Experiment Guide

Cabbage Chemistry: Understanding how pH soil affects plant growth

Aim: In this experiment, you will hypothesize what color the cabbage juice will turn when mixed with common household items to determine how acidic or basic the item is. The basic chemistry concepts that you will be introducing to the kids are acid/base and how that pertains to pH and the application of indicators (pH indicators in this case).

Introduction to the subject matter of the experiment:

Soil pH has a large impact on the solubility of minerals or nutrients in the soil. Fourteen of the seventeen essential plant nutrients are obtained from the soil. Before a nutrient can be used by plants it must be dissolved in the soil solution. Most minerals and nutrients are more soluble or available in acidic soils than in neutral or slightly alkaline (basic) soils.

Strongly acidic soils (pH 4.0-5.0) can have high concentrations of soluble aluminum, iron, and manganese which may be toxic to the growth of some plants. A pH range of 6-7 promotes the ideal levels of soluble and readily available plant nutrients.

The soil pH can also influence plant growth by its effect on activity of beneficial microorganisms. Bacteria that decompose material into organic matter are hindered in strongly acid soils. This prevents organic matter from breaking down, resulting in an accumulation of organic matter and the tie up of nutrients, particularly nitrogen, that are held in the organic matter.

Figure 1. This picture shows some of the different colors that red cabbage juice can become. From left to right, the solutions shown range from very acidic (red) to very basic (yellow).

Theoretical background:

A **solution** is a mixture of **molecules** that are fully dissolved in a liquid, in this case, water. Think about the difference between salt water and tap water. If you add salt to water it looks like it just disappears, that disappearing trick is in fact the salt dissolving and the solution looks clear, but the salt is still there and the solution will taste salty. The water in these solutions has an interesting property in that it can act as either a base or an acid, depending on which other types of molecules are present. This is a property called amphoteric. This part is not as important to the kids, but simply put in here for the instructors understanding. Just remember that water can be either basic or acidic or another way of looking at it is that it can both donate or accept a proton.

To see how this works, please see the illustrations below. For clarity, a **proton** is defined as a positively charged hydrogen atom. The color change that you will be viewing in this experiment is in relation to the pH of the solution. Further pH is a measurement of the amount of free protons in the solution or another way of looking at it is the amount of protonated water molecules, H_3O^+. To make this easier to understand for a kid, you can describe water as the boomeranged looking molecule and illustrate it as two small balls (hydrogen) stuck to one larger ball (oxygen). Now if another molecule is considered acidic, say vinegar, then that acid will add another ball to the water molecule making it protonated. If you have a molecule that is basic, the molecule will take a proton from water, deprotonating it. Protonation and deprotonation can be illustrated or shown by just pulling a ball off or adding a ball to, a water molecule.

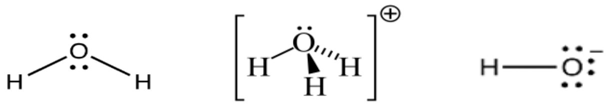


Figure 1: Left: a water molecules, two hydrogen atoms and one oxygen atom; Middle: protanated water; Right: deprotonated water

Figure 2: The ammonia is a base because it takes a proton from the water.

Figure 3: The hydrochloric acid (HCl) is acidic because it donates a proton to the water.

How do you tell if something is an acid or a base? As stated above, an acid will provide protons (H^+, aka balls stuck to water) and a base will take a proton out of the system (aka take a ball from water). So how does one measure this? You use a chemical called an **indicator**, which is a molecule or mixture of molecules, that changes in color depending on whether a solution has a high pH or low pH. The pH of a solution is a numerical measure of how basic or acidic it is. A solution with a pH or ~7 is neutral, >7 is a base, <7 an acid. Specifically, an indicator works by responding to the levels of hydrogen ions (H^+, protons) in a solution. There are many different types of indicators, some are liquids and some are concentrated on little strips of “litmus” paper. Indicators can be extracted from many different sources, including the pigment of many plants.

Terms and Concepts:

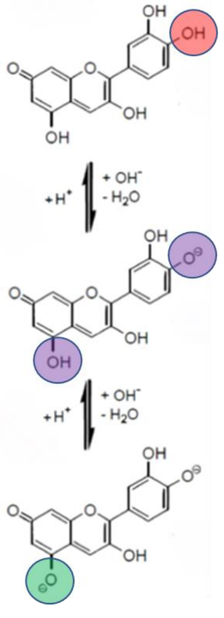
- Solution
- Molecule
- Proton
- Acid
- Base
- Indicator
- Pigment
- pH

Questions:

- What are some examples of plants that grow in different pH soils?
- Can you think of reasons on why a farmer would be concerned with pH of his soil?

Lesson Introduction:

Red cabbage contains an indicator **pigment** molecule called Flavin, which is one type of molecule called an anthocyanin. This water-soluble pigment is also found in apple skin, red onion, plums, poppies, blueberries, cornflowers, and grapes. Very acidic solutions will turn anthocyanin a red color. Neutral solutions result in a purplish color. Basic solutions make a greenish-yellow or yellow color. For some examples, see Figure 1 above.



Protonate, pH < 7
Red Color

Neutral, pH ~7
Purple Color

Deprotonate, pH > 7
Green/Yellow Color

Because red cabbage has this indicator pigment, it is possible to determine the pH of a solution based on the color it turns the purple cabbage juice. The pH of a solution is a numerical measure of how basic or acidic it is. A solution with a pH of ~7 is neutral, >7 is a base, and <7 an acid.

In this science experiment, you can extract your own cabbage juice indicator and use it to test the pH of different solutions around your home. You might be surprised to find out what common items around your house are acids or bases.

Lab safety is a must! To safely explore Chemistry, we need to follow proper lab safety. How do you think we are going to do this? Chemists follow very strict procedures to protect themselves and they include:

- Gloves
- Goggles
- Lab aprons
- Point out any safety features in the classroom (ie. Eyewash or emergency shower)
- Mention housekeeping rules – NO EATING OR DRINKING
- Mention location of bathrooms

Now, put on your gloves and goggles and let's get started!

The Experiment

Materials:

- A small red cabbage
- Boiling pot of water
- Strainer
- Small white Dixie cups (one for each household item)
- Medicine Dropper
- Large bowls or pots (2)
- Worksheets
- A series of household items to test the pH of:
    - Fruit Juice: Lemon, Lime, Orange, Apple
    - Soda Pop (use a clear soda, like Sprite so the color change is more apparent)
    - Vinegar
    - Water
    - Bleach (only a few drops are needed in order to cause the change to yellow)
    - Baking soda
    - Dish Soap (Note: most dish soaps are basic, most hand soaps are acidic)
    - Anything you want!

Experiment steps

**Instructor: Please review the items participants will be using.* —

Note: Steps 1-5 can and in most cases, will be done prior to the event. If you will be storing the cabbage indicator solution for longer than a few days, place the solution in an air tight container such as a mason jar and store in a cool dark location. Otherwise, the solution will react with oxygen and light over time causing a loss or change in color.

Step 1

Grate a small red cabbage and place the pieces into a large bowl or pot, as shown in Figure 2, below.

Figure 2. Grated red cabbage in a pot.

Step 2

Pour boiling water into the bowl to just cover the cabbage. Use caution when handling boiling water.

Step 3

Leave the cabbage mixture steeping, stirring occasionally, until the liquid is room temperature. This may take at least half an hour. The liquid should be reddish purple in color, as shown in Figure 3, below.

Figure 3. While steeping in the water, the liquid in the pot should be reddish purple in color

Step 4

Place a strainer over a second large bowl or pot and pour the mixture through the strainer to remove the cabbage pulp, as shown in Figure 4, below. Press down on the pulp in the strainer, such as by using a large spoon, to squeeze more liquid out of the pulp.

Figure 4. Cabbage pulp being removed from the mixture using a strainer.

Step 5:

In the bowl, you should now have a clear liquid that will either be purple or blue in color, as shown in Figure 5, below. (It should look darker after the pulp is removed.) This is your indicator solution.

Figure 5. This shows what the indicator solution can look like in a clear glass. (Note that you will be using the solution in white Dixie cups.)

Step 6

The color of the liquid will change depending upon the pH. Use Table 1, below, to figure out the pH of the liquid by observing the color.

pH	Color
2	Red
4	Purple
6	Violet
8	Blue
10	Blue-green
12	Greenish-yellow

Table 1. This data table shows what the pH of the liquid should be based on its color.

1) Set aside your indicator solution. You will use it as your "stock" solution for your experiments

Step 7

Next, test various household items with your indicator. Use a separate Dixie cup for each solution you want to test. Do not mix the chemicals in the same cup because you will contaminate your results.

Step 8

Fill the Dixie cups halfway with your cabbage indicator solution. You can use less indicator solution for each cup if you do not have a lot of indicator solution.

Step 9

Add liquid you want to test dropwise until you see the solution change in color. If adding a solid add a few grains at a time until you see the solution change in color. Gently swirl the cup as you add material, being careful not to spill the solution.

Analyzing Your Data

1. Record the pH and a description of each solution on the worksheet that is provided.
2. Discuss if the pH was expected or was a solution different than what you thought it might be.
3. As the last experiment, predict what will happen if you mix a basic and acidic cup, then do it!

Application:

For growers, knowing the pH of their soil can be the difference between a healthy plant versus an unhealthy plant. The healthier the plants, the more likely the grower will have a higher yield to support the farm.

As a partner to growers, BASF researches and provides guidance on how growers can use this knowledge to produce healthy crops.