Dry Ice Rainbow of Colors

Weak Acids and Bases

FLINN SCIENTIFIC CHEM FAX!

Introduction

Add a small piece of solid carbon dioxide to a colored indicator solution and watch as the solution immediately begins to "boil" and change color.

Concepts

- Sublimation
- Acid–base indicators

Materials

Ammonia, household, 5 mL
Beakers, 1-L, 5†
Beakers, 100-mL, 5
Dry ice nuggets, 5 (size of walnuts)
Gloves, insulated type (for handling dry ice)
Water, distilled or deionized (tap water will also work)
Wood splint (optional)

Indicator solutions
- Bromcresol green, 0.04% aqueous, 2 mL
- Bromthymol blue, 0.04% aqueous, 2 mL
- Methyl red, 0.02% aqueous, 2 mL
- Phenol red 0.02% aqueous, 2 mL
- Universal indicator, 2 mL

†Alternatively, use 400- or 600-mL beakers or 2-L plastic soda bottles with the top third cut off.

Safety Precautions

Dry ice (solid carbon dioxide) is an extremely cold solid (–78.5 °C) and will cause frostbite. Do not touch dry ice to bare skin; always handle with proper gloves. Household ammonia is slightly toxic by ingestion and inhalation; the vapor is irritating, especially to the eyes. Universal indicator solution contains alcohol and is therefore flammable. 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 five 1-L beakers (or other large transparent containers) in clear view on a demonstration table.
2. Fill each with approximately 750 mL of distilled water (about ¾ full).
3. Add 2 mL of indicator to the water in the beakers, in the following order:*

Beaker (Before)	Indicator (After)	Basic Color	Acidic Color	pH Range
1	Bromcresol green	Blue	Yellow-green	5.4 to 3.8
2	Universal indicator	Purple	Orange	10 to 4
3	Phenol red	Red	Yellow	8.4 to 6.8
4	Methyl red	Yellow	Red	6.2 to 4.4
5	Bromthymol blue	Blue	Yellow	7.6 to 6.0

**The suggested order shown in the table produces a colorful arrangement of solutions, but any order is OK.*

Each indicator should begin in the basic range and change to the acidic range upon addition of CO_2 (dry ice). The color changes for each of the indicator solutions from basic to acidic are shown in the table above.

4. Add 1 mL of household ammonia to the beakers containing universal indicator and bromthymol blue.
5. The indicator solutions should now all be in their basic color range. If they are not, add ammonia dropwise to obtain the basic color as indicated in the table above. Avoid adding excess ammonia or the colors will take too long to change when dry ice is added.
6. Set up reference solutions in the five 100-mL beakers by pouring approximately 70 mL from each large beaker into its corresponding small beaker. Set the reference beakers next to their corresponding large beakers.

Publication No. 91729
061616

Procedure

1. Use insulated gloves to add a nugget of dry ice (about the size of a walnut) to each beaker of prepared (basic) indicator solution. The dry ice immediately begins to sublime. Vigorous bubbling occurs and a heavy white vapor appears. Shortly afterwards, each indicator solution changes color to its acidic color (see table above).
2. Have students make observations about the temperature of the solutions and of the vapor. Have students feel the sides of the beakers. Notice that the vapor is cool (rather than hot) to the touch, as are the water solutions. Explain to the students that "boiling" does not always occur at high temperature—a common misconception—and that the solution is not actually boiling. The solution appears to be boiling because there is such a large temperature difference between the water and the dry ice (see *Discussion* section).
3. *(Optional)* Take a burning or glowing splint and place it in the vapor. The flame will be extinguished due to the CO_2 gas.

Disposal

Please consult your current *Flinn Scientific Catalog/Reference Manual* for general guidelines and specific procedures governing the disposal of laboratory waste. All materials may be disposed of according to Flinn Suggested Disposal Method #26b. Extra dry ice may be placed in a well-ventilated area and allowed to sublime.

Tips

- The indicator solutions in the beakers can be reused from class to class by adding a small amount of household ammonia, dropwise, after the demonstration is complete. Care must be taken not to make the solutions too basic or else the color changes will not occur.
- Plastic soft drink bottles that are cut off at the narrowing point also work well in place of the large beakers.
- Slabs of dry ice can be broken or cracked using a hammer. Wrap the dry ice slab in a towel or place in a zipper-lock bag before striking it with a hammer. Dry ice may be obtained from a local ice cream store or ice company. Look in your local yellow pages under ice or dry ice. Dry ice costs may vary from $8.00 to $13.00 per 10 lbs, but some sources may supply it free for educational purposes. Dry ice may also be made using the Dry Ice Maker, Flinn Catalog No. AP4416.
- If the prepared indicator solutions sit in the open air for too long (especially the phenol red), they will begin to change color as CO_2 from the air dissolves in the solution, making it acidic. Adding slightly more ammonia will change the solutions back to their basic color.
- If distilled or deionized water is not available, use tap water. Be sure to adjust the pH appropriately as some tap water does not have a neutral pH.
- Try other indicators that change color at a pH of near neutral, such as neutral red (yellow to red, 8.0 to 6.8) and bromcresol purple (purple to yellow, 6.8 to 5.2).
- Use the universal indicator overhead color chart (Flinn Catalog No. AP5367) to follow pH changes in the universal indicator solution.

Discussion

Dry ice is solid carbon dioxide (CO_2). The temperature of dry ice is –78.5 °C (or –109.3 °F), making it extremely cold to the touch. Carbon dioxide is normally found in the gaseous state, making up approximately 0.04% of our atmosphere. It is a colorless, odorless, noncombustible gas with a faint acid taste. Dry ice is made by cooling atmospheric air and compressing the solid into desired forms, such as blocks, nuggets, pucks, etc. The different gases that make up atmospheric air (nitrogen, oxygen, etc.) condense at different temperatures, and therefore may be easily separated. Carbon dioxide forms a frosty, white solid at –78.5 °C. As a solid, carbon dioxide can cause frostbite on contact with skin and will stick to moist tissue (such as wet skin or your tongue). Solid carbon dioxide undergoes sublimation upon exposure to air. This means it transforms directly from the solid phase to the gaseous phase without melting to a liquid.

When dry ice is placed in water (as in this demonstration), it sublimes rapidly since the water is so much warmer than the dry ice. The solution appears to boil. As the dry ice sublimes to gaseous CO_2, some of the gas bubbles away quickly and some dissolves in the water. A heavy white cloud of condensed water vapor forms above the liquid due to the coldness of the escaping CO_2 gas. As the CO_2 gas dissolves in the water, the solution becomes more acidic from the production of carbonic acid (H_2CO_3), a weak acid, according to the following equation:

$$H_2O + CO_2 \rightleftarrows H_2CO_3$$

The indicators change to their acidic forms as the pH levels of the solutions drop, producing a color change. The time required for the change to occur depends on the initial pH of the solution, the transition point of the indicator, and how much dry ice was added to the solution.

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
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.

Answers to Worksheet Discussion Questions

1. Describe the physical changes observed in this demonstration, i.e, color changes, etc.

There were five beakers set up, each of which contained solutions of different colors. Dry ice was added to the beaker, and the solutions bubbled vigorously. A thick white vapor appeared above the beakers, and it looked like the solutions were boiling. The solutions underwent the following color changes:

Beaker #1 – blue to yellow-green

Beaker #2 – purple to orange

Beaker #3 – red to yellow

Beaker #4 – yellow to red

Beaker #5 – blue to yellow

When a burning wooden splint was held in the vapor, the flame was extinguished.

2. Explain how the color changes were produced.

Each beaker contained an acid–base indicator. Respectively, these indicators were bromcresol green, universal indicator, phenol red, methyl red, and bromthymol blue. The indicators were responsible for the color changes, as they are different colors in an acid than they are in a base. The original colors in the beakers were due to ammonia, a base. The other chemical was dry ice, which is solid carbon dioxide. The carbon dioxide reacted with the water to produce carbonic acid, which made the solutions acidic and therefore caused the color changes.

3. When the dry ice was added, the solutions appeared to boil. How hot were the beakers while this was going on? How is this possible?

   The beakers were actually cool to the touch. The dry ice was undergoing sublimation, a process in which a solid becomes gaseous without first melting to a liquid. Since the water was much warmer than the dry ice, the gas bubbled away very quickly, making it appear as though the solutions were boiling.

4. As the dry ice underwent sublimation, it let off carbon dioxide gas into the air and some CO_2 dissolved into the water. Write a balanced chemical equation showing the reaction between the carbon dioxide gas and the water.

   $H_2O + CO_2 \leftrightarrows H_2CO_3$

Acknowledgment

Flinn Scientific would like to thank Lee Marek, Chemistry teacher, Naperville North H.S., Naperville, IL for bringing this demonstration to our attention to share with other teachers.

Flinn Scientific—Teaching Chemistry™ eLearning Video Series

A video of the *Dry Ice Rainbow of Colors* activity, presented by Lee Marek, is available in *Weak Acids and Bases*, part of the Flinn Scientific—Teaching Chemistry eLearning Video Series.

Materials for *Dry Ice Rainbow of Colors* are available from Flinn Scientific, Inc.

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

Catalog No.	Description
AP6201	Dry Ice Color Show—Chemical Demonstration Kit
AP4416	Dry Ice Maker
SE1031	Gloves, Cotton and Canvas
AP5367	Universal Indicator Overhead Color Chart

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

Dry Ice Rainbow of Colors Worksheet

Discussion Questions

1. Describe the physical changes observed in this demonstration, i.e, color changes, etc.

2. Identify all the chemicals used in this demonstration. What role did they serve?

3. When the dry ice was added, the solutions appeared to boil. How hot were the beakers while this was going on? How is this possible?

4. As the dry ice underwent sublimation, it let off carbon dioxide gas into the air and some CO_2 dissolved into the water. Write a balanced chemical equation showing the reaction between the carbon dioxide gas and the water.