Rainbow in a Flask

Welcome to Chemistry

Introduction

A colorless solution is added to each of six beakers which results in each of the six beakers turning a different color of the rainbow.

Concepts

- Acid-base indicators

Materials

Hydrochloric acid solution, HCl, 0.1 M, 1 mL
Phenolphthalein indicator solution, 1%, 1 mL
p-Nitrophenol indicator solution, 3%, 1 mL
Sodium hydroxide solution, NaOH, 0.01 M, 1 L
Thymolphthalein indicator solution, 0.04%, 1 mL
Water, distilled or deionized
Beakers, 250-mL, 6
Graduated cylinder, 100-mL
Stirring rods, 6

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. Wash hands thoroughly with soap and water before leaving the laboratory. Follow all laboratory safety guidelines. 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 50 mL of deionized water to each of the six beakers.
3. Add 3–5 drops of 1% phenolphthalein indicator solution to the first beaker. Use a clean stirring rod to mix the solution. Add a drop of 0.1 M hydrochloric acid if the solution is not completely colorless.
4. Add 3–5 drops of 1% phenolphthalein indicator solution and 3–5 drops of 3% p-nitrophenol indicator solution to the second beaker. Use a clean stirring rod to mix the solution. Add a drop of 0.1 M hydrochloric acid if the solution is not completely colorless.
5. Add 3–5 drops of 3% p-nitrophenol indicator solution to the third beaker. Use a clean stirring rod to mix the solution. Add a drop of 0.1 M hydrochloric acid if the solution is not completely colorless.
6. Add 3–5 drops of 3% p-nitrophenol indicator solution and 3–5 drops of 0.04% thymolphthalein indicator solution to the fourth beaker. Use a clean stirring rod to mix the solution. Add a drop of 0.1 M hydrochloric acid if the solution is not completely colorless.
7. Add 3–5 drops of 0.04% thymolphthalein indicator solution to the fifth beaker. Use a clean stirring rod to mix the solution. Add a drop of 0.1 M hydrochloric acid if the solution is not completely colorless.
8. Add 3–5 drops of 1% phenolphthalein indicator solution and 0.04% thymolphthalein indicator solution to the sixth beaker. Use a clean stirring rod to mix the solution. Add a drop of 0.1 M hydrochloric acid if the solution is not completely colorless.

Procedure

1. Add approximately 75 mL of 0.01 M sodium hydroxide solution to the first beaker. The solution will turn red.
2. Add approximately 75 mL of 0.01 M sodium hydroxide solution to the second beaker. The solution will turn orange.

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3. Add approximately 75 mL of 0.01 M sodium hydroxide solution to the third beaker. The solution will turn yellow.
4. Add approximately 75 mL of 0.01 M sodium hydroxide solution to the fourth beaker. The solution will turn green.
5. Add approximately 75 mL of 0.01 M sodium hydroxide solution to the fifth beaker. The solution will turn blue.
6. Add approximately 75 mL of 0.01 M sodium hydroxide solution to the sixth beaker. The solution will turn purple.

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 neutralized and flushed down the drain with excess water according to Flinn Suggested Disposal Method #26b.

Tips

- Add a few milliliters of 3 *M* hydrochloric acid to each beaker to change the solutions from colored to clear. Add more base, such as 3 *M* sodium hydroxide, to see the color again.
- 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.

Discussion

Acid–base indicators are large organic molecules that behave as weak acids—they can donate hydrogen ions to water molecules to form their conjugate bases (Equation 1). The distinguishing characteristic of indicators is that the acid (HIn) and conjugate base (In–) forms are different colors.

$$\underset{\textit{(color A)}}{HIn(aq)} + H_2O \rightleftarrows \underset{\textit{(color B)}}{In^-(aq)} + H_3O^+(aq) \qquad \textit{Equation 1}$$

The abbreviation HIn represents an uncharged indicator molecule, and In– an indicator ion after it has lost a hydrogen ion. The color changes of acid–base indicators illustrate an application of reversible reactions and equilibrium. Because indicators are weak acids, the reaction summarized in Equation 1 is reversible. Reversible reactions can easily be forced to go in either direction, depending on reaction conditions. The actual color of an indicator solution thus reflects the position of equilibrium for Equation 1 and depends on the concentration of H_3O^+ ions (and hence the pH).

There are three possible cases. (1) All of the indicator molecules exist in the form HIn and the color of the solution is the color of HIn. (2) All of the indicator molecules exist in the form In– and the color of the solution is the color of In^-. (3) The solution contains varying amounts of the two forms and the resulting color is intermediate between that of HIn and In^-. The exact concentrations of H_3O^+ at which cases 1–3 will predominate depend on the structure of the indicator molecule and the equilibrium constant for Equation 1. Different indicators thus change color in different pH ranges.

For an open house or first week demonstration use this demonstration to stress the unique needs of a chemistry class. Make your own script or borrow the lines presented in the video including.

Make sure you have “red” your textbook.

“Orange” you glad you came to class.

Don’t be “yellow.” Do not be afraid to ask questions.

Go to a quiet place to study.

You “blue” this one. Don’t blow the next one.

Treat each other with respect—like royalty.

There will be a rainbow at the end of the course.

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 B: Physical Science, properties and changes of properties in matter
Content Standards: Grades 9–12
Content Standard B: Physical Science, chemical reactions

Flinn Scientific—Teaching Chemistry™ eLearning Video Series

A video of the *Rainbow in a Flask* activity, presented by Mike Roadruck, is available in *Welcome to Chemistry* and in *Open House Demonstrations*, part of the Flinn Scientific—Teaching Chemistry eLearning Video Series.

Materials for *Rainbow in a Flask* 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
P0019	Phenolphthalein Indicator Solution, 1 %, 100 mL
N0073	p-Nitrophenol, 25 g
T0079	Thymolphthalein Indicator Solution, 0.04 %, 100 mL
S0149	Sodium hydroxide, 0.1 M, 500 mL
H0034	Hydrochloric acid, 3 M, 500 mL

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