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Working with heated (hotplate with stirring, heating samples with a burner) and cold (dry ice, liquid nitrogen) samples

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Overview

Working with extreme temperatures, both high and low, is an integral part of many laboratory operations. The laboratory instantly evokes in our mind the picture of a Bunsen burner. Bunsen burners and hot plates are used extensively in small and large operations in research laboratories and industries, thus making it necessary for all users to be aware of their safe handling procedures. Hot plates and Bunsen burners provide high temperature sources, and low temperatures are obtained using dry ice and cryogenic liquids such as liquid nitrogen. Both dry ice and liquid nitrogen can pose significant hazards to the user if not handled carefully.

Principles

Bunsen burners[1] are most prone to cause fire hazards. They produce an open gas flame that can be used for multi-purpose heating, sterilization, and combustion.

Hot plates[1] are commonly used in the laboratory to carry out chemical reactions, and in general for heating various samples. A hot plate consists of a flat surface and is heat is generated by electricity. As opposed to Bunsen burners, they do not have open flames, but higher temperatures can be achieved compared to Bunsen burners and can be more accurately controlled.

Dry ice[1] is the solid form of carbon dioxide. It is primarily used as a cooling agent. Dry ice can provide temperatures as low as −78 °C and is easier to use than normal ice, as it does not leave any residue, hence the name. However, prolonged exposure may lead to frostbite and severe damage to the skin.

Liquid nitrogen[1] is nitrogen in liquid form. It is a cryogenic fluid (boiling point, −195.79 °C). It is used in laboratories primarily as a refrigerant. Owing to the extremely low temperature of liquid nitrogen, it can cause significant health hazards. It rapidly freezes living tissues on contact.

All the above tools and techniques are important and considered standard in most laboratories. In order to prevent hazards there exist standard procedures for their safe handling (e.g. use of thermal protection and cryogenic gloves). Thermal gloves provide effective insulation at temperatures up to 650°C. Cryogenic gloves contain multi-layer insulation which are designed to provide protection to the hands and arms from the hazards encountered when working with cryogenic fluids.

This article describes the details of working with Bunsen burner, hot plates, dry ice, and liquid nitrogen.

Hot Sources

1. Bunsen burner

1.1 Safe Handling Procedure

1. The Bunsen burner should always be placed away from any overhead shelving, equipment, or light fixtures by no less than 12 inches.

2. Any combustible substances such as papers or chemicals should not be kept in the area adjacent to the burner.

3. The user should know the location of the fire extinguisher.

4. Proper clothing is necessary. The user should wear a lab coat, safety glasses, and gloves. Any long hair or jewelry should be tied back. It is recommended to remove all jewelry worn while working with open flames.

5. Before lighting the burner, the hose connected to the gas source should be checked for any leaks or holes.

6. Anyone working in the nearby area should be notified that the burner will be in use. Appropriate signage should be used that alerts users to the burner operation.

7. A lighter with an extended nozzle should be use to light the burner.

8. An open flame should never be left unattended. The gas should be shut off immediately after use.

9. The burner should be allowed to cooled down before handling or cleaning (if necessary) after use.

10. In case of fire or emergency, a call to 911 should be placed immediately.

11. **Table 1** describes the three different types of flames a Bunsen burner produces and their properties.

Table 1

2. Hot Plates

2.1 Features of Hot Plates

1. Most of the hot plates have a built-in magnetic stirrer which are used for running experiments that need to be continuously stirred while being heated.

2. The surface of most hot plates are made from aluminum or ceramic. A hot plate should be selected based on temperature requirements and compatibility of the surface with the materials being heated.

3. Most hot plates either have a digital read-out or a thermocouple input for maintaining the desired temperature.

2.2 Safe Handling Procedure

1. The user should be well acquainted with the use of the hot plate. He/she should be aware of the functions of the different parts of the hot plate—on-off switches, temperature controller, stirrer controller, thermocouple (if used). If stirring is required, a proper temperature (silicone oil) bath and stir bar will be required. Be sure to verify that the chosen bath fluid is compatible with the temperatures at which the experiment will be conducted.

2. Proper laboratory attire is mandatory. The user should wear a lab coat, safety glasses, and gloves. Heat-protection gloves should be worn when handling hot samples.

3. The user should know the location of the fire extinguisher. Liquid nitrogen or water should never be used to extinguish fire from oil bath being heated on a hot plate. Water is immiscible in oil and will therefore be ineffective for extinguishing any flames derived from burning oil. If liquid nitrogen is poured on hot oil, the nitrogen will quickly evaporate causing the oil to splatter.

4. The glassware used for heating should be heat resistant, such as borosilicate, and inspected for any damage or cracks before use.

5. The user should be well aware of the physical and chemical properties of the chemicals being heated. If necessary, condensers or operation within a vented fume hood should be employed.

6. Any object being heated must be smaller in size than the hot plate.

7. Any flammable or combustible chemicals or materials should be kept away from hot plates.

8. It is recommended to use hot plates inside a fume hood, especially when heating volatile or potentially toxic materials.

9. Hot plates should not be used for heating solvents or materials which have very low boiling point such as ether. These substances pose a significant risk of fire. A water bath should be used instead for such materials.

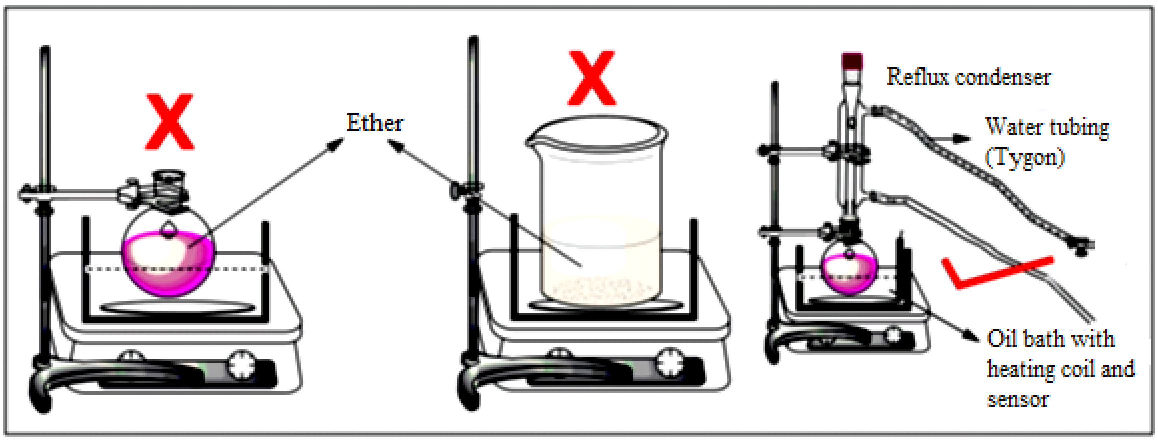
10. An open beaker or flask with chemicals or solvents should never be heated on a hot plate. A condenser should be use to prevent sublimation of chemicals on heating. **Figure 1**. illustrates the correct way of heating chemicals on a hot plate.

11. If solvents need to be added when the system is already hot, a dropping funnel should be used instead of a simple funnel. Direct addition of solvents may create flash fire.

12. Metal foil or metal containers should never be placed on the hot plate. This can cause the top to be damaged and may lead to the user getting burned more easily.

13. No hot plate should be left unattended. After use, when the heating is turned off, the plate should be marked as hot until it has cooled down completely.

Figure 1



Cold Sources

3. Dry Ice

3.1 Safe Handling Procedure

1. Dry ice is extremely cold (-78.5 °C). Protective gloves should be worn whenever handling it. A brief touch may be harmless but prolonged contact can cause the cells in the skin to freeze causing a burn to the skin.

2. Dry ice should be stored in a polystyrene container in a -80 °C freezer to minimize its sublimation.

3. A completely airtight container should never be used to store dry ice since its sublimation to carbon dioxide gas can cause the container to expand or even explode in extreme cases.

4. The storage area should be properly ventilated. The sublimated carbon dioxide gas, (which is toxic at higher concentrations) may sink to low areas and replace oxygenated air. This could cause suffocation if prolong periods of time are spent in areas of high CO_2 concentration.

5. After use, dry ice should never be disposed of in the sink or trash can. It can either be allowed to evaporate off inside a fume hood or stored back in the freezer.

6. Dry ice sublimates at about 5-10 pounds every 24 h (blocks last longer) in a typical storage cooler.[4] Hence purchasing plans should be made as soon as possible to the time needed.

7. In case of dry ice burns, the area should be immediately washed under cold water for at least 10 min. A First Aider should be contacted who can cover up the area with sterile dressing or refer the person for medical attention.

4. Liquid Nitrogen

4.1 Primary Hazards

1. Liquid nitrogen has a boiling point of −195.79 °C and can rapidly freeze skin tissues and eye fluids resulting in frostbite and permanent damage to the eyes even due to a brief exposure.

2. Asphyxiation is the condition of oxygen deficiency. Liquid nitrogen can expand 695 times in volume, and upon vaporization can cause extreme oxygen deficiency in the surrounding air, leading to suffocation, unconsciousness, and death under extreme circumstances.

3. While transferring liquid nitrogen, oxygen in the air surrounding the cryogen containment system can dissolve and create an oxygen-enriched environment. Since the boiling point of nitrogen is lower than oxygen, liquid oxygen evaporates slower than nitrogen and may build up to levels which can increase the flammability of materials such as clothing near the system. Equipment containing cryogenic fluids must be kept free of combustible materials in order to minimize the fire hazard potential. Condensed oxygen in a cold trap may combine with organic material in the trap to create an explosive mixture.[5]

4.2 Safe Handling Procedure

1. Any use and storage of liquid nitrogen should be done in well-ventilated areas.

2. Containers that can withstand extremely low temperatures (Dewar flasks) should be used for storage and transportation. It should never be stored in tightly sealed containers.

3. Liquid nitrogen should not be stored in uncovered containers for long periods.

4. The storage cylinders or Dewar flasks should not be more than 80% full.

5. Liquid nitrogen containers should never be touched with bare hands. The extreme cold can cause the skin to stick to the container walls.

6. Appropriate clothing while handling liquid nitrogen is mandatory. Lab coats, safety glasses, close-toed shoes, and thermal gloves should be worn. When pouring out

liquid nitrogen from large containers, facial masks/helmets should also be worn since the liquid tends to splatter a lot, especially when poured into a large vessel.

7. In case of hazards or emergency situations, the affected person should be moved to an extremely well ventilated area and a physician should be called.

Conclusion

While the use of Bunsen burners, hot plates, dry ice, and liquid nitrogen is commonplace in the laboratory environment, all of them can cause potential hazards if not handled carefully. It is thus the duty of every user to follow all the safety guidelines to eliminate hazards to themselves and their co-workers.

Legend

Table 1. Types of flame from a Bunsen burner[2]

Figure 1. Improper and proper way of heating samples on a hot plate.[3]

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Figure 1:

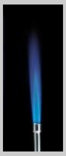
Type of flame	Gas tap	Air hole	Appearance	Properties
Yellow flame	Fully (or partly) open.	Closed		Used to light the burner and when it is not heating anything. It is easy to see and will not readily set fire to clothing, etc. This flame is unsuitable for heating as it coats surfaces with soot (carbon).
Medium flame	Fully (or partly) open	Partially closed		Used for general heating at medium temperature. Sometimes it might difficult to see the flame in bright sunlight.
Roaring flame	Fully open.	Fully open		For very strong heating (which is not very often). The hottest section of the flame is just above the blue cone of unburnt gas.

Figure 2