

Solubility of Carbon Dioxide

Dry Ice Color Show



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

- Carbon dioxide gas
- Sublimation
- Acid–base indicators

Materials

Ammonia, household, NH_3 , 5 mL

Beakers, 1-L, 5

Beakers, 100-mL, 5

Dry ice nuggets, 5–10

Gloves, insulated type

Water, distilled or deionized

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

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 in clear view on a demonstration table.
2. Fill each with approximately 750 mL of distilled water (about $\frac{3}{4}$ full).
3. Add 2 mL of indicator to the water in the beakers, in the following order:

Beaker	Indicator	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

Each indicator should begin in the basic range and change to the acidic range upon addition of dry ice. The color changes from basic to acidic are shown in the table.

4. To the beakers containing universal indicator and bromthymol blue, add 1 mL of household ammonia.
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. 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.

Procedure

1. Use insulated gloves to add one or two nuggets of dry ice to each beaker of 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 on page 59).
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.
3. (*Optional*) Take a burning or glowing splint and place it in the vapor. The flame will be extinguished due to the carbon dioxide 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.

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 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, structure and properties of matter, chemical reactions

Tips

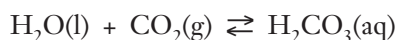
- The indicator solutions in the beakers can be reused from class to class by adding a small amount of household ammonia, dropwise, after the demonstration is complete. Care must be taken not to make the solutions too basic or else the color changes will not occur.
- Slabs of dry ice can be broken or 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 vary from about \$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 carbon dioxide 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.
- Tall-form beakers or hydrometer cylinders give a nice presentation in this demonstration. “Dry Ice Color Show” is

available as a chemical demonstration kit from Flinn Scientific (Catalog No. AP6201).

Discussion

Dry ice is solid carbon dioxide (CO_2). The temperature of dry ice is $-78.5\text{ }^\circ\text{C}$ (or $-109.3\text{ }^\circ\text{F}$), 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 $-78.5\text{ }^\circ\text{C}$. 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 sublimates rapidly since the water is so much warmer than the dry ice. The solution appears to boil. As the dry ice sublimates 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:



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.

Supplementary Information

This demonstration illustrates the sublimation of dry ice—the conversion of carbon dioxide directly from the solid state to the gaseous state. Liquid carbon dioxide cannot be observed at atmospheric pressure. It is possible, however, to obtain carbon dioxide in the liquid state, that is, to observe the melting of dry ice, by warming the dry ice in a closed system. Consider the following simple experiment.

1. Place a small nugget of dry ice in the bulb of a jumbo plastic pipet.
2. Fold over the stem of the pipet, clamp it firmly using a pair of heavy-duty pliers, and place the pipet bulb into a plastic cup half-filled with water.
3. As the dry ice warms up, it is converted to gaseous carbon dioxide. The pressure inside the pipet increases due to the buildup of carbon dioxide gas in the closed system. When the internal pressure reaches 5.2 atm, the dry ice melts and then boils!

The triple point of carbon dioxide occurs at a temperature of $-57\text{ }^\circ\text{C}$ and a pressure of 5.2 atm. This is the point at which all three phases of a substance (solid, liquid, and gas) exist together at equilibrium. For any given substance, there is one and only one specific temperature and specific pressure point at which this can happen.

Note the safety precautions implicit in the experimental procedure described above.

- The dry ice is contained in a small, soft, plastic container. When the container is pressurized, it may explode, but if it does, the explosion will be minimal (although you will get wet).
- The pipet bulb is placed in a plastic cup of water, which serves as a heat sink and also keeps the bulb soft and supple.

Reference

This activity was adapted from *Chemistry of Gases*, Volume 8 in the *Flinn ChemTopic™ Labs* series; Cesa, I., Editor; Flinn Scientific: Batavia, IL (2003).

Materials for *Solubility of Carbon Dioxide* are available from Flinn Scientific, Inc.

Catalog No.	Description
A0038	Ammonia, Household
SE1031	Gloves, Insulated
B0064	Bromcresol Green Indicator Solution, 0.04%
B0173	Bromthymol Blue Indicator Solution, 0.04%
M0159	Methyl Red Indicator Solution, 0.02%
P0100	Phenol Red Indicator Solution, 0.02%
U0009	Universal Indicator Solution

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