Hands-on Activity: **Red Cabbage Chemistry**

Quick Look

Grade Level: 8 (7-9)
Time Required: 45 minutes
Expendable Cost/Group: US $5.00
Group Size: 3
Activity Dependency:
Introduction to Environmental Engineering
Introduction to Water Chemistry
Subject Areas: Chemistry, Measurement, Physical Science, Problem Solving, Reasoning and Proof, Science and Technology

Summary

Students take advantage of the natural ability of red cabbage juice to perform as a pH indicator to test the pH of seven common household liquids. Then they evaluate the accuracy of the red cabbage indicator, by testing the pH of the liquids using an engineer-designed tool, pH indicator strips. Like environmental engineers working on water remediation or water treatment projects, understanding the chemical properties (including pH) of contaminants is important for safeguarding the health of environmental water sources and systems.
This engineering curriculum aligns to Next Generation Science Standards (NGSS).

Engineering Connection

An important consideration for environmental and chemical engineers is pH. The pH of different liquids and solutions, particularly the pH of bodies of water, are important in describing the behavior of different minerals and chemicals. For example, with increasing acidic pH values, water begins to cause harm and destruction of ecosystems and minerals, such as dissolving the calcium carbonate shells of mollusks, or making ecosystems unlivable for plants and animals.

Red cabbage juice is a natural indicator for measuring the pH of solutions.

Learning Objectives

After this activity, students should be able to:

- Define acidity and basicity and how they relate to different liquids.
- Relate the importance of pH to environmental systems such as lakes, rivers and oceans, as well as environmental engineering concerns.
- Explain how pH, acids and bases are important factors in natural systems, such as the human body.

Educational Standards

- NGSS: Next Generation Science Standards - Science
- International Technology and Engineering Educators Association - Technology
- State Standards

Materials List

Each group needs:

- eight 5-ounce (~148 ml) paper cups, containing vinegar, lemon juice, milk, 7-Up or Sprite, baking soda, Windex, and red cabbage juice indicator (prepared by teacher, see below), respectively
- 7 pH indicator strips
- Red Cabbage Chemistry Worksheet, one per student

For the teacher (to prepare group materials; instructions in Procedure section):

- 2 red cabbages
- large pot, water, stove, strainer
- pitcher or jug, to hold red cabbage indicator from pot
- marker, to label paper cups
- tablespoon, to measure baking soda
- extra 5-ounce paper cups, to double-up on the Windex cups
- the seven test items (as listed above), enough for all teams

Worksheets and Attachments

Red Cabbage Chemistry Worksheet (pdf)
Red Cabbage Chemistry Worksheet (doc)

Visit [www.teachengineering.org/activities/view/wst_environmental_lesson02_activity3] to print or download.

Pre-Req Knowledge

Have students complete the Introduction to Water Chemistry lesson before conducting this activity.

Introduction/Motivation

Red cabbage juice contains a natural pH indicator that changes colors depending on the acidity of the solution. The pigment in red cabbage that causes the red color change is called flavin (an anthocyanin).

Flavin is a water-soluble pigment also found in apple skins, plums and grapes. Very acidic solutions turn the indicator a red color, neutral solutions turn the indicator a purple color, and basic solutions turn the indicator a greenish-yellow color.

The pH of a solution expresses the concentration of hydrogen ions (H^+). At a lower pH, more hydrogen ions are in solution, and therefore the solution is acidic. Many reactions in nature involves an increase or decrease in acidity. For example, as CO_2 concentrations in the atmosphere increase, greater amounts are dissolved in the oceans, reacting with H_2O to form carbonic acid (H_2CO_3). Carbonic acid quickly disassociates into bicarbonate($HCO3^-$) and hydrogen ion (H^+).

Environmental and chemical engineers who focus on water quality, water treatment and water remediation need to measure, monitor and sometimes even adjust the pH of water. For example, in the water treatment process, important chemical reactions are affected by the pH of the water. Through today's activity, we will learn more about the pH of different liquids.

Procedure

Before the Activity

- Gather materials and make copies of the Red Cabbage Chemistry Worksheet.
- For each group, label eight paper cups: milk, water, baking soda, Windex, soda pop, lemon juice, vinegar, cabbage indicator.
- The day before the activity, prepare the red cabbage indicator: Fill a large pot with water and bring the water to a boil. Break off the red cabbage leaves and add them to the boiling water. Keep adding leaves until the water is a deep purple, then strain the leaves out and place the cabbage indicator juice in a pitcher.
- On the day of the activity, fill each cup halfway (or less) with its respective liquid or powder (a tablespoon of baking soda). Double up on the Windex cup to prevent it leaking through. It does not take much indicator before one can see a color change, so small amounts of the cabbage indicator from its cup will be added to each of the seven cups of other liquids.

Red cabbage juice changes color to indicate the pH of various everyday items.

With the Students

1. Divide the class into groups of three students each.
2. Hand out the worksheets.
3. Direct student groups to each pour a small amount from the "cabbage indicator" cup into the seven cups of different liquids and a powder. Add just enough indicator until a color change appears. Have students record their observations on the worksheet and rank the test items based on their pH values (1 = lowest pH, 7 = highest pH).
4. Then have students use pH-indicator strips to measure and record the pH of the liquids in each cup.
5. Have students complete the worksheet questions.
6. Conclude by leading a class discussion to compare results and conclusions, and make the connection to real-world applications, as described in the Assessment section.

Vocabulary/Definitions

Acid: A solution with a sour-taste and low pH value.

Base: A solution with a sweet taste and high pH value.

Indicator: A solution that changes colors in the presence of acids and bases to help indicate the pH value.

PH: A scale that measures acidity and basicity.

Assessment

Pre-Activity Assessment

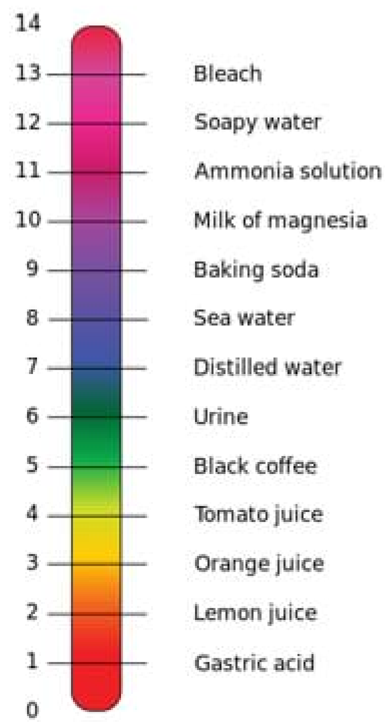
Lesson Recap & Predictions: As a class, review the concepts presented in the associated lesson that relate to pH. Focus the conversation on topics such as acid rain and acid mine drainage. Have students predict which test liquids they think are acidic and which are basic.

Activity Embedded Assessment

Worksheet: Have students use the Red Cabbage Chemistry Worksheet to record their data and answer questions. Observe their written observations, data and answers to gauge their comprehension.

What's Going On? While students are conducting the lab, walk around and ask them questions to keep them engaged and on task, such as: Are the results from the indicator test what you expected? Why or why not?

Post-Activity Assessment



A pH scale with example common items at each pH value.

Wrap-Up Discussion: At lab end, bring students together as a class and ask them the following questions. Make sure everyone understands the answers.

- How did your results from the red cabbage pH indicator compare to the pH indicator strips? (Listen to student experiences; answers will vary. From most acidic to most basic, the pH values of the tested items are: lemon juice [2], vinegar [3], soda pop [4], milk [6], pure water [7, neutral], baking soda [9], Windex [11, an ammonia solution].)
- What other acids and bases do we encounter every day? (Listen to student ideas. Example everyday acids and their typical pH values: Battery acid [0], citrus fruit juices [citric acid] such as in lemonade [2-3], tea [4-6], bananas [5], black coffee [5+], rainwater [5-6], shampoo [varies, usually slightly acidic]. Example everyday bases: Egg whites [8], antacids [9-10], soapy water [12], bleach [13], oven cleaner [13], liquid drain cleaner [14]. Oven cleaners are designed to have pH values greater than 12 because the grease, fat and carbon found in ovens are easily dissolved in reaction with extremely alkaline [base] solutions. A range of pH values are found in the human body from highly acidic gastric acids [1] to skin [5.5] to blood [7.4]. Tums® is a base that is designed to help neutralize stomach acids. See if students want to extend the activity by testing other items of interest.)

- Why is understanding the pH value of liquids important to environmental engineers? (Points to make: Human activity can disturb the natural balance necessary for ecosystems to work. Engineers are focused on preventing and fixing situations that put our natural environment at risk, for example, by the alteration of pH levels from the misuse and overuse of natural resources—acid mine drainage, industrial waste, leaking sewage and fuel tanks, agricultural chemical runoff, dissolved pharmaceuticals, etc. Talk about acid neutralization remediation using bases and make the connection to what students learned in the lab. Engineers also need to know about pH to design tools such as the pH indicator strips.)
- You've heard of "acid rain." Why are we concerned about acid rain? (Answer: The pH of water is generally neutral [7], and rainwater is slightly acidic [5-6], but acid rain is much more acid [2-6] and thus, corrosive. This is not the natural pH of rainwater and it alters the environment for wildlife, trees and plants, and slowly deteriorates buildings and statues. With increasing acidity, water begins to cause harm and destruction of ecosystems, such as slowing the reproduction of fish and other marine life and being too acidic to survive, or dissolving the minerals such as calcium carbonate that form the shells of mollusks.)
- From what you know now, what would happen if we mixed some of our solutions? (If time remains, have students mix solutions they found to be acidic with solutions that they found to be basic to observe any chemical reactions and corresponding color changes. Or, add baking soda to the acidic solutions to neutralize them.)

Troubleshooting Tips

Double up on the paper cup with the Windex; otherwise, it tends to leak after a few minutes.

Activity Extensions

Have students test other liquids for their pH values and/or perform this lab activity at home. Consider testing items found in the kitchen, bathroom, laundry and garden.

Activity Scaling

- For lower grades, conduct the similar Acid (and Base) Rainbows activity, targeted for sixth grade students.
- For upper grades, go into more depth with the definition of pH. Especially if students have had some experience with logarithms in mathematics and ions in chemistry, define pH as a measure of the activity of hydrogen ions. Show students how to calculate pH based on a given concentration of hydrogen ions (and assuming the activity of the hydrogen ions is equal to the concentration of hydrogen ions) by using the equation:

$$\text{pH} = -\log_{10}[a_{H^+}]$$

where $[a_{H+}]$ is the concentration of hydrogen ions. Once students have completed the worksheet, have them manipulate this equation to solve for the concentration. Expect them to come up with the equation:

$$[a_{H^+}] = 10^{-pH}$$

Have students use this equation for each liquid's pH value to determine the concentration of hydrogen ion in each of the seven liquids.

References

- Helmenstine, Anne Marie. Chemistry. *Red Cabbage pH Indicator - How to Make Red Cabbage pH Indicator*. About.com: Accessed September 15, 2009. http://chemistry.about.com/od/acidsbase1/a/red-cabbage-ph-indicator.htm

Copyright

Contributors

Jessica Ray; Phyllis Balcerzak; Barry Williams; Carleigh Samson

Supporting Program

GK-12 Program, School of Engineering and Applied Science, Washington University in St. Louis

Acknowledgements

This curriculum was developed with support from National Science Foundation GK-12 grant number DGE 0538541. However, these contents do not necessarily represent the policies of the NSF, and you should not assume endorsement by the federal government.

Last modified: September 4, 2019