The "Rainbow Connection"

Acid–Base Indicators

Introduction

The procedure described in this publication provides a safe, alternative method using dilute acid and base solutions to produce the rainbow of color changes observed in the Rainbow Connection video presentation. Please see the *Tips* section for more information.

Concepts

- Acids and bases
- pH indicators

Materials

Beakers, 250-mL, 6

Dropping bottles, 6

Indicator solutions, 30 mL each:

Violet—0.45 g of phenolphthalein and 0.2 g thymolphthalein in 30 mL of 95% ethyl alcohol.

Blue—0.2 g of thymolphthalein in 30 mL of 95% ethyl alcohol.

Green—0.2 g of thymolphthalein and 2 g of p-nitrophenol in 30 mL of 95% ethyl alcohol. Add 5 drops of 1 M HCl to acidify.

Yellow—1 g of *p*-nitrophenol in 30 mL of 95% ethyl alcohol. Add 5 drops of 1 M HCl to acidify.

Orange—2 g of *p*-nitrophenol and 0.15 g phenolphthalein in 30 mL of 95% ethyl alcohol. Add 5 drops of 1 M HCl to acidify.

Red—1.5 g of *p*-nitrophenol and 0.75 g phenolphthalein in 30 mL of 95% ethyl alcohol. Add 5 drops of 1 M HCl to acidify.

Sodium hydroxide solution, NaOH, 0.01 M, 800 mL

Hydrochloric acid solution, HCl, 0.01 M, 1 L

Safety Precautions

Hydrochloric acid solution, although dilute, is severely corrosive to eyes, skin and other tissue. Sodium hydroxide solution, although dilute, is corrosive; skin burns are possible; very dangerous to eyes. The indicator solutions contain ethyl alcohol, which is a flammable liquid and a fire risk; keep away from heat and open flame. Wear chemical splash goggles, chemical-resistant gloves, and a chemical-resistant apron. Please review current Material Safety Data Sheets for additional safety, handling, and disposal information.

Preparation

1. Set up the six 250-mL beakers on an overhead projector or light box, or in front of the class.
2. Add 3 drops of "violet" indicator solution to the first beaker. Add 3 drops of "blue" indicator solution to the second beaker. Continue adding three drops of each of the other indicator solutions to the appropriate beakers.
3. Allow time for the solvent of each of the indicator solutions to evaporate.

Procedure

1. Add approximately 50 mL of the 0.01 M hydrochloric acid solution to each of the six beakers. All six resulting solutions should be clear.
2. Add approximately 75 mL of 0.01 M sodium hydroxide solution to each beaker. Each of the six solutions should change from clear to a color of the rainbow!
3. Add approximately 100 mL of the 0.01 M hydrochloric acid solution to each beaker. The solutions will once again be clear.

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Precise amounts of acid and base solutions are not important. Each addition of acid or base solution must neutralize the solution in the beaker and drive the pH in the opposite direction. All solutions can be poured into the large two-liter beaker. The resulting solution will be acidic and clear.

Disposal

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

Tips

- The indicators are dissolved in 95% ethyl alcohol. The alcohol will readily evaporate, leaving the indicator powder in the beaker—unseen to the observers of the demonstration.
- You may use drops of a more concentrated acid or base to change the solutions from colored to clear, or a more concentrated base to change the solutions from clear to colored.
- The "Rainbow Connection" experiment is a popular out-reach demonstration and appropriate for many age groups. This procedure provides instructions for the Rainbow Connection using dilute acid and base, which reduces the hazard of using strong acid or base. However, if you wish to prepare the solution of concentrated sulfuric acid in glycerin as shown in the video, mix 10 mL of concentrated sulfuric acid (18 M) in 20 mL of glycerin. This should be prepared in a hood with proper personal protective equipment. Place the beaker with the glycerin in a separate ice bath and very slowly add the sulfuric acid. Transfer to a dropper bottle. The presenter added 25 drops of the acid/glycerin solution in the center of the large 4-L container and set it aside for the end. As observed in the video, he also added 2 drops to each beaker before stirring vigorously to return the solutions to colorless.

Discussion

The three indicators used in this lab, phenolphthalein, thymolphthalein, and p-nitrophenol, are colorless in acidic solution. In a basic solution, phenolphthalein is red, thymolphthalein is blue and *p*-nitrophenol is yellow. Any color in the spectrum is possible using these primary colors.

The solvent of each indicator solution added to the beakers readily evaporates, leaving only a residue of the indicators on the bottom of each beaker. Students will not see this step of the procedure. They will only see the pouring of the acid and base solutions and the color changes. This demonstration can be done as a "magic" show. It is a great demonstration to get your students to look beyond what is happening and get them asking questions about how the disappearing rainbow occurs. Initially students might think the clear acid–base solutions contain a magical indicator. Knowing there is no such thing, have your students propose explanations for how these six colors could appear.

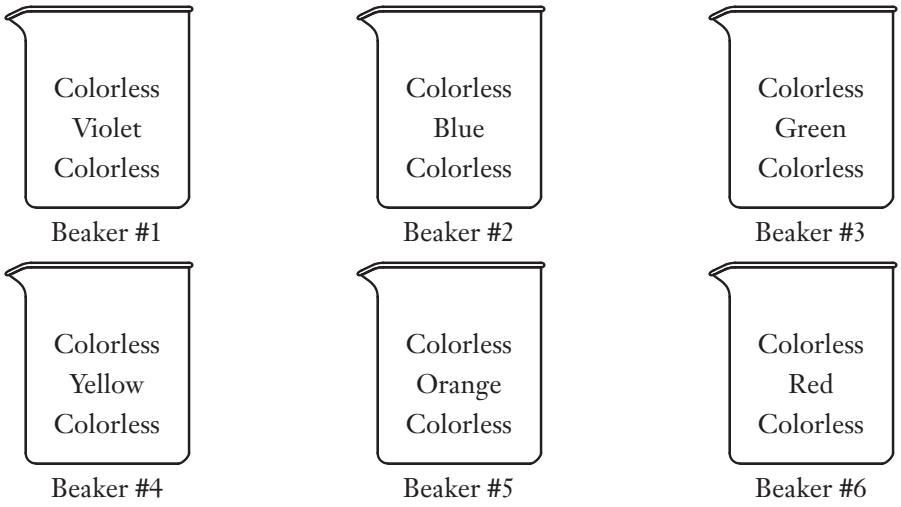
Connecting to the National Standards

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

Unifying Concepts and Processes: Grades K–12
Systems, order, and organization
Evidence, models, and explanation
Content Standards: Grades 5–8
Content Standard A: Science as Inquiry
Content Standard B: Physical Science, properties and changes of properties in matter
Content Standards: Grades 9–12
Content Standard A: Science as Inquiry
Content Standard B: Physical Science, chemical reactions

Answers to Worksheet Discussion Questions

1. Draw a diagram of the set-up. Include the chemicals that were added to the beakers. For each beaker, list the original color of the first solution, the color change after the second solution was added, and the final color after the third solution was added.



First solution: 0.01 M Hydrochloric Acid

Second solution: 0.01 M Sodium Hydroxide

Third solution: 0.01 M Hydrochloric Acid

2. Given that the two chemicals added to the beakers were an acid and a base, what kind of chemical must have already been present in the beakers to produce the color changes?

   An acid-base indicator must have been present in each beaker, since the solutions were different colors when a base, NaOH, was added than when an acid, HCl, was added.

3. Three indicators are used in this demonstration: phenolphthalein, thymolphthalein, and *p*-nitrophenol. Phenolphthalein is an indicator that is colorless in an acidic solution but pink-red in a basic solution. Thymolphthalein is also colorless in an acid, but blue in a base, and *p*-nitrophenol is colorless in an acid and yellow in a base. What indicator or combination of indicators was responsible for the color change in each beaker?

   Beaker #1 – thymolphthalein and phenolphthalein

   Beaker #2 – thymolphthalein

   Beaker #3 – thymolphthalein and p-nitrophenol

   Beaker #4 – p-nitrophenol

   Beaker #5 – phenolphthalein and p-nitrophenol

   Beaker #6 – phenolphthalein

Flinn Scientific—Teaching Chemistry™ eLearning Video Series

A video of *The "Rainbow Connection"* activity, presented by Jamie Benigna, is available in *Acid–Base Indicators,* part of the Flinn Scientific—Teaching Chemistry eLearning Video Series.

Materials for *The "Rainbow Connection"* are available from Flinn Scientific, Inc.

Materials required to perform this activity are available in the *Disappearing Rainbow—Chemical Demonstration Kit* available from Flinn Scientific. Materials may also be purchased separately.

Catalog No.	Description
AP8979	Disappearing Rainbow—Chemical Demonstration Kit
H0014	Hydrochloric Acid Solution, 0.1 M, 500 mL
S0149	Sodium Hydroxide Solution, 0.1 M, 500 mL
E0009	Ethyl Alcohol, 95%, 500 mL
N0073	Para-Nitrophenol, 25 g
P0017	Phenolphthalein, 25 g
T0072	Thymolphthalein, 1 g

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

The "Rainbow Connection" Worksheet

Discussion Questions

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