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Chemistry Laboratory Guidelines

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I. INTRODUCTION

Recognition of laboratory safety and health problems has crystallized since the passage of the Occupational Safety and Health Act of 1970. This Act requires that certain precautions be observed to protect the safety and health of em-ployees on the job. The employee designation includes all teachers employed by private and public school systems in States that have occupational safety and health plans accepted by the Occupational Safety and Health Administration (OSHA) of the U.S. Department of Labor (DOL). OSHA rules and regulations are provided to protect the employees and the facilities.

The importance of laboratory safety has been recognized for many years in in-dustry. However, educational institutions have been slower to adopt such safety practices and programs.

A science program has certain potential dangers. Yet, with careful planning, most dangers can be avoided in an activity-oriented science program. It is es-sential for all involved in the science instruction program to develop a positive approach to a safe and healthful environment in the laboratory. Safety and the enforcement of safety regulations and laws in the science classroom and labora-tory are the responsibility of the principal, teacher, and student—each assum-ing his/her share. Safety and health should be an integral part of the planning, preparation, and implementation of any science program.

NEED OF INDUSTRIL SFETY

Industrial safety is needed to check all the possible chances of accidents for preventing loss of life and permanent disability of any industrial employee, any damage to machine and material. It is needed to eliminate accidents causing work stoppage and production loss.

WHO GUIDELINES

A WHO guideline is defined broadly as any information product developed by WHO that contains recommendations for clinical practice or public health policy. Recommendations are statements designed to help end-users make informed decisions on whether, when and how to undertake specific actions such as clinical interventions, diagnostic tests or public health measures, with the aim of achieving the best possible individual or collective health outcomes.

The Guidelines Review Committee ensure that WHO guidelines are of a high methodological quality and are developed through a transparent, evidence-based decision-making process. Guidelines are subject to a rigorous quality assurance process that helps to ensure that each and every published guideline is trustworthy, impactful and meets the highest international standard**s**

Common types of safety hazards in the workplace

- Slips, trips and falls. ...
- Slips, Trips and Falls.
- Bad housekeeping and poor drainage can make floors and other walking surfaces wet. ...
- Fire and Explosions.
- Transportation and Vehicle-Related Accidents.
- Confined Spaces.

General Laboratory Safety Rules

A standard list of basic laboratory safety rules are given below, and must be followed in every laboratory that uses hazardous materials or processes. These basic rules provide behavior, hygiene, and safety information to avoid accidents in the laboratory. Laboratory specific safety rules may be required for specific processes, equipment, and materials, which should be addressed by laboratory specific SOPs.

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Basic Safety Rules

Basic safety rules for laboratory conduct should be observed whenever working in a laboratory. Many of the most common safety rules are listed below.

- Know locations of laboratory safety showers, eyewashstations, and fire extinguishers. The safety equipment may be located in the hallway near the laboratory entrance.
- Know emergency exit routes.
- Avoid skin and eye contact with all chemicals.
- Minimize all chemical exposures.
- No horseplay will be tolerated.
- Assume that all chemicals of unknown toxicity are highly toxic.
- Post warning signs when unusual hazards, hazardous materials, hazardous equipment, or other special conditions are present.
- Avoid distracting or startling persons working in the laboratory.
- Use equipment only for its designated purpose.
- Combine reagents in their appropriate order, such as adding acid to water.
- Avoid adding solids to hot liquids.
- All laboratory personnel should place emphasis on safety and chemical hygiene at all times.
- Never leave containersof chemicals open.
- All containersmust have appropriate labels. Unlabeled chemicals should never be used.
- Do not taste or intentionally sniff chemicals.
- Never consume and/or store food or beverages or apply cosmetics in areas where hazardous chemicalsare used or stored.
- Do not use mouth suction for pipetting or starting a siphon.
- Wash exposed areas of the skin prior to leaving the laboratory.
- Long hair and loose clothing must be pulled back and secured from entanglement or potential capture.
- No contact lenses should be worn around hazardous chemicals – even when wearing safety glasses.
- Laboratory safety glasses or goggles should be worn in any area where chemicals are used or stored. They should also be worn any time there is a chance of splashes or particulates to enter the eye. Closed toe shoes will be worn at all times in the laboratory. Perforated shoes or sandals are not appropriate.
- Determine the potential hazards and appropriate safety precautions before beginning any work.
- Procedures should be developed that minimize the formation and dispersion of aerosols.
- If an unknown chemical is produced in the laboratory, the material should be considered hazardous.
- Do not pour chemicals down drains. Do NOT utilize the sewer for chemical waste disposal.
- Keep all sink traps (including cup sink traps and floor drains) filled with water by running water down the drain at least monthly.
- Do not utilize fume hoods for evaporations and disposal of volatile solvents.
- Perform work with hazardous chemicalsin a properly working fume hoodto reduce potential exposures.
- Avoid working alone in a building. Do not work alone in a laboratory if the procedures being conducted are hazardous.
- The PEL and the Threshold Limit Values (TLV) will be observed in all areas. If exposure above a PEL/TLV is suspected for an ongoing process, please contact EHS immediately.
- Laboratory employees should have access to a chemical inventory list, applicable SDSs, Department Laboratory Safety Manual, and relevant SOPs.
- Access to laboratories and support areas such as stockrooms, specialized laboratories, etc. should be limited to approved personnel only.
- All equipment should be regularly inspected for wear or deterioration.
- Equipment should be maintained according to the manufacturer's requirements and records of certification, maintenance, or repairs should be maintained for the life of the equipment.
- Designated and well-marked waste storage locations are necessary.
- No cell phone or ear phone usage in the active portion of the laboratories, or during experimental operations.
- Clothing made of synthetic fibers should not be worn while working with flammable liquids or when a fire hazard is present as these materials tend to melt and stick to exposed skin.
- Laboratory coats should not be stored in offices or break rooms as this spreads contaminates to other areas.

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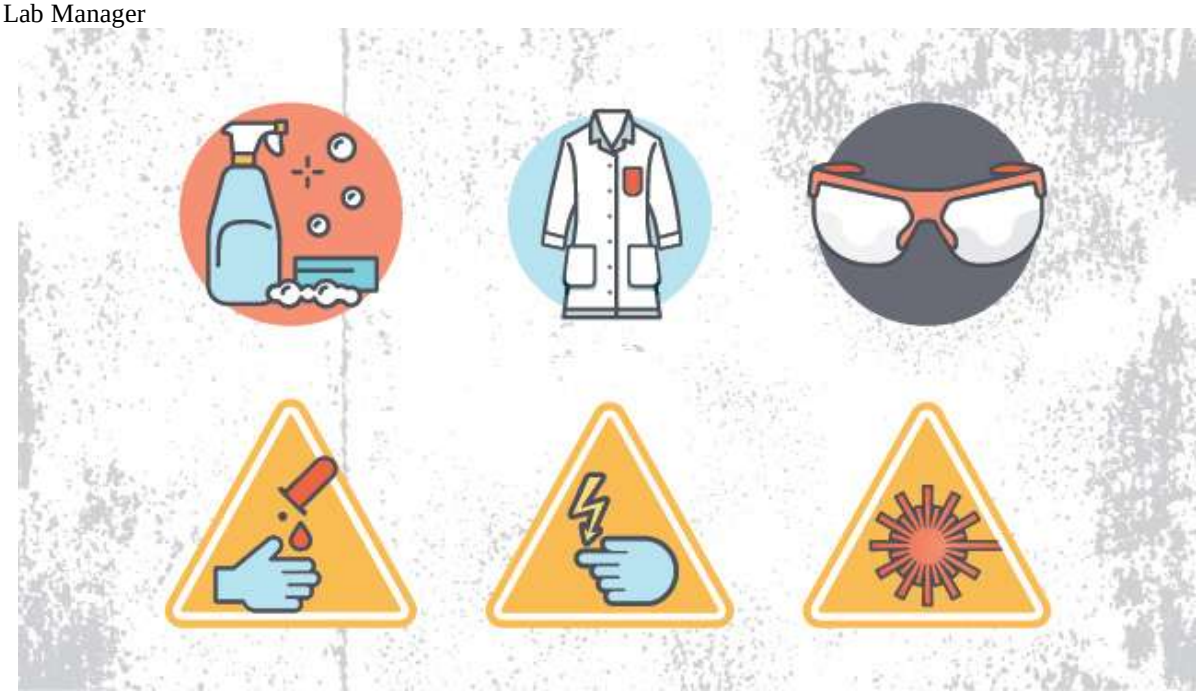
- Computers and instrumentation should be labeled to indicate whether gloves should be worn or not. Inconsistent glove use around keyboards/keypads is a source of potential contamination.
- Avoid wearing jewelry in the lab as this can pose multiple safety hazards.

Lab Safety Rules and Guidelines

Lab Manager



Having a strong set of overall laboratory safety rules is essential to avoiding disasters in the lab. Lab Manager recently scoured the safety policies of several laboratories to determine some

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of the most common lab safety rules out there, to help you whether you're developing or updating a set of policies for your own lab. Of course, safety rules are only effective when they are enforced, which is why strong lab management is so important to a safe laboratory as well. Knowing the proper laboratory safety signs and symbols is also important.

Here are the safety rules that most commonly came up in our look at several laboratories' policies:

General lab safety rules

The following are rules that relate to almost every laboratory and should be included in most safety policies. They cover what you should know in the event of an emergency, proper signage, safety equipment, safely using laboratory equipment, and basic common-sense rules.

- Be sure to read all fire alarm and safety signs and follow the instructions in the event of an accident or emergency.
- Ensure you are fully aware of your facility's/building's evacuation procedures.
- Make sure you know where your lab's safety equipment—including first aid kit(s), fire extinguishers, eye wash stations, and safety showers—is located and how to properly use it.
- Know emergency phone numbers to use to call for help in case of an emergency.
- Lab areas containing carcinogens, radioisotopes, biohazards, and lasers should be properly marked with the appropriate warning signs.
- Open flames should never be used in the laboratory unless you have permission from a qualified supervisor.
- Make sure you are aware of where your lab's exits and fire alarms are located.
- An area of 36" diameter must be kept clear at all times around all fire sprinkler heads.
- If there is a fire drill, be sure to turn off all electrical equipment and close all containers.
- Always work in properly-ventilated areas.
- Do not chew gum, drink, or eat while working in the lab.
- Laboratory glassware should never be utilized as food or beverage containers.
- Each time you use glassware, be sure to check it for chips and cracks. Notify your lab supervisor of any damaged glassware so it can be properly disposed of.
- Never use lab equipment that you are not approved or trained by your supervisor to operate.
- If an instrument or piece of equipment fails during use, or isn't operating properly, report the issue to a technician right away. Never try to repair an equipment problem on your own.
- If you are the last person to leave the lab, make sure to lock all the doors and turn off all ignition sources.
- Do not work alone in the lab.
- Never leave an ongoing experiment unattended.
- Never lift any glassware, solutions, or other types of apparatus above eye level.
- Never smell or taste chemicals.
- Do not pipette by mouth.
- Make sure you always follow the proper procedures for disposing lab waste.
- Report all injuries, accidents, and broken equipment or glass right away, even if the incident seems small or unimportant.
- If you have been injured, yell out immediately and as loud as you can to ensure you get help.
- In the event of a chemical splashing into your eye(s) or on your skin, immediately flush the affected area(s) with running water for at least 20 minutes.
- If you notice any unsafe conditions in the lab, let your supervisor know as soon as possible.

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Housekeeping safety rules

Laboratory housekeeping rules also apply to most facilities and deal with the basic upkeep, tidiness, and maintenance of a safe laboratory.

- Always keep your work area(s) tidy and clean.
- Make sure that all eye wash stations, emergency showers, fire extinguishers, and exits are always unobstructed and accessible.
- Only materials you require for your work should be kept in your work area. Everything else should be stored safely out of the way.
- Only lightweight items should be stored on top of cabinets; heavier items should always be kept at the bottom.
- Solids should always be kept out of the laboratory sink.
- Any equipment that requires air flow or ventilation to prevent overheating should always be kept clear.

Dress code safety rules

As you'd expect, laboratory dress codes set a clear policy for the clothing employees should avoid wearing in order to prevent accidents or injuries in the lab. For example skirts and shorts

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might be nice for enjoying the warm weather outside, but quickly become a liability in the lab where skin can be exposed to heat or dangerous chemicals.

- Always tie back hair that is chin-length or longer.
- Make sure that loose clothing or dangling jewelry is secured, or avoid wearing it in the first place.
- Never wear sandals or other open-toed shoes in the lab. Footwear should always cover the foot completely.
- Never wear shorts or skirts in the lab.
- When working with Bunsen burners, lighted splints, matches, etc., acrylic nails are not allowed.

Personal protection safety rules

Unlike laboratory dress code policies, rules for personal protection cover what employees should be wearing in the lab in order to protect themselves from various hazards, as well as basic hygiene rules to follow to avoid any sort of contamination.

- When working with equipment, hazardous materials, glassware, heat, and/or chemicals, always wear face shields or safety glasses.
- When handling any toxic or hazardous agent, always wear the appropriate gloves.
- When performing laboratory experiments, you should always wear a smock or lab coat.
- Before leaving the lab or eating, always wash your hands.
- After performing an experiment, you should always wash your hands with soap and water.
- When using lab equipment and chemicals, be sure to keep your hands away from your body, mouth, eyes, and face.

Chemical safety rules

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Since almost every lab uses chemicals of some sort, chemical safety rules are a must. Following these policies helps employees avoid spills and other accidents, as well as damage to the environment outside of the lab. These rules also set a clear procedure for employees to follow in the event that a spill does occur, in order to ensure it is cleaned up properly and injuries are avoided.

- Every chemical should be treated as though it were dangerous.
- Do not allow any solvent to come into contact with your skin.
- All chemicals should always be clearly labeled with the name of the substance, its concentration, the date it was received, and the name of the person responsible for it.
- Before removing any of the contents from a chemical bottle, read the label twice.
- Never take more chemicals from a bottle than you need for your work.
- Do not put unused chemicals back into their original container.
- Chemicals or other materials should never be taken out of the laboratory.
- Chemicals should never be mixed in sink drains.
- Flammable and volatile chemicals should only be used in a fume hood.
- If a chemical spill occurs, clean it up right away.

Chemistry lab safety rules

As chemistry labs are one of the most common types, these basic chemistry lab safety rules are relevant to many scientists, dealing with the safe performance of common activities and tasks in the average chemistry lab:

- Before you start an experiment, make sure you are fully aware of the hazards of the materials you'll be using.
- When refluxing, distilling, or transferring volatile liquids, always exercise extreme caution.
- Always pour chemicals from large containers to smaller ones.
- Never pour chemicals that have been used back into the stock container.
- Never tap flasks that are under vacuum.
- Chemicals should never be mixed, measured, or heated in front of your face.
- Water should not be poured into concentrated acid. Instead, pour acid slowly into water while stirring constantly. In many cases, mixing acid with water is exothermic.

Electrical safety rules

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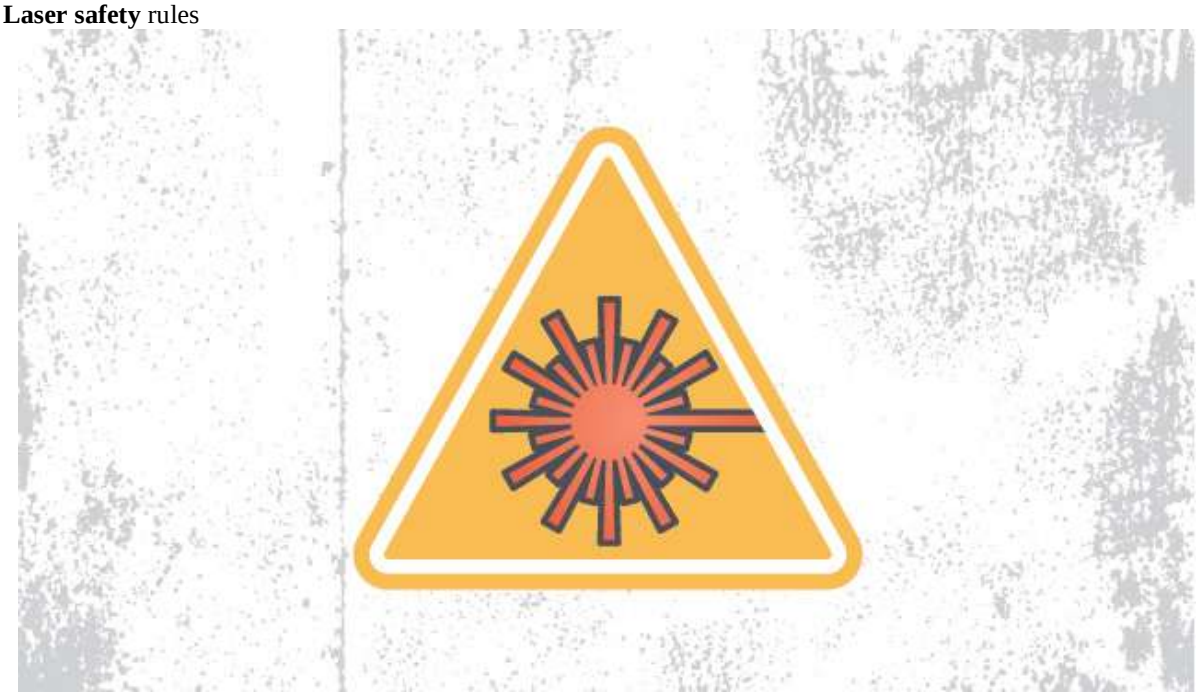
Like almost every other workplace, laboratories contain electronic equipment. Electrical safety rules help prevent the misuse of electronic instruments, electric shocks and other injuries, and ensure that any damaged equipment, cords, or plugs are reported to the appropriate authorities so they can be repaired or replaced.

- Before using any high voltage equipment (voltages above 50Vrms ac and 50V dc), make sure you get permission from your lab supervisor.
- High voltage equipment should never be changed or modified in any way.
- Always turn off a high voltage power supply when you are attaching it.
- Use only one hand if you need to adjust any high voltage equipment. It's safest to place your other hand either behind your back or in a pocket.
- Make sure all electrical panels are unobstructed and easily accessible.
- Whenever you can, avoid using extension cords.

Laser safety rules



Perhaps not as common as some of the other laboratory safety rules listed here, many laboratories do use lasers and it's important to follow some key rules of thumb to prevent injuries. In particular, accidents due to reflection are something that many employees may not think about. A clear set of rules for the use of lasers is essential to ensure that everyone is aware of all hazards and that the appropriate personal protective equipment is worn at all times.

- Even if you are certain that a laser beam is "eye" safe or low power, you should never look into it.
- Always wear the appropriate goggles in areas of the lab where lasers are present. The most common laser injuries are those caused by scattered laser light reflecting either off the shiny surface of optical tables, the sides of mirrors, or off of mountings. Goggles will help you avoid damage from such scattered light.
- You should never keep your head at the same level as the laser beam.
- Always keep the laser beam at or below chest level.
- Laser beams should never be allowed to spread into the lab. Beam stops should always be used to intercept laser beams.

Chemical Hygiene Plan

- Every school should have a Chemical Hygiene Plan (CHP). This is the plan to help protect people working in a laboratory setting. You should be familiar with your school's CHP, and it should be readily available to all. The

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CHP is described in the OSHA document 29 CFR 1910.1450, Laboratory Standard.

- The components of a CHP are listed below. Standard operating procedures involving the use of hazardous chemicals; Criteria to determine and implement control measures to reduce employee exposure to hazardous chemicals; Requirements to ensure that control measures perform properly; Employee information and training; Identification of operations requiring prior employer approval; Medical consultation and examinations; Designation of chemical hygiene officers; Requirements for handling particularly hazardous chemicals; Identification of designated areas (e.g., laboratories, storage rooms, disposal areas);u Containment equipment; Procedures for safe removal of contaminated waste; and Decontamination procedures
- Chemical Hygiene Plan (CHP)OSHA's Occupational Exposure to Hazardous Chemicals in Laboratories standard (29 CFR 1910.1450), referred to as the Laboratory standard, specifies the mandatoryrequirements of a Chemical Hygiene Plan (CHP) to protect laboratory workers fromharm due to hazardous chemicals. The CHP is a written program stating the policies,procedures and responsibilities that protect workers from the health hazards associated with the hazardous chemicals used in that particular workplace.

WHMIS

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- Workplace Hazardous Material Information System, or WHMIS, is the name given to the legislation covering hazardous materials used in Canadian workplaces, including educational institutions. In basic terms, suppliers are required to adequately label their products and provide accompanying Material Safety Data Sheets (MSDS), employers are required to educate workers and ensure that the appropriate safety information is available to the employees, and employees are required to learn the information on hazardous products before using them. In Chemistry laboratories, you are the employee, and therefore, are required to know the properties of the chemicals you will be handling before you enter the laboratory.
- Apart from requiring that MSDS be available to workers, one of the other important aspects of WHMIS is the requirement for clear labels and hazard symbols on hazardous products. The following eight hazard symbols should be used as guides for the handling of chemical reagents:

Symbol	Class Description	Symbol means that the material:
	Compressed Gas (Class A)	▪ poses an explosion danger because the gas is being held in a cylinder under pressure ▪ may cause its container to explode if heated ▪ may cause its container to explode if dropped
	Combustible and Flammable Material (Class B)	▪ is one that will burn and is consequently a fire hazard (*i.e.*, is combustible) ▪ may catch fire at relatively low temperatures (*i.e.*, is flammable) ▪ may ignite spontaneously in air or release a flammable gas on contact with water
	Oxidizing Material (Class C)	▪ may react violently or cause an explosion when it comes into contact with combustible materials ▪ may burn skin and eyes upon contact
	Poisonous Material: Immediate Toxic Effects (Class D1)	▪ is a potentially fatal poisoning substance ▪ may be immediately fatal or cause permanent damage if it is inhaled or swallowed or enters the body through skin contact
	Poisonous Material: Other Toxic Effects (Class D2)	▪ is a poisonous substance that is not immediately hazardous to health ▪ may cause death or permanent damage as a result of repeated exposure over time (*e.g.*, cancer, birth defects or sterility) ▪ may be an irritant
	Biohazardous Infectious Material (Class D3)	▪ may cause a serious disease resulting in illness or death ▪ may produce a toxin that is harmful to humans
	Corrosive Material (Class E)	▪ causes severe eye and skin irritation upon contact ▪ causes severe tissue damage with prolonged contact ▪ may be harmful if inhaled
	Dangerously Reactive Material (Class F)	▪ is very unstable ▪ may react with water to release a toxic or flammable gas ▪ may explode as a result of shock, friction, or increase in temperature ▪ may explode if heated in a closed container

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All chemicals must be used in accordance with the manufacturer's instructions. These can be found in the Hazard Data Sheet books that are kept in the Laboratory Supervisors office. In particular, pay attention to the Risk and Safety phrases (R and S numbered phrases - copies of these phrases are kept by the Laboratory Supervisor) and the Hazard Symbols. Absence of Hazard symbols or Risk and Safety Phrases should not be taken to indicate that these chemicals are non-hazardous.

The following chemicals are used routinely in the basement lab. Even if you are not planning to use these chemicals yourself, make sure you are familiar with the safety procedures in case someone else has an accident with them.

- HYDROCHLORIC ACID
- HYDROFLUORIC ACID
- NITRIC ACID
- SULPHURIC ACID
- ACETIC ACID
- ACETIC ANHYDRIDE
- HYDROGEN PEROXIDE
- SODIUM HYDROXIDE
- POTASSIUM HYDROXIDE
- IODINE
- SODIUM CARBONATE
- POTASSIUM IODIDE
- ter- BUTYL ALCOHOL (2-methyl propan-2-ol)
- METHANOL
- ACETONE

Lab Safety Guide Plan Your Work

- Before conducting any experiment, you should access the hazards related to the work, including; what are the worst possible things that could go wrong, how to deal with them, and what are the prudent practices, protective facilities and equipment necessary to minimize the risk of exposure to the hazards.
- Always know the hazards of the materials used (e.g., corrosivity, flammability, reactivity, and toxicity). Use the Project Hazard Review Checklist (in Adobe PDF format) to help you with this assessment.
- Read the Material Safety Data Sheets (MSDS) for information on all chemicals you plan to use. Make sure all Personal Protective Equipment (PPE) is on hand. Use the MSDS or Personal Protective Equipment Selection Guide (in Adobe PDF format) to select the needed equipment.
- Post a sign on the door to notify others of the lab hazards and list emergency contact numbers.
- Inspect equipment and apparatus for weaknesses, cracks or damage before beginning work.
- Inspect electrical equipment and cords for frayed wiring or damage before use. Discard or repair damaged equipment before use.

Follow All Safety Procedures

- Always wear chemical splash goggles for eye protection when working with chemicals.
- When pouring large quantities of hazardous chemicals, in addition to goggles, wear a face shield large enough to protect your ears and neck as well as your face.
- Always wear gloves when handling chemicals. Select the glove material based on compatibility with the chemicals you may contact.
- Always wear appropriate clothing: chemically resistant lab coats or aprons are recommended.
- Do not wear shorts or miniskirts (anything that would leave your legs bare and unprotected). Do not wear high-heeled shoes, open-toed/heeled shoes, sandals or shoes made of woven materials. Confine long hair and loose clothing.
- Do not work with hazardous chemicals or processes when alone in the laboratory. An instructor must supervise undergraduate students at all times.
- Always use chemicals with adequate ventilation or in a chemical fume hood. Do not allow the release of toxic substances in cold rooms or warm rooms, since these areas have contained, re-circulated air.
- Use chemicals only as directed and for their intended purpose.
- Never use mouth suction to fill a pipette or siphon. Use a pipette bulb or other suitable device.
- Handle needles, syringes and other sharps carefully. Use self-sheathing needles or needless systems whenever possible. Dispose of all sharps in an appropriate sharps container.
- Do not dispose of chemicals down the drain. Most chemicals must be disposed of as hazardous waste.
- Compressed gas cylinders must be secured to prevent them from being knocked over.

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Cylinders must be capped when the regulator is removed or not in use.

- Inspect the lab weekly for hazardous conditions.
- Shield or wrap pressurized or evacuated equipment (dewars& vacuum flasks).
- Know Emergency Procedures
- Know where the nearest emergency eyewash and showers are, and how to use them.
- Know at least two exits from the laboratory area in case of an emergency.
- In the event of an emergency, pull the nearest "Pull BOX", evacuate the area, and close all doors.
- Practice Good Housekeeping and Personal Hygiene
- Avoid direct contact with any chemical.
- Never smell, inhale or taste laboratory chemicals.
- Always wash hands and arms with soap and water after removing gloves and before leaving the work area.
- Never eat, drink, chew gum or tobacco, smoke or apply cosmetics in the laboratory.
- Do not pick up broken glass with your hands. Use tongs or other mechanical means.
- Remove Personal Protective Equipment (PPE) such as gloves and lab coats before leaving the lab.
- Remove gloves before handling common items like phones, instruments, door knobs, etc.
- Keep all work areas clean and uncluttered. Wipe down benches with cleaners or disinfectants regularly.
- Do not block emergency showers, eye washes, exits or hallways.
- Transport Chemicals Safely
- Use secondary containers such as acid buckets or plastic totes.
- Secure containers on carts.
- Wear appropriate PPE.
- Use freight elevators or limit access in passenger elevators.
- Use a hand truck with a safety chain when moving compressed gas cylinders.
- Unattended Operations
- Provide for containment of materials in the event of spills or failures.
- Label all containers and process equipment.
- Post emergency numbers on the lab door.
- Keep lab lights on.
- Report Dangerous Activities or Situations
- Report all accidents, no matter how minor.
- Never perform unauthorized work, preparations or experiments.
- Never engage in horseplay, pranks or other acts of mischief in laboratories.
- Never remove chemicals from the facility without proper authorization.
- Report suspicious people or activities in lab areas to University Police.

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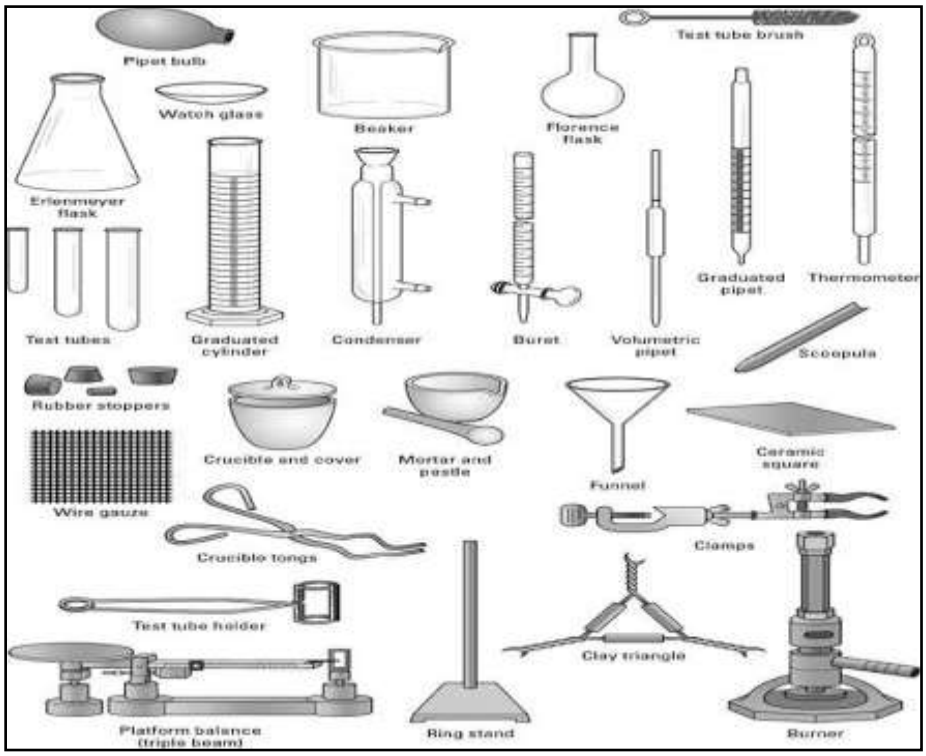
Laboratory Equipment

- Laboratory equipment is an important part of your laboratory safety program. This equipment is considered an "engineering control". Engineering controls eliminate or reduce exposure to a biological, chemical or physical hazard through the use or substitution of engineered machinery or equipment. Examples include self-capping syringe needles, ventilation systems such as a fume hood or biosafety cabinet, sound-dampening materials to reduce noise levels, safety interlocks, and radiation shielding.

- The first and best strategy is to control the hazard at its source. Engineering controls do this, unlike other controls that generally focus on the employee exposed to the hazard. The basic concept behind engineering controls is that, to the extent feasible, the work environment and the job itself should be designed to eliminate hazards or reduce exposure to hazards.

- Engineering controls can be simple in some cases. They are based on the following principles:

- If feasible, design the facility, equipment, or process to remove the hazard or substitute something that is not hazardous.
- If removal is not feasible, enclose the hazard to prevent exposure in normal operations.
- Where complete enclosure is not feasible, establish barriers or local ventilation to reduce exposure to the hazard in normal operations.
- When substitution of hazardous chemicals or processes is simply not possible, additional measures to control employee exposure need to be taken. While personal protective equipment (PPE) such as respirators can help protect an individual from a hazardous material, engineering controls protect all workers by reducing or eliminating the hazard. For example, someone who is spray-painting can wear a respirator to avoid inhaling toxic fumes, but nearby workers without any respiratory protection will be exposed. Through the use of proper local exhaust ventilation everyone can be protected.



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STORAGE OF LABORATORY CHEMICALS

- Recommendations for Storage of Laboratory Chemicals
- The following general suggestions for safe storage of chemicals in the laboratory should be implemented.

- The quantities of chemicals that are stored within a laboratory should be minimized, as specified by NFPA 45 and OSHA. Many authorities recommend that the NFPA guidelines for maximum quantities and sizes of containers should be reduced to one-half or even one-third of the recommended values.
- Bulk quantities of chemicals (i.e., larger than one-gallon) must be stored in a separate storage area. Transfer of flammable liquid from 5 gallon or larger metal containers may not be done in the laboratory.
- Chemicals must be stored at an appropriate temperature and humidity level. This can be especially problematic in hot, humid climates. As a rule, chemicals should not be stored near heat sources, such as steam pipes or laboratory ovens. Chemicals should never be stored in direct sunlight.
- Chemicals should be dated when received and when opened. If the chemical is one that degrades in quality or becomes unsafe after prolonged storage, the shelf-life expiration date should also be included.
- Visual inspection of the material and its container should be conducted routinely. Indications for disposal include:
- cloudiness in liquids
- material changing color
- evidence of liquids in solids or solids in liquids
- "puddling" of material around outside of container o pressure build-up within bottle
- obvious deterioration of container
- Chemicals should not be routinely stored on the benchtops. In such locations they are unprotected from exposure and participation in a fire situation and are also more readily

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knocked over. Each chemical should have a specific storage area and be returned there after use. Large quantities of flammable materials should not be stored in the laboratory. Only the amounts needed should be kept on benchtops, the remainder should be kept in flammable storage cabinets.

- Laboratory shelves should have a raised lip along the outer edge to prevent containers from falling. Never allow the container to hang off the edge of the shelf! Liquid or corrosive chemicals should never be stored on shelves above eye-level. Glass containers should not touch each other on the shelves. Secondary containers or trays should be used for chemical storage whenever possible to minimize the flow of material should a spill or rupture occur. Round bottom flasks should always be supported properly in cork rings or by other means to keep them from tipping.
- Adequate security must be provided so that unauthorized personnel do not have access to hazardous materials.
- Chemicals must never be stored on the floor, not even temporarily!
- Chemicals that are no longer to be used for research purposes should be properly disposed of or given to another research group that has a use for it.
- Flammable materials must never be stored in domestic-type refrigerators. Only explosion-proof or flammable material refrigerators should be used for storage of these chemicals within a laboratory environment.
- All containers stored within the refrigerator should be tightly capped to keep vapors from interacting with each other and to alleviate "smell" problems. Flasks with cork, rubber or glass stoppers should be avoided because of the potential for leaking. All containers stored in the refrigerator must be properly labeled.
- Inventory the materials in your refrigerator frequently to avoid overcrowding with materials that have long since been forgotten. Also make it a point to defrost your refrigerator occasionally so that chemicals do not become trapped in unique ice formations!
- Before flammable materials are stored in a refrigerator, it should be determined if keeping the material chilled will serve any purpose. No benefit is derived from refrigerating a chemical that has a flash point below the temperature of the refrigerator. Never store peroxide formers (i.e., ether) in a refrigerator!
- Fume hoods should not be used as general storage areas for chemicals. This may seriously impair the ventilating capacity of the hood.
- Gas cylinders must be securely strapped to a permanent structure (wall, lab bench, etc.). When they are not in use they should be capped off.
- On termination, graduation or transfer of any laboratory personnel, all hazardous materials must be properly disposed of, or arrangements made to transfer them to the laboratory supervisor.

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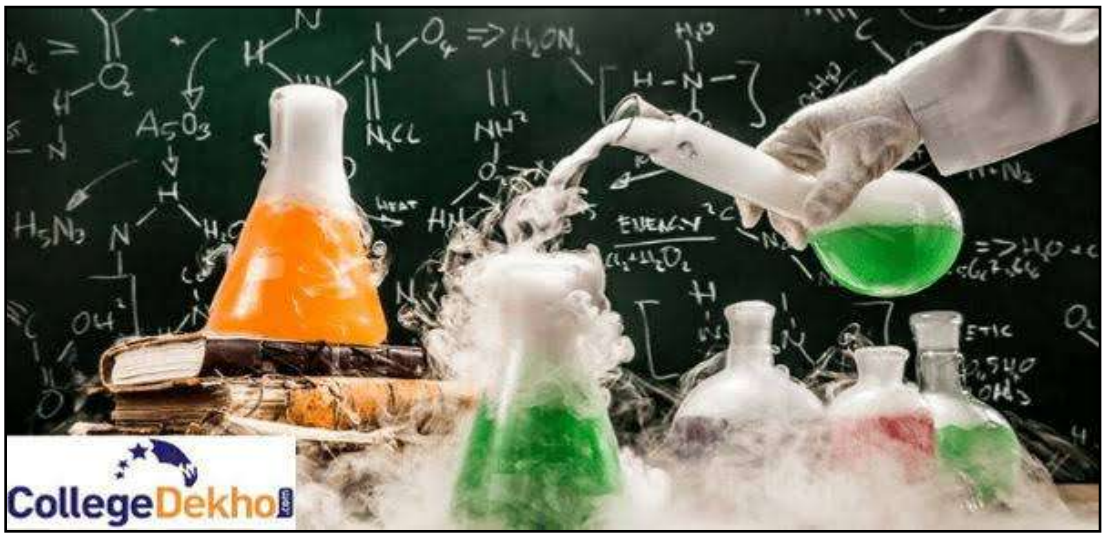
Segregation Based on Hazard Classes

In addition to general safe storage practices, segregated storage of incompatible materials is a must. As a minimum, laboratories should separate chemicals according to similar hazards, such as flammability, corrosivity, sensitivity to water or air, and toxicity. The following major categories of chemicals, each of which will be discussed in greater detail, are strongly recommended:

- Flammables
- Oxidizers
- Corrosives
- acids
- bases
- Highly Reactives
- Extreme Toxics/Regulated Materials
- Low Hazard
- However, problems may arise with a general segregation of chemicals. Below, you will find a few of these potential problems.
- Multiple hazards for chemicals.
- Most chemicals have multiple hazards and a decision must be made as to which storage area would be most appropriate for each specific chemical. First you have to determine your priorities!
- When establishing a storage scheme, the number one consideration should be the flammability characteristics of the material. If the material is flammable, it should be stored in a flammable cabinet.
- If the material will contribute significantly to a fire (i.e., oxidizers), it should be isolated from the flammables. If there were a fire in the lab and response to the fire with water would exaggerate the situation, isolate the water reactive material away from contact with water.



II. CONCUSION

- Integration of the field trip and laboratory experiences was an effective learning mechanism that allowed students to make the connections between field observations and more abstract water quality concepts (oxygen concentration to temperature correlation, estimation of pH using law of mass action equations etc.). This approach is particularly useful to teach education pre-service majors who lack rigorous science content compared to science majors.
- Field trip would provide concrete experiences to facilitate understanding of abstract equilibrium concepts. This methodology can be applied to any college level of chemistry or environmental courses intended for education majors who would be teaching these courses in turn to their students.
- We stress that the student understanding of content gained during this course was not by volume or variety of course but by how the content was actively discovered by students in multiple learning environments.
- The results of this study are consistent with previous research that demonstrates field

experiences attract students to science and make science learning more meaningful.

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