Safe Handling of Cryogenic Liquids

This document describes the principal hazards and appropriate safety procedures associated with three cryogenic liquids that are commonly used in the College: liquid N_2, He and O_2.. The safe handling of cryogenic liquids involves understanding the unique properties of these materials and ensuring that appropriate safety precautions are taken at all times.

Physical Properties

The attached table indicates several physical properties of liquid nitrogen, helium and oxygen. These cryogenic liquids have boiling points below -180 C and are normally used at atmospheric pressure. Thus, they are constantly boiling during use.

Cryogenic liquids are typically odorless and colorless when vaporized to the gaseous state. Most of them have no color as a liquid although liquid oxygen is light blue. However, the extremely cold liquid and vapor have a built in warning property as the cold boil off gases condense moisture in the air, creating a highly visible fog.

Hazards of Cryogenic Liquids

Contact with and destruction of living tissues

Since all cryogenic liquids and their cold "boil-off" vapors are extremely cold they can rapidly freeze human tissue and cause frostbite. Even a brief contact with a cryogenic liquid is capable of causing tissue damage similar to that of thermal burns. Prolonged contact may result in blood clots.

Pressure Build-Up/Explosions

Cryogenic liquids exhibit large volume exchange ratios which can cause rapid pressure changes. One volume of liquid nitrogen, for example, will vaporize to approximately 700 volumes of nitrogen gas when warmed to room temperature at one atmosphere. In addition, all cryogens can condense sufficient moisture from the air to block the opening in storage vessels. This condition can result in an explosion caused by the build up of trapped vapor in the container. As a result, it is critical to contain these liquids in insulated dewars with pressure relief valves (see "Safe Handling Procedures" below).

Flesh tearing and materials embrittlement

The touching of uninsulated containers or other materials that have been cooled by cryogenic liquids can cause serious skin injuries. The extremely cold surface of the cooled material will cause the flesh to stick fast and tear when one attempts to withdraw from it. Even non-metallic materials are dangerous to touch at low temperatures. In addition to the hazards of frostbite or flesh sticking to cold materials, objects that are soft and pliable at room temperature, are easily broken because they become hard and brittle at extremely low temperatures and will easily fracture.

Boiling and splashing

Cryogenic liquids can boil or splash when added to a warm container or when inserting warm objects in the liquid. Always perform these operations slowly to minimize boiling and splashing.

Oxygen enrichment

Cryogenic liquids with a boiling point below that of liquid oxygen (i.e. nitrogen and helium each have boiling points lower than oxygen's boiling point) have the ability to condense oxygen out of the air if exposed to the atmosphere. Violent reactions (e.g. rapid combustion or explosions) may occur if the system or process is not compatible with liquid oxygen (see below).

Accelerating combustion effect of liquid oxygen

Oxygen is not flammable, but it vigorously accelerates and supports combustion. Substances that burn in air will burn more vigorously in oxygen. Do not permit liquid oxygen or oxygen rich atmosphere to come into contact with organic materials or flammable substances of any kind. Some organic materials which can react violently with liquid oxygen include oil, grease, asphalt, kerosene, cloth, tar and dirt.

Oxygen deficiency/Asphyxiation

All cryogenic liquids have a significant potential for creating an oxygen deficient environment. Because of their large liquid to gas expansion ratios, even small quantities of liquefied gas can expand to displace large amounts of oxygen, thereby rendering the atmosphere in a confined area lethal. Without adequate oxygen, one can lose consciousness in a few seconds and die of asphyxiation in a few minutes.

Personal protective equipment

Eye protection

Safety glasses must be worn at all times while handling cryogenic liquids, because the liquid is almost always boiling and can splash into the eyes. Safety goggles provide the best protection for the eyes. When filling dewars or transferring cyrogenic liquids from one container to another, face shields must also be worn.

Hand protection

When cryogenic liquids are spilled on the skin, a thin gaseous layer apparently forms next the skin. This thin layer protects the skin from freezing, provided the contact with the cryogen is brief and in small quantities.

The most likely cause of frostbite to the hands and body is by contact with cold metal surfaces. Because there is no protective layer of gas formed, frostbite will occur almost instantaneously when touching surfaces that have been cooled by cryogenic liquids. Hand protection is primarily required to guard against the hazard of touching cold surfaces. Loose, non-asbestos insulating gloves that can be easily removed may be worn. The use of an insulated pot holder is the preferred method of handling cold surfaces. Never use rags to handle cold surfaces. Use tongs to add or remove materials from cryogenic liquids.

Protective clothing

Closed toed shoes are required when handling cryogenic liquids. Long cuffless trousers which cover the neck of the shoes should also be worn. Long sleeve shirts are also recommended for arm protection. An apron made of leather or other material recommended for use with cryogens is indicated when large quantities of cryogen hare handled.

Safe Handling Procedures

Preparation

1. Always be familiar with the hazards of the liquid in use.
2. Work in an open, well-ventilated location.
3. Ensure that safety glasses and if necessary face shields are worn.
4. Have pot holders or appropriate gloves on hand.
5. Examine containers and pressure relief valves for signs of defect. Never use a container which has defects.
6. Any exposed glass areas of dewars should be taped to prevent the generation of broken glass projectiles in the event the container implodes.
7. Ensure that all equipment and containers are free of oil, grease, dirt or other materials which may create a hazardous condition upon contact with the cryogenic liquid. Researchers should wash their hands and arms with soap and water, rinsing and drying thoroughly prior to handling the liquid. Clothing should be relatively clean.
8. Select working materials carefully. Cryogenic temperatures may alter the physical characteristics of many materials.

Transfer and use

1. Use only fitted transfer tubes designed for use with the dewar container. Damaged transfer tubes should be replaced. Do not handle transfer tubes with bare hands as the fitting is not insulated.
2. When transferring into a secondary container, do not fill the secondary container to more than 80% of capacity (60% if the temperature is likely to be above 30 C).
3. Do not lower experiments into storage dewars unless provisions have been made to vent the dewar and prevent freezing in the narrow neck.
4. Immediately re-cap any container to prevent atmospheric moisture from entering and forming an ice plug.
5. Provide proper venting for the dewars used in experiments
6. Use care in transporting fragile cryogenic containers. Use a hand truck for transport. Always transport cryogenic liquids in service elevators when available.

Storage

1. Store in a well ventilated area to prevent buildup of flammable gases or air displacement.
2. Use only approved storage vessels having pressure relief valves.
3. Avoid contact of moisture with storage containers to prevent ice plugging of relief devices.
4. Periodically check container necks for ice plugging; core out plugs if present.
5. Keep all sources of ignition away from cryogenic liquids.

First Aid

If medical attention is needed following a skin or eye exposure to a cryogenic liquid, immediately call 9-911 and then call 2-9090 (the College Emergency Action Directors line). All personnel using cyrogenic liquids must also be familiar with first aid procedures for treating frostbite:

1. Warm the affected area of the body rapidly by immersion in water not to exceed 105 F, with body heat, or by exposure to warm air. In the event of massive exposure, the emergency shower should be used to warm the body. All clothing must be removed prior to showering. Maintain the affected area of the victim at normal body temperature until medical help arrives.

2. Calm the victim and avoid aggravating injury. People with frostbitten feet should not walk on them. Do not rub or massage the affected parts of the body.

3. Prevent infection--use a mild soap to clean the affected area. Dressings need not be applied if the skin is intact.

4. If affected, flush eyes with warm water for 15 minutes.

Physical Properties of Cryogenic Liquids		Helium (He)	Nitrogen (N_2)	Oxygen (O_2)
Boiling Point (1 atm)	Fahrenheit	-452	-320	-297
	Celsius	-268	-196	-183
	Kelvin	5	77	90
Melting Point (1 atm)	Fahrenheit	NA[1]	-346	-362
	Celsius	NA[1]	-210	-219
	Kelvin	NA[1]	63	54
Density at Boiling Point (1 atm)	lb./cu ft	7.8	50	71
	kg/m3	124.94	800.9	1137.3
Heat of Vaporization at Boiling Point	Btu/lb.	8.72	85.6	91.7
	kJ/kg	20.28	199.1	213
Volume expansion ratio, liquid at 1 atm and boiling point to gas at 70 F and 1 atm		745	696	860
Flammable		No	No	No[2]

1. Helium does not solidify at 1 atm
2. Oxygen does not burn, but supports and accelerates combustion. However, high concentration oxygen atmospheres substantially increase combustion rates of other materials and may form explosive mixtures with other combustibles.

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