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Goldenrod Messages and Name Tags

Observation Skills

Introduction

Reveal a secret message by spraying a sign with a special liquid—and introduce Acids and Bases with a splash!

Concepts

- Acids and bases
- Indicators

Materials

Goldenrod paper, 2–3 sheets*
Ammonia, clear household

Variations:

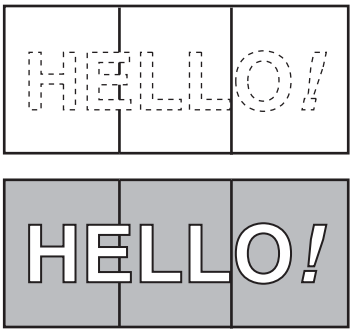
1-L beaker, or bottom half of a 2-L soda bottle
Vinegar, white
Large, flat rectangular plastic container with snap-on lid, such as a 2-quart Rubbermaid™ or Tupperware™ container
White candle
Spray bottle (with a "mist" setting)
Baking soda, $NHCO_3$
Q-tips®
Scotch® brand Magic™ tape or any clear tape that is nearly invisible on the paper

*Please see the *Tips* section.

Safety Precautions

Please review current Material Safety Data Sheets for additional safety, handling, and disposal information. Household ammonia solutions are slightly toxic by ingestion and inhalation; both liquid and vapor are extremely irritating, especially to the eyes. Wear chemical splash goggles, chemical-resistant gloves, and use in a well-ventilated room or perform under an operating fume hood.

Procedure



1. Before class, tape together 2–3 sheets of goldenrod paper, then flip them over so that the tape is on the back side.
2. Use candle wax to write a hidden message (such as "Hi!," "Hello!," "WOW!!"; or if you are using it to introduce the topic: "Acids & Bases" or "Indicators!"). Tape the sign up on the chalkboard. Brush aside any pieces of paraffin that might reveal the letters: the message should be invisible!
3. Place the household ammonia solution in the spray bottle. When the students have entered, spray the sign with the solution. The paper will immediately turn red, except for where the words were written, which will remain bright yellow—and the secret message will be revealed. Then, as the ammonia diffuses out and the sign dries, the message will fade—just in time for you to reuse it for the next class!

Disposal

All the solutions may be reused and the goldenrod paper can be either reused or disposed of in the trash.

Discussion

Reactions: ("HGr" = goldenrod indicator)

1. Inside the spray bottle and on the sign: $NH_3 + H_2O \leftrightharpoons NH_4^+ + OH^-$
2. Color change on the sign: $\underset{\text{(yellow)}}{HGr} + OH^- \leftrightharpoons \underset{\text{(red)}}{Gr^-} + H_2O$

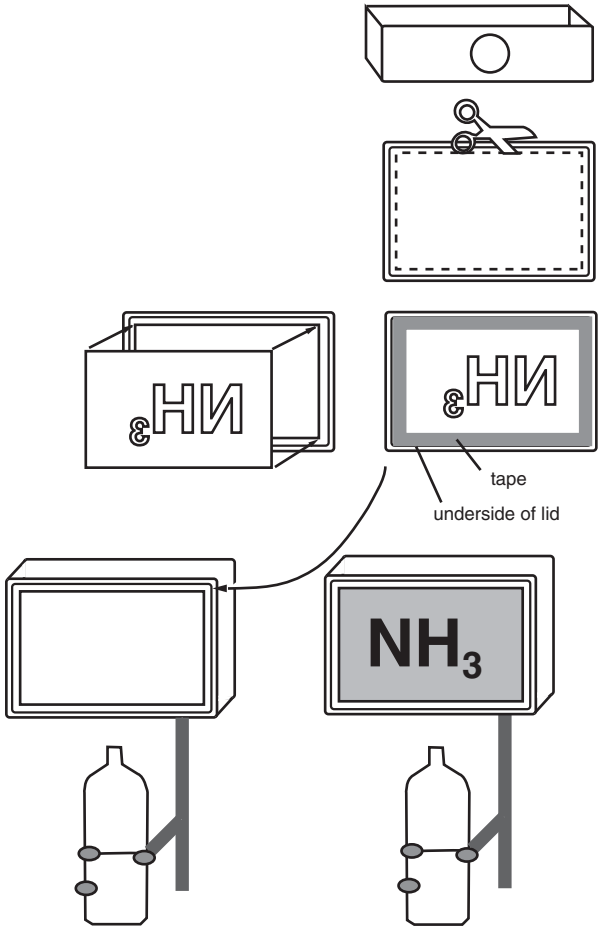
The first reaction shows how ammonia reacts as a base with water, producing OH^- ions. The second reaction accounts for the dramatic color change as the OH^- ions react with the indicator. Then, as NH_3 molecules on the sign diffuse out of solution and evaporate, the equilibrium is shifted to the left in reaction #1, using up the OH^- ions. As the OH^- concentration decreases, the equilibrium in reaction #2 also shifts to the left restoring the original yellow color. Along with illustrating the concepts of acid–base chemistry, indicators, diffusion and equilibrium shifts, these messages also demonstrate the phenomenon of selective solubility; for although the polar ammonia molecules dissolve quite readily in the polar water molecules, neither of the two mixes well with the nonpolar wax molecules and hence, the indicator beneath the wax remains yellow.

Tip

- Paper manufacturers have now switched virtually all paper production to acid-free paper. Acid-free paper, even when "goldenrod" in color, does not work in this demonstration. Thus, the paper required for this demonstration is no longer available from most source supply companies, including Flinn Scientific. If you have an existing supply of goldenrod paper, save it and reuse it for future demonstrations. The reversible color changes may be repeated many times.

Variations

1. Before you prepare the sign, and before the students have any awareness of the ability of goldenrod paper to undergo this dramatic color change, try this little prank: Tell the students about this remarkable liquid that has the ability to loosen up pores in a person's skin and then soften the veins and capillaries inside. Hold up a large beaker (remember your safety glasses), half-filled with this liquid (actually, ammonia, but they don't need to know that yet). Cautiously submerge your hand in the liquid—maybe grimace as you tell them it stings a little. Continue to explain that this liquid is being tested as a new way of obtaining blood samples: that instead of using a needle, medical professionals can just soak a person's hand in this for a minute or two and then literally shake the blood out. (Students: "Ooo . . . gross!") Then go to the board to show them how the blood can be shaken out of your hand . . . but wait, you don't want to get the board all bloody. Pick up a nearby piece of scrap paper (which just happens to be goldenrod), hold it up to the board with one hand and slap it with the other hand that has been soaking in the ammonia. "Blood" spatters across the entire sheet! Then, while their jaws are still on the floor, pick up the spray bottle and spray the sign next to it: "Gotcha!" What a way to introduce acids and bases! To avoid an onslaught of parent phone calls that night, make sure the students are aware that it was ammonia causing an indicator color change, and not actually your blood on the wall!
2. Instead of using candle wax to write the sign, use Scotch® brand Magic™ tape (or any nonvisible adhesive tape). Although it may take longer to write the messages, the letters appear much cleaner and sharper.



3. Use baking soda solution instead of ammonia. The message forms more slowly, and it does not fade since baking soda is a nonvolatile solute. If you want a message that appears quickly and doesn't fade, just use a combination of ammonia and baking soda solution.

4. Start off with goldenrod paper that has been soaked in 2% baking soda solution and dried—so it starts off dark red. Prepare the sign, as before, but this time spray it with some vinegar! Now the effect is just the opposite: the letters remain dark red while the rest of the paper turns bright yellow.

5. Rather than making a message and spraying it, simply post up some goldenrod paper (and some pretreated red goldenrod paper), then use a bundle of cotton swabs dipped in ammonia and/or baking soda solution (or vinegar) to "paint" a message. Students can do this at their desks, as a combination art/science activity. This technique can also be used for making colorful name tags the first day of class!

6. Although the ammonia-sprayed signs described above are infinitely reusable, the paper does tend to wrinkle in the areas around the wax or tape that gets wet, and the effect is somewhat diminished. In the following variation, the paper never gets wet and the message, written in crisp tape letters, remains completely invisible for as many times as you do the demonstration. Fill a small flask or soda bottle half-full of concentrated ammonia solution, cap or stopper the bottle to contain the ammonia fumes. Obtain a large flat plastic container with a snap-on lid (such as a Rubbermaid™ or Tupperware™ food-storage container). Make a hole in one side large enough for the the flask or bottle neck to be easily inserted.* Then cut a rectangular hole in the lid; make the hole as large as possible, yet still retaining a 12–14 mm border between the hole and the sealing groove of the lid. Now cut out a rectangle of goldenrod paper 10–12 mm longer and 10–12 mm wider than the hole in the lid. Use clear tape to write a short message backwards on the paper, then tape the paper to the inside (underside) of the lid. Use tape all along the border to make a tight seal. Then snap the lid in place; make sure the message is right-side-up with the hole on the bottom side of the container—no tape should be visible at all (see figure on previous page). When you are ready to show the demonstration to your students, simply clamp the bottle of ammonia solution to a ring stand for stability, remove the cap or stopper (*Caution:* wear goggles; good ventilation is required), and slide the container down on top of the bottle so that the hole covers the neck of the bottle. The message will gradually appear (forwards, not backwards) as the ammonia diffuses up and dissolves from the back side of the paper. Best of all, the message "develops" from the top of the sign down, showing that ammonia gas (with a molar mass of only 17 g/mol) is less dense than air. Lift off the container (and reseal the bottle of ammonia), and watch as the image gradually fades. Because it stays dry, the same sign can be used over and over again, and will always appear as good as new.

   * This hole may either be cut with a utility knife or with a drill, or it may be melted through by heating the mouth of a large test tube in a burner flame for 5–10 seconds, then pressing it against the plastic container to initiate the hole. Continue heating and pressing against the same spot until a hole is melted completely through.

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 9–12
Content Standard A: Science as Inquiry
Content Standard B: Physical Science, structure and properties of matter, chemical reactions

Answers to Worksheet Discussion Questions

1. Describe what happened in this demonstration.

   A piece of yellow paper was sprayed with ammonia, and the paper turned red, except for a message that had been written on the side with wax. Eventually the paper fades back to yellow.

2. The solution in the spray bottle is ammonia.

   a. Write an equation for the reaction of ammonia with water.

   $NH_3 + H_2O \leftrightharpoons NH_4^+ + OH^-$

   b. Is ammonia an acid or a base?

Ammonia is a base.

3. Goldenrod paper contains an acid–base indicator. What is the color of this indicator in acid? What is the color of this indicator in base?

   The goldenrod indicator is yellow in an acid and red in a base.

4. Why does the sign eventually turn yellow again?

   NH_3 molecules on the sign diffuse out of solution and evaporate, and equilibrium shifts to the left. This uses up the OH^- ions, and as the concentration of OH^- decreases, the color fades back to yellow.

Acknowledgment

Special thanks to Bob Becker of Kirkwood High School in Kirkwood, MO, for providing us with the idea and the instructions for this activity.

Special Acknowledgments

Demonstrators have been using secret messages (made visible by means of a chemical reaction) for many years, but these messages usually involve a great deal of preparation and cost—often for just a one-time use. When Bob learned from a colleague, Marie Sherman, that the dye used in some brands of goldenrod paper acts as indicator, he decided to try using the goldenrod to make signs. Most of the variations were developed at Miami University in Oxford, Ohio, as part of a development grant initiated by Mickey Sarquis and her department.

Flinn Scientific—Teaching Chemistry™ eLearning Video Series

A video of the *Goldenrod Messages and Name Tags* activity, presented by Jeff Hepburn, is available in *Observation Skills* and in *Natural Indicators and Household Substances,* part of the Flinn Scientific—Teaching Chemistry eLearning Video Series.

Materials for the *Goldenrod Messages and Name Tags* are available from Flinn Scientific, Inc.

Catalog No.	Description
A0038	Ammonia, Household, 1 L
AP9113	Goldenrod Paper, pkg/100
C0192	Candles, White, pkg/4

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

Goldenrod Messages and Name Tags Worksheet

Discussion Questions

1. Describe what happened in this demonstration.

2. The solution in the spray bottle is ammonia.

   a. Write an equation for the reaction of ammonia with water

   b. Is ammonia an acid or a base?

3. Goldenrod paper contains an acid–base indicator. What is the color of this indicator in acid? What is the color of this indicator in base?

4. Why does the sign eventually turn yellow again?