10.2 Liquid nitrogen and Charles' Law

Subjects: Behavior of gases, ideal gas law, Charles' Law

Description: Various experiments are performed with liquid nitrogen.

Materials:
Small balloons (water balloon size or long narrow balloons)
Regular size balloon
Shallow dish (use crystallization dish on prep shelf)
Liquid nitrogen in a dewar◊
Insulating gloves
Tongs for handling balloons
Small Tupperware container
Racquet ball (optional)
Fruit or vegetable to freeze – flower, parsley works well (optional)◊

◊Advanced prep item: Get LN_2 ahead of time. Instructor to provide parsley or flower.

Pre-class prep:
1. Blow up balloons (at least 5-7) and immerse in liquid nitrogen.
2. Blow up regular sized balloon to fit in crystallization dish.

Procedure:
Demo 1:
1. Place one last balloon in the dewar with the other balloons.
2. Remove all balloons like a magician's hat and allow to inflate.

Demo 2:
1. Put the regular balloon in the crystallization dish.
2. Pour liquid nitrogen over the balloon. Remove from cold and allow to inflate.

Demo 3:
1. Place parsley or flower in dewar for ~1 minute
2. Smash on bench top.
(Repeat with racquet ball if desired)

Demo 4:
1. Fill Tupperware half way with liquid nitrogen
2. Cap with lid, Tupperware lid will pop off

Discussion:
Charles' Law describes the relationship between temperature and volume. If a given quantity of gas is held at a constant pressure, its volume is directly proportional to temperature. The relationship is given by the equation below:

$V = C_c \times T$

Where C_c is a proportionality constant.

The temperature of liquid nitrogen is 77K (-196°C or -321°F). When an object is immersed in liquid nitrogen, it freezes rapidly and becomes brittle, allowing it to break easily.

When the liquid nitrogen is poured into a container and sealed, the rapid evaporation of the liquid creates a high pressure in the container, causing the lid to pop off.

Safety: Liquid nitrogen is extremely cold and can cause hypothermia or burns. Use insulating gloves and safety glasses while performing the demonstration.

References:

1. Prof. Botch
2. Oliver-Hoyo, M., Switzer, W. L. *J. Chem. Educ.* **2005**, 82, 251.
3. NCSU Department of Chemistry Lecture Demonstration website:
http://www.ncsu.edu/project/chemistrydemos/DemoList.html
4. University of Illinois at Urbana-Champaign Chemistry department Lecture demonstration web site:
http://www.chem.uiuc.edu/clcwebsite/gases.html