Make a Triple Point Apparatus

Student Laboratory

Introduction

View carbon dioxide in the solid, liquid, and gas forms simultaneously using a simple triple point apparatus made by you right in the laboratory!

Concepts

- Sublimation
- Phase diagrams
- Triple point

Background

We have all observed what occurs when dry ice (solid state of carbon dioxide, CO_2) is removed from a freezer. As the temperature on the surface of the dry ice increases above –78 °C, the solid changes directly to a vapor bypassing the liquid phase. This spontaneous change from a solid to a gas is called *sublimation*. Sublimation of CO_2 occurs when the temperature is above –78 °C at a pressure of 1 atm, standard atmospheric pressure. Standard pressure on Earth is 1 atm. Liquid CO_2 is not stable under Earth's standard pressure, and therefore does not exist under normal pressure conditions. Refer to the phase diagram, Figure 1.

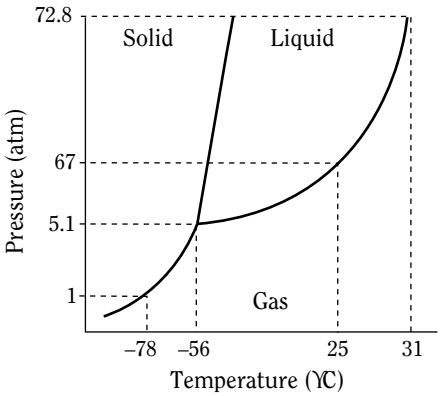

Figure 1. Phase diagram of carbon dioxide.

A phase diagram has temperature as the independent (x) and pressure as the dependent (y) axis. According to the phase diagram that the liquid phase of CO_2 is stable only under a pressure of 5.2 atm or higher, at a temperature above –57 °C. The junction where the gas, liquid, and solid phases all exist in equilibrium is called the triple point. When a substance is at the triple point, all three phases are present simultaneously.

The terms melting point (solid to liquid) and boiling point (liquid to gas) are often used when discussing phase changes. Such values refer to the temperature at which a phase change occurs at a pressure of 1 atm only. When working under different pressure conditions, these terms do not apply. It would be inaccurate to say that the carbon dioxide has reached its melting point when the liquid CO_2 becomes present during the lab, since the pressure in the pipet will be above 1 atm.

Materials

- Dry ice pieces
- Water, tap
- Cup, clear plastic
- Forceps
- Pipets, wide-stem, 6
- Pliers
- Ruler
- Scissors

Safety Precautions

Dry ice is extremely cold, avoid direct contact with skin. Handle only with heavy cloth gloves and never with wet hands. Frostbite is possible with only brief exposure. 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.

Publication No. 10710
061616

Procedure

1. Using scissors, cut the tip off a plastic, wide-stem pipet so that the stem is about 7 cm in length as shown in Figure 2.

Figure 2.

2. Fill a plastic cup half-full with lukewarm water.
3. Obtain crushed pieces of dry ice according to your teacher's instructions.
4. Using forceps, carefully place the pieces of dry ice into the pipet until the bulb is half-full.
5. Fold the top of the pipet stem down and clamp it tightly shut with pliers. Immediately place in the cup of water.
6. View the bulb from the side of the cup. Look for signs of melting and boiling. Release the pressure by unclamping the pliers and observe what happens.
7. Clamp the pipet shut again. Is there evidence of all three phases of carbon dioxide in the pipet? If the pressure is allowed to build up inside the pipet the bulb may pop. Prepare to be splashed!

Post-Lab Questions

1. In your own words, explain the terms *triple point* and *sublimation*.

2. Under what conditions would one observe carbon dioxide in the liquid phase?

3. Rewrite the following statements by adding or removing words to make them completely true.

   "Carbon dioxide is always a gas at temperatures above –57 °C."

   "Liquid CO_2 is not stable."

4. You just observed something relatively few people have seen—liquid CO_2! Explain how a high-pressure environment was created, therefore allowing this to occur.

5. What purpose did the water serve in this experiment?

Teacher's Notes

Make a Triple Point Apparatus

Materials (for a class of 24 working in groups of 3)

Dry ice, large chunk approximately 1 lb.
Water, tap
Cups, clear plastic, 8
Forceps, 8
Hammer
Pipets, wide-stem, 48
Pliers, 8
Rulers, 8
Scissors, 8

Preparation

Dry ice should be obtained the day of the lab. A Styrofoam® cooler works well for transporting the dry ice and for short term storage. Dry ice may be obtained from ice cream shops, gas supply companies, or made using a dry ice maker.

Using a hammer or heavy weight, break tennis ball size clumps of dry ice from a large block of dry ice. Wrap the dry ice chunks inside a paper towel or durable plastic bag and pulverize the dry ice into small pieces using the side of the hammer or other large weight. The ice pieces must be smaller than the hole in the pipet barrel.

Disposal

Please consult your current *Flinn Scientific Catalog/Reference Manual* for general guidelines and specific procedures governing the disposal of laboratory waste. Allow remaining dry ice to sublime in a fume hood or well-ventilated room.

Connecting to the National Standards

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

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, motions and forces, conservation of energy and increase in disorder, interactions of energy and matter.

Tips

- The lab may be performed as a demonstration, however a ChemCam® camera (Flinn Catalog No. AP4560) is recommended so that all students can easily view the demonstration.
- It's easy for students to get wrapped up in exploding the pipets and making splashes—as written the lab provides enough materials for each student to make two tripple point apparatuses.
- This laboratory also presents a good opportunity to discuss the various units that are used when measuring pressure. When the pipet is opened and the pressure is released, solid carbon dioxide is formed almost instantaneously due to a reduction in temperature and pressure. The temperature decrease is due to rapid vaporization (boiling) of liquid CO_2 to gaseous CO_2 The heat of vaporization of carbon dioxide is roughly 16 kJ/mole, whereas the heat of fusion is 9 kJ/mole. The energy required boil the liquid lowers the temperature of the system and causes the liquid carbon dioxide to freeze.

$CO_2(l) \rightleftarrows CO_2(g)\ \Delta H_{vap} = 16$ kJ/mole

$CO_2(l) \rightleftarrows CO_2(s)\ \Delta H_{fus} = 9$ kJ/mole

Answers to Post-Lab Questions *(Student answers will vary.)*

1. In your own words, explain the terms *triple point* and *sublimation*.

   Students answers will vary. Accept all reasonable answers.

2. Under what conditions would one observe carbon dioxide in the liquid phase?

   A pressure of at least 5.2 atm and a temperature above –56 °C.

3. Rewrite the following statements by adding or removing words to make them completely true.

   "Carbon dioxide is always a gas at temperatures above –57 °C."

   "Carbon dioxide is always a gas at temperatures above –57 °C, unless the pressure is 5.2 atm or greater."

   "Liquid CO_2 is not stable."

   "Liquid CO_2 is not stable under standard pressure."

4. You just observed something relatively few people have seen—liquid CO_2! Explain how a high-pressure environment was created, therefore allowing this to occur.

   As the dry ice sublimated, CO_2 gas built up inside the closed system (pipet) causing the pressure to increase.

5. What purpose did the water serve in this experiment?

   Water warmed the dry ice, causing it to sublime at a faster rate. It kept the pipet frost-free so that the contents could easily be viewed. It also worked as a shield to keep the cold contents from splashing onto students when the pipets exploded.

Materials for *Make a Triple Point Apparatus—Student Laboratory* are available from Flinn Scientific, Inc.

Catalog No.	Description
AP8480	Pipet, Wide-Stem, pkg. 500
AP4416	Dry Ice Maker
AP4443	Pliers, Slip-Joint
AP4436	Hammer

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