pH Rainbow Tube

Neutralization Reactions

Introduction

Create a beautiful rainbow of colors in a demonstration tube using universal indicator and a dilute acid and base.

Concepts

- pH indicators
- Acids and bases

Materials

Hydrochloric acid solution, HCl, 0.1 M, 1 mL
Sodium hydroxide solution, NaOH, 0.1 M, 1 mL
Universal indicator, 5 mL
Water, distilled or deionized
Beaker, 400-mL
Glass demonstration tube (18 mm ID, 24≦ long)
Pipets, Beral-type, 2
Rubber stoppers, #6 solid, 2

Safety Precautions

Universal indicator is an alcohol-based solution and is a flammable liquid. Dilute hydrochloric acid and sodium hydroxide solutions are irritating to the skin and eyes. Avoid contact of all chemicals with eyes and skin. Wear chemical splash goggles, chemical-resistant gloves, and a chemical-resistant apron. Wash hands thoroughly with soap and water before leaving the laboratory. Please review current Material Safety Data Sheets for additional safety, handling, and disposal information.

Preparation

Prepare a dilute solution of universal indicator in distilled or deionized water. The solution should be green in color and dilute enough to see through. (Mixing 5 mL of universal indicator with 200 mL of distilled water works well for the demonstration tube described above.)

Procedure

1. Stopper one end of the demonstration tube with a rubber stopper. Make sure the tube is securely sealed. Place the stoppered end firmly on table.
2. Fill the tube to within 3–4 cm of the top with the diluted (green) solution of universal indicator.
3. Add two drops of 0.1 M hydrochloric acid solution to the tube and stopper securely. *Note:* Ensure bottom stopper rests against the table before inserting the stopper.
4. Invert the tube and observe the colors produced. Rest the stopper firmly against the table.
5. Remove the top stopper (which used to be on the bottom) and add two drops of 0.1 M sodium hydroxide solution to the tube. Re-stopper securely. *Note:* Ensure the bottom stopper rests against the table before inserting the stopper.
6. Invert the tube again. Observe the full spectrum of indicator colors spread throughout the tube.

Disposal

Please consult your current *Flinn Scientific Catalog/Reference Manual* for general guidelines and specific procedures governing the disposal of laboratory waste. The contents of the tube may be flushed down the drain with excess water according to Flinn Suggested Disposal Method #26b.

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Tips

- When pushing in the stopper on top of the tube, keep in mind that pressure is easily transferred through a liquid. Always keep the bottom stopper against the tabletop to hold it in place when inverting the tube.
- Ask students to predict how many times the tube would need to be inverted back and forth to thoroughly mix the entire solution and restore the homogeneous green color throughout. Then try it. It turns out that the bubble is surprisingly inefficient at mixing the system.
- Once the solution is brought back to its original uniform color, it is ready to be used again. The solution can usually be recycled many times.
- Instead of mixing the contents, try leaving the tube undisturbed—clamped in a vertical position—for a few hours or days. Make periodic observations. The series of changes that the system undergoes is quite interesting, although not always reproducible!
- You can also use a weak acid (such as acetic acid) and a weak base (such as ammonia) and the demonstration will work just as well . . . the first few times. After that, the spectrum of colors loses its extremes, and the solution eventually becomes resistant to any color changes at all. This variation is a nice demonstration of the properties of buffers.
- The demonstration may be found in *Flinn ChemTopic™ Labs*, Volume 13, *Acids and Bases*, pages 81–82 as *The Rainbow Tube*.
- Complete the demonstration as a student laboratory by using vinegar and saturated sodium carbonate solutions.

Discussion

Universal indicator can be used to illustrate an entire range of pH conditions because it is made up of a mixture of different indicators that change color at different pH values. As an acid is diluted with water, its pH increases—but never above pH 7. Likewise, as a base is diluted, its pH decreases—but, again, never below pH 7.

The half-color spectrum that you see after adding just the hydrochloric acid solution and inverting the tube is comparable to what one would see after performing a series dilution of hydrochloric acid. Although the hydrochloric acid solution concentration may range from 10^{-1} M at the bottom of the tube to 10^{-13} M at the top of the tube, the corresponding pH values will be approximately 1, 2, 3, 4, 5, 6, 7, 7, 7, 7. . . . It is the 1×10^{-7} M H_3O^+ already present in the water that is ultimately responsible for the pH reaching this plateau of 7 and for the color not changing beyond the neutral (green) point. This is important to point out to students who might think that they can use the log of the hydrochloric acid solution concentration, no matter how dilute, to derive the pH of the solution. Certainly you can never add hydrochloric acid solution to neutral water and expect to get a pH greater than 7! Likewise, you cannot expect dilute base solutions to have pH values of less than 7. Therefore, to derive the entire pH scale by series dilutions, you must use both an acid and a base—starting, of course, at opposite ends. This is exactly what is accomplished in the pH rainbow tube.

Connecting to the National Standards

This laboratory activity relates to the following National Science Education Standards (1996):

Unifying Concepts and Processes: Grades K–12
Evidence, models, and explanation
Constancy, change, and measurement
Content Standards: Grades 5–8
Content Standard B: Physical Science, properties and changes of properties in matter
Content Standards: Grades 9–12
Content Standard B: Physical Science, structure and properties of matter, chemical reactions

Acknowledgment

Special thanks to Bob Becker, Kirkwood HS, Kirkwood, Missouri for this activity. Bob believes that this idea is an original one—although the technique is so simple, he cannot imagine something like it had never been tried before! He first published

the activity in *Chem 13 News*, Waterloo, Ontario, in December 1989.

Flinn Scientific—Teaching Chemistry™ eLearning Video Series

A video of the *pH Rainbow Tube* activity, presented by Penney Sconzo, is available in *Neutralization Reactions*, part of the Flinn Scientific—Teaching Chemistry eLearning Video Series.

Materials for *pH Rainbow Tube* are available from Flinn Scientific, Inc.

Catalog No.	Description
U0002	Universal indicator solution, 500 mL
H0014	Hydrochloric acid solution, 0.1 M, 500 mL
S0149	Sodium hydroxide solution, 0.1 M, 500 mL
GP9146	Glass demonstration tube, 24" long
S0233	Sodium Carbonate Solution, Saturated, 500 mL
V0005	Vinegar, White, 3.78 L

Consult your *Flinn Scientific Catalog/Reference Manual* for current prices.