**ACTIVITY: Liquid nitrogen demonstrations**

**Activity idea**

In this activity, students observe the teacher demonstrating changes in the properties of common substances when cooled with liquid nitrogen.

By the end of this activity, students should be able to:

* realise that the properties of materials are often temperature-sensitive
* recognise that the boiling point of liquid nitrogen is extremely low
* show awareness of the potential hazards that exposure to liquid nitrogen can invoke
* explain in simple terms the reason behind the main changes occurring in each of the demonstrations.

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**Introduction/background**

Demonstrations of the changes in the properties of matter due to rapid and extensive cooling with liquid nitrogen have a spellbinding and entertaining effect on science students.

Cooling with liquid nitrogen at -196°C can have a marked change on the properties of common materials.

Most demonstrations involve either a change of state, a drastic change in physical property or simply a physical property.

Behind each of these changes and effects are explanations based on current understandings of the properties of matter.

***Safety notes and concerns***

Liquid nitrogen is a potentially dangerous material.

Although not a poisonous gas, if allowed to build up in an enclosed space, nitrogen could result in a lowering of the normal oxygen percentage composition of 19.5% to a lower and potentially harmful level.

Use only in a large, well ventilated space.

The possibility of freeze burns represents a much more serious threat.

This does not mean that the demonstration itself is dangerous, but it does mean you must be careful:

* Nitrogen can spatter (possibly in eyes) while being poured. Wear goggles whenever pouring or dumping nitrogen. Be aware of trapped liquid nitrogen in a glove or shoe. If the liquid nitrogen can freely run off the skin, it is far less likely to cause serious harm than if trapped.
* Flying chunks of frozen objects could cause eye injury. Use a thermally insulating glove and/or tongs to handle any object going into or out of nitrogen.
* Students will want to reach out and touch nitrogen or other cold objects. Teachers must stress to their students the importance of not touching frozen objects or nitrogen.
* Use a liquid nitrogen Dewar for temporary storage and movement.

**What you need**

Tongs

Thermally insulating glove

Liquid nitrogen

Whistling kettle

Conical flasks

Water

Candle

Water bomb

Balloon

Small toy rubber ball

Hammer

Liquid mercury

Beaker

bowl

**What to do**

1. Properties of liquid nitrogen:
* Place some liquid nitrogen in a whistling kettle. As the liquid boils (BP of N2(l) is -196°C), the N2(g) produced escapes, activating the whistle.
* Place about 100mL of N2(l) into a 250mL conical flask. Into a separate flask, add about 100mL of water. Swirl the contents of each flask and note how long it takes for the swirling motion of each of the liquids to abate. The low viscosity of N2(l) compared to that of liquid water is responsible for the difference.
* Pour a small amount of liquid nitrogen onto a flat surface. Beads of liquid are seen to travel smoothly and rapidly. The beads are floating on a cushion of cold gas produced by the rapidly boiling liquid.
1. Volume change on going from liquid to gas:
* Pour some N2(l) onto the floor of the lab and note its rapid transformation to N2(g). 1mL of N2(l) at -196°C will transform into 691mL of N2(g) at 15°C. This is a huge volume change. If a 5L Dewar of N2(l) was accidentally spilled in an enclosed space such as a storage room of dimensions 2m x 2m x 2.5m, over a third of the air in the room would be displaced by the N2(g) generated. This would have the effect of reducing the level of O2(g) in the room to levels that would be harmful to operators not wearing respirators. **When working with liquid nitrogen, do so only in a well ventilated space.**
1. N2(g) does not support combustion:
* Set up a burning wax candle. Carefully pour N2(g) from a thermos flask containing a small amount of N2(l). As the O2(g) rich air is displaced by the N2(g), the flame is extinguished.
1. Water egg:
* With tongs, place an egg-sized rubber water bomb in a container of N2(l) for about 30 seconds. Remove with tongs and carefully remove the rubber coating. You are left with a ‘water egg’ – ice on the outside and water on the inside. Since ice is a very good insulator (an igloo makes use of this!), the outer ice prevents the inner water from solidifying.
1. Balloon size:
* Inflate a standard balloon to a volume of about 1L. Using tongs to hold the balloon, carefully cool it by immersing in N2(l). Note the size reduction of the balloon.
* Using tongs, remove the balloon and allow it to warm up slowly to room temperature. Note the steady increase in volume as this happens.
* If air was an ideal gas, according to Charles Law, the volume at -196°C should be 258.4mL – one-quarter of its original size. However, the volume decrease is much greater than this because nitrogen does not behave ideally at such low temperatures. The water portion freezes out at 0°C, the CO2 fraction solidifies out at -78°C and the oxygen fraction liquefies at -183°C. The balloon is virtually volumeless. Gases expand and contract by appreciable amounts when heated and cooled.
1. Elasticity changes:
* Demonstrate the bounciness of a small toy rubber ball.
* Holding the ball with tongs, immerse it in N2(l) for 30 seconds.
* Remove the ball and, holding it a gloved hand, test its bounciness.
* Hit the ball with a hammer – it should shatter. By removing internal energy from the molecules comprising the rubber ball, the elasticity of the ball has been compromised. It is now a brittle solid, easily shattered by a strong hammer blow.
1. Freezing of mercury:
* Place a small sample of liquid mercury into a 100mL beaker. Discuss with the class some of its physical properties:
* Density 13.5 gmL-1 (dense, heavy metal).
* Boiling point 356.7°C.
* Melting point -38.9°C (liquid over the range -38.9 to 356.7°C).
* Vapour pressure 0.0018 mm Hg at 25°C. (Compared with water at 23.8 mm Hg, this is an extremely low value.)
* Carefully lower the beaker into a bowl of N2(l) and swirl the contents. A lump of solid mercury forms, which can be lifted out with a pair of tongs and displayed to the class. (A discussion of some of the myths surrounding the hazardous nature of elemental mercury could be considered at this point.)

**Discussion questions**

* Why is liquid nitrogen less viscous than liquid water?
* Why is nitrogen a relatively chemically inert gas?
* What benefits do the insulating properties of ice bring to horticulturists in New Zealand?
* What is an ideal gas?
* From the particle of matter perspective, what is going on when an explosion occurs?
* What makes rubber an elastic material at room temperature but not at very low temperatures?

**Extension ideas**

* How is liquid nitrogen produced?
* Investigate experimentally Boyle’s law and Charles’s law.
* When liquid helium is cooled to -271°C, it becomes a super fluid. What properties do such fluids show?
* The prefix ‘cryo’ comes fro a Greek word meaning ‘very cold’. Investigate what is meant by the terms ‘cryogenics’, ‘cryoelectronics’ and ‘cryonics’.