CRYOGENIC TECHNOLOGY

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Cryogens are substances (liquids or fluids) that can maintain extremely low temperatures , usually (below –150 °C, –238 °F or 123 K). and are often used in the field of cryogenics.

They are typically gases at room temperature but become liquids when cooled. Cryogens can also be referred to as cryogenic fluids.

Cryogenic technology can be defined as the study of the production of low temperature fluids, measurements at low temperatures, and behavior of these materials at low temperature and how to produce them. It is also concerned with the application of low temperature processes and techniques

Low temperature is the temperature obtained by liquefaction of gases whose critical temperatures is below terrestrial temperature. The common gases, which can be liquefied, are: Nitrogen, oxygen, air, hydrogen and helium.

Cryogenic fluids are developed at extremely low temperatures. These are generally fluids which at atmospheric pressure has a boiling point below 25oc . Cryogenic fluids are kept in metallic thermos flasks called Dewar's flasks. These flasks are never sealed, otherwise there would be a danger or a risk of explosion due to pressure build up as the liquids inside evaporates to form gasses.

Characteristics of Cryogens:

1. Low Boiling Points: Cryogens have boiling points significantly lower than room temperature.
2. Phase Changes: They exist as gases at ambient temperatures and can be converted to liquids through cooling and increased pressure.
3. Thermal Conductivity: Many cryogens possess high thermal conductivity, making them effective for transferring heat.

EXAMPLES OF CRYOGENIC FLUIDS

(a) Liquid nitrogen

Have a boiling point of 77. 3^o k at 760mmhg. It is normally a safe refrigerant because it is chemically inner and neither explosive or toxic. in the laboratory, its used for

(i) Maintaining an intermediate heat sink between theroom temperature and other parts that are supposed to be maintained at low temperatures
(ii) Providing pre-cooling in liquefies and refrigerants
(iii) Pre- cooling apparatus that will later beused at lower temperatures
(iv) Cooling adsorbents used for purifyinggases e.g. cold traps

(b) Liquid oxygen

Have a boiling point of 90.2°k at 760mmhg (at atmospheric pressure). It can also be used as a refrigerant, but care should be taken when handling it because serious explosions can occur due to its chemical actions with hydrocarbon substances e.g. lubricating oil, grease etc. it also supports combustion.

(c) **Liquid hydrogen** Have a boiling point of 20.4 °k at 760mmhg? It is nowadays produced in large quantities as a rocket fuel. It ignites so fast and these make it unsafe in the laboratories. It can also be used as a pre-coolant.

(d) Liquid helium

Have a boiling point of 4.2°k , at 760mmhg. It is by far the most commonly used refrigerant for works at temperatures below that of liquid nitrogen. Its safe compared to liquid oxygen and hydrogen.

NB all liquid refrigerants can cause cold burns if they are kept in contact with the skin and therefore put on protective clothing and goggles

Table 1 Common cryogens and their properties

Cryogen	Boiling point (1 atm) oC (oF)	Critical pressure psiga	Liquid density, g/L	Gas density (27oC), g/L	Liquid-to-gas Expansion ratio	Type of gas
Ar	-186(-303)	710	1402	1.63	860	Inert
He	-269(-452)	34	125	0.16	780	Inert
H2	-253(-423)	188	71	0.082	865	Flammable

N2	-196(-321)	492	808	2.25	710	Inert
O2	-183(-297)	736	1410	1.4	875	Oxidizer
CH4	-161(-256)	673	425	0.72	650	Flammable

Why Cryogens?

The use of cryogens is vital for several reasons:

1. Low Temperature Applications: Many scientific and industrial processes require low temperatures to function effectively, such as superconductivity in materials and certain chemical reactions.

2. Preservation: Cryogens are widely used for preserving biological samples, such as sperm, ova, and tissues, at low temperatures to maintain viability.

3. Material Properties: Low temperatures can change the properties of materials, enhancing their strength and durability for specific applications.

4. Research: Cryogenic temperatures allow researchers to explore new physical phenomena, such as quantum mechanics and superconductivity.

Production of Cryogens

The production of cryogens involves several processes:

1. **Fractional Distillation**: Commonly used for the production of liquid air components (e.g., nitrogen and oxygen) by cooling air and separating its components based on boiling points.

2. **Cryogenic Cooling**: Techniques such as Joule-Thomson expansion or Stirling refrigeration are employed to produce cryogens from gases.

3. **Electrolysis**: Used for producing hydrogen, which can be further cooled to create liquid hydrogen.

4. **Gas Compression and Expansion**: Gases can be compressed and then allowed to expand to achieve cryogenic temperatures.

Hazards Associated with Cryogens

Cryogens can pose several hazards: They can cause tissue damage (frostbite), potential explosion due to pressure buildup, and asphyxiation due to oxygen displacement.

1. Frostbite: Direct contact with cryogens can cause severe frostbite due to their extremely low temperatures.
2. Asphyxiation: Gases like nitrogen and helium can displace oxygen in the air, leading to asphyxiation.
3. Pressure Build-Up: If cryogenic liquids are not vented properly, pressure can build up in storage containers, leading to explosions.
4. Chemical Reactivity: Some cryogenic fluids, like liquid oxygen, can be reactive and pose fire hazards.
5. Hazards may include causing fire in case of Oxygen

Handling of Cryogens

Handling cryogens requires careful safety procedures:

1. Personal Protective Equipment (PPE): Gloves, goggles, and face shields should be worn to protect against frostbite and exposure.
2. Training: Proper training on the handling of cryogenic materials is essential to prevent accidents.
3. Equipment: Use appropriate containers designed for cryogenic storage, such as Dewar flasks or specialized cryogenic tanks.
4. Ventilation: Ensure that working areas are well-ventilated to avoid asphyxiation risks from gas expansions.
5. Examine containers and pressure relief valves for signs of defect. Never use a container which has defects.
6. Always handle these liquids carefully to avoid skin burns and frostbite. Exposure that may be too brief to affect the skin of the face or hands may damage delicate tissues, such as the eyes.
7. Boiling and splashing always occur when charging or filling a warm container with cryogenic liquid or when inserting objects into these liquids. Perform these tasks slowly to minimize boiling and splashing. Use tongs to withdraw objects immersed in a cryogenic liquid.

8. Never touch insulated pipes or vessels containing cryogenic liquids. Flesh will stick to extremely cold materials. Even nonmetallic materials are dangerous to touch at low temperatures.
9. Use wooden or rubber tongs to remove small items from cryogenic liquid baths. Cryogenic gloves are for indirect or splash protection only, they are not designed to protect against immersion into cryogenic liquids.
10. When transferring into a secondary container, do not fill the secondary container to more than 80% of capacity
11. Check cold baths frequently to ensure they are not plugged with frozen material.

Storage of Cryogens

Proper storage of cryogens is critical for safety and efficacy:

1. **Dewar Flasks:**

Dewar flasks are Insulated containers designed to store cryogens at low temperatures, minimizing heat transfer.

They consist of a double-walled cryogenic storage containers that usually maintain the liquid at extremely low temperature. They usually have a metal outer wall and a glass inner wall, with the void space under high vacuum for maximum thermal insulation.

Special care should be taken when handling as these flasks can implode.

They have a loose fitting insulated cap that enables gases to escape while preventing moisture buildup at the neck. In many cases they are used at "satellite" cryogenic liquid containers within a lab.

Dewar flasks are constructed or designed to minimize heat leaks into the refrigerants
by:

(a) Thermal conduction down the material of the neck tube of the Dewar vessel

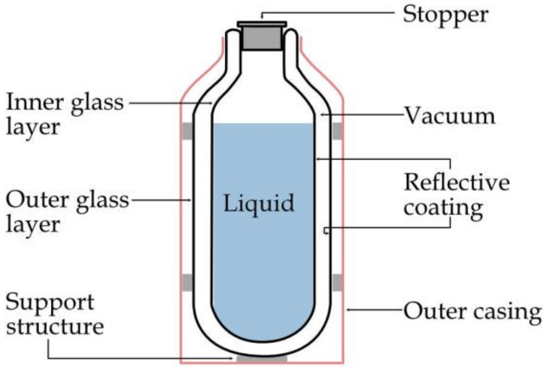
(b) Radiation of the outer shell to the inner shell of the Dewar vessel

c) Conduction through the residual gas between the two shells of the Dewar flask

To minimize heat loss due to thermal conduction, the neck tube of the Dewar is made long and of materials whose thermal conductivity is poor. Whereas to minimize heat lose by radiation, the surface of the two shells should be polished.

Heat loses or leaks due to conduction by residual gas are normally reduced by using a multilayer vacuum insulation, which is referred to as supper insulation.

If any air is allowed to enter a Dewar vessel containing a cryogenic fluid, the air would solidify inside and as a result, these may cause a blockage of the neck tube (causes gas- plug) and prevents the escape of boiled off gases. The gas –plug formed can be removed by directing a steam of room temperature helium gas down through the gas –plug so as to dislodge it.



The Dewar flask

2. **Cryogenic Tanks:** Large storage tanks equipped with pressure relief valves to safely store large volumes of cryogenic fluids.

3. **Labeling:** All storage containers should be clearly labeled to indicate contents and hazards.
4. **Temperature Monitoring:** Regular monitoring of storage temperatures is essential to ensure the stability of cryogenic fluids**.**

TRANSPORTATION OF CRYOGENIC FLUIDS

Cryogenic fluids are transported in cryogenic vessels which are well insulated with vacuum jackets and poor heat transmission jackets e.g. polystyrene. During transportation the containers are not filled to capacity.

Dispensing of the liquids calls for safety precautions e.g. wearing safety clothing and gloves. The liquid is normally dispensed in a well-ventilated place

Ullage space is the region above the cryogenic liquid in a cryogenic vessel, which contains air and vapor. This space provides room for change of liquid state to vapor state in the event of abrupt change of temperature thus avoiding explosion

Transportation of cryogens must adhere to strict regulations:

1. Containers: Use approved cryogenic transport containers that meet safety standards.
2. Labeling: Ensure all cryogenic materials are properly labeled to indicate contents and hazards.
3. Ventilation: Ensure transport vehicles are well-ventilated to prevent gas accumulation.
4. Emergency Procedures: Develop and communicate emergency procedures for accidents during transportation.

DISPOSALS OF CRYOGENS

Disposing of cryogens must be done carefully:

1. Allowing cryogenic liquids to evaporate in well-ventilated areas can be a safe disposal method for small amounts.
2. Follow local regulations for the disposal of cryogenic materials to minimize environmental impact.
3. Some cryogens can be recycled or reused, reducing waste and promoting sustainability.