States of CO_2

Kitchen Table Demonstration

The Rundown

Time: 15 minutes-45 minutes
Content: Phase changes, phase diagrams
Safety Concerns: Minimal
Materials Availability: Small purchases required

**Adapted from "Wet Dry Ice Lab." Flinn Scientific

Students are aware of the temperature dependence of phase changes. Since most students have only studied phase changes at constant pressure (1 atm), they do not have an appreciation for the influence of pressure. In the following demonstration, students will be able to view all three phases of carbon dioxide by increasing the pressure and temperature.

Content Application

- State changes
- Phase diagrams

Enduring Understandings

- Sublimation occurs when a substance changes directly from a solid to a vapor.
- An object's state depends on both temperature and pressure.
- For any given temperature and pressure, certain states of matter are stable and others are not.

Chemistry

A substance's **physical state** is the form that matter takes at a given temperature and pressure. Four states of matter have been recognized including solid, liquid, gas, and plasma.

Phase diagrams are graphs that indicate what states are stable under various conditions of temperature and pressure. They show us that terms like melting point and boiling point are actually misleading. They only apply when pressure is constant. In reality, one must examine a line to appreciate the conditions that allow melting or boiling to occur.

The following demonstration provides students with three relatively rare experiences. First, they will be able to witness **sublimation**, the direct phase change from solid to vapor. This readily occurs for dry ice (solid carbon dioxide) at room temperature and standard pressure. Second, students will observe carbon dioxide as a liquid. Third, students will see the triple point of carbon dioxide. The **triple point** of a substance is the a specific temperature and pressure at which all three phases (solid, liquid, and gas) can exist at equilibrium.

Materials

- Dry ice (available at grocery stores)
- Hammer
- Plastic pipettes (wide stem)
- Pliers
- Clear solo cups (short with flexible sides)
- Metal bar and nail assembly (Figure 1)

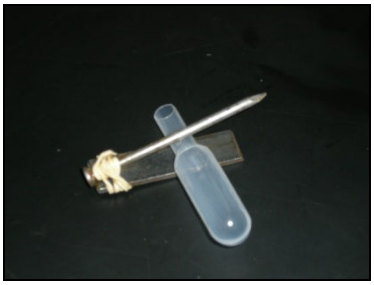


Figure 1. Bar and nail assembly- a nail is attached to a small bar of metal using a rubber band. Pliers will be used to seal the pipette bulb by squeezing the nail and metal bar together.

Safety

- Goggles
- Touching dry ice causes burns
- Do not overload pipette with dry ice
- Demonstration should always occur under water. The water captures any CO_2 or plastic that may be released when the pipette explodes.

Procedure

Dry ice can often be purchased at grocery stores. It is important to call ahead to be sure that it is available. It's best to purchase it on the morning of the demonstration, as the dry is will sublime quickly. The dry ice will keep longer if it is stored in a small cooler under a significant amount of balled up newspaper.

Figure 2. Pressure builds as the pipette bulb is sealed by squeezing the bar and nail assembly with pliers.

1. Cut the stem off of a wide-stemmed plastic pipette as shown in Figure 1.
2. Use a hammer to smash a block of dry ice into smaller chunks. Using the pliers, place a chunk of dry ice into a piece of newspaper. Close the newspaper and smash the dry ice with a hammer until it has the consistency of snow.
3. Fill the pipette bulb half-way using a scoping motion. It will appear as the image on the front.
4. Attach the metal bar and nail assembly as pictured in Figure 1.
5. Tightly squeeze the metal bar and nail together with the pliers as pictured in Figure 2. This should be done in the Solo cup under water. Ultimately, pressure will build and the pipette bulb will explode. This is a small and soft explosion that will cause some of the water to exit the cup.
6. Observe the bulb from the side. As the pressure builds, the dry ice will start to melt. You can turn the liquid back to solid by releasing the pliers and lowering the pressure. Gas will be released from the bulb.
7. Squeeze the metal and nail together. After melting begins you will soon see the liquid boil. Shortly after, the pipette bulb will expand rapidly and will explode. Any remaining CO_2 will once again exist as a solid.
8. As an additional demonstration, try putting a small piece of dry ice in water.

Disposal

- When exposed to the air, dry ice will eventually sublime into a gas.

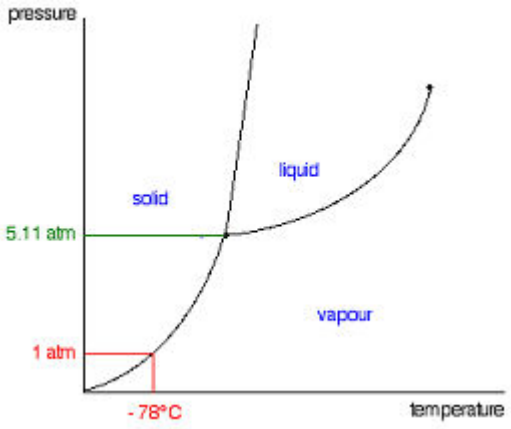
Follow-Up and Student Participation

The demonstration can be done quickly by a teacher in front of the class. However, there is value to letting students complete the activity in small groups. Obviously, this requires more dry ice, equipment, and time.

Try the following follow-up activities:

1. Ask students to come up with explanations for the following:
   - What changes occurred that led to the state changes you observed?
   - What is misleading about "melting point" and "boiling point"?
   - Is it possible to have boiling ice water? Explain.

2. Examine the following phase diagram. In several concise statements, explain what you observed in the demonstration/activity.



3. Draw a labeled phase diagram for water. Assume that it has the same basic shape as the diagram above.

4. What is the triple point? Identify the triple point on each phase diagram.