Solid Nitrogen

Phase Changes and Phase Diagrams

Introduction

If boiling is indeed an endothermic process, then shouldn't it be possible to boil a liquid until it freezes? In this very simple, yet elegant demonstration, liquid nitrogen is placed in a bell jar and once the pressure is decreased to about 0.14 atm, the boiling nitrogen quickly freezes over!

Concepts

- Gas Laws—Pressure, volume, and temperature
- Kinetic molecular theory

Materials

Liquid nitrogen, 100 mL
Bell jar, glass
Bowl, small, dark-colored, at least 15-mm deep
Clay, modeling
Dewar flask, demonstration
Gloves, high/low temperature, insulated
Pump, vacuum
Styrofoam® cup
Syringe tip cap
Syringe, plastic, 10-mL
Tubing, vacuum
Vacuum plate

Safety Precautions

Liquid nitrogen is very, very cold. The extremely low temperature may cause frostbite almost immediately. Never handle liquid nitrogen without protection. Wear insulated gloves, chemical splash goggles, and a chemical-resistant apron. Do not work with liquid nitrogen in an enclosed or poorly ventilated area. Nitrogen gas will tend to displace the air, limiting the amount of oxygen in the area, and may cause asphyxiation. 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

If the bell jar is one in which the air is removed through a small hole in the center of the base, then poke a small hole (1–2 cm diam) in the side of the Styrofoam cup, and place the cup upside-down on the base and place the small bowl on top. Open the syringe on the 1.0-mL mark and screw on the cap. Use the putty to stand it upright on the bell jar base along side the inverted cup as shown in Figure 1.

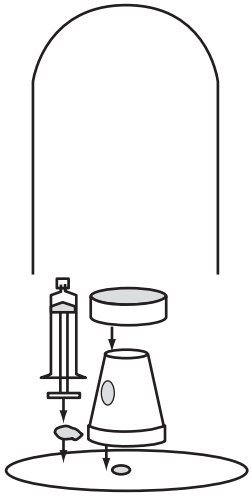

Figure 1.

Procedure

1. Fill the bowl with liquid nitrogen to a depth of about 10–12 mm.
2. Place the bell jar over the set up.
3. Turn on the pump and observe the surface of the liquid nitrogen and the reading on the syringe.

Disposal

Please consult your current *Flinn Scientific Catalog/Reference Manual* for general guidelines and specific procedures governing the disposal of laboratory waste. Excess liquid nitrogen may be allowed to evaporate in a well ventilated area.

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Tips

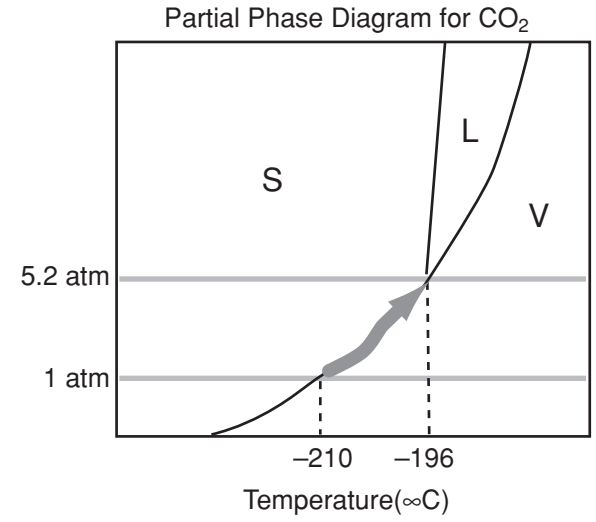
- Liquid nitrogen is available from local welding supply houses or universities. Look up "Gases, liquid" or "Welding supply" in the Yellow Pages. The cost ranges from approximately $2 to $8 per liter. In rural areas, liquid nitrogen may be used by local farmers or veterinarians to freeze cattle sperm.
- A Dewar flask is needed to transport the liquid nitrogen. Do not use the demonstration flask. Providers of liquid nitrogen will often lend or rent out the use of a Dewar flask. Some schools share a Dewar flask because of the expense and infre quent use.
- If a Dewar flask is unavailable, a good temporary substitute would be a Styrofoam cube that 2.5-liter acid bottles are shipped in. The cube can hold a large amount of liquid nitrogen and the Styrofoam is a very good insulator.

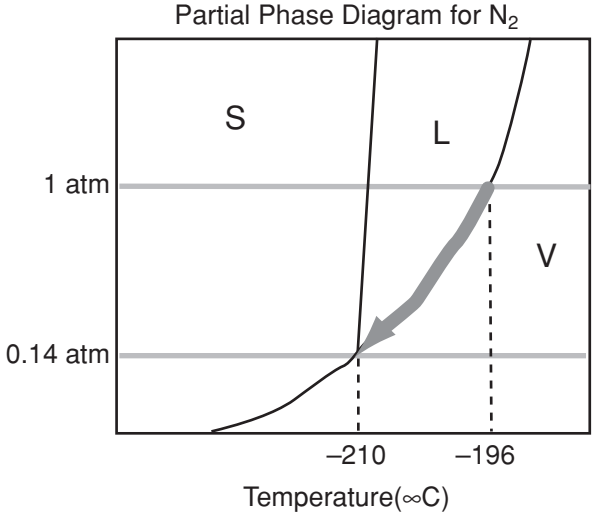
Discussion

As soon as the pump is turned on, the syringe volume begins to increase (Boyle's Law: as pressure decreases, volume increases). At a volume of about 7.0 mL—and a pressure therefore of about one-seventh of an atmosphere (0.14 atm)—the puddle of bubbling liquid nitrogen quickly freezes over. This shell of nitrogen ice then pops open as the boiling beneath it ruptures it, and a new solid layer quickly forms. If the hose connection to the bell jar can be opened slightly to allow air back in, the puddle quickly melts again, only to freeze once more when the connection is re-established.

This demonstration can be discussed on many levels, including nitrogen's phase diagram, since we are witnessing the triple point of nitrogen. At the triple point, one can witness all three phases (solid, liquid and vapor) and all three processes (melting, boiling and subliming) simultaneously.

In the case of nitrogen, we start out at a pressure above the triple point, and so we have to decrease the pressure. We start at nitrogen's normal boiling point of 1 atm and –196 °C. As the pressure on the liquid nitrogen decreases, so does the boiling point. Since the sample is at –196 °C and the boiling point has dropped down to, for example, –197 °C, the liquid nitrogen can be considered a super-heated liquid, existing momentarily at a temperature just above its boiling point. This results in extra vigorous boiling, which is quite easy to observe, and this in turn results in a subsequent drop in the temperature, for boiling is an endothermic process. But as the temperature drops to –197 °C, the pressure has gone down further, and so has the boiling point—to –198 °C. Thus the sample gradually slides down the boiling line all the way to the triple point as shown in the phase diagram at right. If the pressure is quickly restored on the solid nitrogen in the bell jar, it spontaneously changes back into a liquid as it climbs back up the boiling line.





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 5–8
Content Standard B: Physical Science, properties and changes of properties in matter, motions and forces

Content Standards: Grades 9–12
Content Standard B: Physical Science, structure and properties of matter, motions and forces, interactions of energy and matter

Flinn Scientific—Teaching Chemistry™ eLearning Video Series

A video of the *Solid Nitrogen* activity, presented by Jeff Hepburn and Mike Heinz, is available in *Phase Changes and Phase Diagrams*, part of the Flinn Scientific—Teaching Chemistry eLearning Video Series.

Materials for *Solid Nitrogen* are available from Flinn Scientific, Inc.

Catalog No.	Description
AP8938	Dewar Flask, Wide-Mouth Demonstration, 2 L
AP8560	Dewar Flask, Storage, 4 L
AP6655	Bell Jar
AP3240	Gloves, High/Low Temperature, Insulated
AP8958	Syringe Tip Cap
AP1730	Syringe, without Needle, 10-mL
AP8618	Vacuum Plate
AP1597	Vacuum Pump
AP8789	Vacuum Tubing, 10 ft

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