INDIAN INSTITUTE OF TECHNOLOGY (ISM) DHANBAD

OFFICE OF THE DEAN R&D

INSTITUTE LABORATORY & BIOSAFETY COMMITTEE

Guidelines of Laboratory & Biosafety

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Acknowledgements

1. **Office of Laboratory Safety and Environmental Health (OLSEH) , Indian Institute of Science, Bangalore**

   (https://olseh.iisc.ac.in/)

2. **Indian Institute of Technology Bombay**

   (http://www.iitb.ac.in/safety/sites)

3. **Washington University in St. Louis.**

   (https://ehs.wustl.edu/)

INTRODUCTION

The purpose of this manual is to make all users of IIT(ISM) facilities aware of safety and emergency protocols (do and don't) that must be followed. The aim is to give you general safety guide lines. While it does cover a wide variety of hazards-chemical, electrical, biological, etc. The provided document does not (cannot) cover all possible hazards. Please use your discretion and more importantly common sense. Remember that the ultimate responsibility of conducting a safe experiment resides with the experimenter himself/herself. Consistent violation of safety protocols or willful neglect of safety would result in strict penalties that include probations, fines, and in extreme cases disciplinary action from IIT(ISM). The various departments work with several hazardous materials and equipment. The institute and government allow us to operate with considerable autonomy, trusting us to maintain highest levels of safety. We need to sustain this trust by maintaining a safe working environment. Furthermore, safety is an important part of any training in laboratories.
The four essential principles of safety are:

- ***Follow Rules***

Safety may mean different things to different people, sometime because of ignorance and sometime because of lack of sufficient forethought. To prevent confusion, this manual clearly defines standards for safe work practices. These rules need to be followed by everyone in IIT(ISM), both in letter and spirit, even if they sometime appear burdensome and/or pointless (trust us there is a reason for everything). Remember practicing safety means doing things the right way, not the quick way.

- ***Collective Responsibility***

Concern for safety must also include others. All hazards should be clearly labeled in a manner that it easily understood by others, e.g. use warning notes/labels extensively. One should act responsibly in the event of an accident, e.g. pull the alarm to warn others. Finally, unsafe behavior should be confronted everywhere, e.g. remind your friend to wear safety glasses. IIT(ISM), Dhanbad is an open-access laboratory and safety is everyone's responsibility.

- ***Trust structures more than people***

No matter how careful they are, people often make mistakes. An effective safety policy does not rely on people but relies on systems to reduce the probability of accidents. Prior to beginning any project or process, it is essential to think about all that potential hazards – all the things that can possibly go wrong. Focus should be on reducing the probability of all the hazards by intelligently designed safety precautions. Safety precautions also include learning how to store, handle and dispose all hazardous materials. Experiments should only be conducted in designated area with proper ventilation wearing appropriate safety accessories. Equipment should be well maintained with periodic scheduled inspections.

- ***Respond to Emergencies***

Everyone must be prepared to respond quickly and effectively in an emergency. Become familiar with the work area, available exits, and safety equipment such as eyewash stations, fire extinguishers, sinks, spill kits, and first aid boxes. Just a few moments spent in training could save a life during emergency.

GENERAL SAFETY GUIDELINES

This section describes some practices which are basic or fundamental to safety in any laboratory where potential hazards exist. Following these simple, somewhat "common sense" rules are important. They will save you from most of the common accidents that happen in laboratory.

Safety Practices

1. Each lab should have a designated lab-in charge who is responsible for day-to-day enforcement of safety protocols. Each lab will also have a faculty associated with it who is ultimately responsible for safety in the lab.
2. Known and anticipated hazards are considered for all materials or equipment being used. Before using unfamiliar chemicals, equipment, or new products, please read the labels, material safety datasheets (MSDS) and/or user manuals.
3. Training should be provided for all new lab users. Training of existing users must also be provided when new hazards are introduced into a lab, e.g. during introduction of new substances, processes, or equipment.
4. Only proper equipment, in good condition, should be used. Before trying something very different from an equipment's intended use, please talk to the lab-in charge.
5. Boxes, chairs, cartons, shelves, chairs with wheels, or anything else that is not a ladder, should not be used as a ladder.
6. Emergency equipment (e.g. fire extinguishers, emergency eyewash/shower units, etc.) should be unobstructed, clearly visible, and in good working condition.
7. First aid kits are available in quickly accessible, visible and designated places. Ensure that first-aid kits have not expired.
8. Eating, drinking, or applying cosmetics near hazardous materials (radioactive, biohazardous, or chemical) is not permitted. Since all labs in IIT (ISM) count as hazardous, **NO FOOD/DRINK SHOULD BE ALLOWED INSIDE THE LAB.**
9. Food and drinks should not be stored in the refrigerator or freezer used to store hazardous materials. Refrigerators storing hazardous materials should have a clearly visible label saying, "No food or drinks".

Fig: No eating, drinking, or munching in the lab. No food in lab refrigerator

10. All labs need to fill, update and periodically review the "Laboratory Hazard Sheet" (see appendix) and post it on the laboratory door. To conform that the sheet is current, the lab in charge much sign and date the sheet.
11. All labs must maintain a working landline which is kept near the door.

12. All labs must maintain a list of emergency contact numbers posted very near the phone at eye level. The emergency list should include cell phone numbers of the faculty in charge, the lab in charge, and other regular lab users. The emergency list should also include the number for the IIT (ISM) health centre, the campus security, as well as the local police and the fire station.

13. Follow Buddy system. Never work alone in a lab, especially at night and during weekends. Buddy is a fellow lab-user who is working close enough to notice if you are in any distress. Friends on cell-phone, in offices, or hostels don't count.

Good Housekeeping Practices

1. Work areas are kept uncluttered and are cleaned upon completion of operations or at the end of each workday. This is particularly important for areas with hazardous chemicals.
2. materials and equipment.
3. Floors are maintained free from tripping, slipping, and falling hazards (e.g. cords, cables, wires, equipment, and tools).
4. Spills are attended to immediately and thoroughly.
5. Emergency equipment and controls are not blocked
6. Hallways and stairways are not used as storage areas.
7. Workbenches and shelves are not overloaded with unused equipment, chemicals, or other materials.

Personal Care

1. Maintain personal cleanliness, so that hazards don't affect you after you leave the lab.
2. Confine long hair and loose clothing when in the laboratory to keep them from catching fire, dipping into chemicals, or becoming entangled in moving machinery.
3. Avoid wearing dangling jewelry. These can reflect light from lasers or get caught in moving parts.
4. Avoid wrist-bands, rakhees, rings and wrist-watches, and other wrist ornaments. These may become contaminated with chemicals, react with chemicals, or be caught in the moving parts.
5. Remove laboratory coats and gloves before you leave the laboratory to prevent spreading contamination to other areas.

Fig: Important personal safety rules

Fire and Electrical Safety

The best defense against fire is to prevent the fire from starting. Everyone is responsible for fire prevention and for knowing how to handle a fire emergency.

Precautionary procedures

- Each lab will maintain a working landline near the exit.
- All labs must maintain a list of emergency contact numbers posted very near the phone at eye

level. The emergency list should include cell phone numbers of the faculty in charge, the lab in charge, and other regular lab users. The emergency list should also include utility numbers such as the number for the IIT(ISM) health centre, for the campus security, as well as the local police and the fire station.

- Locate the fire exits, fire alarms and extinguishers in your laboratory. Each laboratory should be equipped with extinguishers. See the following section to learn about different types of fire extinguishers.
- Maintain adequate walking space in laboratory, minimum of 2 feet and unobstructed access to exits.
- Ensure adequate ventilation around objects that heat up (e.g.: lamps, CPUs, etc.).
- Avoid long-term storing carton boxes, thermocole and other plastic/packaging materials. These are a major cause of fire incidents.
- Papers, binders and manuals must be stored in enclosed containers/cupboards, away from hot objects.
- Do not block access to fire escape routes, even outside of the laboratory. For example, the stairs should be free of debris, nothing should be stored in front of fire hoses, etc.
- Keep your workspace neat and tidy. Oily rags, carton boxes, waste or papers improperly stored are common causes of spontaneous combustion. Store these materials in covered metal containers.
- Ensure that fire extinguishers are serviced and inspected regularly.
- Keep a small handy fire extinguisher near flammable chemicals and organics.

Electrical Safety

- Access to electrical equipment (e.g. plugs and switches) should be maintained free from obstruction.
- Electrical apparatus is equipped with ground plugs or is properly grounded.
- Make sure that live terminals are not exposed to direct or indirect touching in all switches and outlets.
- Ground fault circuit breakers are used as needed.
- Two-pin appliances (un-grounded) are not within a 5-foot radius of flammable materials.
- All current transmitting parts of electrical devices are enclosed.
- Electrical connections are not handled with wet hands or when standing in or near water.
- Safety devices (e.g. fuses) on electrical equipment are not bypassed.
- Electrical equipment is disconnected from electrical outlets or circuits when being adjusted, lubricated, moved, or cleaned.
- Electrical plugs, cords, and extension cords are maintained in good condition.
- Power strips and extension cords use is kept to a minimum and cords are as short as possible. Series of surge protectors are not a replacement of permanent plug points. If additional plug points are required, ask BMS.
- Cords are placed in areas where they are not exposed to physical damage. They are not run through doorways or ceilings or placed under carpets.
- Don’t splice extension cords or electrical cords without properly insulating the junction with insulation tapes.
- Always make sure that you don’t overload an electrical outlet (e.g. don’t connect a 15A device to a 5A socket). If an outlet is overloaded it may lead to fire in that circuit.
- Never try to extinguish an electrical fire with water (this can result in electric shock if the

burning wires are still live); use only the proper fire extinguisher

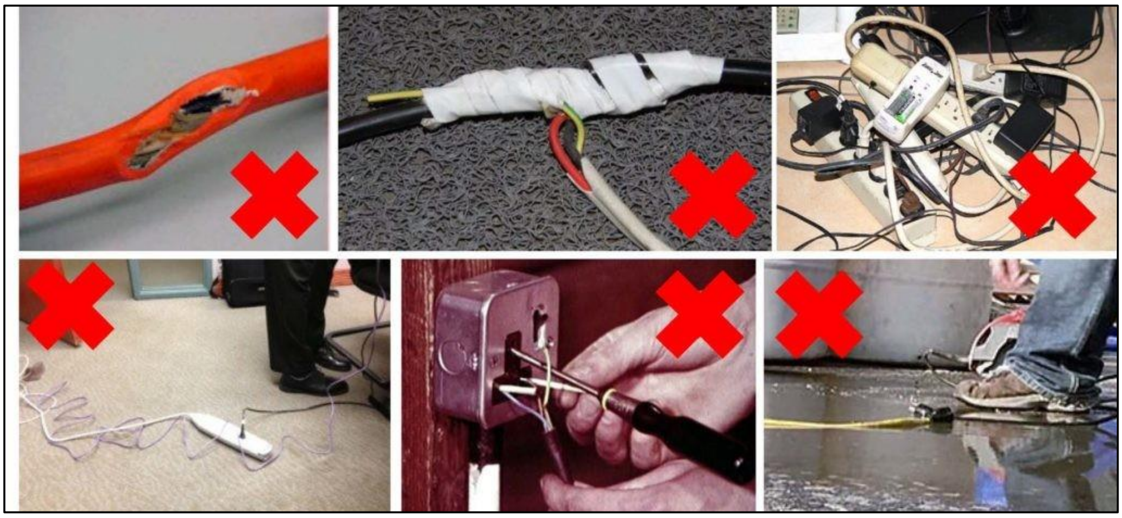
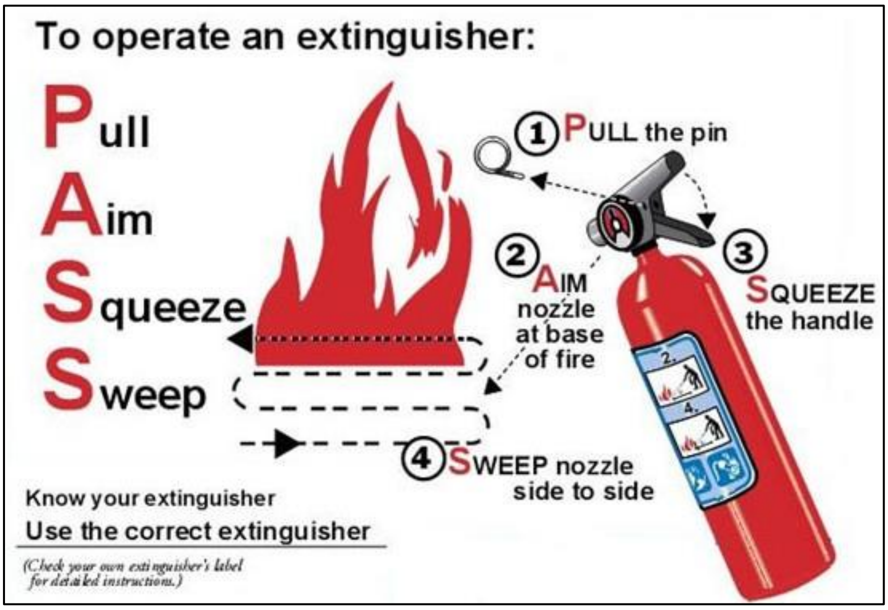


Fig: Avoid these unsafe practices

Fire Extinguisher

- All must learn how to operate a fire-extinguisher. Mnemonic PASS is often used to describe fire extinguisher usage



- Use correct type of extinguisher. Lab must have extinguishers for all type of hazards present inside it.

Type of Fire	Material	Class	Method to Extinguish
Ordinary combustible material	Wood, paper, textiles, etc.	A	Water, Foam spray, ABC powder, Wet Chemical
Flammable liquids	Oils, solvents, grease, paint, etc	B	Foam spray, ABC powder, Carbon Dioxide
Flammable gasses	SiH4, GeH4, organic vapors, etc	C	ABC powder
Metal	Magnesium, Aluminum, Sodium, Potassium, Zirconium, Titanium etc.	Metal	Special metal extinguishers. DO NOT use ordinary extinguishers found in the building or else a violent reaction may result.
Electrical	Short circuit, Hot electrical components, lightening discharge etc	-	Powder type, Carbon dioxide

Following illustration shows different sources of fire and the right type of extinguisher to be used:

Symbol found on Fire Extinguishers and what they mean	Water	Foam Spray	ABC Powder	Carbon dioxide	Wet Chemical
A Wood, Paper & Textiles	✓	✓	✓	✗	✓
B Flammable Liquids	✗	✓	✓	✓	✗
C Flammable Gases	✗	✗	✓	✗	✗
Electrical Contact	✗	✗	✓	✓	✗
F Cooking Oils & Fats	✗	✗	✗	✗	✓

(http://www.vcmfiresafety.com/images/)

Fire Safety infrastructure

- All departments are required to periodically evaluate the fire-preparedness. Depending on the hazards, the department may be required to invest in layers of Fire-alarms, sprinklers, fire-detectors, etc.
- General guidelines: All multi-storied building must have an operational fire hydrant loop. The primary responsibility of maintaining the hydrant loop rests with the departments.
- All building with significant gas, electrical, or chemical hazards must have a sprinkler system. The maintenance and testing of the system are the receptibility of the departments.
- All departments must have an evacuation plan and emergency response team (ERT). Details are in Section on Emergency Response.

Personal Protective Equipment (PPE)

Protective clothing and equipment safeguard against harmful chemical spills on the body, inhalation, projectiles etc. You are responsible for wearing the proper protective gear according to the activity you are doing in your lab.

Eyes

1. Understand the difference between safety glasses, chemical splash goggles and face shields. The first is for mechanical hazards, the second for liquid hazards and the third for extra safety when handling bigger hazards.
2. Eyes are the most easily injured external organ, so whenever in the vicinity of sharp objects, rapidly moving machines, hot material, or flying particles, safety glasses with side shields must be worn. In fact, it is strongly advisable that safety glasses be worn in the lab at all time.

3. Eyes are also covered with blood capillaries, so they can quickly absorb many harmful chemicals. Splash goggles must be worn when there is danger of splashing chemicals.

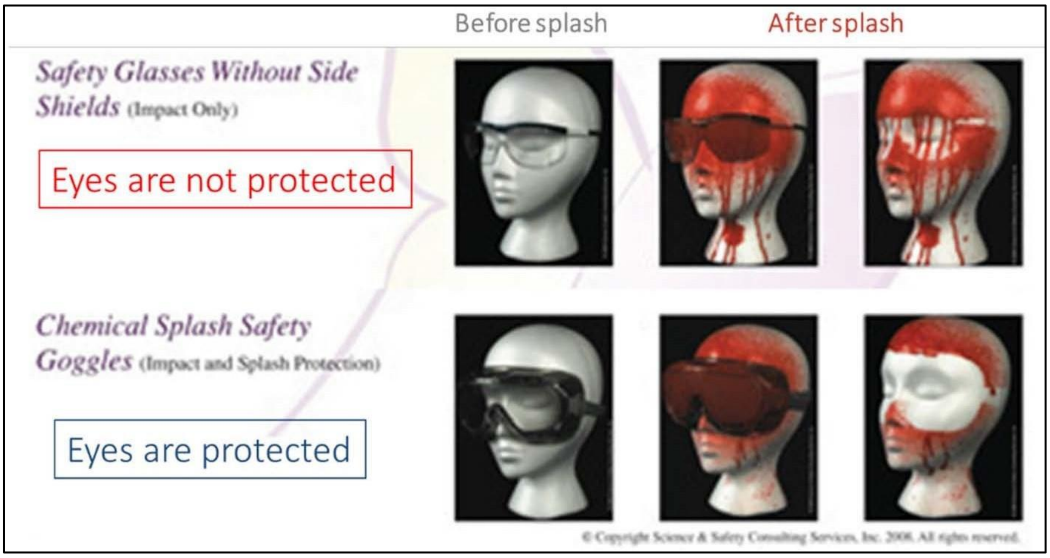


Fig: Difference between safety glasses and chemical splash safety glasses. Ref: Air Clean Systems

4. When working with large amount of chemicals (e.g. 4-liter bottles) or in vicinity of explosive/implosive hazards (e.g. vacuum systems with glass jars), a face shield with safety or splash goggles offers maximum protection.

5. Prescription lenses in spectacles do not provide enough protection. In fact, unless they are shatter resistant, they are hazardous on their own. People who need to wear prescription glasses must wear safety-glasses/splash-goggles over their prescription glasses.

Hands

1. Gloves need to be worn anytime you are handling something in the lab.
2. Gloves are worn to prevent contact with toxic or biological agents, burns from hot or extremely cold surfaces or corrosives, or cuts from sharp objects. Several types of safety gloves are available, each for specific hazards. For adequate protection, select the correct glove for the hazard in question (see for example in the link: http://www.ansellpro.com/downloa/Ansell_7thEditionChemicalResistanceGuide.pdf).

Fig: Always wash hands after lab work

3. Chemicals will eventually penetrate all glove materials. Change gloves periodically to minimize penetration.
4. Wash hands after leaving the lab even if you were wearing gloves. Long term exposure to even minuscule amounts of toxin can have very adverse effects on your health. Such chronic exposures are very hard to diagnose or detect. Prevention is the only option.

Fig: Common gloves their use case

Body and Feet

1. Clothing can prevent small chemical from damaging skin. Cover unprotected skin whenever possible. No shorts. Only wear full-length trousers, salwars, etc.
2. Aprons or laboratory coats must be worn especially when handling chemicals.

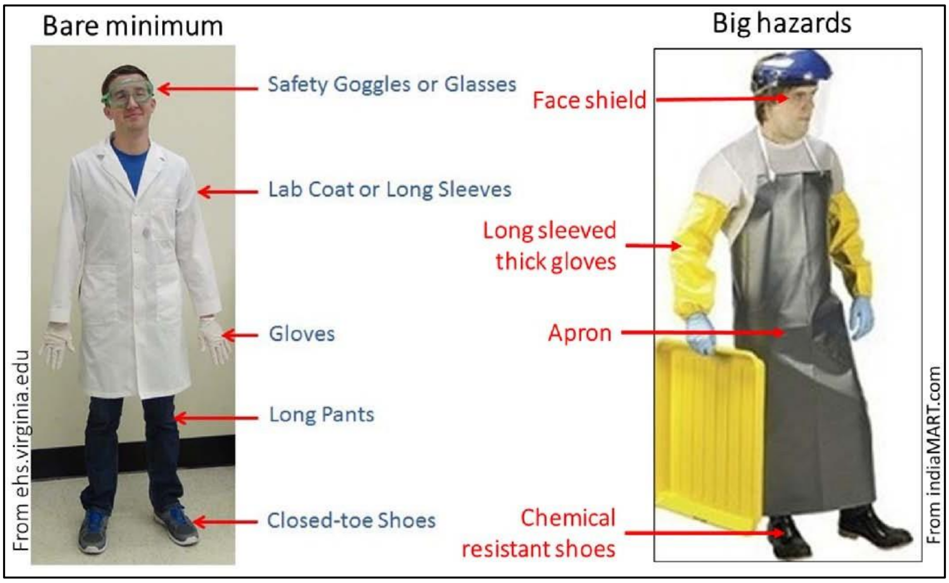
3. Wear stable hard-toe shoes in lab area to protect feet from chemical splashes and sharp objects on the floor. No slippers, sandals, or high heels. No bare feet.

Fig: Only closed-toed shoes allowed in labs.

Breathing Apparatus

1. Proper respirators (self-contained breathing apparatus) must be used whenever there is a chance to inhale hazardous chemicals, gases or nano-particles.
2. Proper respirators (self-contained breathing apparatus) must be used whenever hazardous gas cylinders are being installed/changed.

Summary



Useful Links

1. https://olseh.iisc.ac.in/
2. http://www.iitb.ac.in/safety/en

EQUIPMENT SAFETY

Introduction

Some of the hazards related with equipment used in research labs include

1. Electrical hazards
2. Hot surface which can cause burns and which can be a source of ignition.
3. High noise levels
4. Unguarded rotating parts
5. Use of vacuum which can cause implosion.
6. Use of high pressure
7. Generation of magnetic fields
8. Ultra violet and infra red radiation

Many accidents in research laboratories result from improper use and lack of maintenance of equipment.

The following precautions must be adopted while working with equipment in the laboratory.

- Refer the operating manual/user manual of the equipment before starting operation. The manual will contain details of hazards and safety precautions to be taken during installation, operation and maintenance.
- The operating manuals of equipment must be located at an easily accessible location in the laboratory.
- Personnel who are not authorized and trained must not carry out operation of the equipment.
- New users must carry out the operation under guidance of senior research scholars.
- A schedule for maintenance and inspection of equipment must be prepared as per manufacturer's instruction and must be adhered to.
- Unauthorized maintenance activity must not be done. Service personnel must be contacted where required.
- Switch off and unplug the equipment while making adjustments.
- Switch off the equipment at the end of the operation and when not in use.
- Use personal protective equipment as recommended by the manufacturer while operating the equipment.
- Equipment with specific hazards must not be left unattended.
- Display contact details and action to be taken in case of emergency near the equipment.
- Display caution signages to warn visitors about the hazards. Equipment out of order or not in use must be labelled.
- Precautions must be taken to prevent inadvertent energization of the equipment during maintenance activities.
- High pressure equipment must not be located inside the laboratory work area. Same must be in a separate room.

- Standard operating procedures (SOP) must be prepared and followed.
- Source of power must be at an easily accessible location so that it can be switched off quickly in case of emergency.
- Electric wires of equipment must not be laid along the passage where it can be a trip hazard. Same must be kept away from hot surfaces which can cause damage to the insulation of the wire.
- Emergency stop switch must be prominently labelled.
- Rotating parts of the equipment must be guarded. Loose clothing, jewelry that can get entangled must not be used. Confine long hair while working in the laboratory.
- Always use safety glasses while working with laboratory equipment.

Commonly used laboratory equipment and precautions to be taken during usage

Heating Devices

- Ensure that the heating element of the equipment is in good condition. If the elements are exposed, ensure that it is repaired or replaced.
- Variable transformers must be placed outside the fume hood. This helps to prevent spillage of chemicals/water over it and prevent chances of ignition of flammable vapors due to the spark produced by it.
- Electrical connections to the heating device must be fully insulated to prevent electric shock.
- Keep combustible materials away from heating devices.
- Care to be taken to prevent chemicals from coming in contact with the heating element.
- Overheating of the heating equipment can lead to fire. Use of temperature sensing devices helps to cutoff power if there is a sudden increase of temperature.
- Display caution signages to warn against hot surface.

Ovens

- Laboratory ovens must not be used for heating food items, as the air inside would be contaminated.
- Ensure that the materials placed inside for heating are thoroughly washed and doesn’t contain traces of chemicals.
- Maintain air space around the oven as recommended by the manufacturer.

- Use protective equipment while handling hot materials.

Hot plates

- Always consider the surface of the hot plate as hot.
- Ensure that the electrical cord of the hot plate doesn't come in contact with the heating surface.
- The controls on the hotplate must be properly labelled to easily distinguish between the stirrer and temperature controls.

Heating Mantles

- Care must be taken to prevent water or other chemicals from spilling into the mantle.
- Placing the heating mantle on a lab jack helps to quickly remove it in case of a sudden increase of temperature.

Oil baths

- Prevent water being spilled into the bath, as this can cause the splatter of the hot material.
- Prevent overheating of the oil. Monitor the temperature of the oil.
- Use of thermal sensing devices helps to turn off the electric power if the oil bath overheats.
- Oil baths must be well mixed to ensure that there are no hot spots around the heating elements.
- The heated oil must be placed in a secondary container (heat resistant tray) to contain the spill in case of breakage.
- The oil bath must be placed on a stable support, e.g., lab jack.
- The equipment used must be clamped high enough so that if there is a sudden overheating the heating element on the lab jack can be lowered immediately.
- Wear heat resistant gloves when handling a hot bath.

Heat guns

- Never use heat guns near open containers containing flammable liquid or inside the fume hood where flammable vapors could be present.
- The heating element or the switch of the heat gun can become a source of ignition.

Microwave Ovens

- Use lab purpose microwave ovens.
- Do not place any material between the sealing surface and the door on the oven's front face.
- Do not overheat samples.
- The materials used inside the oven must be those specified by the manufacturer.
- Do not use metal containing objects in the microwave, as they can cause arcing.
- Do not heat-sealed containers in a microwave oven, as they can explode.


Centrifuges

- The centrifuge rotor is subjected to high mechanical stress at rotation speeds.
- Accidents result from improper loading or balancing of the rotors. These cause them to dislodge during spinning, resulting in serious damage and personal injury.

The following precautions must be taken while using centrifuges:

- Balance the load properly.
- Do not overfill the centrifuge tubes.
- Ensure that the centrifuge tubes are placed properly.
- Ensure that the lid of the centrifuge is closed before starting the centrifuge.
- Do not run a rotor beyond its maximum rated speed.
- Keep a maintenance log.
- Always use the rotor specified by the manufacturer.
- Look for signs of corrosion of the rotors.
- Check the cone area for cracks.
- Check for corrosion or cracks in the tube cavity.

Vacuum work

- Use of vacuum has the risk of implosion which can result in flying glass fragments and spillage of chemicals.
- Evacuated glass vessels may collapse violently either by strain to which it is subjected or due to an accidental blow.
- Glassware under vacuum must be kept behind a shield.
- Vacuum pumps must be protected by cold traps and their vents must be exhausted to a hood.
- If the oil is contaminated, it must be changed before further use.
- The belt drive of the vacuum pump must be covered with a machine guard.
- Check the glass apparatus for cracks each time before they are used.
- Use only thick-walled glass apparatus specifically designed for vacuum use.

Desiccators

- If a glass vacuum desiccator is used, it must be made of Pyrex or similar glass.
- It must be wrapped with friction tape or shields must be provided around the same for protection from flying particles if the vessel implodes.
- Take care while opening the valve, as sudden inrush of air can cause spraying of the contents.

Rotary evaporators

- Completely enclose in a shield to guard against flying glass, or tape the components for protection from implosion.
- Rotation speed and application of vacuum to the flask must be increased gradually.

Refrigerators

- The chemicals stored inside the refrigerators can release vapors, which can form a flammable vapor air mixture inside. In domestic refrigerators the light or the thermostat can become a source of ignition.
- Only lab purpose intrinsically safe refrigerators must be used for storing flammable chemicals.
- Solvents in open containers or uncapped bottles must not be stored inside the refrigerator.
- Secondary containers must be used for storing chemicals to contain spill.
- Incompatible chemicals must not be stored together.
- Lab refrigerators must never be used to store food or beverages meant for human consumption.

MACHINE SAFETY

Introduction

- Unguarded moving parts of machines/equipment and the sudden or uncontrolled release of their power systems can result in serious injuries.

- Personnel working with machines must be aware of the risks involved and follow safe work practices.

Causes of accidents while working with machinery

- Loose clothing, hair, jewelry being caught in moving parts.
- Materials ejected from the machine when it is operational.
- Inadvertent starting of the machine.
- Slipping and falling into an unguarded nip.
- Contact with sharp edges, e.g., cutting blade.
- Making adjustments while the machine is operational.
- Unauthorized operation of machines.
- Lack of preventive maintenance.

Hazards

1. Rotating machine parts give rise to nip points. Examples are:

- Rotating gears
- Belt and its pulley
- Chain and sprocket
- Between grinding wheel and tool rest
- Between rotating and fixed parts

2. Rotating parts operating alone

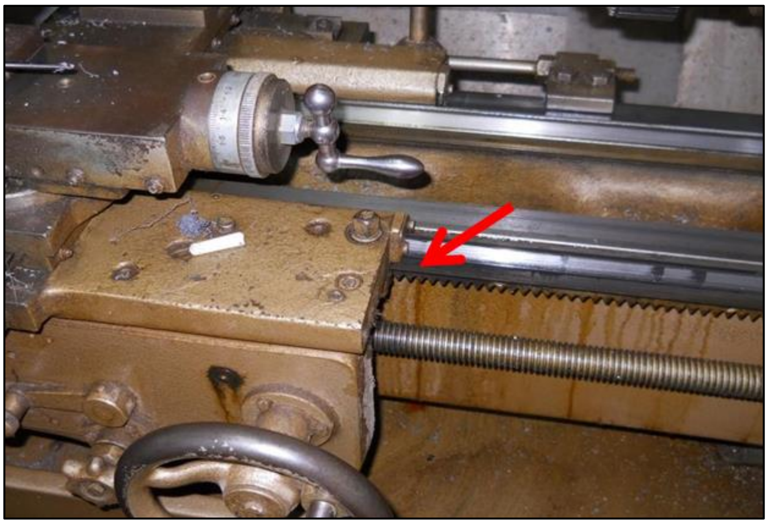
- Shafts
- Couplings

3. Reciprocating and sliding motions

Dangerous parts of machinery

1. Running nips between parts rotating in opposite directions, for e.g., gear wheels.
2. Rotating parts operating alone e.g., couplings.
3. Between rotating and tangentially moving parts e.g., belt drives.

4. Wherever there is a rotating part operating close to a fixed structure there is a danger of trapping or crushing.
5. Reciprocating and sliding motions.



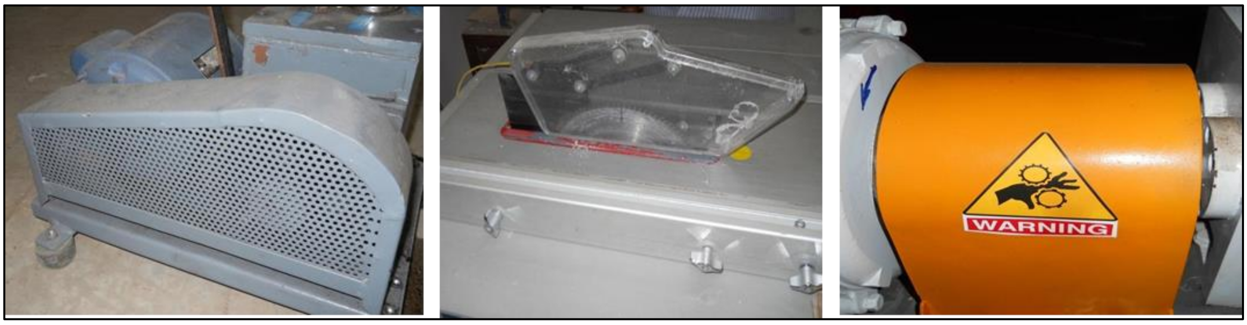
Machine Guarding

1. Any machine part which can cause injury, must be guarded.
2. Machine guards help to eliminate personnel hazards created by points of operation, ingoing nip points, rotating parts and flying chips.

Types of guards

Commonly used machine guards are

- **Fixed guard-** is kept in place permanently by fasteners that can only be released by the use of a tool.
- **Interlocked guard-**shuts off or disengages power to the machine and prevents it from starting when the guard is removed/opened.
- **Adjustable guard**-provides a barrier which can be adjusted to suit the varying sizes of the input stock.
- **Self-adjusting guard**-provides a barrier which moves according to the size of the stock entering the danger area.
- **Pull back device**- the device is attached to the wrist of the operator which pulls the operator's hands away from the point of operation or other hazardous areas when the machine operates.
- **Two-hand control**- concurrent use of both hands is required to operate the machine, preventing the operator from reaching the danger area.



Miscellaneous safeguarding aids

- Shields can be used to provide protection from flying particles, splashing metal working fluids or coolants.
- Holding tools can be used to place and remove stock. Example, reaching into the danger area of a power press.
- Holding tools must not be used as a replacement of machine guards.

Safety precautions while working with machinery

- Ensure that the guards are in position and in good working condition before operating.
- Know the location of emergency stop switch.
- Do not wear loose clothing or jewelry that can be caught in the rotating parts.
- Confine long hair.
- The keys and adjusting wrenches must be removed from the machine before operating it.
- Stop the machine before measuring, cleaning or making any adjustments.
- Do not handle metal turnings by hand as they can cause injury. Use brush or rake to remove turnings.
- Keep hands away from the cutting head and all moving parts.
- Cutting tools and blades must be clean and sharp, so that they can be used without force.
- Avoid awkward operations and hand positions. A sudden slip could cause the hand to move into the cutting tool or blade.
- Keep work area clean. Floors must be level and have a non-slip surface.
- There must be enough space around the machine to do the job safely.
- The person working with the machine must not be distracted.
- Machines must not be left unattended. Switch off the machine before leaving.
- Rotating parts of machines must not be stopped with hands after switching off.
- Compressed air must not be used to clean machines, as this can force small particles to fly off and can cause injury.

Personal protective equipment

1. Safety glasses must always be used while working with machinery for protection from flying particles.
2. Safety glasses must be worn by all personnel entering an area where machines are operated.
3. Ear protection must be worn for protection from high noise.
4. Safety shoes must be worn if there is handling of heavy materials.
5. Hand gloves must NOT be used while working with machinery, due to the chances of getting caught in the nip point.


Safe work practices – Drill press

1. When making deep holes, clean the holes frequently.
2. Use a clamp or drill vise to prevent work from spinning.
3. The drill bit or cutting tool must be locked securely in the chuck.
4. Remove the chuck key before starting the drill press.
5. Lubricate drill bit when drilling metal.
6. Reduce the drilling pressure when the drill begins to break through the work piece. This prevents drill from pulling into the work and breaking.
7. Do not force the drill with extra pressure.
8. Do not hold the work by hand.
9. Do not place hands under the stock being drilled.

Safe work practices- Lathe

1. Centre the drill work deeply enough to provide support for the piece while it is turning.
2. Secure and clamp the piece being worked.
3. Guard must be provided to the chuck.
4. Inspect chucks for wear or damage.
5. Remove chuck wrench immediately after adjusting chuck.

Safe work practices -Grinding machine

Causes of personal injury while working with abrasive wheels are follows:

1. Holding the work incorrectly.
2. Incorrect adjustment or lack of work rest.
3. Using the wrong type of wheel or disk or a poorly
4. maintained or imbalanced one.
5. Grinding on the side of the wheel.
6. Grinding too high above the center of a wheel.
7. Incorrect mounting and exceeding speeds recommended by manufacturer can lead to bursting of wheel.
8. Using spindle with incorrect diameter.

Tool/Work rest

1. The work rest must be securely clamped and the gap between the tool rest and wheel must not be more than 3mm.
2. The work rest height must be on the horizontal center
3. line of the machine spindle.
4. The rest must never be adjusted while the wheel is in motion as the work rest may slip and strike the wheel and break it, or cause injury to the operator.
5. Lockout-tagout or lock and tag is a system used to ensure that machines are properly shut off and not started up again before the completion of maintenance or servicing work.
6. Hazardous power sources must be isolated before any repair procedure is started.
7. Different types of locks are used for locking the machine or the power source in a manner that no hazardous power sources can be turned on.
8. A tag is also attached to the locked device indicating that it must not be turned on.

CRYOGENICS SAFETY

Introduction

- Cryogenics is the science of ultra-low temperatures.
- Low temperatures are achieved by the liquefaction of gases.
- The gases which are most widely used in industry and research are helium, hydrogen, nitrogen, fluorine, argon, oxygen and methane.

Properties of cryogenic fluids

- Extreme low temperatures.
- Large ratio of expansion in volume from liquid to gas.
- Most cryogenic liquids are odorless and colorless when vaporized to gas.

Boiling points of cryogens

- **Helium** **- 269.9 ^{O}C**
- **Hydrogen** **- 252.7 ^{O}C**
- **Neon** **- 245.9 ^{O}C**
- **Nitrogen** **- 195.8 ^{O}C**
- **Oxygen** **- 183.0 ^{O}C**

Liquid to gas expansion ratios of cryogens

- **Helium** **1 to 757**
- **Hydrogen** **1 to 851**
- **Neon** **1 to 1438**
- **Nitrogen** **1 to 696**
- **Oxygen** **1 to 860**

Storage

- Cryogenic fluids are stored in well insulated containers to minimize loss due to boil off.
- The most commonly used container for handling cryogenic fluids is the Dewar flask.
- Dewar flasks are non-pressurized, vacuum jacketed vessels.

Potential hazards

Potential hazards in handling cryogens are

- They displace oxygen in non-ventilated confined spaces
- causing oxygen deficient atmosphere.
- On contact with skin, they can cause frost burns due to extreme cold.
- Pressure build up in the container can cause explosion.

- Affects properties of materials.
- Oxygen enrichment

Fig. Containers for storing cryogens

Oxygen deficiency

- Cryogens can displace oxygen in enclosed spaces resulting in asphyxiation.
- A work space is considered unsafe for entry if the oxygen level falls below 19.5%.

Precautions

- Cryogenic liquids must be handled in well ventilated areas to prevent excessive concentrations of gas in enclosed spaces.
- The gas released from equipment must not be disposed of in confined/enclosed areas.
- Oxygen level detectors to be installed in enclosed spaces where there is chance of buildup of gases causing oxygen deficiency.

Frost burns

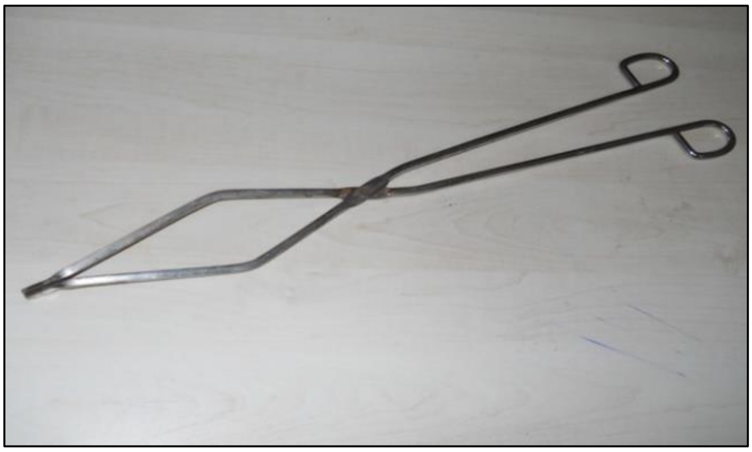
- Contact with cryogens (liquid and vapor) can cause burns similar to that caused by high temperature thermal burns.
- Cryogens can cause embrittlement of the exposed body surface because of high water content of the human body.
- Splashing of cryogens can result in permanent eye damage.

Precautions during handling

- Keep safe distance from boiling and splashing liquid and its issuing cold gas.
- Boiling and splashing occur when charging a warm container or when inserting objects into the liquid.
- These operations must be performed slowly to minimize boiling and splashing.

- Any unprotected part of the body must never be allowed to touch uninsulated pipes or vessels containing liquefied gases.
- The extremely cold metal can stick fast and tear the flesh, if an attempt is made to withdraw from it.
- Liquefied gases must be transported only in suitably insulated containers that provide means for the escape of gas as liquid evaporates. Never plug the outlet of such containers.
- When pouring liquefied gases from one container to another, the receiving container must be cooled gradually to prevent thermal shock.
- The liquid must be poured slowly to avoid spattering.
- A discharge tube must be used when it is not safe or convenient to tilt the container or to remove liquid from large 50- or 100-litre containers.
- Cryo-flask for handling liquid nitrogen
- Portable trolleys must be used for moving large containers of cryogens.

- Cryogenic containers must not be dropped or tipped on their sides.
- Frost spots may appear in case of loss of insulating vacuum. A vessel in this condition must be removed from service. Repairs must be handled by the manufacturer.
- Prevent the entry of liquid cryogen inside the glass vials while inserting the same inside the container. As later the liquid can expand causing the explosion of the vial.
- Tongs must be used to withdraw objects immersed in liquid.



Protective equipment

- Safety glasses and face shield should be used for eye and face protection.
- Cryo-hand gloves must be worn when handling cryogenic liquids.
- The gloves must be loose fit so that they can be quickly removed in case any liquid splashes into them.
- Aprons must be worn to protect the body from splashing.
- Open toed footwear not to be worn while handling cryogens as they won’t offer protection incase of spill of the liquid.
- Watches, rings or any other item must not be worn that
- could trap the liquid in case of a spill.

Pressure hazard

- Usage of cryogens always present a high-pressure hazard as the gases are stored at or near their boiling point.
- The liquefied gas will be evaporating continuously into the gaseous state and as a result there is always some gas present in the container.
- The large expansion ratio from liquid to gas provides a source for the build up of high pressure in the container.

Precautions

- Dewars must be kept covered with a loose-fitting cap to prevent air or moisture from entering the container, and to allow build up pressure to escape.
- Make sure that no ice accumulates in the neck or on the cover and causes a blockage and subsequent pressure buildup.
- Only containers specifically designed for holding cryogenic liquids must be used.

Material hazards

- Ordinary carbon steels and most alloy steels, rubber becomes brittle when subjected to the low temperatures of cryogens. These materials are considered unsuitable for use with cryogens.
- Metals which are suitable for cryogenic temperatures are copper, brass, bronze, monel and aluminium.

Oxygen enrichment

- When liquid nitrogen is transferred through uninsulated metal pipes, surrounding air can condense on it.

- An oxygen-enriched condensate is formed on the surface as nitrogen evaporates, increasing the flammability of materials near the system.
- Combustible materials must be stored clear of equipment containing cryogenic fluids to reduce the risk of fire.

Handling liquid helium

- Air liquifies and solidifies readily when exposed to the extremely low temperature of liquid helium.
- If solidified gases are allowed to form and collect, they may plug pressure relief passages and relief valves.
- The fill and vent ports of storage containers must be kept closed at all times (except during filling) to prevent blockages from forming in the exit passage and a resultant pressure build up.
- Always store and handle liquid helium under positive pressure or in closed systems to prevent the infiltration and solidification of air or other gases.
- Cylinders whether full or empty must not be subjected to rough handling.
- In case of spill of large quantity of fluid, evacuate the area.

ELECTRICAL SAFETY

Introduction

All systems which use electrical energy have the potential to cause serious harm.

Injuries caused by electric current

Electric current can pass through the body when the body becomes part of the electric circuit. Electric current flowing through the body can cause:

- electric shock
- electrocution
- burns caused by electric current and arc flash

The severity of the injury depends on:

- Amount of current flowing through the body.
- Path of the current through the body.
- Length of time the body is in the circuit.
- The voltage of the current.

The following table contains details of the effect of alternating electric current during a hand-to- foot shock of one second duration:

Current level (milliamperes)	Probable Effect on Human Body
1 mA	Perception level. Slight tingling sensation.
5 mA	Slight shock felt; not painful but disturbing. Average individual can let go.
6 – 16 mA	Painful shock. Loss of muscular control. Commonly referred to as the freezing current or "let-go" range.
17 – 99 mA	Extreme pain, respiratory arrest, severe muscular contractions. Individual cannot let go the source in contact with. Can cause ventricular fibrillation.
100 – 2000 mA	Ventricular fibrillation (uneven pumping of the heart.) Muscular contraction and nerve damage begin to occur. Death likely.
> 2,000 mA	Cardiac arrest, internal organ damage, and severe burns. Death probable.

- A person receiving a shock caused by grabbing a bare conductor can generally release himself when the current passing through his body is less than 15 mA.

- The high resistance of a dry skin is rapidly broken down by a high voltage. High voltages can cause violent muscular contraction, often so severe that the victim is thrown clear.

An electric shock may injure the human body in several ways:

- Contraction of chest muscles causing interference with breathing, leading to asphyxiation.
- Temporary paralysis of the nerve center leading to breathing failure.
- Ventricular fibrillation which is an irregular movement of heart muscles leading to failure of blood circulation. The heart cannot spontaneously recover, causing death.
- Hemorrhage and destruction of nerves, tissues and muscles, caused mainly by heat.
- When electricity passes through the body, it can interfere with the normal electrical signals between the brain and other body systems.
- Arc flashes result in intense heat causing burns or ignition of other materials.
- Contact with high voltage can cause burns in internal tissues.

Precautions to be taken while working with electricity:

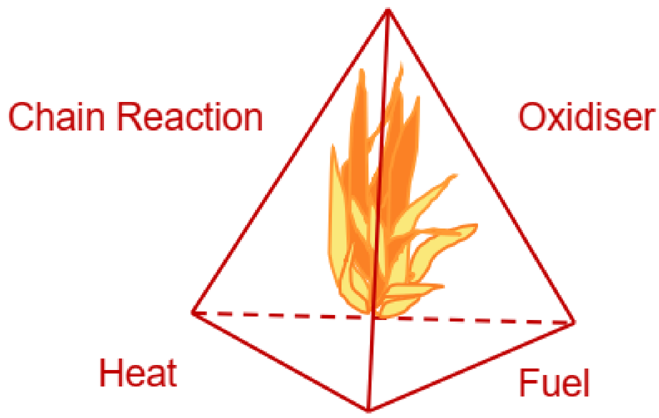
- Check for damage on power plugs, wire and other electrical fittings. If found damaged, repair or replace damaged equipment immediately.
- Keep electrical wires of equipment away from hot surfaces to prevent damage of the insulation.
- Do not lay electric wires along passage. It can be a trip hazard. Further contact with sharp edges can cause damage to insulation leading to short circuit.
- Know the location of switches/circuit breaker boxes for use in case of an emergency.
- All circuit breakers in the switch board must be clearly labelled for easy identification.
- Access to circuit breakers must not be blocked.
- Extension cords must be used only to supply power temporarily.
- Do not handle electrical equipment when hands, feet or body are wet or perspiring, or when standing on a wet floor.
- Consider all floors as conductive unless covered with insulating matting of suitable type for electrical work.
- Whenever possible, use only one hand when working on circuits or control devices.
- Do not wear rings, metallic watchbands, chains etc. when working with electrical equipment.

Precautions to be taken while using power tools:

- Before connecting the tool to the power supply, switch the tool OFF.
- Disconnect power supply before making adjustments.
- The tool must be properly grounded with a 3-wire cord with a 3-prong plug. Use double insulated tools wherever possible.
- Do not use electrical tools in wet conditions or damp locations unless the tool is connected to an Earth Leakage Circuit Breaker.

FIRE SAFETY

Fire is a rapid chemical reaction of oxidant with fuel accompanied by the release of energy, indicated by incandescence or flame.



Fire Tetrahedron

Combustion Characteristics

For a fire to happen, the following elements are essential

- Oxidizer to sustain combustion.
- Heat to reach ignition temperature.
- Fuel or combustible material.

This results in a chemical chain reaction which starts a fire. Removing any of these elements will extinguish the fire.

Heat Transfer

During a fire heat transfer occurs by

- Conduction - transfer of heat within the material itself.
- Convection - transfer of heat by the physical movement of hot masses of air.
- Radiation - refers to the emission of heat in the form of electromagnetic waves.

Ignition

Ignition is the process of initiating self-sustained combustion.

The ignition temperature of a substance is the minimum temperature to which it must be heated for it to ignite.

Sources of Ignition

Ignition can occur by

- Electrically powered equipment- Arcing, damaged wiring, over heating of cables due to excess loads, loose electrical connections, heat from electric bulbs etc.
- Open flame
- Hot surfaces
- Sparks from welding operations
- Chemical reaction between incompatible chemicals
- Smoking
- Batteries

Flash Point

In a flammable liquid fire, it is the vapors released from the surface of the liquid that burns.

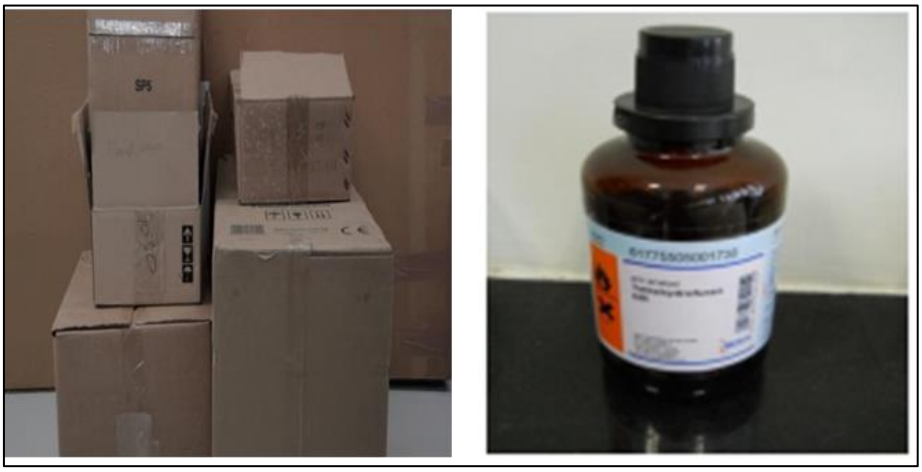
- Flash point is the lowest temperature at which a liquid produces enough vapor to form an ignitable mixture.
  Examples: Diethyl ether (-45^{o}C)
  Methyl alcohol (11.1^{o} C)
- Lower the flash point of a flammable liquid, greater the hazard.

Classification of Fire

On the basis of the type of fuel, fires are classified into the following

Class A Fires - solid combustible materials of organic nature such as wood, paper, rubber, plastics, etc.

Class B Fires- flammable liquids



Class C Fires — flammable gases under pressure including liquefied gases.

Class D Fires — combustible metals, such as magnesium, sodium, potassium, etc.

Extinguishing Fire

- Fire can be extinguished by Cooling the fuel by removing heat (e.g., by applying water).
- Fire can be extinguished by Smothering by cutting off oxygen supply (e.g., by applying foam, carbon dioxide).
- Fire can be extinguished by Starving the fire by removing the fuel. (e.g., stopping gas flow during a pipeline fire).
- Inhibition by stopping the chain reaction. (e.g., by applying dry chemical powder).

Fire Extinguishers types

Type of extinguishers and the classes of fire for which they can be used	
Water	**Class A fire**
Dry chemical powder	**Class B & C fire**
Foam	**Class A & B fire**
Carbon dioxide	**Class B & C fire**
Special dry powder	**Class D fire**

Water Extinguisher (A)

- They are used for Class A fires.
- Water removes heat and extinguish the fire.
- Water must not be used on fires involving live electrical equipment as it can cause electrocution.
- Water must not be used on metal fires.

Carbon Dioxide Extinguisher (B & C)

- CO_2 extinguishers are mainly used for Class B and C fires.
- CO_2 extinguish the fire by displacing oxygen in the surrounding air.
- CO2 is not suitable for fires involving metals.
- It's principal advantage is that it does not leave any residue.
- Can be used on electrical/electronic equipment.

AFF Foam Type Extinguishers (A & B)

- The extinguishing agent is aqueous film forming concentrate in water which forms air foams when discharged through an aspirating nozzle.
- It has a blanketing effect excluding oxygen from the surface of the fuel as it spreads on the fuel.
- Prevents vapor formation from the surface of the burning liquid.
- It develops a floating aqueous film of solution under the foam on fuel surface and cool the burning surface.
- AFF extinguishers must not be used on electrical and metal fires.

Dry Chemical Powder (DCP) Extinguisher (B & C)

- The main base chemicals used in DCP extinguishers are sodium bicarbonate and potassium bicarbonate.
- DCP extinguishers puts out fire by coating the fuel surface with chemical powder.
- This separates the fuel from the oxygen in the air and prevent vapor formation.
- The powder also interrupts the chemical chain reaction of fire.
- The disadvantage is that it leaves residue particularly making it difficult to clean up in case of sensitive equipment.

Special Dry Powder Extinguisher

- Special extinguishing agents are used for extinguishing metallic fires.
- Dry powders extinguish the fire by forming a crust on metal surface excluding air and also absorbs heat from the metal surface.
- Examples: Blended sodium chloride based dry powder, ternary eutectic chloride (TEC) powder, graphite etc.

Propellant for extinguishing media.

- The extinguishing media is expelled from the extinguisher by carbon dioxide gas contained in a cartridge inside the extinguisher.
- CO2 extinguisher contains liquefied carbon dioxide. The gas present in the vapor space above the liquefied CO2 itself acts as the propellant. So, no separate cartridge is used in CO2 extinguisher.

Extinguisher Operation

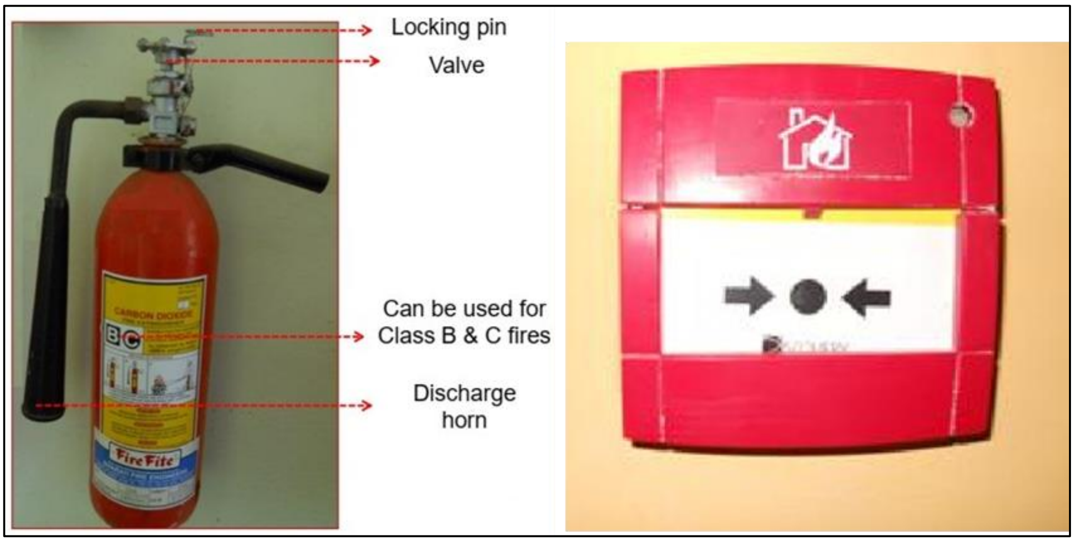
- Pull/remove the locking clip.
- Aim the nozzle at the base of the fire.
- Press the knob/lever down.
- Starting from the edge of the fire sweep the nozzle from side to side advancing ahead.

Operating Foam type Extinguisher

- When using AFFF on a container of burning liquid the foam must be directed towards the back or side wall of the container and allowed to spread over the surface.
- Where the fire is in a liquid spill the foam must be allowed to drop slightly ahead of the fire and moved forward with a side to side movement of the nozzle.

Operating a CO_2 extinguisher

- Remove the locking pin.
- Aim the horn at the base of the fire.
- Open the valve by turning it anticlockwise.
- Sweep the horn from side to side, gradually advancing ahead.



Extinguishing Fire

- The successful use of a fire extinguisher depends on the following conditions:
- The extinguisher must be easily accessible and in good working order.
- The extinguisher must be the right type for the fire.
- The fire must be discovered in its incipient stage for the extinguisher to be effective.

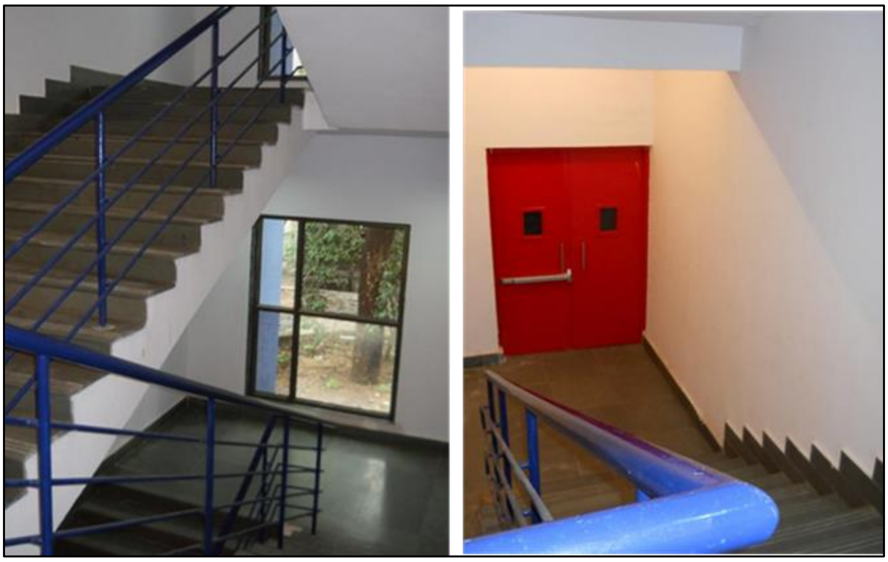
Emergency Response

In case of a fire

- Actuate the manual fire alarm call point.
- Alert personnel nearby so that they can come to your help/inform security section.
- Determine what is burning.
- Use the right type of extinguisher for fighting the fire.
- Use the fire extinguisher only if you have attended practical training.
- Always position yourself with an exit or means of escape behind you before you attempt to use an extinguisher to put out a fire.
- If the person who notices the fire feels that it cannot be tackled by extinguishers, he can

directly inform the fire station without delay.

- On hearing the alarm evacuate the building and assemble at the designated assembly point.
- As you evacuate close the doors of the rooms (do not lock) as this will slow down the spread of smoke and fire.
- While moving out of the building always use stairways.
- Do not use lifts, they may fail mid-way trapping people inside.



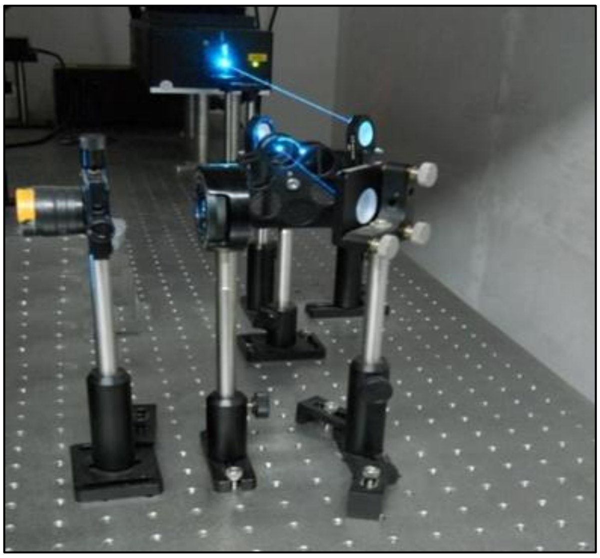
Precautions

- Keep fire doors of the staircase closed. If kept open, heat and smoke will enter the staircase during fire and prevent escape of occupants.
- Do not obstruct emergency equipment. Fire extinguishers must be easily accessible.
- Materials must not be stored in front of exits or along stairways blocking them.
- Know the exits in the laboratory and in the building.
- Display emergency contact numbers near the telephone.

LASER SAFETY

Introduction

- The term LASER is an acronym for **L**ight **A**mplification by **S**timulated **E**mission of **R**adiation.
- Laser emits electromagnetic radiation by the process of optical amplification based on stimulated emission of photons.



Characteristics of Lasers

- Monochromatic – laser consist of mostly single wavelength rather than different wavelengths.
- Coherent - wavelengths in a laser beam are in phase. The wave crests and troughs are parallel to each other.
- Collimated – very narrow, travel in the same direction.

As a result of these properties intense power is produced at a small point of concentration.

Components of a Laser

A laser consists of:

- An optical cavity,
- A pumping system (energy source)
- An appropriate lasing/gain medium.

Types of Lasers

Lasers can be classified by the type of lasing material in the optical cavity.

- Solid state lasers make use of a crystalline lasing material. e.g., ruby or neodymium-YAG (yttrium aluminum garnet) lasers.
- Gas lasers uses pure gas or mixture of gases. e.g., carbon dioxide and helium-neon.
- Semiconductor/diode lasers employ n-type and p-type semiconducting element materials.
- Liquid/dye lasers employ organic dye in a liquid solution or suspension as lasing media.
- Excimer lasers (the name is derived from the terms excited and dimers) use gases such as chlorine and fluorine mixed with inert gases such as argon, krypton or xenon.

Laser beam exposure

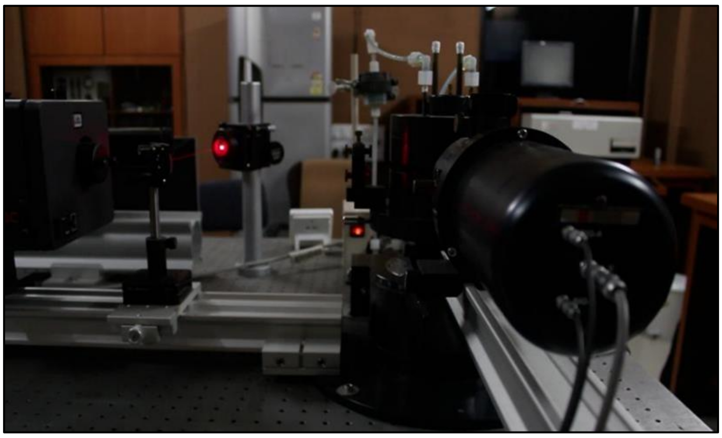
Exposure to laser beam can occur by the following means

- Direct viewing of the beam
- Specular reflection – from a shiny surface
- Diffuse reflection – from an irregular surface

Classification of Lasers

On the basis of the damaging effects on the eyes and skin lasers are classified into the following types:

- ***Class 1***
- ***Class 1C***
- ***Class 1M***
- ***Class 2***
- ***Class 2M***
- ***Class 3R***
- ***Class 3B***
- ***Class 4***



Class 1 Laser System

- Is usually not capable of producing damaging radiation levels during normal operation.
- Class 1 laser systems are exempted from control measures.
- Lasers used in laser printers and compact disc players are examples.

Class 1C Laser System

- Class 1C lasers are laser products used on the skin or internal body tissues for medical procedures.

Class 1M Laser System

- Is not capable of producing hazardous exposure conditions during normal operation, except when the beam is viewed with an optical instrument.
- Control measures are not recommended but potentially hazardous optically aided viewing to be avoided.
- Lasers used for fiber optic communication system comes under this classification.

Class 2 Laser System

- Because of the human aversion response, these lasers do not normally present a hazard, but may be a potential hazard if viewed directly for a long time.
- Laser pointers are examples of lasers coming under this classification.

Fig. Class 2 Laser System

Class 2M Laser System

- Aversion response of eyes offer protection to the eyes.
- Class 2M can be potentially hazardous when viewed with optical aids.
- Lasers used in level and orientation instruments in civil work are examples of Class 2M lasers.

Class 3R Laser System (medium power)

- Potentially hazardous under direct and specular reflection viewing condition if the eye is appropriately focused and stable, but the probability of injury is small.
- Is not a fire hazard or diffuse-reflection hazard.
- Some laser pointers are classified as Class 3R lasers.

Class 3B Laser System (medium power)

- Can be hazardous under direct and specular reflection viewing conditions.
- Is normally not a diffuse reflection or fire hazard.
- Class 3B laser systems are used in physiotherapy treatments and research work.

Class 4 Laser system (high-power)

- Is a hazard to the eye and skin from the direct beam.
- May pose a diffuse reflection hazard.
- Can cause fire.
- May produce laser generated air contaminants and hazardous plasma radiation.
- Class 4 lasers are used in displays and cutting of metals.

Biological effects of Laser Beam

Lasers can cause damage in biological tissues, both to the eye and to the skin, by the following mechanisms.

- Thermal damage - burns occur when tissues are heated to the point where denaturation of proteins occurs.

- Photochemical damage - where light triggers chemical reactions in tissue.

Eye injury

- The ocular focus region is a range of wavelengths from 0.4-1.4 µm, which is focused by the eye's components with a power of approximately 100,000 times.
- This portion of the spectrum reaches the retina and are absorbed there resulting in injury.
- All rays outside the ocular region are absorbed by the outer components of the eyes.
- Moderate and high-power lasers in the visible to near infrared range (0.4 -1.4 µm) will cause burns on the retina resulting in permanent blind spots.
- Laser radiation with wavelengths less than 0.4 µm and greater than 1.4 µm are largely absorbed by the cornea and lens, leading to the development of cataracts or burn injuries.

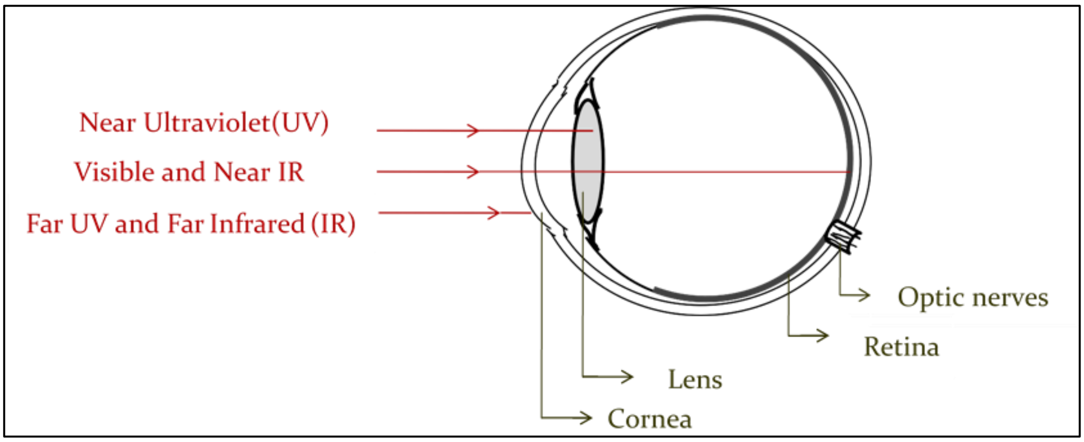


Fig. Absorption of electromagnetic radiation in the eye

Skin injury

Excessive exposure to UV light from lasers can cause effects similar to sunburn, while visible and infrared rays can cause thermal damage.

- UV-A (**0.315 µm-0.400 µm**) can cause hyper pigmentation and erythema.
- UV-B range (**0.280 µm - 0.315 µm**) is most injurious to skin. Can cause radiation carcinogenesis.
- UV-C (**0.200 µm-0.280 µm**) is less harmful to human skin.

Causes of laser accidents

- Eye exposure during alignment
- Misaligned optics
- Non use of laser safety glasses
- Equipment malfunction
- Improper methods of handling high voltage
- Unauthorized operation
- Lack of protection for non-beam hazards

Control measures for Class 3B and Class 4 Lasers

- To be operated by authorized personnel only.
- Access to the area for visitors to be limited, by the provision of partitions.
- Visitors not to be allowed when the laser is in operation.
- Any potentially hazardous beam to be terminated in a beam stop of an appropriate material.
- Warning sign to be posted at the entrance.
- Warning lights to be provided outside the laser room to warn visitors when the laser is in operation.
- Materials that can cause specular reflection must not be kept in the laboratory.
- Laser safety glasses must be used if the permissible exposure limits for the laser are exceeded.
- Wherever possible the beam path must be enclosed. Use fire resistant materials for enclosing Class 4 laser beam path.
- All windows and doors in the laser room to be made opaque.
- The laser system must be disabled (e.g., removal of the key) after use to prevent unauthorized use.

- A screen or curtain must be used to prevent exposure to the laser beam at the entrance of the laser room.
- Secure optical components to the table to prevent stray reflections from misaligned optics.
- Users must never view the beam at the level of the horizontal plane where they are passing.
- Watches and jewelry must not be used in the laboratory.

- Alignment of beams and optical components must be performed at a reduced beam power whenever possible.
- Fire extinguishers must be at an easily accessible location in labs using Class 4 lasers. Keep flammable materials away from open beams.

Factors in determining appropriate eyewear

- Wavelength of the laser output
- Potential for multi wavelength operation
- Optical density of eyewear at laser output wavelength
- Visible light transmission requirement
- Peripheral vision requirement
- Comfort and fit

Non-beam laser hazards

Non-beam hazards are also associated with use of laser systems.

- Lasers use high voltages which can be a hazard during normal operation and maintenance.
- The laser system must be properly grounded.
- Electrical switches must be locked and tagged while servicing electrical equipment to prevent inadvertent energization.
- Capacitors can contain dangerous charge even after disconnecting from the main power. They must be safely discharged by grounding before maintenance.
- Electrical equipment must be installed a few inches above the floor to prevent contact with water in case of flooding.
- Organic dyes used must be labelled and Material Safety Data Sheet for the same to be referred before use.
- High-pressure arc lamps and filament lamps shall be enclosed to contain lamp explosion.

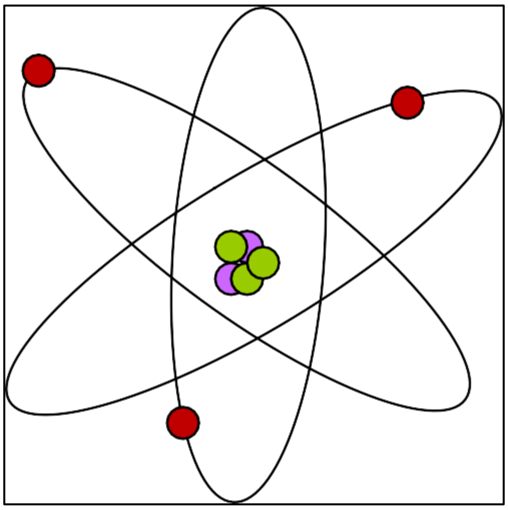
RADIATION SAFETY

Introduction

- Radioactive isotopes occur naturally or can be generated artificially.
- They emit ionizing radiation in the form of electromagnetic waves or energetic particles.
- Exposure to ionizing radiation above permissible limits can result in serious biological damage.

Atoms - constituents

- All matter is made up of atoms.
- An atom consists of a nucleus in the center and electrons orbiting around it in defined shells.
- The nucleus of an atom consists of positively charged protons and neutral particles called neutrons.



Radioactive emission

- A radioactive nucleus is unstable due to an imbalance in the proton to neutron ratio.
- The unstable nucleus can become stable by ejecting particles and electromagnetic waves.
- If an atom loses an orbiting electron it becomes a positive ion as it will have more positive charges than negative charges. The electron that was removed becomes a negative ion.

Types of emissions

The electromagnetic wave/particles emitted by the radioactive isotopes are:

- ***Alpha***
- ***Beta***
- ***Gamma***

Alpha radiation

- Alpha particle consists of two protons and two neutrons.
- Their range in air is about 10 cm. They will not penetrate through the dead layers of the skin.
- They can be stopped completely by a piece of paper or by clothing worn.

- Alpha source is not an external hazard to the body. But they are an internal hazard if it gets inside the body through ingestion or via a wound, etc.
- Once inside the body they disintegrate, causing serious damage to the surrounding tissue within few microns depth.

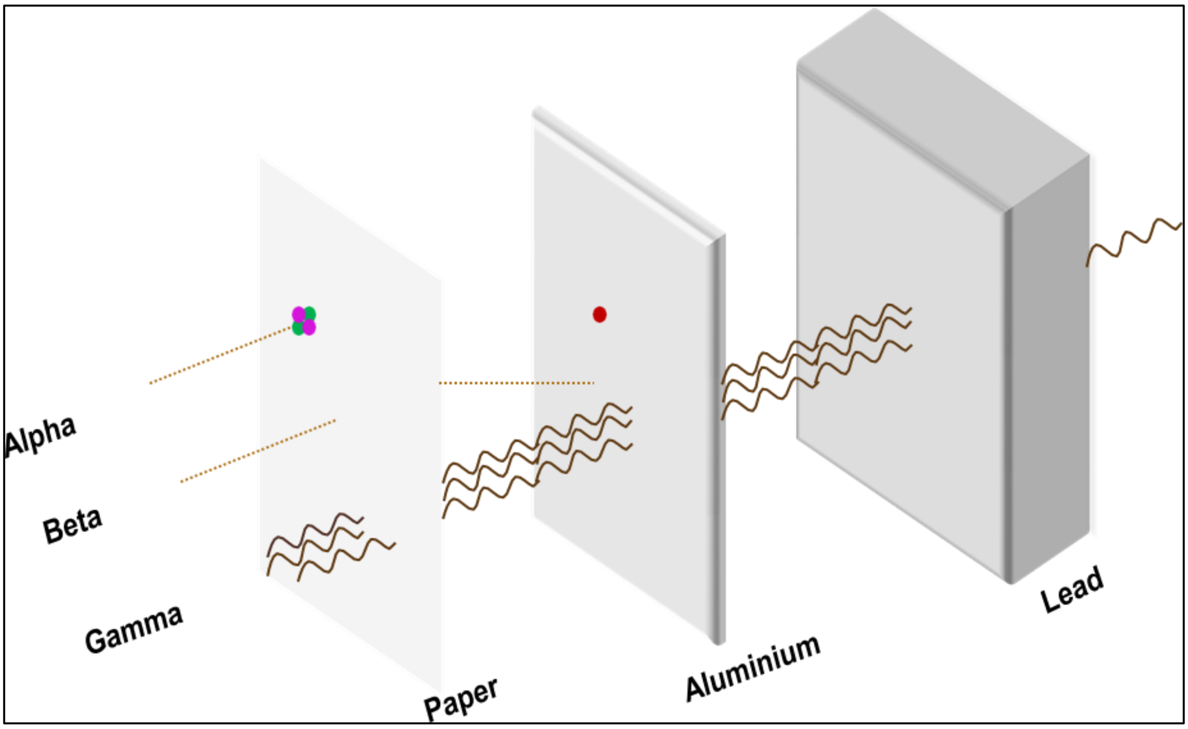
Beta radiation

- Beta particles are electrons which are ejected from the nuclei of radioactive atoms by disintegration.
- They can penetrate into the human body from 0.2 to 1.3 cm and can travel few meters through air.
- If they are deposited on the skin for long periods of time, they could cause severe burns.
- Beta emitters are internal radiation hazards when taken inside the body.
- When the beta particle is slowed down or stopped, secondary X radiation known as bremsstrahlung may be produced.
- Beta particles can be stopped by the walls of a room or by a sheet of plastic about 1.3 cm thick.

Gamma radiation

- Gamma rays are electromagnetic radiation of short wavelength that are deep penetrating.
- Due to the deep penetration, they present an external exposure hazard.
- They can travel many meters in air.

Penetration power of radiation



Biological effects of radiation

- As radioactive photons/particles pass through living cells, they cause rupture of bonds in the molecules resulting in molecular changes that injure the affected cells.
- This destroys the capacity of reproduction in some cells or causes mutation, in which the cells resulting from division are different from parent cell.
- A very weak exposure over several years, can be as potentially injurious as a large single exposure.
- An important characteristic of injuries arising from penetrating radiation is the latent period that intervenes between the exposure and the visible signs of its effects.
- The time between the exposure and the first signs of radiation damage is called the "latent period". The larger the dose, the shorter the latent period.

Basic safety factors

For external radiation exposure hazards, the basic protection measures are associated with

- **Time**
- **Distance**
- **Shielding**

Time

- The simplest method for protection from ionizing radiation is to spend as little time as possible in the vicinity of radiation source.
- This is applicable even when other protection methods are adopted.
- Reducing the exposure time by one half reduces the dose received by one half.

Distance

- Doubling the distance between the person and the source helps to reduce the exposure to a quarter of its original value.
- Maintaining a safe distance is important when working near inadequately shielded sources of radiation.

Shielding

- The more mass that is placed between a source and a person, the less radiation the person will receive.
- Transparent plates of thick plastic or aluminium is used for shielding beta particles.
- Gamma rays can be attenuated by using lead shields or concrete.

Monitoring Instruments

Film badges

- The film badge is worn on the outer clothing of the user.
- It consists of a photographic film. Radiation interacts with the silver atoms in a photographic

film, resulting in the darkening of the film.

- The darkened film is then compared to a control film that was not exposed to radiation to determine the amount of radiation exposure.

Thermo luminescence detectors (TLD)

- TLDs are worn by the person as badges or as finger rings, which consists mostly of lithium fluoride chips.
- The absorbed radiation displaces electrons from their ground state. The electrons are trapped in a meta stable state and light is emitted when electrons return to the ground state.
- The amount of light released is related to the absorbed radiation dose.

Fig. Thermo luminescence detectors (TLD)

Pocket Dosimeter

- It consists of electrostatically charged quartz fiber and ionization chamber. When chamber is exposed to radiation, the air atoms in the chamber become ionized.
- This allows the static electricity charge to leak from the quartz fiber in direct relationship to the amount of radiation present.
- The advantage is that it allows the individual to determine his/her radiation dose while working with radioactive isotopes.

Ionization Chamber

- It consists of an ionization chamber with a positive and negative electrode.
- When exposed to a beam of radiation, a current will flow in the circuit because the electrons that are knocked out of the air atoms by the radiation will be attracted by the positive electrode.
- The flow of current will be in proportion to the radiation received.

Geiger- Mueller Counters

- Capable of detecting very small amounts of radiation.

- It uses an ionization chamber but it is filled with a special gas and has a greater voltage supplied between its electrodes.

Fig. Geiger- Mueller Counters

Becquerel (Bq)

- The strength of a radioactive source is measured in units of Becquerel (Bq).
- It is equivalent to one disintegration per second. This unit provides a measure of the rate of radioactive disintegration.
- There are 3.7×10^{10} Bq per curie of radioactivity.

Absorbed dose

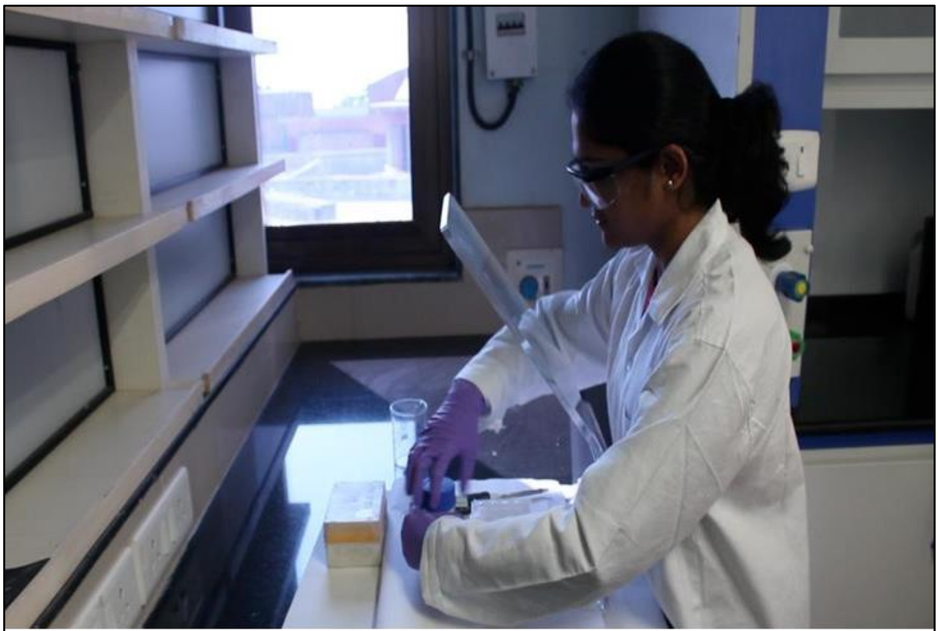
- The amount of energy absorbed per unit weight of the organ or tissue is called the absorbed dose. It is expressed in units of Gray (Gy).
- One Gy is equal to one Joule of absorbed energy per kilogram of matter.
- Rad is the older unit and 1 Gy = 100 rads.

Equivalent dose

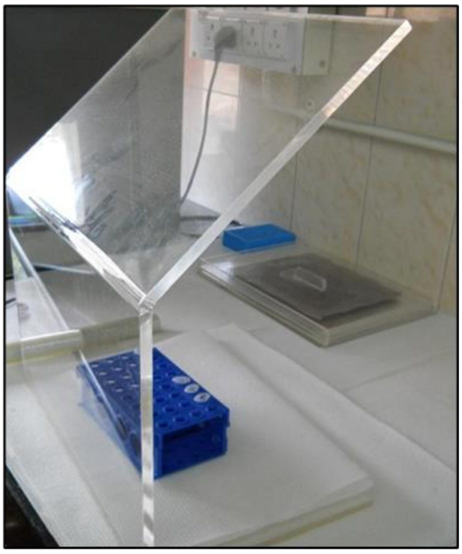
- The equivalent dose in Sv is equal to "absorbed dose" multiplied by a "radiation weighting factor".
- Rem is the older unit of equivalent dose.
- 1 Sv = 100 rem

Safety Precautions

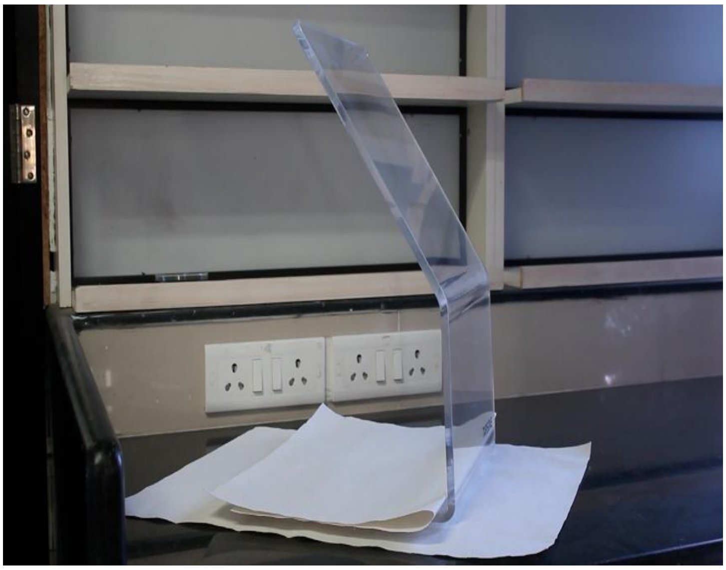
- Lab coats, shoes and safety glasses must be worn in the laboratory.
- Materials/equipment which are not required must not be brought into the laboratory or stored inside.
- An inventory of radioactive sources used in the laboratory must be maintained and updated.
- Food items must not be stored or consumed inside the laboratory.



- Radiation symbols must be displayed wherever active sources are being manipulated or stored.



- Gloves, clothing, apparatus and benches must be monitored after work with radioactive materials.
- Always use appropriate shielding when working with radioactive materials
- Use remote handling devices such as forceps, tongs wherever possible.
- Never pipette solutions by mouth.
- Work surface must be covered with smooth, non absorbent materials.



COMPRESS AIR AND GAS CYLINDER SAFETY

Compressed air safety

Introduction

Compressed air when used for cleaning machinery and bench tops can result in injury from the air jet, as well as from the particles made air borne.

Hazards

- Particles that are dislodged by compressed air can cause eye injury or abrasions on the skin.
- Compressed air can enter the blood stream through a break in the skin. This can cause a condition known as embolism where the blood vessel is blocked by an air bubble. This can cause coma or paralysis depending upon its size, duration and location of the block.
- Compressed air forces the dirt and dust particles into the air creating a respiratory hazard.

Fig. Compress air blower

Precautions

- Use wet cleaning methods or vacuum cleaners wherever possible.
- Never use compressed air to clean dust from clothes or skin.
- Never direct compressed air towards others.
- The nozzle pressure must be maintained below 10 psi.
- Use personal protective equipment particularly eye protection, for protection from flying particles.

GAS CYLINDER SAFETY

Introduction

• Certain specific properties of compressed gases make them highly useful in various research activities.

• These gases, however, can be dangerous if not handled in an appropriate manner.

• Many of the odorless and colorless gases are highly toxic and flammable and this calls for utmost care while handling them.

Types of gases

• **Flammable gas** burns or explodes if it is mixed with air, oxygen or other oxidant, in the presence of a source of ignition.

Please note that flammable and inflammable are synonyms & non-inflammable is their antonym.

• **Inert gas** is resistant to chemical action under normal temperature and pressure conditions.

• **Oxidizing gas** supports combustion.

• **Pyrophoric gas** spontaneously ignites upon exposure to air.

• **Corrosive gas** can burn and destroy body tissues on contact. Corrosive gases can also attack and corrode metals.

• **Poisonous (Toxic) gas** is harmful to humans when it exceeds the maximum allowable concentration in air.

Routinely used gases

Inert gases	**Argon, Helium, Neon and Nitrogen**
Flammable gases	**Hydrogen, Methane, Ethylene, Ethane, Propylene, Acetylene, Isobutylene, LPG and Deuterium**
Toxic gases	**Carbon monoxide, Sulphur dioxide, Phosgene, Boron trichloride, Germane, Diborane, Chlorine and Ammonia**
Pyrophoric gases	**Silane and Phosphine**
Oxidizers	**Oxygen and Nitrous oxide**

Hazards in gas cylinder usage

• Oxygen deficient atmosphere resulting in asphyxiation.

• Formation of flammable gas air mixtures in case of leakage of flammable gas.

- Oxygen enriched atmosphere in case of leakage of oxygen gas.
- Injury caused by fall of gas cylinders during handling.
- Exposure to high concentrations of toxic or corrosive gases in case of leakage.
- Gas cylinders can explode when exposed to high temperatures, e.g., in case of fire.
- If the valve breaks, the sudden release of compressed gas can turn it into a lethal projectile.
- Gas cylinders should be capped when they are not connected to the system

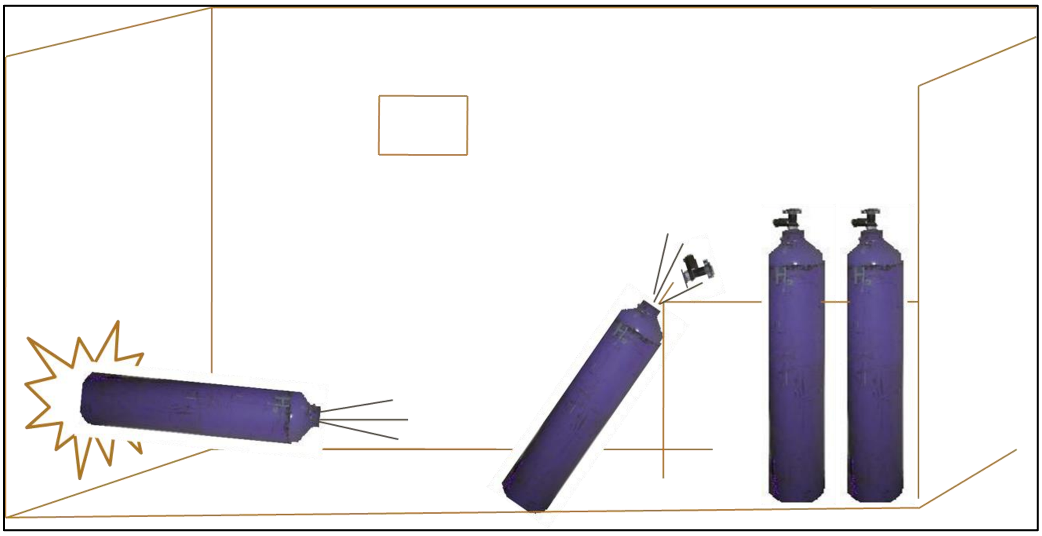


Fig. Breakage of valve can turn the cylinder into a projectile

Oxygen deficiency

- Leakage of any gas (except oxygen) inside a confined/enclosed space can cause displacement of oxygen resulting in an oxygen deficient atmosphere.
- Entry into a workspace with oxygen level below 19.5% is unsafe and not permitted

Oxygen levels and effects

Above 21%	• Oxygen enriched atmosphere.
20.95 %	• Normal atmospheric level.
19.5%	• Minimum required level.
19.5 - 12%	• Increased breathing rates, accelerated heartbeat, and impaired thinking.
10-12%	• Faulty judgment, intermittent respiration, and exhaustion.
6-10%	• Nausea and unconsciousness.
Less than 6%	• Cessation of breathing followed by cardiac arrest.

Oxygen enrichment

• An atmosphere having more than 21% of oxygen is considered as an oxygen enriched atmosphere and is not safe for entry/working.

• A leakage of oxygen gas in an enclosed space can result in an oxygen enriched atmosphere.

• An excess of oxygen in the air can be a fire hazard, as oxygen is a supporter of combustion and it causes materials to burn violently.

Flammable vapor air mixtures

• A leakage of a flammable gas would form a flammable vapor air mixture.

• If the vapor air mixture is within the flammable range, it can explode in the presence of an ignition source.

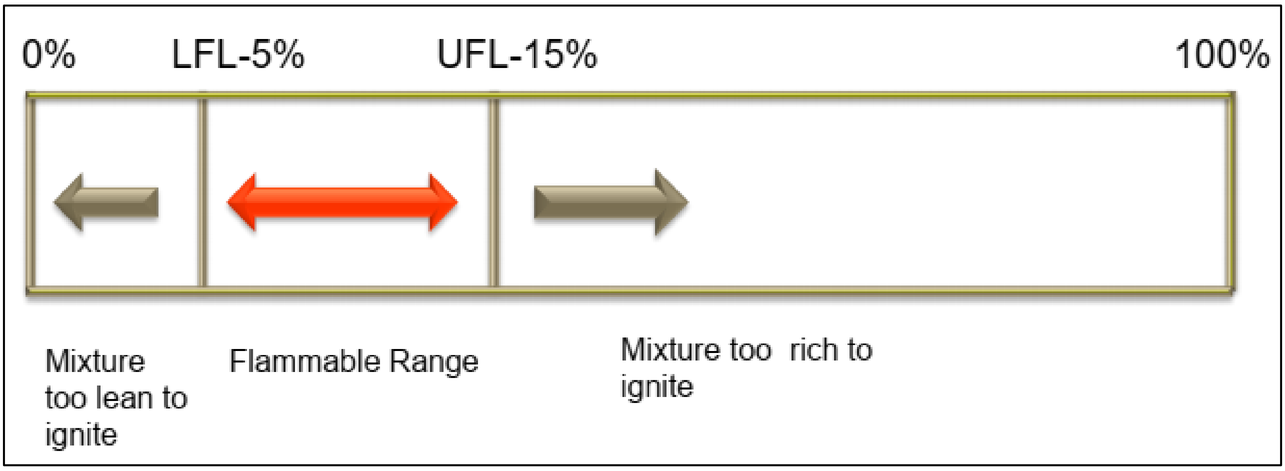
Flammability limits

• Vapor air mixtures will only ignite within a well-specified range of composition.

• The lower flammable limit (LFL) is the leanest mixture that can ignite, i.e., the mixture with the smallest fraction of combustible gas.

• The upper flammable limit (UFL) is the richest fraction of combustible gas mixture that can ignite.

Flammable limits for methane gas.



Flammability limits examples

Flammable gas	LFL	UFL
Ethylene	2.7%	36%
Propane	2.4%	9.5%
Hydrogen	4.0%	75%
Carbon monoxide	12.5%	74%

Toxicity

Toxicity is the ability of a substance to produce an unwanted physiological effect when the substance has reached a sufficient concentration at a certain site in the body.

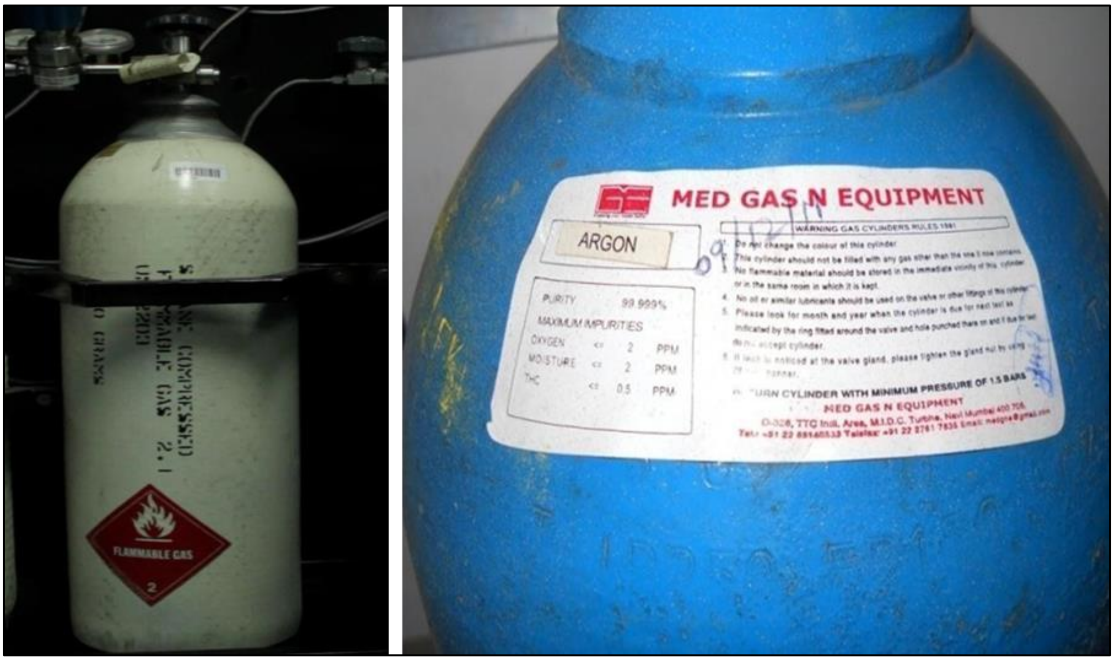
Toxicity- Threshold Limit Value (TLV)

The concentration of an airborne substance to which an average person can be repeatedly exposed without adverse effects.

Toxic gas	TLV
Carbon monoxide	29 mg/m^3
Phosgene	0.4 mg/m^3

Purchasing/ Receiving gas cylinders

- Purchase smallest quantities wherever and whenever possible.
- When receiving gas cylinders: Ensure that they are properly labelled.
- Do not accept cylinders without label of the content.
- The color of the cylinder alone must not be depended upon.
- Visually inspect for damage.
- Ensure that the gas cylinders are received with valve caps.



Storage of gas cylinders

- Gas cylinders must be stored in a separate storage area outside the building.
- The storage area must be protected from weather.
- Flammable gas cylinders must be separated from oxygen cylinders by a distance of 6m or by a wall of 30 minutes fire resistance.
- Empty cylinders must be marked /tagged and stored separately.

Storage of gas cylinders inside labs

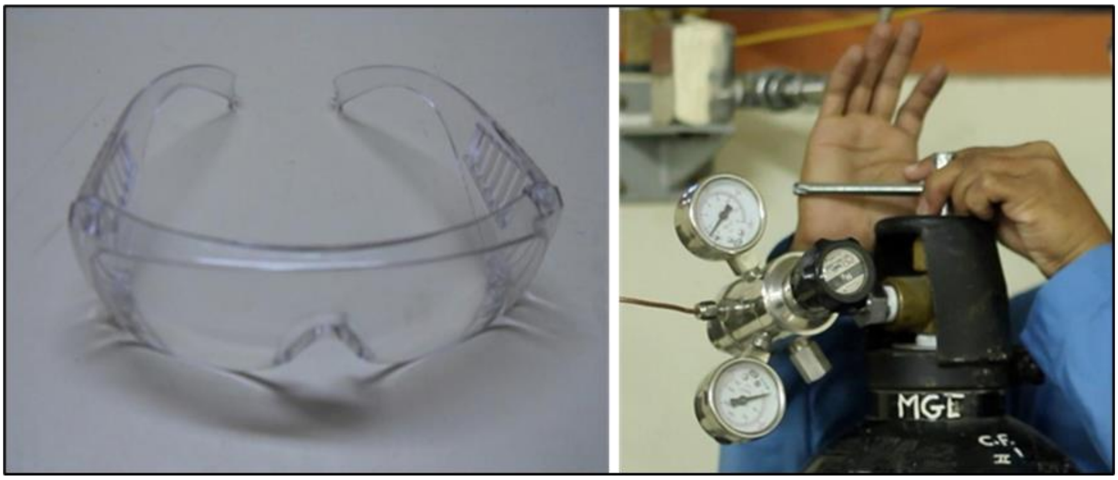
- Only gas cylinders for immediate use must be stored inside the laboratory.
- Materials must not be stored in front or on top of gas cylinders.
- All cylinders in the laboratories must be clearly labeled.
- Gas cylinders must not be stored near exits and passages.
- Gas cylinders must be stored away from heat sources.
- Place the valve cap on the cylinder whenever the regulator is removed.
- Cylinders must always be kept chained or supported in a manner to prevent fall.

Transportation of gas cylinders inside labs

Before moving gas cylinder

- Valve must be closed.
- Regulator must be removed.
- Cylinder must be capped.
- Secure the cylinder in a cylinder cart (with chain).

Safe use of gas cylinders

- Refer the Material Safety Data Sheet (MSDS) for the gas before usage, to know about the hazards and precautions to be taken.
- Do not tamper with the cylinder valves.
- Always use the correct regulator for the cylinder.
- Inspect the regulator for damage before use.
- Never use damaged regulators, piping, etc.
- After the regulator is attached, the cylinder valve must be opened just enough to indicate pressure on the regulator gauge and all connections must be checked with a compatible solution for leaks.
- Do not stand in front of the regulator gauge or the valve outlet side, while opening the valve.
- Use safety glasses while working with gas cylinders.
- Before a regulator is removed from a cylinder, the cylinder valve must be closed and the regulator relieved of gas pressure.
- Ensure proper ventilation in the area where gas cylinders are stored.
- Spindle key must always be placed at an easily accessible location, for closing the valve in case of emergency.
- A cylinder must never be emptied to a pressure lower than 25 psi as the residual contents may become contaminated if the valve is left open.
- Close cylinder valve whenever: work is finished, cylinder is empty.
- 

- Store toxic/pyrophoric gases in gas cabinets.
- Gas detectors must be installed for detecting gas leaks.
- The cylinder valve and other fittings used with gas cylinders must be compatible with the type of gas used. Incompatible materials can cause gas leak.
- Greasy and oily materials must never be used on oxygen cylinders or fittings as it can cause explosion.
- Regulators for oxygen service must never be used with flammable gases. Cross contamination of internal parts may result in rapid oxidation and fire.

Emergency measures

- If a gas leak occurs from the cylinder inside the gas cabinet it must not be removed from the cabinet.
- No attempt must be made to repair a leak from the base of the valve.
- Personal protective equipment must be used while dealing with toxic/corrosive gas leaks.
- The building must be evacuated immediately if a gas (flammable/pyrophoric/toxic/corrosive) leak becomes uncontrollable.
- Emergency measures must be undertaken only by trained personnel.
- The gas supplier must be intimated immediately.
- Self-Contained Breathing Apparatus (SCBA) must be used while dealing with toxic/corrosive gas leaks or if an oxygen deficient atmosphere exists.

CYLINDER TAG

NAME OF GAS: ______________________________

RECEIVED BY:__________________DATE:__________

MOBILE NO: ______________________________

CYLINDER NO.: ____________________________

GAS HAZARD CLASS: _________________________

CYLINDER STATUS

☑ Tick on Appropriate Status with Date.

STATUS	DATE
IN USE	☐
EMPTY	☐

SEE OTHER SIDE

IN EMERGENCY CONTACT
Main Gate: 0326 2235 5692

CYLINDER STORAGE & HANDLING

1. **RESTRAIN** cylinder properly when in storage and use
2. **STORE** cylinder in cool, well ventilated and fire-resistant area
3. **INSTALL** cylinder where they will not be knocked over or damaged by falling objects.
4. **CLOSE** valve and **SECURE** caps when not in use.
5. **INSPECT** cylinder for leaks after connecting.
6. **TRANSPORT** cylinder using hand truck/trolley designed for this purpose
7. **REPORT** any leak or damage to your supervisor immediately

IIT (ISM) Dhanbad-826004

IIT(ISM) Dhanbad
Safety Signage
Cylinder Tag 1.0

CYLINDER TAG

NAME OF GAS: ______________________________

RECEIVED BY:__________________DATE:__________

MOBILE NO: ______________________________

CYLINDER NO.: ____________________________

GAS HAZARD CLASS: _________________________

CYLINDER STATUS

☑ Tick on Appropriate Status with Date.

STATUS	DATE
IN USE	☐
EMPTY	☐

SEE OTHER SIDE

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IIT(ISM) Dhanbad
Safety Signage
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CHEMICAL SAFETY

Introduction

- Wide range of chemicals are used in research laboratories of the Institute, each with its own inherent hazards.
- An understanding of the potential hazards and precautions required in handling of chemicals is of outmost importance in preventing exposure to chemicals and mishaps.

Routes of entry

The main routes of entry of the chemicals into the human body are:

- Inhalation into lungs.
- Absorption through skin membrane/cuts in the skin.
- Ingestion via mouth into the gastrointestinal system.

Corrosives

- Typical examples are sulfuric acid, nitric acid, potassium hydroxide (caustic potash), sodium hydroxide (caustic soda), bromine and phenol.
- Corrosive substances cause destructive burns on the tissue by chemical action at the site of contact.
- Corrosive effect can also occur in the respiratory tract in case of inhalation and in the gastrointestinal tract in case of ingestion.

Hazard Symbol-Corrosives

Hazard Symbol-Oxidizers

Oxidizers

- Typical examples include hydrogen peroxide, nitric acid, perchloric acid, sulphuric acid, chlorates, chromates, nitrates, peroxides, permanganates and picrates.
- Oxidizers are chemicals which decompose readily under certain conditions to yield oxygen.
- They can cause a fire to burn violently.
- Oxidizers must not be stored with flammables.

Flammables

- Flammable substances are those that readily catch fire and burn in air.
- The vapors released from a flammable liquid are a common fire hazard in a laboratory.
- The degree of hazard associated with a flammable liquid depends on its flash point, flammability limit and ignition temperature.

Hazard Symbol-Flammables

Hazard Symbol-Explosive

Pyrophoric chemicals (flammables)

- The rapid oxidation of a pyrophoric chemical by oxygen or moisture in air causes the compound to ignite spontaneously.

  Example: butyl lithium.

Potentially explosive chemicals

- Chemicals when subjected to heat, impact, or friction, undergoes rapid chemical change, evolving large volumes of gases which cause sudden increase in pressure.
- Heat, light, mechanical shock and certain catalysts can initiate explosive reactions.
- Shock sensitive substances include **acetylides, azides, nitrogen triiodide, organic nitrates, nitro compounds, perchlorate salts and organic peroxides**.
- **Perchloric acid**, if allowed to dry on wood or other combustibles, will explode and cause a fire on impact or friction.
- **Picric acid** and **picrates** are detonated by heat and impact.
- **Ethers** that have aged and dried to crystals are extremely unstable and potentially explosive.

Toxic chemicals

- Toxic chemicals produce injurious or lethal effects upon contact with body cells due to their chemical properties.
- The toxic effects depend upon the extent of exposure and the inherent toxicity of a chemical.
- The extent of exposure is determined by the dose, duration and frequency of exposure and the route of exposure.

Hazard Symbol-Toxic

- Toxic effects of a chemical may occur after a single (acute) exposure or long term repeated (chronic) exposure.
- Examples of acute toxins are **sodium- cyanide, sodium azide** and **dimethyl mercury**.
- **Benzene** is an example of a chronic toxin which can cause damage after repeated or long-term exposure.

Types of toxins - target organ/tissue - examples

- **Neurotoxins (nervous system)**- mercury (metallic, inorganic and organic), xylene, carbon disulphide, n-hexane, trichloroethylene.
- **Hematotoxins (blood)**-carbon monoxide, nitrates aromatic amine compounds.
- **Hepatotoxins (liver)**- chloroform, dinitrobenzene
- **Nephrotoxins (kidney)**- cadmium, mercury, carbon tetrachloride
- **Dermatotoxins (skin)**- organic solvents

Water reactive chemicals

- These chemicals react violently when they come in contact with moisture or water.

Examples: **Lithium, Sodium, Potassium, Aluminium Bromide, Calcium Oxide, Sulfur Trioxide and Phosphorus Pentachloride**.

Ordering of chemicals

- Always order the smallest possible quantity of chemical. This reduces hazards and chemical waste.
- Understand the hazardous properties of the chemical that is to be purchased.
- Where possible, purchase a less hazardous chemical.

Receipt of chemicals

- Received packages must be checked to ensure that the containers are in good condition.

- Details of new chemicals must be entered in the laboratory inventory and stored in a designated area.
- The date of receipt and date of first usage must be recorded on the bottles of peroxide forming chemicals.
- ***Ensure that the Material Safety Data Sheet (MSDS) is obtained with the chemical and is readily available for reference.***

Sigma-Aldrich.

www.sigmaaldrich.com

SAFETY DATA SHEET
according to Regulation (EC) No. 1907/2006

Version 7.4
Revision Date 16.06.2020
Print Date 04.07.2020
GENERIC EU MSDS - NO COUNTRY SPECIFIC DATA - NO OEL DATA

SECTION 1: Identification of the substance/mixture and of the company/undertaking

1.1 Product identifiers

Product name	:	Nitric acid
Product Number	:	438073
Brand	:	SIGALD
Index-No.	:	007-004-00-1
REACH No.	:	01-2119487297-23-XXXX
CAS-No.	:	7697-37-2

1.2 Relevant identified uses of the substance or mixture and uses advised against

Identified uses : Laboratory chemicals, Manufacture of substances

1.3 Details of the supplier of the safety data sheet

Company : Sigma-Aldrich Chemical Pvt Limited
Industrial Area, Anekal Taluka
Plot No 12,
12 Bommasandra - Jigani Link Road
560100 BANGALORE
INDIA

1.4 Emergency telephone

Emergency Phone # : +91 98802 05043

SECTION 2: Hazards identification

2.1 Classification of the substance or mixture

Classification according to Regulation (EC) No 1272/2008
Oxidizing liquids (Category 3), H272
Corrosive to Metals (Category 1), H290
Acute toxicity, Inhalation (Category 3), H331
Skin corrosion (Sub-category 1A), H314
Serious eye damage (Category 1), H318

For the full text of the H-Statements mentioned in this Section, see Section 16.

2.2 Label elements

Labelling according Regulation (EC) No 1272/2008
Pictogram

Signal word Danger

SIGALD- 438073 Page 1 of 8

Fig. Chemical bottle with Material Safety Data Sheet

Storage of chemicals

- Bulk stocks must be stored in a separate building.
- A spill or fire involving bulk containers will be difficult to tackle when compared with that involving smaller bottles.
- Chemicals must not be placed indiscriminately in the storage shelf. They must be grouped based on their compatibility.
- Separate chemicals into compatible groups and store alphabetically within compatible groups.
- In the event of an accidental breakage or seismic activity, incompatible chemicals that are stored in close proximity can mix to start a fire, hazardous fumes or explosions.

The following chemical groups must be separated by storing them in different cabinets/shelves or by providing secondary containment (trays).

- **Oxidizers, including peroxides**
- **Acids**
- **Bases**
- **Flammable materials**
- **Reproductive toxins**
- **Carcinogens**

Any incompatibles within the above group must be stored separately.

- To prevent accidents caused by overreaching do not store chemicals on shelves higher than 1.5 meter (from floor level).

• Fix the shelf to the wall to prevent its fall.

• Store heavier or larger bottles on lower racks.

• Store flammable chemicals in approved safety cabinets.

• There must be a fixed storage place for each chemical and the same must be returned to that location after each use.

• Toxic or odoriferous chemicalsmust be stored in a ventilated cabinet.

• Chemicals must not be exposed to heat or direct sunlight.

• Heat and sunlight can degrade chemicals, deteriorate storage containers and labels.

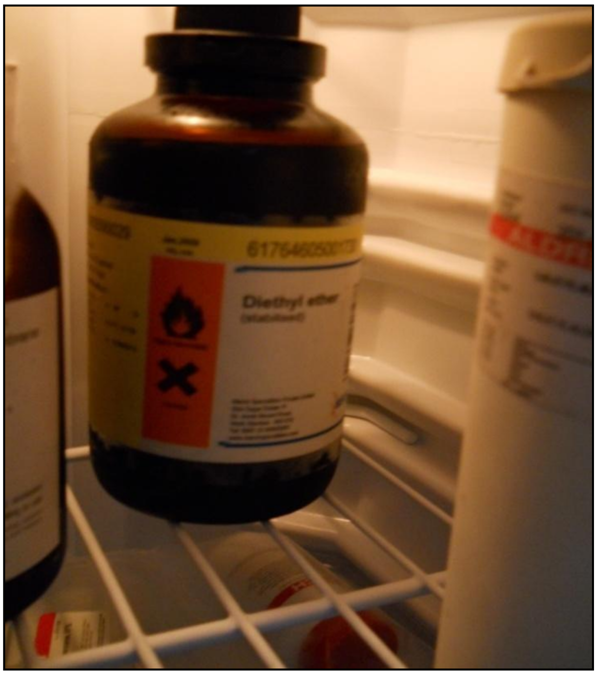
• Chemicals must not be stored at locations where they can be knocked over.

• Rim guards must be fixed on the edge of shelves to prevent bottles from falling.

• Flammable chemicals must not be stored on bench tops.

• After use they must be immediately removed to a safety cabinet.

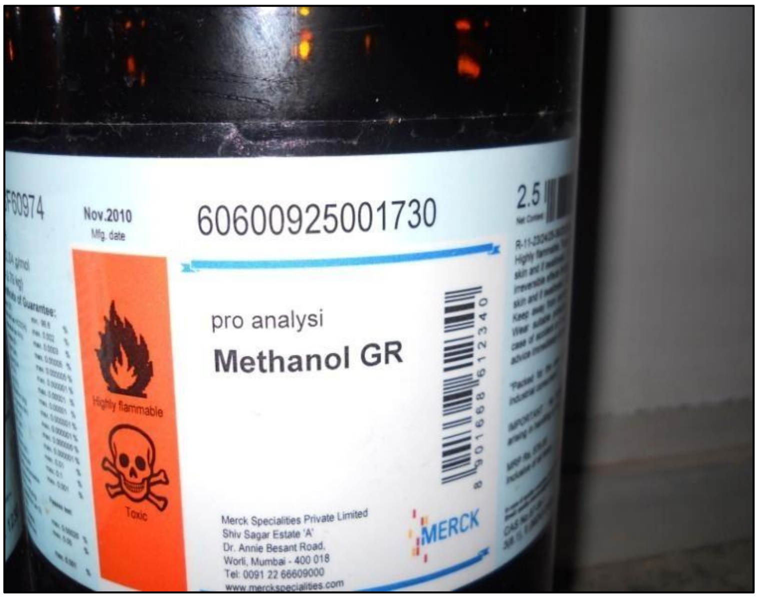
- Flammable solvents must not be left open in containers or beakers.
- Same must be stored and handled away from sources of ignition and oxidizers.
- **Flammable chemicals must not be stored in domestic refrigerators.**



- Vapors can leak out from the bottles and form a flammable vapor air mixture.
- The bulb or thermostat can be a source of ignition.
- Flammable chemicals must be stored only in intrinsically safe lab purpose refrigerators.

Handling of chemicals

- Bench tops must not be used as storage area to prevent clutter. Keep only chemical bottles that is for immediate use on bench tops.
- All chemical bottles must be tightly closed after use and must not be placed on edge of the bench or shelf from which they can fall.
- Chemical formulae or short forms must not be used for labelling chemical bottles.



- Labels must include the full name of the chemical, hazard pictogram and a brief description of the hazards and precautions to be taken.
- It will not be possible to identify the chemical in case of a spill or body contact due to inadequate labelling.
- Worn out labels must be immediately replaced by new ones. Unlabeled chemical bottles can create difficulty at the time of disposal of chemical bottle.
- Chemicals must not be stored in drinking water bottles.

Transporting chemicals

- Use secondary containment when transporting chemicals.
- When transporting several containers, use carts with attached side rails and trays with provision for spill containment.
- Bottle carriers must be used while moving single container.

Chemical inventory

The inventory of stored chemicals must be examined at least annually. Annual inventory checks help in many ways:

- It ensures that chemicals are segregated according to their compatibility.
- Discarding expired chemicals and help to save space.
- Help to quickly locate the chemicals.
- The expiration date of peroxides can be monitored.
- Help to identify bottles with worn out labels or those which are leaking.

Chemical spills

The following equipment must be maintained in laboratories for dealing with chemical spills:

- Chemical spill kits
- Personal protective equipment, e.g., chemical cartridge respirators.
- Scoops and dustpans
- Dry sand

The following actions must be taken in the event of a chemical spill:

- Evacuate non-essential personnel from the area.
- Ventilate the area by opening the windows.
- If the spilled material is flammable, extinguish all open flames. Do not operate electric switches near the spill.
- Avoid inhaling vapor from spilled material.
- Use personal protective equipment.

- Ensure that there is an exit near by.
- Use spill containment kits to clean up the spill.

Safety precautions

- Fume-hood is mandatory for chemical experiments or reactions.
- The sliding glass doors of the fume hood must be partially open to ensure the air-flow.

Fig. Modern fume hood (https://en.wikipedia.org/wiki/Fume_hood)

- Do not work alone in the laboratories particularly when performing hazardous procedures.
- Do not perform unauthorized experiments.
- Plan appropriate procedures and the positioning of all equipment before beginning any experiment.
- Wear appropriate personal protective equipment, a laboratory apron or coat, safety glasses and toe covered footwear at all times in the laboratory.
- Wear suitable gloves when handling chemicals. Inspect all gloves for defects before usage.

- Know the location of emergency equipment.
- Be aware of the hazards posed by the work of others in the laboratory.
- Make others in the laboratory aware of any specific hazards associated with your work.
- When heating a test tube or other apparatus, never point it towards yourself or others.
- Be sure that glassware has cooled before touching it.
- Dilute concentrated acids and bases by slowly pouring the acid or base into the water while stirring.
- Keep work area clean and uncluttered. Maintaining good housekeeping helps to prevent accidents.
- Laboratory equipment must be regularly inspected and serviced as per manufacturer's recommendations.
- Store coats, bags and other personal items in a designated area, not on bench tops.
- Keep drawers and cabinets closed when not in use.
- Never heat flammable substances with an open flame. Use a water bath.

Emergency measures

- All chemical splashes on the skin must be immediately flushed under running water.
- Contaminated clothing must be removed while flushing the body. Flushing must be continued for at least 15 minutes.
- Eyes must be immediately flushed with copious amount of water for at least 15 minutes.
- In case of contact with hydrofluoric acid, apply 2.5% calcium gluconate gel on the skin after flushing the affected part with water.
- Refer safety data sheets for more information.

Fig. Emergency Washing Equipment (https://ehs.research.uiowa.edu/)

Disposal of chemicals

- Laboratories must maintain labelled carboys/cans for collecting spent chemicals.
- Care must be taken to prevent mixing of incompatible chemicals while transferring spent chemicals.
- There should be at least 2-inch head space above the liquid surface in the chemical container.

Chemical Label

IIT (ISM), Dhanbad
826004

Name:____________________Dept________

Lab:______________Date ________________

Composition (no acronyms or initialisms)

____

____

____

Select the hazard symbol

Oxidizer | Corrosive Acid | Corrosive Base | Toxic | Environment Hazard | Flammable

Chemical Waste

IIT (ISM), Dhanbad
826004

Name:____________________Dept________

Lab:______________Date ________________

Composition (no acronyms or initialisms)

____

____

____

Select appropriately

Oxidizer | Corrosive Acid | Corrosive Base | Toxic | Environment Hazard | Flammable

BIO SAFETY

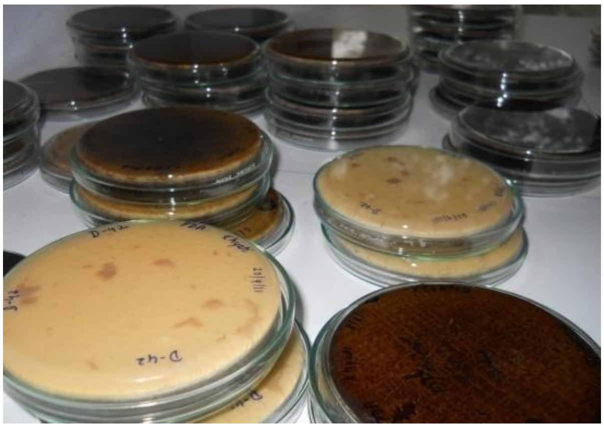
Introduction

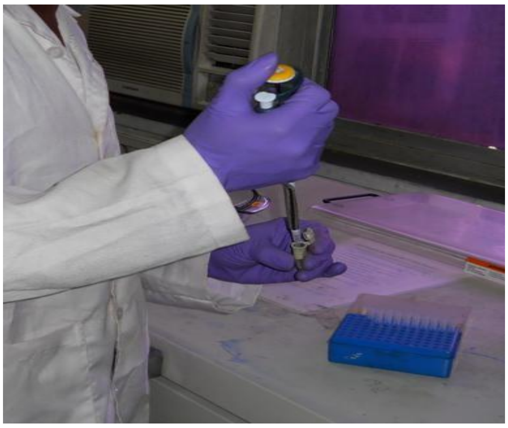
- Bio-related research activities may involve manipulation of microbial, animal or plant cells.
- The risks associated with these activities arise from the samples and /or the procedural requirements.
- Adherence to standard microbiological techniques and using facilities suitable to the risk level of the pathogen helps to protect the researcher from laboratory-acquired infections.

Bio hazards

Hazards related to bio research can be classified into two categories.

- hazards related with the pathogen or human/animal cells being used in research.
- related with the procedures and practices followed in the lab.





Pathogenic risks

Cell cultures

- Researchers who handle or manipulate human or animal cells are at risk of possible exposure to potentially infectious pathogens that may be present in those cells/ tissues.
- The human cell lines may contain blood borne pathogens, which can be transmitted due to improper handling.

Routes of entry for pathogen

The probable routes of entry are:

- Inhalation of infectious aerosols.
- Contact of the agent with the skin, eyes or mucous membrane.
- Inoculation by contaminated sharps.
- Bites from infected animals or contact with their body fluids.
- Ingestion of infectious agent through mouth pipetting or contaminated hands.

Aerosols

- Aerosols generated during research activities remain undetected and can spread easily and remain suspended in the laboratory atmosphere for a long time.

- They possess a serious hazard to the person performing the task and also to others who are exposed to the air from the laboratory.

Aerosols can be generated during the following activities:

- Pipetting
- Blending
- Centrifugation
- Use of sonicators and vortex mixers

These respirable size particles when inhaled are retained in the lungs and can cause infection to the person.

Pathogenic risks

The risk from the pathogen handled depends on the following factors:

- Capability to cause infection in the host and the severity of the same.
- Preventive measures and treatment available.
- Route of entry
- Infective dose level
- Stability in the environment
- The range of cells/strains that can act as a host.

Based on the above factors the microorganisms are classified into four risk groups.

Classification of pathogenic microorganisms

Risk group 1

- A pathogen that is unlikely to cause any disease in humans or animals.
- All bacterial, fungal and parasitic agents not included in higher groups.

Risk group II

- A pathogen that can cause disease in humans or animals but is unlikely to be a serious hazard.
- Effective treatment and preventive measures are available and the risk of spread of infection is limited.
- **Bacterial-** ***Vibrio cholerae***
- **Fungal-** ***Aspergillus fumigatus, Actinomycetes***
- **Parasitic-** ***P.falciparum, Plasmodium thcilera***
- **Viral and Rickettssial -*****Vole rickettsia, Mumps virus***

Risk group III

- A pathogen that can cause serious human or animal disease, but does not ordinarily spread from one infected person to another.
- Effective treatment and preventive measures are available.
- **Bacterial -** ***Clostridium botulium, Francisella tularensis***
- **Fungal -** ***Coccidioides immitis, Histoplasma capsulatum***
- **Parasitic-** ***Schisistosoma mansomi***
- **Viral and Rickettssial -** ***Foot-and- Mouth disease virus***

Risk group IV

- A pathogen that usually causes serious human or animal disease and that can be readily transmitted from one individual to another, directly or indirectly.
- Effective treatment and preventive measures are not usually available.
- ***Korean hemorrhagic fever***
- ***Omsk hemorrhagic fever***
- ***Central European Encephalitis viruses***

Containment

The term containment is used to describe the safe work practices in handling infectious agents to reduce exposure to laboratory personnel and others.

Types of containment

- **Biological containment (BC)**
- **Physical containment (PC)**

Biological containment (BC)

Any combination of vector and host which is to provide biological containment must be chosen or constructed to limit the infectivity of vector to specific hosts and control the host-vector survival in the environment.

Physical containment (PC)

Physical containment helps to confine the pathogenic organisms being handled and prevent exposure to personnel.

Physical containment is achieved by

- *Laboratory practices*
- *Containment equipment*

Primary containment

- *Special laboratory design*

Secondary containment

Primary containment

Offers protection to personnel and immediate laboratory environment whereas secondary containment offers protection to the environment outside the laboratory.

Laboratory practices-Consists of adhering to standard microbiological practices and techniques and awareness of potential hazards.

Containment equipment-This includes biological safety cabinets and enclosed containers (e.g. safety centrifuge cup).

Secondary containment

Proper design of the facility helps in protecting personnel inside the facility and also prevents the release of pathogenic organisms outside the facility.

Facility designs are of three types

- **Basic Laboratory** (for Risk Group I and II)
- **Containment Laboratory** (for Risk Group III)
- **Maximum Containment Laboratory** (for Risk Group IV)

Biosafety levels

- It consists of a combination of laboratory practices, equipment and facilities suitable to the procedures being performed and hazards of the pathogen.
- The four biosafety levels correspond to four risk groups.
- A lower risk group can be assigned a higher biosafety level, if a biological risk assessment carried out requires so.

Biosafety level I (BSL I)

- Suitable for teaching laboratories and for facilities in which work is done with defined and characterized strains of agents not known to cause any disease.
- Good microbiological techniques (GMT) to be followed.

Biosafety level II (BSL II)

Applicable to facilities in which work is done with indigenous moderate-risk agents present in the community and associated with human disease of varying severity. **BSL II** is appropriate when work is done with any human- derived blood, body fluids, tissues, or primary human cell lines, in which presence of an infectious agent may be unknown

BSL II requires

- ***Following GMT***
- ***Use of personal protective equipment***
- ***Use of BSC***
- ***Use of autoclaves***

Biosafety level III (BSL III)

Applicable to facilities in which work is done with indigenous or exotic agents where the potential for infection by aerosols is real and the disease may have serious or lethal consequences.

BSL III requires in addition to that of **BSL II** requirements

- ***Special clothing***
- ***Directional airflow***
- ***Controlled access***
- ***Double door entry/Anteroom***
- ***Supervision***

Biosafety level IV (BSL IV)

Applicable to work with dangerous and exotic agents which pose a high individual risk of life-threatening disease.

BSL IV requires in addition to **BSL III** requirements

- Positive pressure personnel suits
- Strictly limited access
- Double ended autoclave
- Class III BSC
- Airlock with shower
- Supervision

Good microbiological techniques (GMT)

- Specimen containers must be correctly labelled for easy identification.
- Use secondary containers (autoclavable) while transporting specimens to contain spill.
- Specimen containers received from external agencies must be opened in the biosafety cabinet.

• Use mechanical pipettes.

• Open flame must not be used in BSC as it can distort the air flow pattern and damage the filters.

• Always use disposable gloves. Do not touch mouth, eyes and face with contaminated hands.

• Food and drink must not be stored or consumed in the laboratory.

• Glassware must be replaced with plasticware wherever possible.

• Sharps (e.g., needle sticks, glass) must be avoided wherever possible as it can transmit blood borne pathogens in case of injury.

• Use engineered sharp-safety devices when syringes and needles are necessary.

• Needles must not be recapped, to prevent needle stick injury.

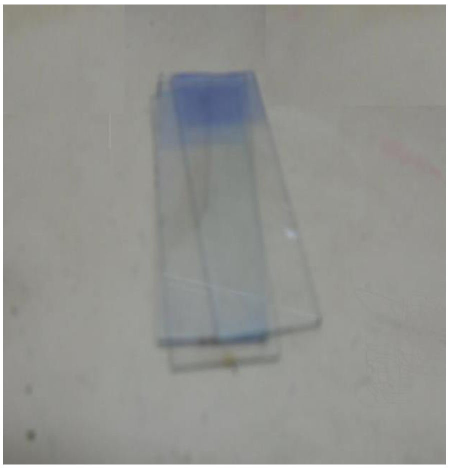
• Puncture-proof containers fit ted with covers must be used for disposing sharps.

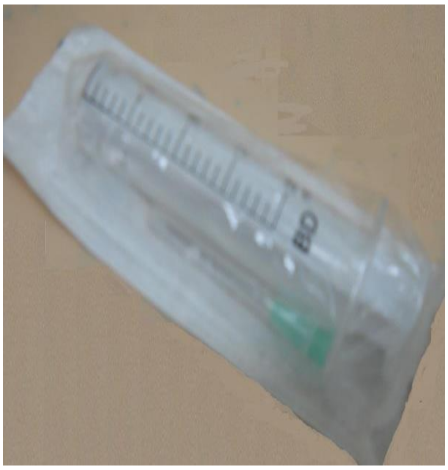
• Tubes and specimen containers must always be securely capped (screw-capped if possible) for centrifugation.

• Refer to manufacturer's instructions before operating equipment.

• Work area must be decontaminated with a suitable disinfectant at the end of the work.

• Han ds must be thoroughly washed before leaving the lab.





Personal protective equipment (PPE)

- Personal protective equipment acts as a barrier to minimize the risk of exposure to aerosols, splashes and other injuries.
- Personal protective equipment must be selected on the basis of the risks involved in the task performed.
- Lab coat, safety glasses and toe covered footwear is a minimum requirement while working in the lab.
- Face shield must be used if there is any risk of splashing of infectious materials.
- Gloves must be worn for all procedures that may involve direct contact with blood, infectious materials, or infected animals.
- Gloves must be removed aseptically and autoclaved with other laboratory wastes before disposal.
- If re-usable gloves are used, on removal they must be cleaned and disinfected before re-use.
- Lab coats and other personal protective equipment used must not be used outside the laboratory.

Biosafety cabinets (BSC)

Biological safety cabinets provide containment of infectious aerosols generated during the laboratory procedures.

There are three types of BSCs used in microbiological laboratories.

These are:

- **Class 1-BSC**
- **Class 2-BSC**
- **Class 3-BSC**

Fig. Biosafety cabinet

Class 1-BSC

Offers protection to laboratory personnel and to the laboratory environment. It doesn't protect the samples from external contamination.

Class II BSC

Provides protection to the samples in the cabinet from external contamination in addition to personnel and laboratory environment protection.

Class III BSC

Provides the maximum attainable level of protection to personnel and the environment.

Factors reduce the efficiency of the BSC:

- Poor location
- Room air currents
- Decreased airflow
- Leakage in HEPA filters
- Working with raised sashes
- Overcrowding the work surface
- Improper user methodology

Emergency measures

In case of exposure to bio samples

- Remove the contaminated clothing.
- Wash the skin thoroughly with soap and water.
- In case of eye contact flush, the eyes with water.
- Report the exposure to the Lab in charge.
- Get medical attention immediately.

Decontamination

- Decontamination renders an item (work bench, equipment, etc.) safe to handle by reducing the number of organisms to below the threshold infectious dose level such that transmission is unlikely to occur.
- Decontamination requirements will depend on the experimental work and the nature of the infectious agent handled.
- Decontamination is usually accomplished by steam sterilization or autoclaving.
- Sterilization and disinfection are different forms of decontamination.

Sterilization

- Sterilization makes an item free from all living microorganisms and viruses.
- The process of sterilization can be accomplished by applying heat.

Disinfection

- Is not as effective as sterilization, as some organisms
- such as bacterial endospores may survive.
- A disinfectant is a chemical or mixture of chemicals used to kill microorganisms, but not spores. They are usually applied to inanimate surfaces or objects.

Disinfectants

- Sodium hypochlorite and formaldehyde are the
- disinfectants recommended for general laboratory use.
- For special purposes phenolic compounds, alcohols, iodine etc., can be used effectively.

Biohazard waste disposal

- Biohazard waste generated in laboratories must be segregated into the following:
    a) Non-contaminated general waste
    b) "Sharps"-needles, glass pieces, etc.
    c) Contaminated material for autoclaving and recycling
    d) Contaminated material for incineration
- Biohazard waste for autoclaving must be collected in red plastic bags and those for incineration in yellow non chlorinated plastic bags.
- Biohazard waste of human and animal origin must be incinerated