Nano at Home

How to Make pH Paper with Cabbage

Science concepts you will learn about in these experiments:

1. Acid/base/pH
2. Plants contain chemicals, color can be an indicator for other chemistry concepts

Background:

Have you ever considered how some fruits, vegetables, and flowers are so brightly colored? The answer is CHEMICALS! Plants contain a variety of different natural pigments which can help the plants protect themselves against harmful insects and bacteria, encourage or discourage certain herbivores (plant eaters) from eating them, and protect the plant against damaging sunlight and extreme temperature! As humans, we can also appreciate the variety of plant colors for more than their beauty. First, eating all these different colored fruits and vegetables helps indicate that you're eating a bunch of different nutrients (which is another word for chemicals that are health for you).

Plants contain a variety of vitamins, minerals, and antioxidants, some of which are colorful. There are numerous different kinds of plant pigments, but some of the most well-known are carotenoids (red, orange, and yellow color), anthocyanins (red, blue, and purple), and, of course, chlorophyll (green). But even as human, we also can use plant colors to indicate the chemical characteristics of plants. For instance, consider a banana. Banana peels can range in color from bright green, yellow, and dark brown. When you prefer a certain color of banana, you are selecting a banana that is at a different stage of ripening. During ripening, there are a lot of chemical changes that are happening in the fruit—it gets softer (changes in the structure of the walls of all of the cells), becomes sweeter (chemical conversion from starch to sugar), and a color change (break down of chlorophyll and production of anthocyanins or carotenoids).

We use color to indicate chemistry concepts all the time! Just like you, scientists can also use color to indicate different chemical properties when they are doing research in a laboratory.

If you're interested in learning more about how color can be used to indicate chemical properties, check out our blog post at sustainable-nano.com/2020/09/27/chemistry-color-tests

In this activity you will continue to use your scientific mind to use color to make conclusions about chemistry.

What you will need:

- Red cabbage
- Sharp knife
- Surface to cut on
- Water
- Stove and pan
- Tray or container for dying paper
- Paper
- White vinegar
- Baking soda
- Cups
- Paint brush or other tool to paint with
- Optional: clear cups

Note: These instructions are very forgiving and the only reason I ever specify a quantity is just to give an idea, but nothing needs to be very precise for this to work well.

Instructions:

1. Obtain a red cabbage. I used a quarter of a small red cabbage and that was more than enough!

2. Slice the red cabbage as thinly as possible. Don't agonize over it, but the smaller the slices are, the more surface area there will be to extract the anthocyanins from the cabbage.

3. Then, in a pot or high-sided pan, combine your sliced cabbage with enough water to cover about half of your cabbage (around equal parts cabbage and water). I had a heaping cup of cabbage and used 1.5 cups of water.

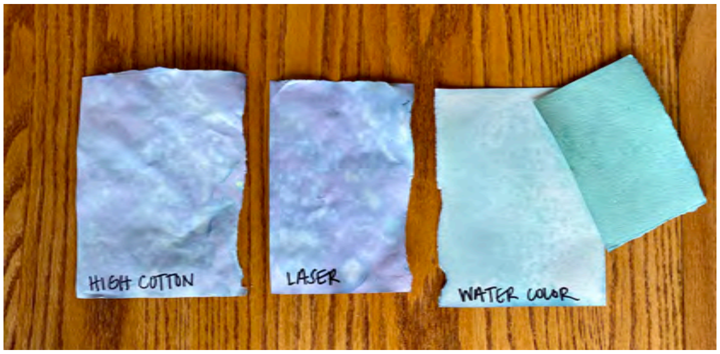
4. Simmer for around 10 min, stirring occasionally. You will notice the cabbage lose its bright purple color and the water will turn purple. These are the anthocyanins coming out of the cabbage. This is called an *extraction* in a chemistry lab because you are extracting the anthocyanin from the cabbage into water. You can let this simmer longer to extract more purple color, but after a while there is a diminishing return.

5. Let the cabbage and water cool. Yes, your house will smell like boiled cabbage, so maybe open a window if that's not for you.

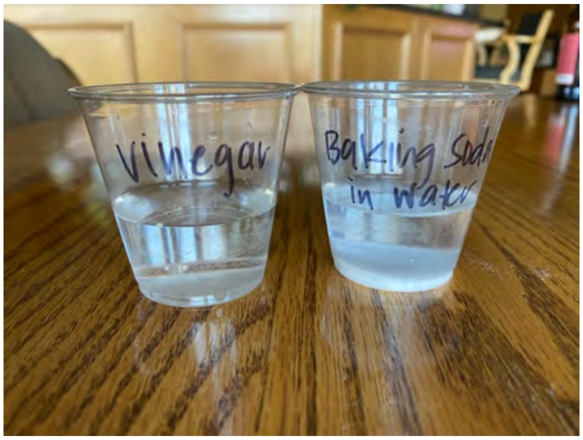
6. Once the cabbage extract is at room temperature, collect the purple or bluish water from the boiled cabbage. You can us a fine metal mesh colander/strain to separate the liquid and solid or pour this off slowly using a spatula to hold the cabbage back. Don't throw away the boiled cabbage, you can eat it or add it to your compost or garden for a good source of nitrogen.

7. Dying the paper works best in a wider, flat surface, like a sandwich Tupperware or a baking sheet (if you made a lot of cabbage liquid). Any paper should work for dying. If you happen to have watercolor paper at home, this paper works the best for trapping more of the anthocyanin pigments to give you a more intense color change.

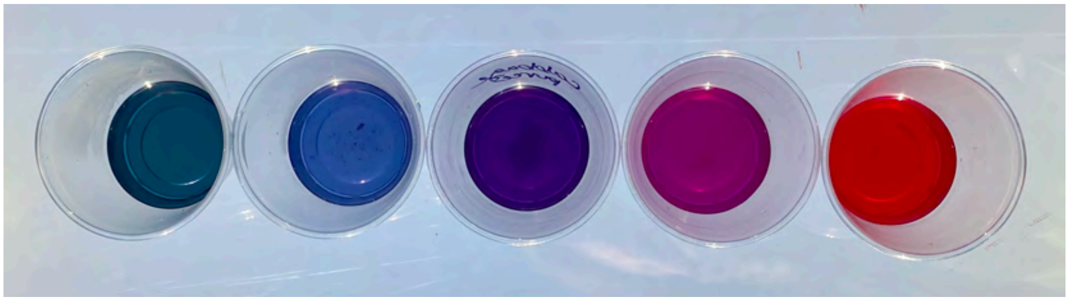
8. Submerge your paper in the purplish pigment liquid. (Note: if your cabbage extract is not purple, most likely bluer, it's still okay to use as is. But, to improve visual result, you can color correct by stirring in a little bit of vinegar until you've achieved your desired purple) Soaking for longer than 5 seconds does not improve the color intensity, so a quick dip is just fine. Put the wet paper to the side to dry. The paper should be completely dry before using, so you might need to turn it over part way through drying to ensure both sides are dry. If you want an even more intense color change even after dyeing is complete, you can continue to spray cabbage juice onto the papers.



9. While the paper is drying, fill one cup with a small amount of vinegar (a couple tablespoons is all you need to start) and another with baking soda and water (one teaspoon of baking soda to around a quarter cup water). Baking soda does not dissolve in water very well (a principle called *solubility*. For example, table salt is very soluble in water, but pepper is not). Give the baking soda and water a good stir to mix them up. The baking soda will eventually settle to the bottom and this is totally fine! One of these cups contains an acid—the vinegar. The other contains a base—baking soda.



10. Optional: While the paper is continuing to dry you can begin investigating the color changing properties! Take the left-over cabbage juice and pour a small amount into several small cups. Add different amounts of acid (vinegar) and base (baking soda) to the cups and try to make a rainbow from pink to blue! If the colors look a little dark, adding a bit of water to the colored liquids can help make the colors more obvious.



11. Once the paper is dry, and a purple color, take a paint brush or whatever utensil you have, dip into the vinegar and paint on the paper. You'll notice a color change from purple to pink. Next, dip the brush in the liquid portion of the baking soda cup and then paint on the paper. You'll notice a different color change, this time from purple to more green/blue. In fact, if when you extracted your cabbage juice into water and it appeared little more blue than purple, then your water is likely basic. Or, if your cabbage juice extract was purple, but turned blue after contact with the paper, then it means your paper has basic properties as well!

12. Go wild and paint a picture!

Disposal:

Left over cabbage can be used as fertilizer or composting. The everything else can be safely poured down the drain or thrown in the trash.

A couple more ways to experiment!

1. Use this paper to test the acidity or basicity of any other liquids in your home.
    a. For example, laundry detergent, lime juice, etc.
    b. You only need a tablespoon of indicator, 1-12 drops of your product of interest, and something to stir the two together, like a chopstick.

2. Does anything else in your home contain pH sensitive pigments? You can collect something outside or use something that would have otherwise been food waste and test with the acid and base.
    a. Collect the products you're interested in and boil them in water as you did the cabbage
    b. For example, I tested with red onion skin, avocado skin and pits, daffodils, and tulips

Acid (left), neutral (middle), base (right). Results not as stunning as the anthocyanins in cabbage, but still fun!

    c. Not all indicators make good paper dyes. I tried dying watercolor paper with all four of these, and they didn't produce as good of a color change as the cabbage. You might barely be able to see the white smiley and flower on this sheet.