Rainbow in a Tube

Use a pH indicator to create a chemical rainbow

Lesson Plan

Description: Visitors create "rainbows" in clear acrylic tubing, using universal indicator, a dilute solution of acid, and a dilute solution of base.

Audience: Hands-on activity for families and children ages 8 and up

Length: 20 minutes

Learning Objectives

Visitors learn:

- Chemicals (including common household products) can be acids, bases, or neutral.
- Acids and bases have characteristic properties.
- When acids and bases react they can cancel each other out, in a process called *neutralization.*
- Scientists measure acids and bases using the pH scale.
- pH indicator is used to measure the pH of a chemical.

Visitors develop skills related to chemistry and science, including:

- Developing and testing predictions
- Observing, communicating and discussing experimental results

Learning Standards

National Science Education Standards

1. Science as Inquiry
   - K-4: Abilities necessary to do scientific inquiry
   - K-4: Understanding about scientific inquiry
   - 5-8: Abilities necessary to do scientific inquiry
   - 5-8: Understanding about scientific inquiry
   - 9-12: Abilities necessary to do scientific inquiry
   - 9-12: Understanding about scientific inquiry

2. Physical Science
   - K-4: Properties of objects and materials
   - 5-8: Properties and changes of properties in matter
   - 9-12: Chemical reactions

Background Information

When most people hear the word "**acid**," they think of something very dangerous that can dissolve metal and burn skin. In fact, many acids are not dangerous at all. Some are even found in the foods we eat! Any food that tastes sour is acidic. For example, vinegar in salad dressing is acetic acid, oranges and lemons contain citric acid, and apples contain malic acid. Vitamin C is an acid, ascorbic acid.

Bases are also found in common household products. Bases can be very strong and dangerous, or relatively weak and safe for use around the house. Lye or washing soda are very strong bases. Weaker bases are often used as cleaning products, like household ammonia used to clean windows. We don't find many bases in our foods because they taste bitter—think about the taste of soap!

Chemists use a scale known as the **pH scale** to indicate the amount of acid or base present in a solution. The pH scale goes from 1-14. Neutral substances have a pH of 7. A pH less than 7 is an acid, with lower numbers indicating stronger acids. A pH greater than 7 is a base, with higher numbers indicating stronger bases.

1	2	3	4	5	6	7	8	9	10	11	12	13	14
			acid			neutral				base			

A universal indicator (such as Bogen's universal indicator) identifies pH by turning a rainbow of colors:

- **Red** (acids of pH ~2-4)
- **Orange** (acids of pH ~5)
- **Green** (pH ~6-7)
- **Blue** (pH ~9)
- **Purple** (pH ~10 and up)

If an acid and base are mixed in equal amounts they react together to make a salt and water.

ACID + BASE → SALT + WATER

In the first part of this activity, the educator creates a "rainbow in a tube," to demonstrate how acids and bases come in a range of strengths, how they can neutralize each other. Next, visitors create their own rainbow tubes, using a universal indicator, a dilute solution of acid, and a dilute solution of base. Finally, visitors can continue to mix acids and bases to try and get each pH level (indicated by a different color).

Materials

For each pair of visitors (hands-on activity with small tubes)

- Small tube with rubber stoppers (1 per person/pair)
- Funnel that fits into the small tube (1 per person/pair)
- Set of two small, labeled dropper bottles, one with an acid and one with a base
- Beaker of Bogen's universal pH indicator solution (25 ml per person/pair)
- Optional: Tray (to contain spills)
- Paper towels (to clean up spills)

For the presenter (demonstration with large tube)

- Large tube with rubber stoppers
- Large bottle (~500 ml) of Bogen's universal pH indicator solution
- Similar large bottle of water
- Set of two small, labeled dropper bottles, one with an acid and one with a base
- Funnel that fits into the large tube (optional)
- Chart showing pH scale and colors of Bogen's universal indicator (optional)

Sources

- Bogen's universal indicator, sodium hydroxide, and hydrochloric acid solution are available from scientific suppliers, including Flinn Scientific (www.flinnsci.com).
- Safety supplies (glass and gloves) are available from Flinn or other scientific suppliers.
- Polycarbonate tubes and stoppers are available from hardware and building supply stores.
    - The small tubes that visitors use should be 5/8-inch exterior diameter (OD) and 1/2-inch interior diameter (ID). They should each be 12 inches long.
    - The large, demonstration tube should be 1-inch exterior diameter (OD). It should be 3 feet long.

Notes to the Presenter

Labeled dropping bottles are easy for visitors to use and minimize spills.

CAUTION: Always supervise visitors during this activity. Be sure visitors wear safety glasses and don't let them taste any chemicals.

Set Up

Set up takes approximately 30 minutes. (Set up will take longer the very first time you do the activity.)

Prepare chemicals for hands-on activity:

- Prepare the acid solution by adding 8.5 mL of HCl to 1000 mL of water.
- Prepare the base solution be adding 4 grams of NaOH to 1000 mL of water.
- Pour each solution into a labeled dropper bottle for each pair of visitors.

Prepare chemicals for the demonstration:

- Prepare the acid solution by adding 85 mL of HCl to 1000 mL of water.
- Prepare the base solution be adding 40 grams of NaOH to 1000 mL of water.
- Pour each solution into a labeled dropper bottle for each pair of visitors.

Note that the hands-on activity and demonstration require chemicals of different concentrations! Be sure you label them clearly and keep them separate.

Program Delivery

Welcome visitors. Explain that they will be working in pairs or groups of three, and divide them among the workstations. Explain to parents that this is a family activity, and they should work with their children.

In today's program, we're going to make a liquid rainbow, inside this tube! We're going to do it using acids and bases.

Do you know what acids and bases are? Can you name any examples? *Responses will vary.*

Lots of people think of acids as being super strong chemicals that can burn through your skin. But there are lots of weak acids, too. Acids come in a range of pHs, meaning a range of strengths.

You even eat some acids! Acids taste sour. *Name or reiterate acids in foods: citric acid in lemons, acetic acid in vinegar, malic acid in apples.*

What about bases? Bases are the opposite of acids. We don't eat bases, because they taste soapy or bitter. Bases can be harmless or dangerous, too—like acids, they come in a range of pHs.

Can anyone name any common bases? *Name or reiterate bases found around the house: baking soda, washing soda, ammonia, lye soap.*

Chemists use something called the pH scale to measure whether a chemical is an acid or a base, and how strong it is.

The pH scale goes from a strong acid at one end (1) to a strong base at the other end (14). In the middle are weaker acids, things that are neutral (meaning they're not acids or bases), and weaker bases. On a pH scale, 7 is neutral. Anything less than 7 is an acid, and anything greater than 7 is a base.

Let's say we had a chemical, like the stuff in this bottle. *Hold up bottle of water.*

How would you figure out what pH this is? Would you want to taste it to see if it's bitter or sour? *No!* Here's what you could do: You could use something called an *indicator*. An indicator is a chemical that turns different colors if it's in an acid or a base. I have a kind of indicator called a *universal indicator.*

This indicator turns green when it's in something neutral, like water. *Hold up bottle of Bogen's indicator.*

It turns all the colors of a rainbow, a different color for different pHs. We're going to use it to make our liquid rainbows.

Let's see what color the indicator turns when we add acids and bases. I'm going to use my large tube for this, so you can see well. *Describe what you are doing as you go through the following demonstration procedure.*

<u>Demonstration procedure (large tube)</u>

1. Tightly stopper one end of the tube.
2. Hold the tube vertically, with the stoppered end at the bottom and the open end at the top.
3. Fill the tube with the universal indicator solution. Leave about 6 inches of space at the top.
4. Add 10 drops of dilute acid to the tube. The indicator solution at the top of the tube should turn red.
5. Tightly stopper the tube.
6. Turn it over, spinning the tube so the end that was down before is now up. The air bubble will travel through the tube, mixing the red with the green and creating orange and yellow.
7. Remove the second stopper, which is now at the top of the tube.
8. Add 10 drops of base to the tube. The green indicator solution at the top of the tube will turn dark purple.
9. Tightly stopper the tube.
10. Turn the tube over again. The air bubble will travel through the tube, mixing the purple with the green to create blues.

We made a rainbow! How did we do it? First we added an acid, and we got what color? *Red!*

When I turned the tube over, what colors did we get? *Orange and yellow.*

How did we get those colors? *The air bubble mixed the acid with the water, making weaker acids toward the middle of the tube. The indicator turned a different color where the acids were weaker.*

When I added the base, what color did we get? *Purple.*

When I turned the tube over the second time, what colors did we get? *Blues.*

Why? *The air bubble mixed the base with the water, making weaker bases toward the middle of the tube. The indicator turned a different color where the bases were weaker.*

What will happen if the tube is turned over again? Will it all turn red? Will it all turn purple? Will it all turn green? Should we try and find out? *Try it again.*

The rainbow colors remain even after the tube is turned over several times because the liquid flows around the air bubble and the acid and base ends of the tube do not mix very well. It is very difficult to mix things in a long tube, but after turning it over many, many times, acid and base would use each other up and the entire tube would be green.

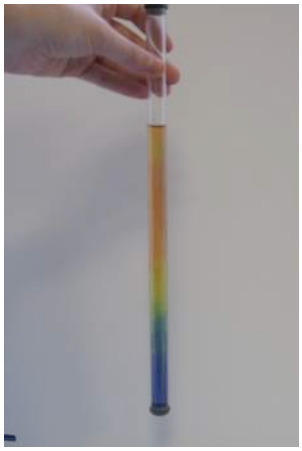
Now, would you like to make your own mini rainbow tubes? I'll show you how, and then you can try it yourself. *Demonstrate the following procedure.*

Demonstration procedure (small tubes)

1. Tightly stopper one end of the tube.
2. Hold the tube vertically, with the stoppered end at the bottom and the open end at the top.
3. Fill the tube with the universal indicator solution. Make sure you use the funnel, and hold your tube over the tray. Leave 2-3 inches of space at the top.
4. Add 5 drops of dilute acid to the tube. The indicator solution should turn red.
5. Tightly stopper the tube.
6. Turn it over, spinning the tube so the end that was down before is now up. The air bubble will travel through the tube, mixing the red with the green and creating orange and yellow.
7. Remove the second stopper, which is now at the top of the tube.
8. Add 5 drops of base to the tube. The green indicator solution will turn dark purple.
9. Tightly stopper the tube.
10. Turn the tube over again. The air bubble will travel through the tube, mixing the purple with the green to create blues.

Circulate and help any visitors who need assistance. After visitors have made a rainbow, they might like additional challenges. Can they make a double rainbow? Can they turn the entire tube green again using the chemicals?





Clean Up

- The universal indicator can be poured into a storage bottle and saved to use again. It's fun to have the audience watch you pour the tubes into the storage container, and see if it comes out neutral. If not, you can have them help you use the dropper bottles to adjust the pH so that it is neutral (bright green).
- The dropper bottles of acids and bases can be stored to use again.
- Rinse the tubes, stoppers, and trays, and leave them out to dry before storing them.
- Paper towels (used to clean up spills) can be disposed of in the trash.

Credits
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