

# pH Rainbow Tube



## Introduction

Create a beautiful rainbow of colours 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 | Eyedroppers or Beral-type pipets, 2           |
| Sodium hydroxide solution, NaOH, 0.1 M, 1 mL | Glass demonstration tube (12 mm ID, 24" long) |
| Universal indicator, 5 mL                    | Parafilm® M                                   |
| Water, distilled or deionized                | Rubber stoppers, #00 solid, 2                 |
| Beaker, 400-mL                               | Support stand and clamp                       |

## 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. Be sure to fire polish any cut edges before using glass tube. 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 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 colour 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 and seal with Parafilm® M. Make sure the tube is securely sealed and clamp the tube vertically to a support stand. Place an empty beaker under the tube to protect against leaks.
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, stopper securely, and seal with Parafilm® M. Remove the clamp, invert the tube, and observe the colours produced.
4. Remove the top Parafilm® M 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, reseal with Parafilm® M, and invert the tube.
5. Clamp the tube to the support stand again and observe the full spectrum of indicator colours spread throughout the tube.

## Disposal

It is recommended that you consult your local school board and/or municipal regulations for proper disposal methods that may apply before proceeding.

## Tips

- When pushing in the stopper on top of the tube, be sure to use Parafilm® M to form a tight seal. Keep in mind that pressure is easily transferred through a liquid. Always keep one hand on the bottom stopper to hold it in place when inverting the tube.
- When fire polishing glass tubing, wear protective eyewear. Rotate the tube evenly in the burner flame until the edges are smooth and rounded. Remember—glass may look cool but still be hot.
- 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 colour 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 colour, 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 colours loses its extremes, and the solution eventually becomes resistant to any colour changes at all. This variation is a nice demonstration of the properties of buffers.

## 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 colour 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-colour 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  $1 \times 10^{-7}$  M  $\text{H}_3\text{O}^+$  already present in the water that is ultimately responsible for the pH reaching this plateau of 7 and for the colour 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.

## Acknowledgement

Special thanks to Bob Becker, K.H.S., 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.

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

| Catalogue No. | Description                               |
|---------------|---|
| UJ0002        | Universal indicator solution, 500 mL      |
| HJ0014        | Hydrochloric acid solution, 0.1 M, 500 mL |
| SJ0149        | Sodium hydroxide solution, 0.1 M, 500 mL  |
| GP9146        | Glass demonstration tube, 24" long        |
| AP1500        | Parafilm® M, roll, 2" × 250', roll        |

Consult [www.flinnsci.ca](http://www.flinnsci.ca) or your *Flinn Scientific Canada Catalogue/Reference Manual* for current prices.