Liquid Nitrogen Ice Cream

Demonstration

Explore the properties of liquid nitrogen while making a tasty treat. This demonstration is great for club/chapter socials and smaller outreach events.

Number of Participants: 2 – 20

Audience: Middle (ages 11-13) and up

Duration: 10-30 mins

Difficulty: Level 2

Materials Required:

- Liquid nitrogen (typically in a dewer)
- Gloves meant for cold materials
- Steel Bowl with wooden spoon
- Small serving cups with spoons

- Small batch ingredients*
  - 2 cup whole milk
  - 1 cup heavy cream
  - 1 Tablespoon pure vanilla
  - 4 Tablespoon (1/4 cup) sugar
- Large batch ingredients*
  - 1/2 gallon whole milk
  - 1 quart heavy cream
  - 4 Tablespoon pure vanilla
  - 1-1.25 cup sugar
- Optional: chocolate syrup, sprinkles, nuts, fruit bits, caramel, whipped cream

Setup:

1. Set out materials.

2. Pour milk and cream into steel bowl. A 2-1 ratio is good for whole milk to cream. You can adjust the ratio to taste.

*Can replace milk and heavy cream with coconut/soy/cashew milk and creamer as a dairy free option.

3. Add pure vanilla. Note that there is a wide variety in the quality of vanilla and amount should be added to taste.

4. Add 1/2 of the desired sugar while mixing slowly. Be sure to move the crystals on the bottom. Add remaining sugar to taste.

5. Slowly pour liquid nitrogen into bowl while continually and vigorously stirring with wooden spoon. Continue to add in liquid nitrogen and stir until mixture is thick but not hard. Adding too much liquid nitrogen will result in very hard ice cream. If it becomes too hard to stir, you've added too much. You want to introduce air into the mixture to make it smoother.

6. Serve only after all liquid nitrogen has evaporated. Material might soften quickly on warm days – it is ok to refreeze the mixture with additional liquid nitrogen before serving.

7. Optional: Participants can add toppings to their ice cream.

Presenter Brief:

Caution should be exercised when using liquid nitrogen. Wear gloves and safety goggles when handling. Students will want to be very close to the mixture but remember that liquid nitrogen can burn people if in contact with skin. Discuss the thermodynamics of materials, how liquid nitrogen is made, and what ice cream is while making it for the audience.

Vocabulary:

- Phase change – when a material changes from one form of matter to another (e.g. liquid to solid)
- Phase diagram – a plot of pressure vs. temperature for a specific substance.
- Emulsion - a mixture of two or more liquids that normally are unmixable (e.g. oil/fat and water)
- Ice cream emulsion – when milk fats disperse (mix) into a mixture of water, sugar, ice, and air bubbles

Physics & Explanation:

Middle (ages 11 - 13) and general public:

Liquid nitrogen is typically made from air. Air is about 78% nitrogen. Hence, nitrogen is a clear, odorless gas at atmospheric temperature and pressure. A useful way to look at what conditions make a substance liquid or solid is through a phase diagram. We can

examine what phase a material is in by knowing its environmental pressure and temperature. Below are phase diagrams for water and nitrogen.

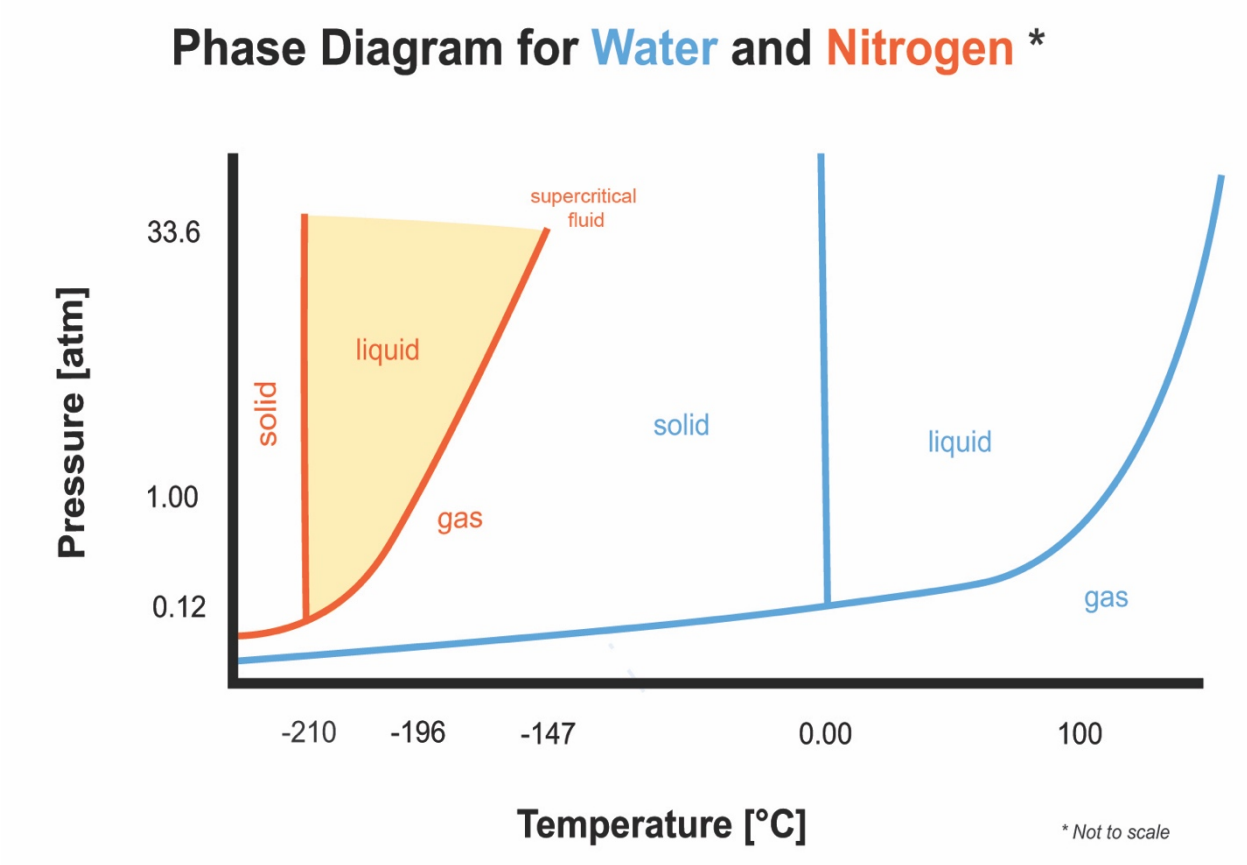

Figure 1 A graph comparing phases of nitrogen, and water for reference. The yellow highlight is the window of environmental conditions that nitrogen can exist in a liquid state. Given the window in liquid nitrogen can exist, it is not found on Earth naturally.

🔑 Nitrogen has to be at an extremely low temperature to be in a liquid phase.

There is no pressure at room temperature at which nitrogen can exist as a distinct liquid. Cold temperatures are needed. At atmospheric pressure, the temperature needs to be between -210 and -196° C, as shown in nitrogen's phase diagram. At higher pressures, slightly warmer (between -196 and -147° C) temperatures can achieve liquid phase. Most liquid nitrogen is produced through compressing air, letting the resultant gas cool, and repeating the process until it liquifies. This is typically done in very large machines on an industrial scale.

Once nitrogen is liquified, it is very cold at room pressure. Specifically, it's about 77 K (or 196 ºC) and will boil if taken out into an average room on Earth. It's not wrong to say that the liquid is boiling because the room is very warm compared to the liquid. Liquid nitrogen is very effective at cooling. Everything it touches will become very cold in a very short amount of time. Liquid nitrogen is so cold that it will freeze water very quickly and even change the structural properties of other materials it touches. Going from the

cold insulated dewer to air temperature, nitrogen quickly phases from liquid to gas. The liquid appears to be smoking because as it boils it's lowering the temperature of the surrounding air, causing it to not to be able to hold as much water vapor. The water vapor forms small water droplets, or fog, just like you see early in the morning or over the ocean.

Additional Resources:

- Reading phase diagrams http://chemed.chem.purdue.edu/genchem/topicreview/bp/ch14/phase.php
- Ice cream recipe inspiration https://www.thekitchn.com/the-4-bases-to-know-for-making-homemade-ice-cream-221723
- The process of putting nitrogen into liquid phase https://www.brainstuffshow.com/blogs/how-do-they-make-liquid-nitrogen.htm