2O – do you remember what that is? This is referred to as *neutralization*, since you are turning the acid and the base into water, which has a neutral pH.

In order for neutralization to work, you need an equal number of H^+ ions and OH^- ions. If you have extra H^+ left over, the solution will still be acidic. If you have extra OH^- ions left over, it will still be basic. Only when the number of ions is equal can you be at a neutral pH.

To determine how much of an acid or a base you will need to neutralize a solution, you will need to figure out how many ions there are at a given pH. The pH scale is logarithmic, meaning that one “step” in the scale (from 5 to 4, for example) reflects a difference of 10-times the number of extra hydrogen ions. Similarly, a step from 8 to 9 has 10-times the number of extra hydroxyl ions. A pH of 7 has an equal number of hydrogen and hydroxyl ions.

Q11. Lemon juice has a pH of about 2, and glass cleaner a pH of about 10. How many hydrogen ions would you predict in a solution at pH 2, assuming that a pH of 7 has 1 ion? How many hydroxyl ions would you predict in a solution at pH 10, assuming that a pH of 7 has 1 ion?

Q12. To get to a neutral pH, do you think you'll need more lemon juice, more glass cleaner, or equal amounts of each? Why?

1. Add 10 drops of water to 1 Tbsp of red cabbage juice in a clear cup.
2. Add 10 drops of lemon juice to 1 Tbsp of red cabbage juice in a second cup.

Q13. How many drops of glass cleaner do you think it will take to get to a neutral pH?

3. Now add 1 drop at a time of glass cleaner to the lemon juice, swirling carefully after each drop. Count how many drops it takes to turn the solution the same color as the water.
4. Consult with others in your group to see how many drops they used, and enter the numbers into the chart below.

	Trial 1	Trial 2	Trial 3
Number of Drops:			

Q14. Why does the solution turn from reddish to dark purple as you add the glass cleaner?

Although the math isn't very straight-forward for weak acids and bases (like we have here), you can actually calculate the volume of strong acid needed to neutralize a strong base, and vice versa, using the formula below.

Acid volume x Concentration of ions in acid = Base volume x Concentration of ions in base

Q15. If I have 1 volume of a strong acid at pH 5, how much of a strong base at pH 10 would I need to get to a neutral pH?

Concept Questions

Q16. Look at the list of things which have very acidic pH's. What do these substances have in common? Can you think of other foods that probably also have acidic pH's?

Q17. Fats and oils (like butter, vegetable oil, or even the oil on your skin!) can react with the OH- ions in bases and feel "slippery" or "soapy." Can you think of instances where that property would be useful? What kinds of things do you think basic products would be useful for (besides neutralizing acids)?

Q18. Stomach acid has a pH of about 2. Normally the stomach protects itself by producing a slippery substance that's resistant to the acid, but sometimes it breaks down. What do you think happens? Do you know what this is called? How could you reduce the amount of acid (think of things that we tested!)?

Q19. What is acid rain? Why do you think it's bad for oceans, rivers, lakes, and other natural environments?

