KING ABDULLAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

Laboratory Safety Manual

August 2023

Health, Safety and Environment

Contents

INTRODUCTION

King Abdullah University of Science and Technology (KAUST) intends to be a leading international research institution with a strong commitment to protecting the health and safety of its faculty, staff, students, and visitors, as well as protecting its assets and the environment. Moreover, it is the vision of KAUST to be a leader among its peers in the international research community for its health, safety, and environmental performance.

KAUST's commitment to health, safety, and environmental performance extends to all functions within the University. However, because of the special safety concerns that arise in a laboratory setting, this Laboratory Safety Manual has been developed by the Health, Safety, and Environmental (HSE) Department to serve as a general guide to laboratory safety within KAUST. It is to be used as a resource to assist laboratories in designing their own Laboratory Safety Plans.

This Laboratory Safety Manual is intended to establish basic safe operating practices so that faculty, staff, and students of KAUST may carry out effective educational and research programs in a safe and healthy environment. It is not intended to be a complete or final listing of all laboratory hazards or safe work practices. Because of the diverse nature of work being conducted at KAUST, additional procedures or requirements may be necessary for individual research labs.

The information contained within this laboratory safety manual is intended to comply with national regulations, international standards and laboratory best management practices.

LABORATORY SAFETY PLAN

Each laboratory where there is a risk of health or physical hazards is required to have a written Laboratory Safety Plan to protect against hazards to personnel, property, or the environment. This includes laboratories having hazardous materials (chemical, biological or radioactive), compressed gases, high-pressure, high-energy, Laser, X-Ray, or other significant physical, mechanical, or electrical hazards. The Laboratory Safety Plan should outline the lab-specific practices and procedures, personal protective equipment, training requirements, standard operating procedures, emergency procedures, and other safety requirements to protect employees from the hazards they may encounter in the laboratory. The Laboratory Safety Plan must be updated whenever there is a significant change in laboratory operations and/or hazards present, or a change in emergency contact personnel. A Laboratory Safety Plan template is available on the Lab Safety webpage.

It is the responsibility of the Principal Investigator to ensure a Laboratory Safety Plan is written, reviewed yearly and that all personnel working in laboratories under their supervision have reviewed and understood the plan.

CHAPTER ONE: RESPONSIBILITIES

LABORATORY SAFETY RESPONSIBILITIES

The ultimate responsibility for health and safety within laboratories falls on each individual who works in the laboratory; however, it is the responsibility of the Principal Investigator, faculty, and laboratory manager to ensure that persons working in the laboratory have received all appropriate training, and have been provided with all the necessary information to work safely in laboratories under their control. Principal Investigators, faculty, and lab managers have numerous resources available to them for helping to ensure a safe and healthy laboratory.

It is the responsibility of Principal Investigators and laboratory managers to ensure that all persons in the laboratory are familiar both with this Laboratory Safety Manual and the relevant Laboratory Safety Plan, and are properly trained and competent to safely carry out their job duties and research.

RESEARCH CENTER DIRECTORS AND PRINCIPAL INVESTIGATORS (PIs)

Research center directors and Principal Investigators are accountable for the health and safety of employees engaged in activities under their supervision. This responsibility cannot be delegated. To fulfill this responsibility, they should be familiar with KAUST's HSE policy and this Laboratory Safety Manual. Their responsibilities include:

- Communicate and implement KAUST's HSE policy and the Lab Safety Manual requirements to faculty, staff, visiting scholars and students working in laboratories within their units;
- Ensure laboratory personnel know and follow the guidelines and requirements contained within the KAUST Laboratory Safety Manual;
- Ensure laboratory personnel develop and adhere to proper health and safety protocols.
- Support staff participation on campus, center, and lab safety committee(s); training programs; and safety meetings;
- Ensure that a written Laboratory Safety Plan has been prepared and communicated to laboratory personnel;
- Ensure that the Laboratory Safety Plan is reviewed at least yearly with the review being documented;
- Ensure that standard operating procedures for handling and disposing of hazardous substances used in their laboratories are written, communicated, and followed. Ensure laboratory personnel

have been trained in these standard operating procedures and use proper control measures. Ensure that all persons working in the laboratory are properly trained to safely carry out their job duties and research;

- Require all staff members and students under their direction to obtain and maintain required health and safety training;

- Ensure procedures are established and communicated to identify the potential for, and the appropriate response to accidents and emergency situations;

- Ensure that all incidents and near misses occurring in their laboratories are reported to their director and that an incident report is submitted to KAUST HSE using the online Report It System.

LABORATORY STAFF

Laboratory staff consists of those personnel who conduct their work in a laboratory and are at risk of possible exposure to hazardous materials or other health or physical hazards on a regular or periodic basis. These personnel include laboratory technicians, instructors and researchers, visiting researchers, graduate assistants and students.

The laboratory safety responsibilities of laboratory staff are:

- Comply with KAUST's HSE policy and the KAUST Laboratory Safety Manual guidelines by maintaining work and laboratory areas safe and free from hazards;

- Attend required health and safety training as designated by your supervisor;

- Inform your supervisor, laboratory manager, or instructor of any safety hazards or unsafe working conditions in the workplace, classroom, or laboratory (e.g., faulty fume hoods, or other emergency safety equipment);

- Review the Safety Data Sheets (SDSs) for chemicals you are working with and check with your laboratory manager or Principal Investigator if you ever have any questions;

- Conduct hazard evaluations/risk assessments with your supervisor for procedures conducted in the laboratory and maintain a file of standard operating procedures documenting those hazards;

- Follow the standard operating procedures for your laboratory and incorporate the guidelines and requirements outlined in this Laboratory Safety Manual into everyday practice;

- Be familiar with what to do in the event of an emergency situation;

- Report all incidents, unsafe conditions, and workplace injuries immediately to your supervisor by using the online Report It System.

LABORATORY SAFETY REPRESENTATIVES

The Laboratory Safety Representative (LSR) serves a very important function in implementing the Laboratory Safety Manual within their lab(s). The role of the LSR is to assist the director, unit head, and faculty member meet their responsibilities for safety and compliance. Each Laboratory Safety Representative shall be delegated authority in regard health and safety matters by the unit head to whom they report.

The appointment of a safety representative does not diminish the particular responsibilities of the unit head, lab manager and/or supervisor or the primary responsibility of every individual for maintaining health and safety standards inside the laboratory. The main role of a Laboratory Safety Representative is to act as a focal point for all health and safety matters arising at the particular location. Carrying out the role of a Laboratory Safety Representative includes:

- Assisting with promoting health and safety awareness in their center or area;
- Assisting with hazard/risk assessments and/or obtaining advice on unfamiliar problems from HSE, the Research Safety Team, or other sources;
- Communicate health and safety training requirements to all staff and students working in labs they represent;
- Communicate to individuals working within the areas they represent about health and safety policies and procedures, including this Laboratory Safety Manual, and the safety, health, and environmental services available to them;
- Bringing to the attention of staff and students any health & and safety hazards associated with their work;
- Bringing to the attention of the relevant unit heads unresolved health and safety problems;
- Attend monthly meetings of the Lab Safety Forum, and other health and safety training, and communicate back relevant information to others working in their laboratory or area;
- Serve as a liaison with HSE on health and safety activities in their unit or area through activities such as forwarding emails, safety bulletins, and other information from HSE;
- Report and assist with the investigation of all incidents, injuries and occupational health problems and notifying HSE staff of incidents and hazards using the online Report It System.

- Work with campus stakeholders to annually evaluate, implement, review, and make updates as needed to the Laboratory Safety Manual;

- Provide technical expertise to the laboratory community in the area of laboratory health and safety, and serve as a point of contact to direct inquiries to other appropriate resources;

- Serve as a resource to review academic research protocols and standard operating procedures developed by Principal Investigators and laboratory personnel for the use, disposal, spill cleanup, and decontamination of hazardous chemicals, and the proper selection and use of personal protective equipment;

- Conduct laboratory safety training sessions for laboratory personnel and upon request, assist laboratory managers in developing and conducting hands-on training sessions with employees;

- Review reports of laboratory incidents, accidents, chemical spills, and recommend follow up actions where appropriate;

- Stay informed of plans for renovations or new laboratory construction projects and serve as a resource in providing code citations and internal standards to assist with the design and construction process;

- Establish a Fire Warden program and help facilitate emergency evacuations during drills or actual emergencies by communicating with emergency responders, HSE personnel, and laboratory personnel critical pieces of information such as but not limited to: hazards present, exits, non-functioning alarms, identifying people that have not evacuated;

- Keep the senior administration informed on the progress of continued implementation of the Laboratory Safety Manual and bring campus-wide issues affecting laboratory safety to their attention.

CHAPTER TWO: EMERGENCY ACTIONS

For any emergency, including fires, chemical spills, injuries, accidents, explosions, and medical emergencies, dial 911 from any KAUST landline, including blue-light phones located in common areas throughout the campus. If a KAUST landline is unavailable or inaccessible during an emergency, dial 012-808-0911 from a mobile phone. The 911 Dispatch Center will send appropriate responders (Fire, Security, and/or Medical) to your location.

Each laboratory should include its own protocol for emergency situation s as part of its Laboratory Safety Plan.

911 NOTIFICATIONS

- Dial 911 from KAUST landlines or 012-808-0911 from mobile phones for all emergencies;
- Give the location of the event as clearly as possible;
- Indicate if an ambulance is needed;
- Specify the location where ambulance attendants, fire fighters or security will be met by the caller;
- Do not hang up the phone until told to do so.

FIRE

- KAUST policy is such that individuals are not supposed to fight fires; but that those who choose to do so may fight small, incipient stage fires (no bigger than a wastepaper basket) as long as they have been trained in the proper use of fire extinguishers.
- If you have been trained in the use of a fire extinguisher, fight the fire from a position where you can escape, and only if you are confident that you will be successful in extinguishing the fire.

IF YOU DISCOVER A FIRE OR SMELL SMOKE

- Sound the alarm by pulling the nearest fire alarm pull station or warn others by verbal means;
- Call 911 from KAUST landlines or 012-808-0911 from mobile phones;
- Evacuate the building using the nearest exit and report to the designated assembly point;

- Close doors behind you;
- Do not re-enter the building until you have been told it is safe to do so.

ON HEARING A FIRE ALARM

- Leave the building immediately by the nearest available exit;
- Close all doors behind you;
- Report to the designated assembly point;
- Do not re-enter until you have been told it is safe to do so.

MEDICAL EMERGENCY

In the event of injury or illness where medical assistance is needed, contact 911 from a KAUST landline or 012-808-0911 from a mobile phone. KAUST Emergency Medical Services will provide ambulance transport, if necessary. Follow these tips:

- Protect the victim from further injury or harm by removing any persistent threat to the victim or by removing the victim to a safe place if needed. However, do not move the victim unnecessarily (as this may cause further injury). Do not delay in obtaining trained medical assistance if it is safe to do so;
- Provide first aid until help arrives if you have appropriate training and equipment, and it is safe to do so;
- Send someone outside to escort emergency responders to the appropriate location, if possible.

KAUST has fully trained emergency responders on call 24 hours a day, 7 days a week. Injured personnel are encouraged to use this service by calling 911 from a KAUST landline or 012-808-0911 from a mobile phone.

FIRST AID KITS

First aid kits should be available to all laboratory personnel. First aid kits can be obtained at the Chemical Warehouse. It is the responsibility of each center or laboratory to have the appropriate first aid kit for the likely risks occurring in that work area. A responsible person should be should be designated to maintain the kit and properly trained individuals should be available to administer first aid, if necessary. First aid training classes may be arranged through the HSE Department.

First aid kits maintained by University laboratories and offices must:

- Be kept in sanitary condition.
- Include the following personal protective equipment:
    - At least one pair of large size examination or laboratory gloves;
    - An airway resuscitator, such as the "pocket mask", for use in mouth-to-mouth resuscitation;
    - A spill kit containing an appropriate disinfectant and other cleanup and disposal materials for handling spills of blood or other body fluids.

CHEMICAL SPILL

When a chemical spill occurs, it is necessary to take prompt and appropriate action. The type of response to a spill will depend on the quantity of the chemical spilled and the severity of the hazards associated with the chemical. The first action to take is to alert others in your lab or work area that a spill has occurred. Then you must determine if the spill can be safely cleaned up by laboratory staff without the help of outside responders.

> NOTE: YOU SHOULD ONLY ATTEMPT TO CLEAN UP INCIDENTAL CHEMICAL SPILLS IF YOU ARE TRAINED, HAVE THE PROPER SPILL CLEANUP MATERIALS AND PERSONEL PROTECTIVE EQUIPMENT AVAILABLE, AND ARE COMFORTABLE DOING SO.

KAUST has fully trained emergency responders on call 24 hours a day, 7 days a week. Injured personnel are encouraged to use this service by calling 911 from a KAUST landline or 012-808-0911 from a mobile phone.

INCIDENTAL CHEMICAL SPILLS

A spill is considered incidental (or, minor) if the criteria below are met.

- The spill is a small quantity of a known chemical;
- No gases or vapors are present that require respiratory protection;
- Spill clean-up materials and equipment are immediately available;

- Necessary proper personal protective (PPE) equipment is immediately available;
- You understand the hazards posed by the spilled chemical;
- You know how to clean up the spill;
- You feel comfortable cleaning up the spill.

MAJOR CHEMICAL SPILLS

A major spill is any chemical spill for which the researcher determines they need outside assistance to safely clean up the spill.

The KAUST fire department provides a 24/7 hazardous material response service. If there is any doubt about safely cleaning up a chemical spill, call 911 from a KAUST landline or 012-808-0911 from a mobile phone.

Actions to be taken when a major spill occurs:

- Alert people in the immediate area of the spill and evacuate the area;
- If an explosion hazard is present, do not unplug, or turn electrical equipment on or off – doing so can result in a spark and ignition source;
- Confine the hazard by closing doors while leaving the room;
- Use eyewash or safety showers as needed to rinse spilled chemicals off people or yourself;
- Evacuate any nearby rooms that may be affected. If the hazard will affect the entire building, then evacuate the entire building by pulling the fire alarm;
- Notify the Fire Department by calling 911 from a KAUST phone or 012-808-0911 from a mobile phone. Always call from a safe location;
- Make a Safety Data Sheet (SDS) for spilled material available to responders.

CHEMICAL SPILL KITS

Spill kits must be available in each laboratory where hazardous chemicals are used or kept. Spill clean-up kits suitable for responding to typical laboratory spills are available from the Chemical Warehouse. Alternatively, you may prepare your own spill kit.

A spill kit should contain the following items:

- Spill pillows/solvent absorbent
- Acid/base neutralizer
- 5 kg (10 lbs) of calcium carbonate or calcium bicarbonate - for HF spills
- Dustpan
- Broom or brush
- Plastic bags
- Waste labels
- Rubber gloves (check chemical compatibility before use)
- Rubber boots or shoe covers
- Chemical splash goggles

The spill kit should be clearly labeled as “SPILL KIT”, with a list of the contents posted on or in the kit.

MERCURY SPILL KITS

All labs that use mercury must have a mercury spill kit. Mercury spill kits can be obtained at the Chemical Warehouse. These kits can include mercury absorbent sponges and powders, vapor absorbent powders, small pumps and shovels, and bags or jars to contain any spills. <u>All spills of mercury must be cleaned up immediately</u>. During such incidents the area should be evacuated and ventilated, if possible. After cleaning up the mercury spill, contact HSE so the area can be monitored for any mercury contamination.

SPILL KIT TRAINING

Laboratory personnel should be properly trained on:

- How to determine if they can or should clean up the spill, or if they should call 911 from a KAUST phone or 012-808-0911 from a mobile phone;
- Where the spill kit will be kept within the laboratory;
- How to use the items in the kit properly;
- How to clean up the different types of chemical spills;
- How to dispose of spill cleanup material.

HSE can provide assistance in assembling spill kits for laboratories and can provide training on cleaning up small chemical spills.

CHEMICAL EXPOSURES

Always preplan your experiments and what you will do in case of an emergency. Always identify the locations of the nearest emergency shower and eyewash before working with hazardous chemicals.

The first 10 to 15 seconds after exposure to a hazardous substance, especially to corrosive substances, is critical. Delaying treatment, even for a few seconds, may cause serious injury.

For small chemical splashes to the skin, remove any contaminated gloves, lab coats, etc., and wash the affected area with soap and water for at least 15 minutes. Seek medical attention afterward, especially if symptoms persist.

For large chemical splashes to the body, it is important to get to an emergency shower and start flushing for at least 15 minutes. Once under the shower, and after the shower has been activated, it is equally important to remove any contaminated clothing. Failure to remove contaminated clothing can result in the chemical being held against the skin and causing further chemical exposure and damage. After flushing for a minimum of 15 minutes, seek medical attention immediately.

Always report any accidents or injuries using the online Report It System.

USING AN EYEWASH

1. Remove any contact lenses immediately if a chemical or other substance gets into your eye.

2. Immediately go to the nearest eyewash and push the activation handle all the way on.

3. Put your eyes or other exposed area in the stream of water and begin flushing.

4. Forcibly hold your eyelids open and place them over the spray heads on the eyewash station. Roll your eyeballs around to get maximum irrigation of the eyes. This is probably the hardest thing to do but also the most important.

5. Continue to hold your eyes open and have someone else turn the water on. Stations are designed to deliver continuous flushing under gentle pressure to ensure that the substance is flushed from your eye. If you splash hydrofluoric acid in your eyes, follow the special hydrofluoric acid precautions.

6. Have one of your co-workers call the emergency response unit while you continue to irrigate your eyes. Irrigation should last for at least 15 minutes, even after the emergency crews arrive.

7. If you are alone, call 911 from a campus phone or 012-808-0911 from a mobile phone -after you have finished flushing your eyes for at least 15 minutes.

8. After seeking medical attention, submit an accident report using the online Report It System.

USING AN EMERGENCY SHOWER

1) Immediately go to the nearest emergency shower and pull the activation handle.

2) Once under the stream of water, begin removing your clothing to wash off all chemicals.

3) Keep flushing for at least 15 minutes or until help arrives. The importance of flushing for at least 15 minutes cannot be overstated! If you spill hydrofluoric acid on yourself, follow the special hydrofluoric acid precautions.

4) If you are alone, call 911 from a campus phone or 012-808-0911 from a mobile phone - after you have finished flushing for at least 15 minutes.

5) Seek medical attention.

6) After seeking medical attention, submit an accident report using the online Report It System.

If someone else in the lab needs to use an emergency shower (and it is safe for you to do so), assist them to the emergency shower, activate the shower for them, and help them get started flushing using the procedures above and then call 911 from a campus phone or 012-808-0911 from a mobile phone. After calling 911, go back to assist the person using the shower and continue flushing for 15 minutes or until help arrives and have the person seek medical attention.

NOTE: Although an emergency is no time for modesty, if a person is too modest and reluctant to use the emergency shower, you can assist them by using a lab coat or other piece of clothing or barrier to help ease their mind while they undress under the shower. If you are assisting someone else, you should wear gloves to avoid contaminating yourself. When using an emergency shower, do not be concerned about the damage from flooding. The important thing to remember is to keep flushing for 15 minutes.

HYDROFLUORIC ACID (HF)

Hydrofluoric acid (HF) is corrosive and highly toxic. HF burns can be severe and extremely painful, causing extensive damage to the skin and eyes, and to the mucous membranes if breathed or swallowed. HF is absorbed quickly and can cause widespread damage to the body and even death. Any person contaminated with HF must have immediate first aid, followed by medical treatment from a physician as soon as possible.

***All laboratories using hydrofluoric acid must have calcium gluconate gel readily available. Calcium gluconate can be obtained at the Chemical Warehouse.

SKIN EXPOSURE

1. Move the victim immediately under an emergency shower or other water source and flush the affected area with large amounts of cool running water. Immediately washing off the acid is of primary importance.

2. Remove all contaminated clothing while flushing with water.

3. While the victim is being rinsed with water, arrange for immediate emergency medical assistance by calling 911 from a campus phone or 012-808-0911 from a mobile phone.

4. Immediately after flushing with water, begin massaging the calcium gluconate gel into the burn site. Apply the gel every 15 minutes and massage until pain/redness resolve or until medical care is available. Wear gloves when applying the gel to prevent transfer of HF and secondary burns.

EYE EXPOSURE

1. Immediately flush eyes for at least 15 minutes with copious amounts of cool flowing water.
2. If only one eye is affected, be careful not to flush contaminated water into the other eye.
3. Call 911 immediately and apply ice water compresses during transport.

All laboratories working with hydrofluoric acid must have an adequate supply of calcium gluconate immediately available. All persons must be familiar with hydrofluoric first aid procedures. See Guidelines for Working with Hydrofluoric Acid for more information.

CHAPTER THREE: LABORATORY SAFETY POLICIES

The following policies provide proper guidance for safe laboratory work practices and set the standard for behavior within the laboratory and must be adopted by all KAUST laboratories. They provide a common sense approach to frequently encountered situations in the research environment.

It is the responsibility of the Principal Investigator and laboratory manager to ensure that personnel working in laboratories under their supervision are informed and follow laboratory specific, research center, and campus-wide policies and procedures related to laboratory safety – such as the guidelines and requirements covered in this Laboratory Safety Manual.

***While this Laboratory Safety Manual provides the minimum requirements across campus labs; center directors, Principal Investigators, and laboratory managers have the authority to implement more stringent policies within laboratories under their supervision and are encouraged to do so.

EMPLOYEE TRAINING

All KAUST faculty, staff, and students who work in labs with chemical, biological, radiological hazards and/or physical hazards present are required to attend the HSE Laboratory Safety Training, Emergency Incident Preparedness and Hazardous Waste Training. This training must occur before any individuals are permitted to work in KAUST laboratories. Additionally, the Principal Investigator or laboratory manager is responsible for informing all staff, students, and visitors who work in their labs of any potential health and safety risks that may be present in their workplace, and provide any additional training above and beyond the KAUST minimum training. Laboratory personnel who attend HSE training classes will have documentation entered and maintained for them within the HSE training database. Faculty, laboratory managers, and Laboratory Safety Representatives can request a list of attendees for their labs from HSE to verify all personnel have attended the required training.

It is the responsibility of Principal Investigators and laboratory managers to ensure personnel working in laboratories under their supervision have been provided with the proper training,

received information about the hazards in the laboratory they may encounter, and been informed about ways they can protect themselves.

STANDARD OPERATING PROCEDURES

Laboratories are responsible for developing Standard Operating Procedures (SOPs) for any processes or operations that involve the use of any hazardous chemical, biological, radiological, equipment or other hazardous processes or operations.

SOPs can be stand-alone documents or supplemental information included as part of research notebooks, experiment documentation, or research protocols. The requirement for SOPs is to ensure a process is in place to document and address relevant health and safety issues as part of every experiment. SOPs can also help to ensure consistency for good scientific results as well.

At a minimum, SOPs should include details such as:

- The hazards (chemical, energy, mechanical, etc.) involved and their properties.
- Special hazards and circumstances.
- Use of engineering controls (such as fume hoods).
- Required PPE.
- Spill response measures.
- Waste disposal procedures.
- Decontamination procedures.
- Description of how to perform the experiment or operation.

SOPs applicable to pieces of equipment or operations that may pose any physical hazards should include but not limited to items such as:

- Safe use and considerations of LASERs.
- Use of cryogenic liquids and fill procedures.
- Connecting regulators to gas cylinders and cylinder change outs.
- Use of equipment with high voltage.

- Etc…

SOPs do not need to be lengthy or wordy dissertations and it is perfectly acceptable to point laboratory personnel to other sources of information. Some examples of what to include as part of SOPs are:

> "To use this piece of equipment, see page 4 in the operator's manual (located in file cabinet #4)." "The chemical and physical hazards of this chemical can be found in the SDS – located in the SDS binder. Read the SDS before using this chemical." "When using chemical X, wear safety goggles, nitrile gloves, and a lab coat."

HSE can assist laboratories with developing general and specific SOPs. Due to the variety of research and the large number of laboratories on the KAUST campus, it is the responsibility of each Principal Investigator to ensure that SOPs are developed and the practices and procedures are adequate to protect lab workers who are exposed to any chemical, biological, radiological, or physical hazards.

It is the responsibility of the Principal Investigator and laboratory manager to ensure written SOPs incorporating health and safety considerations are developed for work involving the use of hazards in laboratories under their supervision and that PPE and engineering controls are adequate to prevent overexposure. In addition, Principal Investigators and laboratory managers must ensure that personnel working in laboratories under their supervision have been trained on those SOPs.

Examples of Standard Operating Procedures and blank SOP template include:

- Standard Operating Procedure template
- Guidance documents for creating SOPs
- Links to other SOP examples

WORKING ALONE POLICY

Whenever possible, laboratory personnel should avoid working alone when conducting research, especially when experiments involve hazardous substances and procedures. Laboratories should establish specific guidelines and standard operating procedures specifying when working alone is not allowed and develop notification procedures when working alone occurs. All work to be performed by someone working alone, and the monitoring system that is established, must be approved in advance by the Principal Investor or laboratory manager.

Avoid working alone when conducting hazardous activities in the laboratory.

If a laboratory person determines it is necessary to work alone, consideration should be given to notifying someone else in the area – in an adjacent room, another lab on the same floor, or a lab on a different floor. It is recommended that a "buddy system" be established for regular, routine checks on personnel working alone, such as every 15 – 30 minutes, to ensure no accidents have occurred. This could be accomplished by physically walking to the room where the lab worker is, or through the use of a phone. If the person working alone is doing highly hazardous work, then the person checking on the lab worker should not enter the same room. A system of visual checks should be established to indicate there are no problems or to determine if help is needed.

Examples of activities where working alone is permissible include:

- Office work such as writing papers, making calculations, doing computer work, and reading;
- Housekeeping activities such as general cleaning, reorganization of supplies or equipment, etc., as long as no moving of large quantities of chemicals is involved;
- Assembly or modification of laboratory apparatus when no chemical, electrical, or other physical hazards are present;
- Routine lab functions that are part of a standard operating procedure and have been demonstrated to be safe and not involve hazardous materials.

Examples of activities where working using a “buddy system” should be considered include:

- Experiments involving toxic (category 1 by GHS standards) chemicals;
- Experiments involving high-pressure equipment;
- Experiments involving large quantities (>2 liters) of cryogenic materials;
- Experiments involving work with unstable (reactive/explosive) materials;
- Experiments involving Class 3B or 4 Lasers;
- Transfer of large quantities (>4 liters) of flammable materials, acids, bases, and other hazardous materials;
- Work involving highly energized electrical systems;
- Changing out compressed gas cylinders containing hazardous materials.

It is the responsibility of Principal Investigators and laboratory managers to ensure procedures for working alone are developed and followed by personnel working in laboratories under their supervision.

LABORATORY HOUSEKEEPING

Housekeeping refers to the general condition and overall appearance of a laboratory. Safety performance and orderliness in the laboratory are directly related. Good housekeeping standards serve not only to protect the health and safety of personnel, but are a common sense way of increasing productivity in a laboratory, making efficient use of valuable laboratory space, and increasing the reliability of experiments due to less potential for contamination. When housekeeping standards fall, safety performance inevitably deteriorates. Good housekeeping standards must be maintained in all KAUST laboratories. Good housekeeping standards include:

- Keep all areas of the lab free of clutter, trash, packaging, extraneous equipment, and unused chemical containers. Areas within the lab that should be addressed include benches, hoods, refrigerators, cabinets, chemical storage cabinets, sinks, trash cans, etc.;

- Aisles and hallways shall have proper egress and a minimum clearance of one meter (three feet). Do not block or impede exit ways or doors. See the Service Corridor Policy for more information;

- Clean up all chemical spills immediately, regardless if the chemical is hazardous or not. When cleaning up a chemical spill, look for any related splashes on nearby equipment, cabinets, doors, and counter tops;

- Keep areas around emergency equipment and devices clean and free of clutter. This includes items such as eyewash/emergency showers, electric power panels, fire extinguishers, and spill cleanup supplies;

- Keep a minimum of one meter or three feet of clearance (as required by fire codes) between benches and equipment. Exits must be clear of obstacles and tripping hazards such as bottles, boxes, equipment, electric cords, etc. Combustible materials may not be stored in exits (including corridors and stairways), exit enclosures, or mechanical electrical equipment rooms;

- When storing items overhead, keep heavier and bulkier items closer to the floor. In sprinklered rooms, all storage must be kept at least 45 centimeters (18 inches) below the level of the sprinkler head deflectors to ensure that fire sprinkler coverage is not impeded;

- Keep all containers of chemicals and waste closed when not in use.

It is the responsibility of Principal Investigators and laboratory managers to ensure laboratories under their supervision are maintained in a clean and orderly manner and personnel working in the lab practice good housekeeping.

TELEPHONE AVAILABILITY

Laboratories should have a means of communication in the event of an emergency. This can include a desk phone or mobile phone (if service is available) within the lab or access to a central phone located nearby.

UNATTENDED OPERATIONS

Whenever it is necessary to have unattended operations occurring in a lab, it is important to ensure safeguards are put into place in the event of an emergency. Laboratory personnel should adhere to the following guidelines when it is necessary to carry out unattended operations. For unattended operations involving highly hazardous conditions and/or materials, an appropriate warning/explanation sign should be placed on the laboratory door, or in a conspicuous place that could be easily seen without putting someone else in danger in the event of an emergency. The warning sign should list the following information:

- The nature of the experiment in progress.
- The chemical(s) in use.
- Hazards present (electrical, heat, etc.)
- The name of the person conducting the experiment and a contact number. A secondary name and contact number is also recommended.

When setting up an experiment that will be left unattended, try to take into account potential incidents that could occur if something went wrong. For example:

- Use secondary containment such as trays to contain any spills that may occur.
- Use safety shields and keep the hood sash down low to contain chemicals and glass in case an explosion occurs.
- Remove any chemicals or equipment that are not necessary for the experiment or items that could potentially react with the chemicals or other materials being used in the experiment.
- Whenever possible, use automatic shutoff devices to prevent accidents such as loss of cooling water shutoff, over-temperature shut off, etc.
- Use emergency power outlets for those pieces of equipment that could be negatively affected in the event electric service or other city utilities are interrupted.

It is the responsibility of Principal Investigators and laboratory managers to ensure procedures for unattended operations are developed and followed by personnel working in laboratories under their supervision.

INJURY/ILLNESS REPORTING

All accidents and injuries, no matter how minor, are required to be reported to HSE officials using the online Report It System. Reports are required to be completed within 24 hours of the incident.

ACCESS TO LABORATORIES

Access to KAUST University laboratories, workshops and other work areas housing hazardous materials or machinery is restricted to the relevant University faculty, staff, students, or other persons on official business.

VISITORS AND CHILDREN IN LABS

Due to the potential hazards and liability issues, other persons (in particular children under the age of 16) are not permitted in hazardous work areas, with the exception of KAUST-sanctioned activity, e.g., tours, open houses, or other KAUST-related business as authorized by the Principal Investigator or laboratory manager. In these instances, all children under the age of 16 must be under careful and continuous supervision.

If a Principal Investigator or laboratory manager authorizes visitors or children to enter a hazardous work area, then that Principal Investigator or laboratory manager is responsible for the health and safety of those individuals.

VISITING SCIENTISTS AND OTHER SIMILAR USERS

There are potential risks associated with allowing access to labs and equipment by visiting scientists. These risks include theft or questions of ownership of intellectual property, bodily injury, and property damage. Departments should verify that all users of the lab have the required safety and health training and competence prior to allowing access to the lab and/or specialized equipment. It is the user's responsibility to have or obtain the appropriate training.

It is the responsibility of the center directors, Principal Investigators, and laboratory managers to ensure visiting scientists and other similar users have been properly trained and made aware of any potential health and physical hazards that may exist in their labs.

PETS IN LABS

Pets are prohibited in KAUST laboratories. In addition, while on University-controlled property, animals must be attended and restrained at all times.

EATING, DRINKING, AND APPLYING COSMETICS IN THE LABORATORY

To prevent exposure to hazardous materials through ingestion, do not eat, drink, chew gum, or apply cosmetics in areas where hazardous materials are used.

Wash your hands thoroughly after using any chemicals or other laboratory materials, even if you were wearing gloves, and especially before eating or drinking.

To help promote awareness, laboratories refrigerators and freezers should be properly labeled. Refrigerators used for the storage of chemicals should be labeled “Chemicals Only, No Food”. Examples of these signs can be found on the Signs and Labels webpage.

Keep in mind that some chemical exposure can result in immediate effects (acute exposure) while other effects may not be seen for some time despite repeated exposure (chronic exposure). Consuming food or drink or applying cosmetics in the lab can result in both types of exposure.

PERSONAL HYGIENE

Good chemical hygiene practices include the use of personal protective equipment (PPE) and good personal hygiene habits. Although PPE can offer a temporary barrier of protection against chemicals and biological materials, good personal hygiene habits are essential to prevent chemical exposure, even when using PPE.

Some general guidelines that should always be followed include:

- Do not eat, drink, chew gum, or apply cosmetics in a lab or other area where chemicals are used.
- Do not store food or drink in refrigerators that are used to store chemicals.
- Do not ever try starting a siphon or pipette by mouth, doing so can result in ingestion of chemicals or inhalation of chemical vapors. Always use a pipette aid or suction bulb to start a siphon.
- Always confine long hair, loose clothing, and jewelry.
- Wear a lab coat when working with hazardous materials.
- Shorts, skirts, sandals, and open toed shoes are not permitted in KAUST laboratories.
- Remove laboratory coats, gloves, and other PPE immediately when chemical contamination occurs. Failure to do so could result in chemical exposure.
- After removing contaminated PPE, be sure to wash any affected skin areas with soap and

water for at least 15 minutes.

- Always remove lab coats, scrubs, gloves, and other PPE before leaving the lab. Do not wear lab coats, scrubs, or other PPE (especially gloves) in areas outside the lab, particularly not in areas where food and drink are served, or other public areas.

- Always wash hands with soap and water after removing gloves and before leaving the lab or using items such as the phone, turning doorknobs, or using an elevator.

- Always wash lab coats separately from personal clothing. Be sure to identify contaminated lab coats to commercial laundry facilities to help protect their workers by placing the contaminated lab coat in a separate plastic bag and clearly identifying the bag with a note or label indicating the lab coat is contaminated.

SELF INSPECTIONS

An important part of any research safety program is implementation of a self-inspection program. Self-inspections provide a number of useful benefits and further help to create a culture of safety within the lab. Benefits of self-inspections include:

- Raising the level of awareness of laboratory personnel and determining the level of compliance with KAUST policy regulations.

- Providing an opportunity for lab specific training by identifying potential issues within the lab and then training lab personnel to look for these issues.

- Serving as a regular health and safety check of laboratory facilities.

- Serving as an outlet for faculty, staff, and student concerns.

HSE recommends the following frequency for self-inspections:

- On a daily basis lab personnel should maintain good housekeeping within their lab.

- Informal weekly lab walkthroughs or end of the week cleanups.

- Ideally, self-inspections should occur once per month. These could include participation of research staff, LSRs, and/or safety committee members, and use of an inspection checklist, such as the self-inspection checklist found on the Lab Safety webpage.

LABORATORY SECURITY

The following are guidelines designed to minimize opportunities for intentional removal of any hazardous materials from your laboratory:

- *Recognize that laboratory security is related to, but different from laboratory safety.* Security is preventing intrusion into the laboratory and the theft of equipment or materials from the lab.

- *Develop a site-specific security policy.* Make an assessment of your laboratory area for hazardous materials and particular security issues. Then develop and implement lab security procedures for your lab group and train lab group members on security procedures and assign responsibilities.

- *Control access to areas where hazardous chemicals are used and stored.* Limit laboratory access to only those individuals who need to be in the lab and restrict off-hours access only to individuals authorized by the Principal Investigator.

    - Be sure to lock freezers, refrigerators, storage cabinets, and other containers where stocks of biological agents, hazardous chemicals, or radioactive materials are stored when they are not in direct view of workers (for example, when located in unattended storage areas).

    - Do not leave hazardous materials unattended or unsecured at any time. Most importantly, close and lock laboratory doors when no one is present.

- *Know who is in the laboratory area at any given time.* Approach anyone who you don't recognize and appears to be wandering in laboratory areas and hallways and ask if you can help direct them.

- *Secure your highly hazardous materials.* Consider using a log to sign hazardous materials in and out of secure storage and be sure to take a periodic inventory of all highly hazardous chemicals, biological agents/toxins, and controlled substances (this is required for use of radioactive materials). This could be as simple as frequently looking at your chemical containers to be sure that none are missing. Report any missing inventory to KAUST security immediately.

- *Know what materials are being ordered and brought into the laboratory area.* Visually screen packages before bringing them into your lab. Packages containing potentially infectious materials should be opened in a biological safety cabinet or other appropriate containment device. Know what materials are being removed from the laboratory area and consider tracking the use and disposal of hazardous materials.

- *Pay special attention to the following:*
    - Open labs
    - Unrestricted access to toxic chemicals
    - Unlocked support rooms
    - Toxic gas security
    - Unsecured biological materials and waste
    - Access to controlled substances
    - Changes in chemical inventory
    - Storeroom security
    - Chemical waste collection areas
    - Unusual activities

CHAPTER FOUR: PERSONAL PROTECTIVE EQUIPMENT

Proper Personal Protective Equipment must be worn at all times in the laboratory. The minimum PPE for a laboratory is safety glasses, a buttoned laboratory coat and appropriate gloves. Depending on activities being conducted, additional PPE may be required. For additional information, see the **PPE Standard for KAUST Laboratories**.

HAZARD ASSESSMENTS

Laboratory personnel should conduct hazard assessments of specific operations occurring in their laboratories to determine what PPE is necessary to safely carry out the operations. Information on the specific PPE required to carry out procedures within the laboratory using hazardous chemicals must also be included in the laboratory's standard operating procedures. PPE must be made available to laboratory workers to reduce exposures to hazardous chemicals in the lab. Proper PPE includes items such as gloves, eye protection, lab coats, face shields, aprons, boots, hearing protection, etc.

When deciding on the appropriate PPE to wear when performing any operations or experiments, a number of factors must be taken into consideration such as:

- The chemicals being used, including concentration and quantity.
- The hazards the chemicals pose.
- The routes of exposure for the chemicals.
- The material the PPE is constructed of.
- The permeation and degradation rates specific chemicals will have on the material.
- The length of time the PPE will be in contact with the chemicals.

Careful consideration should be given to the comfort and fit of PPE to ensure that it will be used by laboratory personnel. All personal protective equipment and clothing must be maintained in a sanitary and reliable condition. KAUST provides a laundry service for laboratory coats.

While HSE can provide information, training, and assistance with conducting hazard assessments and the selection and use of proper PPE, the ultimate responsibility lies with the Principal Investigator or laboratory manager.

Please Note: Principal Investigators, laboratory managers, and centers are free to set policies that establish minimum PPE requirements for personnel working in and entering their laboratories above the KAUST minimum standards.

PPE TRAINING

Laboratory personnel must be trained in the selection, proper use, limitations, care, and maintenance of PPE. Training requirements can be met in a variety of ways including videos, group training sessions, and handouts. Periodic retraining should be offered to both the employees and supervisors as appropriate. Examples of topics to be covered during the training include:

- When PPE must be worn.
- What PPE is necessary to carry out a procedure or experiment.
- How to properly put on, take off, adjust, and wear PPE.
- The proper cleaning, care, maintenance, useful life, limitations, and disposal of the PPE.

It is the responsibility of Principal Investigators and laboratory managers to ensure laboratory staff and students have received the appropriate training on the selection and use of proper PPE, that proper PPE is available and in good condition, and laboratory personnel use proper PPE when working in laboratories under their supervision.

EYE PROTECTION

Eye protection is one of the most important and easiest forms of PPE to wear. Laboratory personnel must use eye protection for many of the chemical and physical hazards found in laboratories including flying particles, broken glass, molten metal, acids or caustic liquids, chemical liquids, chemical gases or vapors, or potentially injurious light radiation.

Appropriate eye protection is required whenever working in or entering a laboratory in which hazardous chemical or infectious materials, or other mechanical or physical eye hazards are present. Eye and face protection must be selected on the basis of hazard and assessment of risk.

All laboratory employees and visitors are required to wear protective eyewear while in laboratories where chemicals are being handled or stored, at all times, even when not working directly with chemicals.

Ordinary prescription glasses do not provide adequate protection from injury to the eyes. Adequate eye protection requires the use of hardened-glass or plastic safety spectacles with side shields. When selecting proper eye protection, be aware there are a number of different styles of eyewear that serve different functions.

NOTE: NORMAL PRESCRIPTION GLASSES AND/OR CONTACT LENSES BY THEMSELVES ARE <u>NOT</u> CONSIDERED AS PROTECTIVE EYEWEAR.

SAFETY GLASSES

Safety glasses provide eye protection from moderate impact and particles associated with grinding, sawing, scaling, broken glass, and minor chemical splashes, etc. Side protectors are required when there is a hazard from flying objects. Safety glasses do not provide adequate protection for processes that involve heavy chemical use such as stirring, pouring, or mixing. In these instances, splash goggles should be used. If you need prescription safety glasses, the research safety team has a bulletin describing how to purchase them.

SPLASH GOGGLES

Splash goggles provide adequate eye protection from many hazards, including potential chemical splash hazards, use of concentrated corrosive material, and bulk chemical transfer. Goggles are available with clear or tinted lenses, fog proofing, and vented or non-vented frames. Be aware that goggles designed for woodworking are not appropriate for working with chemicals. These former types of goggles can be identified by the numerous small holes throughout the facepiece. In the event of a splash, chemicals could enter into the small holes, and result in a chemical exposure to the face. Ensure the goggles you choose are rated for use with chemicals.

FACE SHIELDS

Face shields provide additional protection to the eyes and face when used in combination with safety glasses or splash goggles. Face shields consist of an adjustable headgear and face shield of tinted or clear lenses or a mesh wire screen. They should be used in operations when the entire face needs protection and should be worn to protect the eyes and face from flying particles, metal sparks, and chemical/biological splashes. Face shields must **not** be used alone and are **not** a substitute for appropriate eyewear. Face shields should always be worn in conjunction with a primary form of eye protection such as safety glasses or splash goggles.

WELDING SHIELDS

Welding shields are similar in design to face shields but offer additional protection from infrared or radiant light burns, flying sparks, metal splatter, and slag chips encountered during welding, brazing, soldering and cutting operations. Equipment fitted with appropriate filter lenses must be used to protect against light radiation. Tinted and shaded lenses are not filter lenses unless they are marked or identified as such.

LASER PROTECTION

A single pair of safety glasses is not available for protection from all LASER outputs. The type of eye protection required is dependent on the spectral frequency or specific wavelength of the laser source. If you have questions on the type of eyewear that should be worn with your specific LASER, contact the LASER Safety Officer at researchsafety@kaust.edu.sa.

CONTACT LENSES

The University permits the wearing of contact lenses in laboratories, only if the wearer has other forms of eye protection mentioned above to be used in conjunction with contact lenses.

HAND PROTECTION

Gloves must be worn whenever significant potential hazards from chemicals, cuts, lacerations, abrasions, punctures, burns, biologicals, or harmful temperature extremes are present. The proper use of hand protection can help protect from potential chemical and physical hazards. Gloves must be worn when using chemicals that are corrosive or easily absorbed through the skin.

There is not one type of glove that offers the best protection against all chemicals or one glove that totally resists degradation and permeation to all chemicals. All gloves must be replaced periodically, depending on the type and concentration of the chemical, performance characteristics of the gloves, conditions and duration of use, hazards present, and the length of time a chemical has been in contact with the glove.

All glove materials are eventually permeated by chemicals; however, they can be used safely for limited time periods if specific use and other characteristics (i.e., thickness, permeation rate, and time) are known. Glove manufacturers publish glove selection charts for their products. These should be consulted to determine the resistance to chemicals of common glove materials and determining the specific type of glove material that should be worn for use with a particular chemical.

SELECTING THE PROPER GLOVES

Before working with any chemical, always read manufacturer instructions and warnings on chemical container labels and SDSs. Recommended glove types are sometimes listed in the PPE section in SDSs. If the recommended glove type is not listed on the SDS, then laboratory personnel should consult with the manufacturers' glove selection charts. These charts typically include commonly used chemicals that have been tested for the manufacturers' different glove types. Different manufacturers use different formulations so check the glove chart of the specific manufacturer for the glove you plan to use

If the manufacturers' glove chart does not list the specific chemical you will be using, then contact the manufacturer directly and work with their technical representatives to determine which glove is best suited for your particular application.

GENERAL GUIDELINES FOR GLOVE USE

Some general guidelines for glove use include:

- Wear appropriate gloves when the potential for contact with hazardous materials exists. Laboratory personnel should inspect gloves for holes, cracks, or contamination before each use. Any gloves found to be questionable should be discarded immediately.

- Disposable gloves must not be re-used.

- Reusable gloves should be replaced periodically, depending on the frequency of use and permeability to the substance(s) handled. Reusable gloves should be rinsed with soap and water between uses. Discard disposable gloves after each use and whenever they become contaminated.

- Due to potential chemical contamination, which may not always be visible, gloves must be removed before leaving the laboratory. Do not wear gloves while performing common tasks such as answering the phone, grabbing a door handle, using an elevator, etc. If gloves are needed to transport anything, wear one glove to handle the transported item – using a secondary container such as a bucket. The free, ungloved hand is then used to touch door knobs, elevator buttons, etc. If you are wearing gloves to “protect your sample from you” and are in the hall, no one else understands this and will be concerned about the items you have contaminated with those gloves.

DOUBLE GLOVING

A common practice to use with disposable gloves is “double-gloving”. This is accomplished when two pairs of gloves are worn over each other to provide a double layer of protection. If the outer glove becomes contaminated, starts to degrade, or tears open, the inner glove continues to offer protection until the gloves are removed and replaced.

The best practice is to check outer gloves frequently, watching for signs of degradation (change of color, change of texture, tears, etc.). At the first sign of degradation or contamination, always remove and dispose of the contaminated disposable gloves immediately and double-glove with a new set of gloves. If the inner glove appears to have any contamination or degradation; remove both pairs of gloves, and double glove with a new pair.

When working with mixtures of chemicals, it may be advisable to double glove with two sets of gloves made from different materials. This method can offer protection in case the outer glove material becomes permeated by one chemical in the mixture, while allowing for enough protection until both gloves can be removed. The type of glove materials selected for this type of application will be based on the specific chemicals used as part of the mixture. Check chemical manufacturers glove selection charts first before choosing which type of glove to use.

To properly remove disposable gloves, grab the cuff of the left glove with the gloved right hand and remove the left glove. While holding the removed left glove in the palm of the gloved right hand, insert a finger under the cuff of the right glove and gently invert the right glove over the glove in the palm of your hand and dispose of them properly. Be sure to wash your hands thoroughly with soap and water after the gloves have been removed.

CHOOSING GLOVES

Consider the following factors when choosing gloves:

- Chemical(s) to be used: No one glove is appropriate for protection from all chemicals. A glove may protect against a specific chemical, but it may not protect the wearer from another. Consult the compatibility charts to ensure that the gloves will protect you.

- Dexterity needed: The thicker the glove, typically the better the chemical protection, as the glove will be more resistant to physical damage, like tears and cracks, but it will harder be to handle and feel the work.

- Extent of the protection required: Determine if a wrist length glove provides adequate protection, or if a glove that extends further up the arm is required.

- Type of work to be done: The type of glove chosen should be specific to the task being performed. Ensure the correct glove is chosen to avoid injuries. Examples: A nylon cryogenic glove will be damaged if a hot item is handled, where as a “hot mitt” will not protect the wearer when liquid nitrogen is used, as it may be too porous.

CHEMICALLY RESISTANT GLOVES

Chemically-resistant gloves come in a wide variety of materials. The recommendations given below for the specific glove materials are based on incidental contact. Once the chemical makes contact with the gloved hand, the gloves should be removed and replaced as soon as practical. Often a glove specified for incidental contact is not suitable for extended contact, such as when the gloved hand can become covered or immersed within the chemical in use. Before selecting chemical resistant gloves; consult the glove manufacturers' recommendations or their glove selection charts, or contact HSE at researchsafety@kaust.edu.sa for more assistance.

Some general guidelines for different glove materials include:

- Natural Rubber Latex*** **-** Resistant to ketones, alcohols, caustics, and organic acids. See note below.

- Neoprene - Resistant to mineral acids, organic acids, caustics, alcohols, and petroleum solvents.

- Nitrile - Resistant to alcohols, caustics, organic acids, and some ketones.

- Norfoil **-** Rated for chemicals considered highly toxic and chemicals that can be easily absorbed through the skin. These gloves are chemically resistant to a wide range of materials that readily attack other glove materials. These gloves are not recommended for use with Chloroform. Common brand names include: Silver Shield by North Hand Protection, 4H by Safety4, or New Barrier by Ansell Edmont.

- Polyvinyl chloride (PVC) - Resistant to mineral acids, caustics, organic acids, and alcohols.

- Polyvinyl alcohol (PVA) - Resistant to chlorinated solvents, petroleum solvents, and aromatics.

A note about latex gloves

THE USE OF LATEX GLOVES, ESPECIALLY THIN, DISPOSABLE EXAM GLOVES, FOR CHEMICAL HANDLING **SHOULD BE AVOIDED** BECAUSE LATEX OFFERS LITTLE PROTECTION FROM COMMONLY USED CHEMICALS. LATEX GLOVES CAN DEGRADE SEVERELY IN MINUTES OR SECONDS, WHEN USED WITH COMMON LAB AND SHOP CHEMICALS. LATEX GLOVES CAN CAUSE AN ALLERGIC REACTION IN A PERCENTAGE OF THE POPULATION DUE TO SEVERAL PROTEINS FOUND IN LATEX. SYMPTOMS CAN INCLUDE NASAL, EYE, OR SINUS IRRITATION, HIVES, SHORTNESS OF BREATH, COUGHING, WHEEZING, OR UNEXPLAINED SHOCK. IF ANY OF THESE SYMPTOMS BECOME APPARENT IN PERSONNEL WEARING LATEX GLOVES, DISCONTINUE USING THE GLOVES AND SEEK MEDICAL ATTENTION IMMEDIATELY.

Due to possible health concerns associated with latex allergy, the use of pre-powdered disposable latex gloves is not permitted. Only under the following conditions shall the use of non-powdered latex gloves be permitted:

- The users must demonstrate that latex provides a distinct advantage over alternative glove materials.

- The reason for selecting the glove material is documented in a risk assessment.

- All persons in the area when latex gloves are used shall be provided information on latex allergy.

See Appendix 4 for a list of recommended gloves for specific chemicals, definitions for terms used in glove selection charts, glove materials and characteristics, and a list of useful references.

PROTECTIVE CLOTHING

Protective clothing includes laboratory coats or other protective garments such as disposable coveralls, chemical splash aprons, and other items that can be used to protect street clothing from biological or chemical contamination and splashes, as well as providing additional body protection from some physical hazards.

Laboratory coats must always be worn during active work in the laboratory that involves hazardous materials. A lab coat helps prevent contact with minor chemical splashes or spills encountered in laboratory-scale work. Laboratory coats do not significantly resist penetration by many liquid chemicals. Remove your lab coat immediately upon significant contamination. Do not take lab coats home and launder them because of the potential for contamination of the home environment. KAUST offers a laundry service for lab coats – see the Lab Services Bulletin on the Lab Safety webpage for more information.

Lab coats should remain buttoned to protect more completely. Laboratory coats are loose-fitting by design, so that in case of chemical contact there is ample time to react before it contacts the skin. Lab coats provide minimum protection. In some cases, disposable outer garments (e.g. Tyvek) may be necessary. Many disposable garments, however, offer only limited protection from vapor penetration and you need to exercise considerable judgment when using them. Impervious suits fully enclosing the body may be necessary in emergencies.

Please note: shorts (short skirts and similar clothing, etc.) and open toed shoes (sandals, flip flops, etc.) are not permitted in KAUST laboratories. See the PPE Standard for KAUST Laboratories for more information.

RESPIRATORS

Respiratory protection includes disposable respirators (such as N95 filtering facemasks commonly referred to as “dust masks”), air purifying, and atmosphere supplying respirators. Respirators are generally not recommended for laboratory workers. Engineering controls, such as dilution ventilation, fume hoods, and other devices, which capture and remove vapors, fumes, and gases from the breathing zone of the user are preferred over the use of respirators in most laboratory environments. There are certain exceptions to this general rule, such as the changing out of cylinders of toxic gases and emergency response to chemical spills.

The use of disposable respirators (e.g., N95 filtering facepieces/dust masks) for weighing powdery or dusty materials is acceptable. However, please note that most disposable respirators do not offer protection against chemical vapors and fumes; they are for use of nuisance dust only. As a measure of coworker protection, when weighing out dusty materials or powders, consider waiting until other coworkers have left the room to prevent possible exposure and thoroughly clean up and decontaminate working surfaces.

A laboratory worker at KAUST may not purchase a respirator and bring it to their lab for personal use without prior consultation with HSE.

RESPIRATORY PROTECTION PROGRAM

KAUST employees who must wear respirators will be included in KAUST's Respiratory Protection program, which includes the following:

- You will receive a medical evaluation by medical staff to ensure you are physically fit to wear a respirator. Wearing any type of respirator puts a large amount of stress on the body;
- You will be given a fit test to determine which size respirator fits you the best. Due to the differences in the sizes and shapes of faces, there is no one respirator that fits all sizes and shapes of faces;
- You will be shown how to properly put on and take off the respirator, and how to check to make sure it is functioning properly;
- You will be shown how to properly clean and care for your respirator, including proper maintenance;
- You will be shown how to choose the right respirator or respirator cartridge for the specific processes and types of chemicals you will be using.

NOTE: AS WITH CHEMICAL PROTECTIVE GLOVES, THERE IS NO ONE UNIVERSAL RESPIRATOR CARTRIDGE THAT CAN BE USED WITH EVERY CHEMICAL.

For more information about the use of respirators at KAUST, please contact HSE at researchsafety@kaust.edu.sa.

HEARING PROTECTION

Hearing protective devices includes earplugs, earmuffs, or similar devices designed to protect your hearing. If occupational noise exposures exceed permissible levels and cannot be reduced through engineering or other controls, then hearing protective devices must be worn. If you have questions about whether you are receiving an occupational noise exposure, or would like to request workplace monitoring or additional information, then please contact HSE at researchsafety@kaust.edu.sa.

FOOT PROTECTION

Laboratory personnel (and other personnel) must wear appropriate footwear at all times in laboratories, laboratory support areas, and other areas with chemical, biological and physical hazards are present. Laboratory personnel must not wear sandals or similar types of perforated or open toe shoes whenever working with or around hazardous chemicals or physical hazards. This is due to the potential exposure to toxic chemicals and the potential associated with physical hazards such as dropping pieces of equipment or broken glass being present. In general, shoes should be comfortable, and leather shoes are preferable to cloth shoes due to the better chemical resistance of leather compared to cloth. Leather shoes also tend to absorb fewer chemicals than cloth shoes. However, leather shoes are not designed for long term exposure to direct contact with chemicals. In such instances, chemically resistant rubber boots are necessary.

NOTE: LABORATORY PERSONNEL MUST NOT WEAR SANDALS OR SIMILAR TYPES OF PERFORATED OR OPEN-TOE SHOES WHEN WORKING IN THE LABORATORY.

CHAPTER FIVE: ENGINEERING CONTROLS

Engineering controls are considered the first line of defense in the laboratory for the reduction or elimination of potential exposure to hazardous chemicals. Examples of engineering controls used in laboratories at KAUST include dilution ventilation, local exhaust ventilation, chemical fume hoods, glove boxes, safety shields, and proper storage facilities.

EXHAUST VENTILATION

The laboratories at KAUST are provided with general ventilation adequate for comfort and sufficient to supply air for chemical fume hoods and other local ventilation devices. Because manipulating hazardous materials on an open lab bench does not provide protection from such hazards, volatile or toxic chemicals shall be handled in a chemical fume hood or other appropriate containment device.

The air pressure in laboratories is maintained at a pressure that is negative with respect to the rest of the building in order to keep airborne substances generated in the laboratory from entering the outside public spaces. In general, doors to labs should remain closed to ensure the laboratory maintains a proper air balance.

CHEMICAL FUME HOODS

Chemical fume hoods are installed in laboratories to protect individuals from airborne substances (gases, vapors, mists, fumes) generated by laboratory experiments. However, simply conducting these experiments in the fume hood does not guarantee adequate protection. The fume hood must be used properly.

USING A FUME HOOD EFFECTIVELY

These guidelines will help you optimize the effectiveness of your fume hood.

- Check the airflow indicator prior to use to ensure the fume hood is drawing air. Many of the hoods at KAUST are equipped with airflow monitors that display a digital readout of the face velocity and/or beep or light up when the velocity is too low. If an airflow monitor is not installed, test the hood airflow with a piece of light material (such as a tissue or chemwipe) held to the bottom of the sash. The material will deflect inward if the hood is drawing air.

- Minimize the number of objects stored in the hood – keep at least 50% of the working surface clear, if possible.

- Always place containers and equipment at least 15 centimeters (6 inches) into the hood from the face.

- Place containers and equipment toward the sides of the hood to reduce obstruction of the exhaust slots.

- If possible, elevate equipment and containers 4 to 8 centimeters (two to three inches) above the working surface using perforated or slotted shelving to minimize disruption to the airflow.

- When working in a fume hood, keep doors closed within the lab and minimize traffic in front of the hood. Minimize rapid movements while working in the hood, including opening and closing the sash. All of these precautions will help to prevent air currents from forming, which can result in hazardous vapors being pulled out of the hood and into the laboratory personnel's breathing zone.

- Always work with the fume hood sash as low as possible and always keep your fume hood sash closed when you are not working in it. This offers better protection against splashes and explosions and saves a significant amount of energy and electricity.

- Do not use fume hoods to evaporate hazardous waste. Evaporating hazardous waste as a means of disposal is prohibited at KAUST.

- When pouring flammable liquids (>4 liters), especially from metal containers, always make sure both containers are electrically interconnected to each other by bonding and grounding in order to prevent the generation of static electricity - which can cause the flammable liquid to ignite.

- As with any work involving chemicals, always practice good housekeeping and clean up all chemical spills immediately. Be sure to wash both the working surface and hood sash frequently and always maintain a clean and dry work surface that is free of clutter.

- Always report any malfunctioning fume hoods by submitting a ticket via the Help Desk to 959 immediately. If the fume hood is not working properly, then let other people in the lab know by hanging up a Do Not Use sign on the hood.

NOTE: FUME HOODS ARE NOT THE SAME AS BIOSAFETY CABINETS. LABORATORY HOODS AND BIOSAFETY CABINETS (OR TISSUE CULTURE HOODS), ALTHOUGH SIMILAR IN APPEARANCE, ARE VERY DIFFERENT DEVICES. BIOSAFETY CABINETS ARE DESIGNED FOR PROTECTION AGAINST EXPOSURE TO BIOLOGICAL MATERIALS AND FOR PROTECTION AGAINST CONTAMINATION OF BIOLOGICAL EXPERIMENTS AND TYPICALLY OFFER NO PROTECTION AGAINST CHEMICAL VAPORS.

PERCHLORIC ACID USE

Be aware that the use of heated perchloric acid requires a special perchloric acid fume hood with a wash down function. DO NOT use heated perchloric acid in a regular fume hood. If heated perchloric acid is used in a regular fume hood (without a wash down function), shock sensitive metallic perchlorate crystals can form inside the duct work, and could result in causing an explosion during maintenance work on the ventilation system. If you are considering working with heated perchloric acid, then please contact HSE at researchsafety@kaust.edu.sa for more information.

FUME HOOD CERTIFICATION

Fume hoods must be inspected and tested annually to ensure that they are working properly. During the inspection, the air flow face velocity is measured and compared against recommended standards, and a smoke test is conducted to ensure adequate capture and containment. The fume hood is also checked for potential air flow interferences including excessive storage in the fume hood, blockage of the exhaust slots, HVAC vents located near the face of the hood, and location of the fume hood in a heavy traffic area. Fume hood inspections are conducted in accordance with the following standards:

- ANSI/ASHRAE 110-1995, “Method of Testing Performance of Laboratory Fume Hoods”

Many of the fume hoods at KAUST are equipped with monitors that display a digital readout of the velocity of air being drawn into the hood. The monitor will alarm when airflows are too low or too high. Do not use the fume hood unless it is operating properly.

If you suspect your fume hood is not functioning properly, alert others by placing a sign that reads “Do Not Use” and report it to the Help Desk at 959 immediately.

OTHER LOCAL EXHAUST DEVICES

Other engineering controls for proper ventilation include glove boxes, compressed gas cabinets, vented storage cabinets, canopy hoods, and snorkels. These pieces of equipment are designed to capture hazardous chemical vapors, fumes, and dust particles at the source of potential contamination. Examples where these capture-devices would be appropriate include atomic absorption units, vacuum pumps, welding activities, and other operations.

To ensure maximum effectiveness, it is important that remote capture devices (i.e., snorkel) be located very close to the contaminant source.

BIOLOGICAL SAFETY CABINETS

Biological Safety Cabinets (BSC) are engineering devices that reduce the risk of working with biohazardous and infectious microorganisms. Cabinets are also used for maintaining aseptic conditions when working with cell cultures. BSCs utilize High Efficiency Particulate Air (HEPA) filters in the supply air and exhaust systems to create a nearly sterile work environment. Thus, BSCs provide personnel, environmental, and product protection when appropriate practices and procedures are followed.

LAMINAR FLOW CLEAN BENCHES

The laminar flow clean bench protects the product from airborne contamination, but does not protect the operator. Because of the risk to personnel, work with hazardous material on a laminar flow clean bench is not permitted. Use of clean benches should be limited to the preparation of sterile media, the assembly of sterile components into complete units (e.g., membrane filters), the examination of sterilized equipment and materials for possible contamination, and similar operations.

GLOVE BOXES

Glove boxes are sealed enclosures designed to protect the user, the process, or both. They are usually equipped with at least one pair of gloves attached to the enclosure. The user manipulates the materials inside using the gloves. Typically, a glove box has an antechamber that is used to take materials in and out of the box. Gloves should be regularly inspected for cuts, tears, cracking and pinhole leaks. If defects are found, the gloves should be replaced. Note that there are many different types of glove box gloves that vary in thickness, material, size, etc. Choose the correct one for the glove box and application.

Regular maintenance and inspection is essential to ensure that a glove box is adequately protecting the user, the environment, and the experiment. Routine maintenance procedures and the frequency of inspection (or certification) should follow the manufacturers and regulatory recommendations.

DUCTLESS FUME HOODS AND WEIGH STATIONS

Ductless fume hoods and weigh stations utilize filter technology to remove chemical contaminants before discharging exhausted air back into the laboratory. Care must be taken to ensure that the unit has the appropriate filter for the intended application. Some units, intended for weighing powders only, afford no protection against chemical gases or vapors. Contact HSE at researchsafety@kaust.edu.sa if you have questions about the types of chemicals that can be used in ductless hoods and weigh stations.

CHAPTER SIX: HAZARD IDENTIFICATION DOOR SIGNS

Hazard identification signs are to be posted outside laboratory locations where hazards (chemical, electrical, biological, radioactive, etc.) are present. The purpose of the sign is to provide clear hazard warning to those entering a laboratory area and for emergency response situations.

All laboratories containing hazardous materials or operations must have a hazard identification door sign posted. Information included on the Signs:

- Hazard Symbols
- PPE Requirements
- Emergency Contact Information

Authorized Personnel Only

HSE Department
012-8080911

Emergency Contact Information

Area Hazards

Flammables
Oxidizers
Skin Corrosion/Burn
Eye Damage
Corrosive to Metals
Irritant (skin and eye)
Acute Toxicity (harmful)
Carcinogen
Reproductive Toxicity
Aquatic Toxicity
Cryogens
Cold Temperatures
Ultraviolet Light
Radio Frequency

Regulatory Information

BSL-1
Carcinogenic

PPE/Precautions

Lab Coat
Eye Protection
Foot Protection
Gloves
Face Shield
No Food/Drink

It is important that all employees and visitors comply with the policy for entering areas where these signs have been posted. The hazard identification door signs must be kept updated whenever emergency contact information changes or the hazards found in the lab changes significantly.

CHAPTER SEVEN: EYEWASH AND SHOWERS

All laboratories using hazardous chemicals, particularly corrosive chemicals, must have access to eyewash and/or an emergency shower.

The ANSI Standard Z358.1-2014 - Emergency Eyewash and Shower Equipment provides guidance by stating that emergency eyewash and/or emergency showers must be readily accessible, free of obstructions, and within 10 seconds from the hazard.

> NOTE: DUE TO THE FLOW REQUIREMENTS OUTLINED IN THE ANSI STANDARD, HAND HELD BOTTLES DO NOT QUALIFY AS APPROVED EYEWASHES.

TESTING AND INSPECTION OF EMERGENCY EYEW ASH AND SHOWERS

The ANSI Standard provides guidance by stating that plumbed emergency eyewash and safety showers should be activated weekly to verify proper operation and inspected annually. Regular activation (weekly flushing) ensures the units are operating properly, helps to keep the units free of clutter, and helps prevent the growth of bacteria within the plumbing lines, which can cause eye infections.

Laboratories are responsible for ensuring that access to eyewashes and emergency showers are kept free of clutter and ensuring the eyewash nozzle dust covers are kept in place. If nozzle dust covers are not kept on the eyewash nozzles, dust or other particles can clog the nozzles and result in poor or no water flow. This could result in dust or other particles being forced into the eyes when the eyewash is used.

Always report any malfunctioning eyewashes and emergency showers to your manager immediately and submit a ticket through the Help Desk at 959 to have the unit repaired. If either the emergency shower or eyewash is not working properly, then let other people in the lab know by hanging up a “Do Not Use” sign on the unit.

Eyewash stations and safety showers are inspected annually by a campus service provider. Laboratory personnel should test eyewash stations and safety showers on a weekly basis. An eyewash/shower test can be found on the Signs and Labels webpage.

CHAPTER EIGHT: SAFE CHEMICAL USE

WORKING SAFELY WITH HAZARDOUS CHEMICALS

The safe use of chemicals in the laboratory must be based on an analysis of the hazards, rather than merely the perception of the risks involved. Once this has been accomplished, a reasonable means of controlling the hazards through experimental protocol, engineering means (suitable local exhaust ventilation), appropriate work practices, and personal protective equipment can be made.

In order to assess the hazards of a particular chemical, both the physical and health hazards of the chemical must be considered.

It is the responsibility of the Principal Investigator to determine the hazards associated with all of the chemicals used in laboratories under their supervision.

HAZARDOUS CHEMICALS

The following is a list of types of hazardous chemicals, divided into eight general classes based on the predominant effects of those general chemical types.

1. *Acid-sensitive chemicals*: These chemicals react with acids to evolve heat, flammable, explosive or toxic gases. Examples include alkali metals, cyanides, sulfides, carbonates, arsenic and related elements.

2. *Corrosives:* These are typically acids or bases which may burn or otherwise damage human tissue on contact. The corrosion of equipment should also be considered. Examples include chromic acid cleaning solutions, concentrated acids such as hydrochloric, sulfuric and nitric, and acid-releasing substances such as thionyl chloride and halogens (bromine, chlorine).

3. *Explosives*: Chemicals in this class should be protected from shock, elevated temperatures, sparks, light, rapid temperature changes, and mixture with other reactive chemicals. Examples include nitroglycerin, nitrocellulose and organic peroxides.

4. *Flammables*: These are materials that will easily ignite and serve as a fuel for a fire. Examples include most common laboratory organic solvents such as acetone, tetrahydrofuran, diethyl ether, and petroleum distillates (pentanes, hexanes).

5. *Oxidizers*: These chemicals increase the intensity and severity of a fire. The reactions of oxidizing agents can generate heat and are often explosive. Oxidizing agents include oxygen, hydrogen peroxide, nitric and perchloric acid.

6. *Pyrophoric agents:* These chemicals ignite when exposed to air. In general, they require absolute protection from air. Examples include white phosphorus, Raney nickel catalyst, tert-butyllithium and silane gas.

7. *Toxics or poisons:* The relative toxicity of this general class of chemicals is dependent on a large number of factors. This class also includes carcinogens and reproductive toxins. Examples include hydrofluoric acid, dimethyl mercury, cyanide and azide salts.

8. *Water-reactive chemicals:* These chemicals react with water, steam and moisture in the air to produce heat and/or flammable, corrosive or explosive gases. Isolate water sensitive substances from other reactive chemicals and store in a cool, dry area. Examples of chemicals that liberate heat only are strong acids and bases. Substances that liberate flammable or corrosive gases are alkali metals, hydrides, phosphoryl chloride, and thionyl chloride.

See the Chemical Hazards Section for more information.

BASIC PRECAUTIONS

The best way laboratory personnel can protect themselves from chemical hazards is to minimize their exposure to them. In order to minimize chemical exposure:

1. Substitute less hazardous chemicals in your experiments whenever possible.

2. Always use the smallest possible quantity of chemical for all experiments.

3. Be sure to select the proper PPE and regularly inspect it for contamination, leaks, cracks, and holes. Pay particular attention to gloves.

4. Do not ever try starting a siphon or pipette by mouth, doing so can result in ingestion of chemicals or inhalation of chemical vapors. Always use a pipette aid or suction bulb to start a siphon

5. Do not smell or taste chemicals. When it is necessary to identify a chemical's odor, lab personnel should hold the chemical container away from their face and gently waft their hand over the container without inhaling large quantities of chemical vapor.

6. In order to identify potential hazards, laboratory personnel should plan their experiments in advance. These plans should include the specific measures that will be taken to minimize exposure to the chemicals to be used, the proper positioning of equipment, and the organization of dry runs.

7. When working with mixtures of chemicals, laboratory personnel should assume the mixture to be more toxic than the most toxic component in the mixture.

8. Consider all substances of unknown toxicity to be toxic until proven otherwise.

9. Request HSE to conduct exposure monitoring to determine airborne concentrations are not in excess of safe limits.

10. Promptly clean up all chemical spills regardless of whether the chemical is considered hazardous or nonhazardous. When cleaning up spills, remember to clean up any splashes that may have occurred on the sides of cabinets and doors in the immediate area.

11. When working in cold rooms, keep all toxic and flammable substances tightly closed as cold rooms have recirculated atmospheres.

12. Be aware of the potential asphyxiation hazard when using cryogenic materials and compressed gases in confined areas such as cold rooms and environmental chambers. If necessary, install an oxygen monitor/oxygen deficiency alarm and/or toxic gas monitor before working with these materials in confined areas.

13. Do not eat, drink, chew gum, or apply cosmetics in areas where hazardous chemicals are being used.

14. Keep all food and drink out of refrigerators and freezers used to store chemicals. Refrigerators used to store chemicals should be labeled as “Chemicals Only – No Food”. Refrigerator signs can be found on the Lab Safety Signs and Labels webpage.

15. Always wash hands with soap and water after handling chemicals and especially before leaving the lab and eating – even if gloves were worn during chemical handling.

16. Always remove personal protective equipment, such as gloves and lab coats, before leaving the lab.

17. Do not attempt to scale up experiments until after you have run the experiment according to published protocols and you are thoroughly familiar with the potential hazards. General rule of thumb: Always scale up 3-5 fold each step. When scaling up an experiment – change only one variable at a time, i.e. don’t change the heat source, the solvent, and the chemical lot number all at once. It is also advisable to let one of your other lab group members to check your setup prior to each run.

18. Always conduct procedures involving volatile chemicals, and those involving solid or liquid chemicals that may result in the generation of aerosols in a laboratory hood, glove box, or other suitable containment equipment.

FLAMMABLE SUBSTANCES

1. A chemical fume hood should be used for reactions in which flammable vapors are released, e.g. during the distillation of ether. If flammable gases are likely to be released in any process, the experiment must be confined to a chemical hood. A blast/explosion shield may also be required.

2. Date all peroxide-forming chemicals (e.g. diethyl ether, THF, dioxane) when they are received and when they need to be disposed. Peroxide formers should not be stored past their expiration date. Purchased peroxide formers generally contain inhibitors (BHT) to prevent the formation of peroxides. Any distilled or processed peroxide former no longer contains these inhibitors and should be kept under inert conditions, used immediately or disposed.

3. Do not pour any flammable liquids into sinks to be washed down with water. Fires and explosions have been caused in laboratories by vapors returning through the drainage system (e.g., during aspiration or rotary evaporation).

REACTIVE SUBSTANCES

1. When conducting a reaction where there is any possibility of even a mild explosion, use a face shield that is sufficiently large and strong to protect the face and neck, or use a standing blast/explosion shield. Splash goggles must be worn even when using a shield.

2. When sodium, potassium, or lithium is used, the cuttings or residual pieces must be properly disposed immediately. Store any of these metals in oil, toluene, xylene, or other saturated hydrocarbon with a high boiling point. These hydrocarbon solvents must be dry.

3. Never leave unattended chemical reactions that have not achieved kinetic equilibrium.

CORROSIVE SUBSTANCES

1. Always pour acid into water, never water into acid, as it can cause an exothermic reaction. For the same reason, pour concentrated solutions into water or less concentrated solutions while stirring.

2. All corrosive spills, regardless of the size, must be cleaned up immediately.

3. Keep corrosive bottles tightly stoppered; rinse and dry them before replacing them on the reagent shelf. Make certain that no spills remain on tables, floor, or bottle.

4. Bottles containing acids or other corrosive liquids shall be carried in the protective containers supplied for that purpose.

ROUTES OF CHEMICAL EXPOSURE

The potential health effects that may result from exposure to chemicals depend on a number of factors. These factors include the properties of the specific chemical (including toxicity), the dose and concentration of the chemical, the route of exposure, duration of exposure, individual susceptibility, and any other effects resulting from mixtures with other chemicals.

In order to understand how chemical hazards can affect you, it is important to first understand how chemicals can get into your body and do damage. The four main routes of entry are inhalation, ingestion, injection, and absorption through the skin and eyes.

INHALATION

Inhalation of chemicals results in absorption of chemicals via the respiratory tract (lungs). Once chemicals have entered into the respiratory tract, the chemicals can then be absorbed into the bloodstream for distribution throughout the body. Chemicals can be inhaled in the form of vapors, fumes, mists, aerosols, and fine dust.

Symptoms of exposure to chemicals through inhalation include eye, nose, and throat irritation, coughing, difficulty in breathing, headache, dizziness, confusion, and collapse. If any of these symptoms are noted, leave the area immediately and get fresh air. Seek medical attention if symptoms persist and complete an accident report using the online Report It System.

Laboratory workers can protect themselves from chemical exposure via inhalation through proper use of a functioning fume hood, use of dust masks and respirators when a fume hood is not available, avoiding bench top use of hazardous chemicals, ensuring chemical containers are kept tightly capped, and ensuring all chemical spills are promptly cleaned up.

INGESTION

Chemical exposure through ingestion occurs by absorption of chemicals through the digestive tract. Ingestion of chemicals can occur directly and indirectly. Direct ingestion can occur by accidently eating or drinking a chemical. With proper housekeeping and labeling, the chances of this happening are greatly reduced.

A higher probability of receiving a chemical exposure can occur by way of indirect ingestion. This can occur when food or drink is brought into a chemical laboratory. The food or drink can then absorb chemical contaminants (vapors or dusts) in the air and result in a chemical exposure when the food or drink is consumed. This can also occur when food or drink is stored with chemicals, such as in a refrigerator. Ingestion can occur when a laboratory worker who handles chemicals does not wear gloves or practice good personal hygiene, such as frequent hand washing, and then leaves the laboratory to eat, drink, or smoke. In all cases, a chemical exposure can result, although the effects of chronic exposure may not manifest itself until years later.

The best protection against ingestion of chemicals is to properly label all chemical containers, never consume food or drink or chew gum in laboratories, always wear PPE (such as gloves), and practice good personal hygiene, such as frequent handwashing.

Symptoms of chemical exposure through ingestion include metallic or other strange tastes in the mouth, stomach discomfort, vomiting, problems swallowing, and a general ill feeling. **If you think you may have accidentally ingested a chemical, seek medical attention immediately.** After seeking medical attention, complete an accident report using the online Report It System.

INJECTION

Chemical exposure via injection can occur when handling chemically contaminated items such as broken glass, plastic, pipettes, needles, razor blades, or other items capable of causing punctures, cuts, or abrasions to the skin. When this occurs, chemicals can be injected directly into the bloodstream and cause damage to tissue and organs. Due to direct injection into the bloodstream, symptoms from chemical exposure may occur immediately.

Laboratory workers can protect themselves from an injection hazard by wearing proper PPE such as safety glasses/goggles, face shields, and gloves. Inspect all glassware for chips and cracks before use, and immediately discard any glassware or plastic ware that is damaged. To help protect coworkers in the lab and building care staff, all broken glass should be disposed of in a puncture resistant container labeled as “Broken Glass”. This can be a commercially purchased “broken glass” container or simply a cardboard box or other puncture resistant container labeled as “Broken Glass”. Broken glass signs can be found on the Lab Safety Signs and Labels webpage.

Whenever cleaning up broken glass or other sharp items, always use a broom, scoop or dustpan, or devices such as pliers and wear leather gloves when handling broken glass. For other items that can cause cuts or puncture wounds, such as needles and razor blades, never leave these items out in the open where someone could come into contact with them.

If you do receive a cut or injection from a chemically contaminated item, if possible, gently try to remove the object and immediately rinse under water while trying to flush the wound and remove any chemical contamination, administer first aid and seek medical attention if necessary, and then complete an accident report using the online Report It System.

EYE ABSORPTION

Some chemicals can be absorbed by the eyes and skin, resulting in chemical exposure. Most situations of this type of exposure result from a chemical spill or splash to unprotected eyes or skin.

Once absorbed by these organs, the chemical can quickly find its way into the bloodstream and cause further damage, in addition to the immediate effects that can occur to the eyes and the skin. Symptoms of eye exposure can include itchy or burning sensations, blurred vision, discomfort, and blindness. The best way to protect yourself from chemical splashes to the eyes is to always wear safety glasses in the laboratory whenever eye hazards exist (chemicals, glassware, lasers, etc.). If you are pouring large quantities of chemicals (>4 liters), then splash goggles are more appropriate than safety glasses. Whenever a severe splash hazard may exist, the use of a face shield, in combination with splash goggles is the best choice for protection. Please note, a face shield by itself does not provide adequate eye protection.

If you do get chemicals in your eyes, immediately go to an eyewash station and flush your eyes for at least 15 minutes. The importance of flushing for at least 15 minutes cannot be overstated! Once the eyewash has been activated, use your fingers to hold your eyelids open and roll your eyeballs in the stream of water so the entire eye can be flushed. After flushing for at least 15 minutes, seek medical attention immediately and complete an accident report using the online Report It System.

SKIN ABSORPTION

Symptoms of skin exposure to chemicals include dry, whitened skin, redness, swelling, rashes, blisters, itching, chemical burns, cuts, and defatting. Please note that some chemicals can be readily absorbed by the skin.

Laboratory workers can protect their skin from chemical exposure by selecting and wearing the proper gloves, wearing a lab coat and other personal protective equipment for special hazards (such as protective sleeves, face shields, and aprons), and not wearing shorts and sandals in areas where chemicals are being used - even if you are not using chemicals, but someone else in the lab is using chemicals nearby.

For small chemical splashes to the skin, remove any contaminated gloves, lab coats, etc., and wash the affected area with soap and water for at least 15 minutes. Seek medical attention afterward, especially if symptoms persist.

For large chemical splashes to the body, it is important to get to an emergency shower and start flushing for at least 15 minutes. Once under the shower, and after the shower has been activated, it is equally important to remove any contaminated clothing. Failure to remove contaminated clothing can result in the chemical being held against the skin and causing further chemical exposure and damage. After flushing for a minimum of 15 minutes, seek medical attention immediately and complete an accident report using the online Report It System.

Please note that some chemicals, such as hydrofluoric acid, require use of a special antidote (such as calcium gluconate gel) and special emergency procedures. Be sure to read SDSs for any chemical you work with to determine if a special antidote is needed when a chemical exposure occurs.

CHEMICAL EXPOSURE MONITORING

As a laboratory worker, you may use a variety of potentially hazardous materials on a daily basis. Safe use of these materials depends heavily on following proper laboratory work practices and the utilization of engineering controls. In certain circumstances, it is necessary to verify that work practices and engineering controls are effective in limiting exposures to hazardous materials. HSE can help evaluate the effectiveness of your controls by monitoring exposures to a variety of laboratory materials. Exposure monitoring is the determination of the airborne concentration of a hazardous material in the work environment. Exposure monitoring data is compared to existing exposure guidelines and is often used to make recommendations concerning engineering controls, work practices, and PPE.

If you think you are receiving a chemical exposure in excess of exposure limits, such as feeling symptoms commonly associated with exposure to hazardous materials, then contact HSE at researchsafety@kaust.edu.sa.

TOXICITY

Toxicity refers to the ability of a chemical to cause harmful effects to the body -- as was described by Paracelsus (1493-1541):

> *"What is it that is not poison? All things are poison and nothing is without poison. It is the dose only that makes a thing not a poison."*

There are a number of factors that influence the toxic effects of chemicals on the body. These include, but are not limited to:

- The quantity and concentration of the chemical.
- The length of time and the frequency of the exposure.
- The route of the exposure.
- If mixtures of chemicals are involved.
- The gender, age, and lifestyle of the person being exposed to the chemical.

TOXIC EFFECTS

Toxic effects are generally classified as acute toxicity or chronic toxicity.

- Acute toxicity is generally thought of as a single, short-term exposure where effects appear immediately and are often reversible.

- Chronic toxicity is generally thought of as frequent exposures where effects may be delayed (even for years) and are generally irreversible. Chronic toxicity can also result in acute exposures, with long-term chronic effects.

EVALUATING TOXICITY DATA

SDSs and other chemical resources generally refer to the toxicity of a chemical numerically using the term *Lethal Dose 50 (LD_{50}).* The LD_{50} describes the amount of chemical ingested or absorbed by the skin in test animals that causes death in 50% of test animals used during a toxicity test study. Another common term is Lethal Concentration 50 (LC_{50}), which describes the amount of chemical inhaled by test animals that causes death in 50% of test animals used during a toxicity test study. The LD_{50} and LC_{50} values are then used to infer what dose is required to show a toxic effect on humans.

As a general rule of thumb, the lower the LD_{50} or LC_{50} number, the more toxic the chemical. Note there are other factors (concentration of the chemical, frequency of exposure, etc.) that contribute to the toxicity of a chemical, including other hazards the chemical may possess.

While exact toxic effects of a chemical on test animals cannot necessarily be directly correlated with toxic effects on humans, the LD_{50} and LC_{50} can give a good indication of the toxicity of a chemical, particularly in comparison to another chemical. For example, when making a decision on what chemical to use in an experiment based on safety for the lab worker, a chemical with a high LD_{50} or LC_{50} would be safer to work with, assuming the chemical did not possess multiple hazards and everything else being equal. In addition to having a toxic effect on the body, some chemicals can be carcinogenic, mutagenic, teratogenic, and acutely toxic.

In general terms, the resource Prudent Practices in the Laboratory lists the following table for evaluating the relevant toxicity of a chemical:

Toxicity Class	**Animal LD50**	**Probable Lethal Dose for 70 kg Person (150 lbs.)**	**Example**
Super Toxic	Less than 5 mg/kg	A taste (7 drops or less)	Botulinum toxin
Extremely Toxic	5 - 50 mg/kg	< 1 teaspoonful	Arsenic trioxide, Strychnine
Very Toxic	50 - 500 mg/kg	< 30 ml (1 ounce)	Phenol, Caffeine
Moderately Toxic	0.5 - 5 g/kg	< 475 ml (1 pint)	Aspirin, Sodium chloride
Slightly Toxic	5 - 15 g/kg	< 0.9 Li (1 quart)	Ethyl alcohol, Acetone

CHEMICAL HAZARD INFORMATION

All persons working with chemicals are to be provided with information and training to ensure that they are aware of the hazards of chemicals present in their work area. Such information shall be provided at the time of an employee's initial assignment to a work area where hazardous chemicals are present, and any time new hazardous chemicals are introduced to the lab.

It is the responsibility of the Principal Investigator and laboratory manager to ensure staff and students under their supervision are provided with adequate training and information specific to the hazards found within their laboratories.

CHEMICAL CONTAINER LABELING REQUIREMENTS

Proper labeling of chemicals is an important way of informing people who work in laboratories of potential hazards that exist, preventing the generation of unknowns, and facilitating an emergency response such as cleaning up spills and obtaining the proper medical treatment.

All chemical containers (both hazardous and non-hazardous) must be properly labeled with a clear indication of their contents and an appropriate warning of their physical and health hazards (flammable, corrosive, toxic, carcinogen, etc.).

Chemical containers must be labeled in English – abbreviations, acronyms, chemical structures, or formulas are not permitted as the sole means of identification. Whenever chemical abbreviations, formulas, or structures are used, then an abbreviation key must be hung up in a visible location for emergency response situations. An example abbreviation key can be found on the Lab Safety Signs and Labels webpage. If a label is starting to fall off a chemical container or is becoming degraded, then the container needs to be relabeled (using tape, permanent marker, commercial label, etc.) or the chemical needs to be transferred to another properly labeled container.

ORIGINAL CONTAINERS

Original (primary) container labels should be maintained when possible. Reused containers must be completely defaced of the old label, prior to relabeling with the new contents.

NON-ORIGINAL CONTAINERS

Non-original containers (referred to as secondary-use containers) such as wash bottles, squirt bottles, temporary storage containers, beakers, flasks, bottles, vials, etc. or any container that a chemical from an original container is transferred into, must be properly labeled as described above.

SAFETY DATA SHEETS (SDSs)

Safety Data Sheets (SDSs) are an important part of any laboratory safety program in communicating information to chemical users. SDSs are documents that provide detailed information for all of the hazards associated with a specific chemical or chemical mixture. SDSs provide useful information such as:

- The identity of the chemical substance.
- Physical and chemical characteristics.
- Physical and health hazards.
- Primary routes of entry.
- Occupational Exposure Limits.
- Carcinogenic and reproductive health status.
- Precautions for safe handling and use (including PPE).
- Spill response procedures.
- Emergency and first aid questions.
- Date the SDS was prepared.

All laboratories are required to have immediate access to SDSs for every chemical used or stored in that lab.

It is the responsibility of Principal Investigators and laboratory managers to ensure that staff and students working in laboratories under their supervision have obtained required health and safety training and have access to SDSs (and other sources of information) for all hazardous chemicals used in laboratories under their supervision.

SDSs are available through the websites of many chemical manufacturers. Each chemical manufacturer is required to provide SDSs for all of their chemicals.

CHEMICAL PURCHASING

Before ordering new chemicals, search your existing inventories and use those chemicals currently in stock. An accurate and up-to-date chemical inventory can help to minimize purchase of chemicals already on hand and can facilitate acquisition of Safety Data Sheets (SDSs). KAUST has an institutional subscription to the chemical inventory system that can help facilitate maintaining a chemical inventory.

If it is necessary to purchase new chemicals, laboratory personnel should order the smallest amount necessary to carry out the experiment. Avoid ordering extra quantities because the chemical “might be needed in the future”. Try to take advantage of “Just-In-Time” delivery rather than stockpiling chemicals in your lab.

Some chemical purchases may require special KSA approval or permits. Therefore, be sure to purchase all chemicals through the KAUST procurement system.

CHEMICAL INVENTORY MANAGEMENT

All laboratories that use or store chemicals at KAUST are required to maintain a chemical inventory for purposes of building, fire, and life safety code compliance, and to provide critical information to responders during an emergency. To assist chemical users at KAUST in meeting this requirement, chemicals inventories are managed using **Salute Chemical Inventory.** Authorized users have the ability to update chemical inventory information, prepare inventory reports, locate chemicals, and quickly and easily obtain chemical safety information.

KAUST laboratory personnel are responsible for maintaining an accurate chemical inventory for their laboratory.

CHEMICAL STORAGE

Chemical storage areas in the laboratory setting include central stockrooms, storerooms, laboratory work areas, storage cabinets, refrigerators, and freezers. There are established building requirements as well as recommended practices for proper storage of chemicals. Proper storage of chemicals promotes safer and healthier working conditions, extends the usefulness of chemicals, and can help prevent contamination.

Chemicals that are stored improperly can result in:

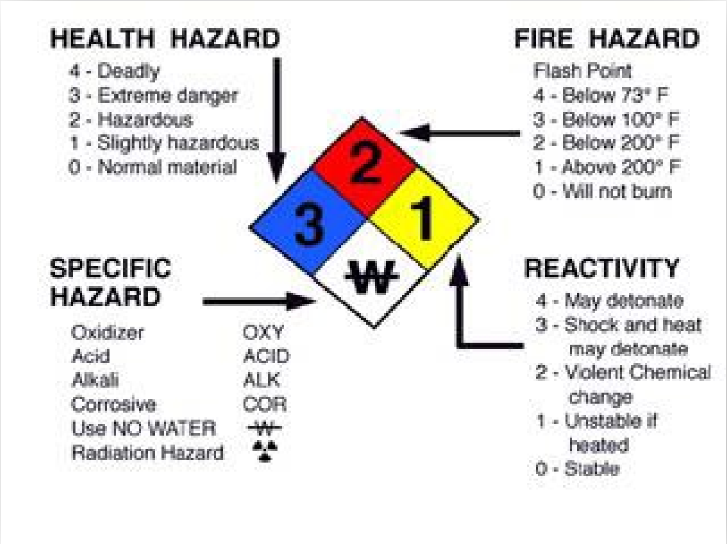
- Degraded containers that can release hazardous vapors that are detrimental to the health of laboratory personnel.

- Degraded containers that allow chemicals to become contaminated, which can have an adverse effect on experiments.

- Degraded containers that can release vapors, which in turn can affect the integrity of nearby containers.

- Degraded labels that can result in the generation of unknowns.

- Chemicals becoming unstable and/or potentially explosive.



GENERAL STORAGE GUIDELINES

Laboratories should adhere to the following storage guidelines for the proper and safe storage of chemicals. By implementing these guidelines, laboratories can ensure safer storage of chemicals and enhance the general housekeeping and organization of the lab. Proper storage of chemicals also helps utilize limited laboratory space in a more efficient manner.

- Highly toxic chemicals (NFPA diamond health hazard rating of 3 or greater or GHS category 1), should be kept in locked chemical cabinets, unless intended for immediate use.

- Every chemical should have an identifiable storage place and should be returned to that location after use.

- Do not store corrosive chemicals above eye level. In general and where practical, no chemicals should be stored above eye level.

- Do not store chemicals on hard-to-reach shelves.

- The storage of chemicals on bench tops should be kept to a minimum to help prevent clutter and spills, and to allow for adequate working space.

- All chemical containers MUST be labeled. Labels should include the name of the chemical constituent(s) and any hazards present. Be sure to check chemical containers regularly and replace any labels that are deteriorating or falling off and/or re-label with another label before the chemical becomes an unknown.

- Chemical storage in fume hoods should be kept to a minimum - limited to the experiment being conducted. Excess storage of chemical containers in hoods can interfere with airflow, reduced working space, and increase the risk of a spill, fire, or explosion.

- For chemical storage cabinets, larger chemical bottles should be stored towards the back and smaller bottles should be stored up front where they are visible. Chemical bottles should be turned with the labels facing out so they can be easily read.

- Chemicals should not be stored on the floor due to the potential for bottles to be knocked over which could result in a spill. If it is necessary to store bottles on the floor, then the bottles must be placed in a secondary containment, such as trays, and the bottles should be placed away from aisle spaces.

- For multiples of the same chemical, older containers should be stored in front of newer chemicals and containers with the least amount of chemical should be stored in front of full containers. This allows for older chemicals to get used up first and helps to minimize the number of chemical containers in the storage area.

- Do not store chemicals in direct sunlight or next to heat sources.

- All chemical containers shall remain closed when not in use.

- Lab chemicals shall be procured in container sizes that are easy to handle and manipulate. Chemicals should not be obtained in larger size containers unless there is an approved method for transfer (pump, dispensing apparatus, etc.).

- Liquid chemical containers should be stored in secondary containment, such as trays, to minimize the potential for bottle breakage and minimize the potential for spills.

- Always segregate and store chemicals according to compatibility and hazard classes.
- Chemical containers should be dated when they arrive and should be checked regularly and disposed of when they get past their expiration date. ***Please Note***: Due to the potential explosion hazard, peroxide forming chemicals should be dated when received and 1st opened, and then tested every six months. See Appendix 8 for more information on peroxide forming chemicals.

- Flammable and Combustible Liquid Storage. Fire protection regulations (NFPA 45) limit the storage of flammable and combustible liquids as follows:

Flammable or Combustible Liquid Limits ([1]per lab unit):

[1]Per NFPA 45 a lab unit is defined as a separate fire area. For a Class B building a fire area requires a 1 hour rated fire separation. At KAUST an entire lab neighborhood (area), about 929m^2 (*10,000 ft ^{2}*)

is considered a single lab unit.

Flammable liquid storage limits shall be maintained as low as reasonably achievable. To comply with fire code, flammable liquids shall not exceed a limit of 40 liters (10 gallons) per 9.3m^2 (100 ft^2) of lab space. See examples below:

Lab Size	**Maximum Quantity Allowed** (includes in storage cabinets, under hoods, in safety cans, service corridor, waste, etc.)
929m^2 (10,000 ft^2)	2,292 liters (600 US gallons)
557m^2 (5,000 ft^2)	1,136 liters (300 US gallons)
186m^2 (2000 ft^2)	227.3 liters (60 US gallons)

- Flammable liquids shall be stored inside flammable liquid storage cabinets when not in use. No more than 40 liters (10 US gallons) flammable liquids should be stored on the open bench.

- Do not store acids in flammable liquid storage cabinets. This can result in serious degradation of the storage cabinet and the containers inside. Corrosive chemicals should be stored in corrosion resistant cabinets. The exceptions to this rule are organic acids, such as Acetic acid, Lactic acid, and Formic acid, which are considered flammable/combustible and corrosive and can be stored in flammable or corrosive storage cabinets.

- Do not store flammable liquids in standard (non-explosion proof) refrigerators or freezers. Due to the potential explosion hazard, only store flammables in refrigerators or freezers approved by the manufacturer for storage of flammables.

- Always keep spill kits and other spill control equipment on hand in areas where chemicals are used. Ensure all personnel working in the lab have been properly trained on the location and use of the spill kit.

CHEMICAL SEGREGATION

Chemicals should be stored according to compatibility and hazard classes. Rather than store chemicals alphabetically, or by carbon number, or by physical state, etc., HSE recommends that you segregate them by hazard class first.

The potential hazards of storing incompatible chemicals together, and when an emergency occurs, include:

- Generation of heat.

- Possible fires and explosion.
- Generation of toxic and/or flammable gases and vapors.
- Formation of toxic compounds.
- Formation of shock and/or friction sensitive compounds.
- Violent polymerization.

The benefits of chemical segregation by hazard class include:

- Safer chemical storage.
- Understanding the hazards a chemical exhibits will increase your knowledge about the chemical.
- Identifying potentially explosive chemicals.
- Better reagent quality
- Identifying multiple containers of the same chemical.

There are a number of segregation schemes recommended in the literature by government agencies, chemical manufacturers, safety supply companies, and other universities. However, HSE recommends segregation of chemicals using a modified version of the International Air Transport Association (IATA) Hazard Class System. While this modified IATA system results in most common chemicals being segregated properly, there is no one system that solves all problems. The modified IATA system is less complicated than other segregation schemes and the information to make decisions of which hazard classes to use can easily be found in SDSs, container labels, container markings and stickers, and other resources.

Please note that IATA hazard classes segregate chemicals according to the hazards posed during transportation and not necessarily based on health hazards. Keep in mind that chemicals do not always fall neatly into one hazard class and can pose multiple hazards – including both physical and health hazards (such as flammable liquid, corrosive liquid or flammable liquid, poison).

When you are making decisions on how to segregate, keep in mind the following:

- Physical hazards of the chemical.
- Health hazards of the chemical.
- The chemical form (solid, liquid or gas).

- Concentration of the chemical.

Segregation of different chemical hazard classes (such as oxidizing acids and organic acid) can occur in the same cabinet as long as there is some form of physical separation, such as using trays with high sides or deep trays. However, never store acids with azides, cyanides, sulfides, hypochlorites in the same cabinet.

Once chemicals have been segregated, ensure everyone in the lab knows the process and what system is being used. It is best to clearly identify where chemicals in each hazard class will be stored by labeling cabinets with signs, or hazard class labels. These can be purchased from a safety supply company, created by lab personnel, or downloaded from the Lab Safety Signs and Labels webpage.

If you need assistance with segregating your chemicals, contact HSE at researchsafety@kaust.edu.sa. Examples of incompatible chemicals can be found in Appendix 9.

HSE MODIFIED IATA HAZARD CLASS SYSTEM

The basic IATA hazard classes and hazard class numbers are:

IATA HAZARD CLASS NUMBER	*HAZARD CLASS*
Class 1	Explosives
Class 2	Compressed gases
Class 3	Flammable liquids
Class 4	Flammable solids
Class 5	Oxidizers
Class 6	Toxic
Class 7	Radioactive materials
Class 8	Corrosives
Class 9	Store with Class 6

The IATA hazard class numbers can be found on hazard class labels, in SDSs (under the "Transportation Information Section"), on container labels, and in other reference texts. The HSE chemical segregation scheme modifies the IATA system by breaking down hazard classes into subcategories. A handout on the HSE Chemical Segregation Scheme can be found on the Lab Safety Signs and Labels webpage and in Appendix 10.

TRANSPORTING CHEMICALS

When transporting chemicals between laboratories or other buildings on campus, the following guidelines should be implemented for protection of people and the environment, and to minimize the potential for spills to occur.

- Whenever transporting chemicals by hand, always use a secondary container such as a rubber acid carrying bucket, plastic bucket, or a 20 liter (5-gallon) pail. If necessary, a small amount of packing material (shipping peanuts, vermiculite, or cardboard inserts), that is compatible with the chemical(s), should be used to prevent bottles from tipping over or breaking during transport. You should have proper PPE accessible in the event of a spill.

- Wheeled carts with lipped surfaces (such as Rubbermaid carts) should be used whenever feasible.

- Do not use passenger elevators when transporting chemicals, only freight elevators should be used.

- When transporting compressed gas cylinders, always use a proper gas cylinder hand truck with the cylinder strapped to the cart and keep the cap in place. NEVER roll or drag a compressed gas cylinder.

- Avoid riding in passenger elevators with cryogenic liquids or compressed gas cylinders. Use a buddy system when transporting these materials. Have one person send the properly secured dewars or cylinders on the elevator, while the other person waits at the floor by the elevator doors where the dewars or cylinders will arrive.

NOTE: IF YOU PLAN ON TRANSPORTING OR SHIPPING ANY HAZARDOUS CHEMICALS OFF CAMPUS, BE AWARE THERE ARE SPECIFIC PROCEDURES, TRAINING AND OTHER LEGAL REQUIREMENTS THAT MUST BE FOLLOWED. CONTACT HSE AT researchsafety@kaust.edu.sa FOR MORE INFORMATION.

CHAPTER NINE: CHEMICAL HAZARDS

Chemicals can be broken down into hazard classes and exhibit both physical and health hazards. It is important to keep in mind that chemicals can exhibit more than one hazard or a combination of several hazards. Several factors can influence how a chemical will behave and the hazards the chemical presents, including the severity of the response:

- Concentration of the chemical.
- Physical state of the chemical (solid, liquid, gas).
- Physical processes involved in using the chemical (cutting, grinding, heating, cooling, etc.).
- Chemical processes involved in using the chemical (mixing with other chemicals, purification, distillation, etc.).
- Other processes (improper storage, addition of moisture, storage in sunlight, refrigeration, etc.).

The following sections describe general information and safety precautions about specific hazard classes. The chemical hazards listed are based on the International Transport Association (IATA) hazard class system. A general description of the hazards of various chemical functional groups can be found in Appendix 10.

It is important to note that the following sections are general guidelines. Laboratory personnel should always review SDSs and other resources FIRST, before working with any chemical.

EXPLOSIVES

An explosive is defined as a chemical that causes a sudden, almost instantaneous release of pressure, gas, and heat when subjected to sudden shock, pressure, or high temperature. Under the International Transport Association (IATA) hazard class system, explosives are listed as hazard class 1.

Fortunately, most laboratories do not use many explosives; however, there are a number of chemicals that can become unstable and/or potentially explosive over time due to contamination with air, water, other materials such as metals, or when the chemical dries out (e.g. Picric acid).

If you ever come across any chemical that you suspect could be potentially explosive, do not attempt to move the container as some of these compounds are shock, heat, and friction sensitive. In these instances, you should contact HSE at researchsafety@kaust.edu.sa immediately.

Explosives can result in damage to surrounding materials (hoods, glassware, windows, people, etc.), generation of toxic gases, and fires. If you plan to conduct an experiment where the potential for an explosion exists, first ask yourself the question; “Is there another chemical that could be substituted in the experiment that does not have an explosion potential?" If you must use a chemical that is potentially explosive, or for those compounds that you know are explosive, (even low powered explosives) you must first obtain prior approval from the Principal Investigator to use such chemicals. After obtaining prior approval from your Principal Investigator, thoroughly read the SDSs and any other chemical resources related to the potentially explosive compound(s) to ensure potential incidents are minimized.

Whenever setting up experiments using potentially explosive compounds:

- Conduct a thorough hazard/risk assessment of the experiment.
- All experiments involving potentially explosive chemicals and reactions must receive prior approval from the Principal Investigator.
- Always use the smallest quantity of the chemical possible.
- Do not scale up experiments without prior approval of the Principal Investigator.
- Always conduct the experiment within a fume hood and use in conjunction with a properly rated safety shield. PLEASE NOTE: The fume hood sash does NOT provide blast protection, but provides a secondary barrier when used in combination with a weighted safety shield. Always use a safety shield when working with any potentially explosive chemicals or reactions.
- Be sure to remove any unnecessary equipment and other chemicals (particularly highly toxic and flammables) away from the immediate work area.
- Be sure to notify other people in the laboratory what experiment is being conducted, what the potential hazards are, and when the experiment will be run. It is advisable to clearly identify the experiment by placing a prominent sign in a visible location.
- Do not use metal or wooden devices when stirring, cutting, scraping, etc. with potentially explosive compounds. Non-sparking plastic devices should be used instead.
- Ensure other safety devices such as high temperature controls, water overflow devices, etc., are used in combination to help minimize any potential incidents.
- Never concentrate a reaction mixture containing potentially explosive chemicals to dryness.
- Properly dispose of any hazardous waste and note on the hazardous waste tag any special precautions that may need to be taken if the chemical is potentially explosive.
- Always wear appropriate PPE, including the correct gloves, lab coat or apron, safety goggles used in conjunction with a face shield, and explosion-proof shields when working with potentially explosive chemicals.
- For storage purposes, always date chemical containers when received and opened. Pay particular attention to those compounds that must remain moist or wet so they do not become explosive

(ex. picric acid, 2,4-dinitrophenyl hydrazine, etc.). Pay particular attention to any potentially explosive compounds that appear to exhibit the following signs of contamination:

- Deterioration of the outside of the container.
- Crystalline growth in or outside the container.
- Discoloration of the chemical.

If you discover a potentially explosive compound that exhibits any of these signs of contamination, then please contact HSE at researchsafety@kaust.edu.sa.

Examples of explosive and potentially explosive chemicals include:

- Compounds containing the functional groups azide, acetylide, diazo, nitroso, haloamine, peroxide, and ozonide
- Nitrocellulose
- Di- and Tri-nitro compounds
- Peroxide forming compounds
- Picric acid (dry)
- High purity *m*CPBA (meta-Chloroperoxybenzoic acid)(dry)
- 2,4-Dinitrophenylhydrazine (dry)
- Benzoyl peroxide (dry)

FLAMMABLE AND COMBUSTIBLE LIQUIDS

A flammable liquid is defined as any liquid having a flashpoint below 37.8^{0}C (100^{0}F), except any mixture having components with flashpoints of 37.8^{0}C (100^{0}F) or higher, the total of which make up 99% or more of the total volume of the mixture.

Flashpoint is defined as the minimum temperature at which a liquid gives off enough vapor to ignite in the presence of an ignition source. The risk of a fire requires that the temperature be above the flashpoint and the airborne concentration be in the flammable range above the Lower Explosive Limit (LEL) and below the Upper Explosive Limit (UEL).

A combustible liquid is defined as any liquid having a flashpoint at or above 37.8^{0}C (100^{0}F), but below 93.3^{0}C (200^{0}F), except any mixture having components with flashpoints of 93.3^{0}C (200^{0}F), or higher, the total volume of which make up 99% or more of the total volume of the mixture. Flammables are further broken down into Class I liquids, and combustibles into Class II and Class III liquids. Please note this classification is different than the criteria used for IATA classification. This distinction is important because allowable container sizes and storage amounts are based on the particular Class of the flammable liquid.

Classification	Flash Point	Boiling Point
Flammable Liquid		
Class IA	<23^{0}C (73^{0}F)	<38^{0}C (100^{0}F)
Class IB	<23^{0}C (73^{0}F)	>=38^{0}C (100^{0}F)
Class IC	>=23^{0}C (73^{0}F), <38^{0}C (100^{0}F)	>38^{0}C (100^{0}F)
Combustible Liquid		
Class II	>=38^{0}C (100^{0}F), <60^{0}C (140^{0}F)	--
Class IIIA	>=60^{0}C (140^{0}F), < 93^{0}C (200^{0}F)	--
Class IIIB	>=93^{0}C (200^{0}F)	--

Under the International Aviation Transport Association (IATA) hazard class system, flammable liquids are listed as hazard class 3.

Flammable and combustible liquids are one of the most common types of chemicals used at KAUST and are an important component in a number of laboratory processes. However, in addition to the flammable hazard, some flammable liquids also may possess other hazards such as being toxic and/or corrosive.

When using flammable liquids, keep containers away from open flames; it is best to use heating sources such as steam baths, water baths, oil baths, and heating mantels. Never use a heat gun to heat a flammable liquid. Any areas using flammables should have a fire extinguisher present in the immediate area. If a fire extinguisher is not present, then contact the Help Desk at 959.

Always keep flammable liquids stored away from oxidizers and away from heat or ignition sources such as radiators, electric power panels, etc.

When pouring flammable liquids (>4 liters), it is possible to generate enough static electricity to cause the flammable liquid to ignite. If possible, make sure both containers are electrically interconnected to each other by bonding the containers, and connecting to a ground.

Always clean up any spills of flammable liquids promptly. Be aware that flammable vapors are usually heavier than air (vapor density > 1). For those chemicals with vapor densities heavier than air (applies to most chemicals), it is possible for the vapors to travel along floors and, if an ignition source is present, result in a flashback fire.

FLAMMABLE STORAGE IN REFRIGERATORS/FREEZERS

It is important to store flammable liquids only in specially designed flammable storage refrigerators/freezers or explosion-proof refrigerators/freezers. Do not store flammable liquids in standard (non-flammable rated) refrigerators/freezers. Standard refrigerators are not electrically designed to store flammable liquids. If flammable liquids are stored in a standard refrigerator, the build-up of flammable vapors can be in sufficient quantities to ignite when the refrigerator’s compressor or light turns on, resulting in a fire or an explosion.

Properly rated flammable liquid storage refrigerators/freezers have protected internal electrical components and are designed for the storage of flammable liquids. Explosion-proof refrigerators/freezers have both the internal and external electrical components properly protected and are designed for the storage of flammable liquids. Refrigerators and freezers rated for the storage of flammable materials will be clearly identified as such by the manufacturer. For most laboratory applications, a flammable storage refrigerator/freezer is acceptable. However, some operations may require an explosion-proof refrigerator/freezer.

FLAMMABLE STORAGE CABINETS

The requirements for use of flammable storage cabinets are determined by the classification of the flammable liquids, the quantities kept on hand, the building construction (fire wall ratings), and the floor of the building the flammables are being stored on. As a general rule of thumb, if you have more than 40 liters (10 gallons) of flammable liquids, including materials in use, then you should store the flammable liquids in a properly rated flammable liquid storage cabinet. All flammable liquids not in use should be kept in a flammable liquid storage cabinet.

For stand-alone flammable liquid storage cabinets (as opposed to cabinets underneath fume hoods), there are vent holes on each side of the cabinet (called bung holes) that must have the metal bungs screwed into place for the cabinet to maintain its fire rating. Venting of flammable cabinets is NOT required, however, if a flammable cabinet is vented, it must be vented properly according to the manufacturer’s specifications and NFPA 30. Typically, proper flammable cabinet ventilation requires that air be supplied to the cabinet and the air be taken away via non-combustible pipes. If you are planning on venting your flammable storage cabinet, please contact HSE at researchsafety@kaust.edu.sa for more information.

FLAMMABLE SOLIDS

A flammable solid is defined as a “solid, other than a blasting agent or explosive, that is liable to cause fire through friction, absorption of moisture, spontaneous chemical change, or retained heat from manufacturing or processing, or which can be ignited readily and when ignited, burns so vigorously and persistently to create a serious hazard.” An example of a flammable solid is gunpowder.

Under the IATA hazard class system, flammable solids are listed as hazard class 4. Flammable solids are further broken down into three subcategories:

- Flammable Solids – Class 4.1
- Spontaneously Combustible – Class 4.2
- Dangerous When Wet – Class 4.3

Many of the same principles for handling and storing flammable liquids apply to flammable solids. Always keep flammable solids stored away from oxidizers, and away from heat or ignition sources such as radiators, electric power panels, etc.

SPONTANEOUSLY COMBUSTIBLE

Spontaneously combustible materials are also known as pyrophorics. These chemicals can spontaneously ignite in the presence of air, some are reactive with water vapor, and most are reactive with oxygen. Two common examples are *tert*-butyl lithium and Raney nickel.

Special "Class D" fire extinguishers are required for use with metals. In addition to the hazard of the spontaneously combustible chemical itself, many of these chemicals are also stored under flammable liquids. In the event of an accident, such as a bottle being knocked off a shelf, the chemical can spontaneously ignite and a fire can occur. Extra care must be taken when handling spontaneously combustible chemicals. When transporting these chemicals, it is best to use a bottle carrier and carts.

DANGEROUS WHEN WET

Dangerous when wet compounds react violently with water to form toxic vapors and/or flammable gases that can ignite and cause a fire. Please note, attempting to put out a fire involving dangerous when wet materials with water will only make the situation worse. Special "Class D" fire extinguishers are required for use with metals. Common examples include sodium metal and potassium metal.

It is important to note that any paper toweling, gloves, etc., that have come into contact with these materials need to be quenched with water before disposing of them in metal trash cans in order to prevent potential fires.

If you are using dangerous when wet compounds and do not have a Class D fire extinguisher present, then please contact the Help Desk at 959.

OXIDIZERS AND ORGANIC PEROXIDES

An oxidizer is defined as "a chemical other than a blasting agent or explosive that initiates or promotes combustion in other materials, thereby causing fire either of itself or through the release of oxygen or other gases." Under the IATA hazard class system, oxidizers are listed as hazard class 5.1 and organic peroxides are listed as hazard class 5.2.

An organic peroxide is defined as "an organic compound that contains the bivalent –O-O- structure and which may be considered to be a structural derivative of hydrogen peroxide where one or both of the hydrogen atoms have been replaced by an organic radical." Oxidizers and organic peroxides are a concern for laboratory safety due to their ability to promote and enhance the potential for fires in labs.

As a reminder of the fire triangle (now referred to as the fire tetrahedron), in order to have a fire, you need:

- A fuel source.
- An oxygen source.
- An ignition source.
- A chemical reaction.

Oxidizers can supply the oxygen needed for the fire, whereas organic peroxides supply both the oxygen and the fuel source. Both oxidizers and organic peroxides may become shock sensitive when they dry out, are stored in sunlight, or due to contamination with other materials, particularly when contaminated with heavy metals. Most organic peroxides are also temperature sensitive.

As with any chemicals, but particularly with oxidizers and organic peroxides, quantities stored on hand should be kept to a minimum. Whenever planning an experiment, be sure to read the SDS and other reference documents to understand the hazards and special handling precautions that may be required, including use of a safety shield. Also be aware of the melting and autoignition temperatures for these compounds and ensure any device used to heat oxidizers has an over- temperature safety switch to prevent the compounds from overheating.

Laboratory staff should be particularly careful when handling oxidizers (especially high surface area oxidizers such as finely divided powders) around organic materials.

Avoid using metal objects when stirring or removing oxidizers or organic peroxides from chemical containers. Plastic or ceramic implements should be used instead. Laboratory personnel should avoid friction, grinding, and impact with solid oxidizers and organic peroxides. Glass stoppers and screw cap lids should always be avoided and plastic/polyethylene lined bottles and caps should be used instead.

If you suspect your oxidizer or organic peroxide has been contaminated (evident by discoloration of the chemical, or if there is crystalline growth in the container or around the cap), then dispose of the chemical as hazardous waste or contact HSE at researchsafety@kaust.edu.sa for more information. Indicate on the hazardous waste tag that the chemical is an oxidizer or organic peroxide and that you suspect contamination.

PEROXIDE FORMING COMPOUNDS

Many commonly-used chemicals (organic solvents in particular) can form shock, heat, or friction sensitive peroxides upon exposure to oxygen. Once peroxides have formed, an explosion can result during routine handling, such as twisting the cap off a bottle – if peroxides are formed in the threads of the cap. Explosions are more likely when concentrating, evaporating, or distilling these compounds if they contain peroxides.

When these compounds are improperly handled and stored, a serious fire and explosion hazard exists. The following guidelines should be adhered to when using peroxide forming chemicals:

1) Each peroxide-forming chemical container MUST be dated when received and opened. A list of common peroxide forming chemicals can be found in Appendix 8. Those compounds in the appendix listed in Table A should be disposed of within 3 months of opening and those compounds in the appendix listed in Tables B, C, and D should be disposed of within 12 months of opening.

2) Each peroxide-forming chemical container must be tested for peroxides when opened and at least every 6 months thereafter. The results of the peroxide test and the test date must be marked on the outside of the container. There are sample peroxide labels on the Lab Safety Signs and Labels webpage.

3) Peroxide test strips can be purchased from the Chemical Warehouse or from a variety of safety supply vendors, such as VWR and Fisher Scientific. An alternative to peroxide test strips is the KI (potassium iodide) test. References such as Prudent Practices in the Laboratory and the American Chemical Society booklet - Safety in Academic Chemistry Laboratories outline ways to test for peroxides and ways to remove them if discovered. When using the test strips, if the strip turns blue, then peroxides are present. Light blue test results may be acceptable for use if your procedure does not call for concentrating, evaporating or distilling. Containers with darker blue test results must be deactivated or disposed of. You can test older test strips for efficacy with a dilute solution of hydrogen peroxide.

4) Due to sunlight's ability to promote formation of peroxides, all peroxidizable compounds should be stored away from heat and sunlight.

5) Peroxide forming chemicals should not be refrigerated at or below the temperature at which the peroxide-forming compound freezes or precipitates as these forms of peroxides are especially sensitive to shock and heat. Refrigeration does not prevent peroxide formation.

6) As with any hazardous chemical, but particularly with peroxide-forming chemicals, the amount of chemical purchased and stored should be kept to an absolute minimum. Only order the amount of chemical needed for the immediate experiment.

7) Ensure containers of peroxide-forming chemicals are tightly sealed after each use and consider adding a blanket of an inert gas, such as nitrogen, to the container to help slow peroxide formation.

8) A number of peroxide-forming chemicals can be purchased with inhibitors added. Unless absolutely necessary for the research, labs should never purchase uninhibited peroxide formers.

9) Before distilling any peroxide-forming chemicals, always test the chemical first with peroxide test strips to ensure there are no peroxides present. Never distill peroxide forming chemicals to dryness. Leave at least 10-20% still bottoms to help prevent possible explosions.

While no definitive amount of peroxide concentration is given in the literature, a concentration of 50 ppm should be considered dangerous and a concentration of >100 ppm should be disposed of immediately. In both cases, procedures should be followed for removing peroxides or the containers should be disposed of as hazardous waste.

******However, compounds that are suspected of having very high peroxide levels because of age, unusual viscosity, discoloration, or crystal formation should be considered extremely dangerous. If you discover a container that meets this description, DO NOT attempt to open or move the container. Notify other people in the lab about the potential explosion hazard and notify HSE at researchsafety@kaust.edu.sa immediately.***

A list of common forming chemicals can be found in Appendix 8. Please note this list is not all-inclusive, there are numerous other chemicals that can form peroxides. Be sure to read chemical container labels, SDSs, and other chemical references.

TOXICS

For the purpose of this manual, the word “toxic” will be used interchangeably with the word “poison”. A “toxic” is defined as a chemical falling within any of the following categories:

(a) A chemical that has a median lethal dose (LD_{50}) of more than 50 milligrams per kilogram, but not more than 500 milligrams per kilogram of body weight when administered orally to albino rats weighing between 200 and 300 grams each.

(b) A chemical that has a median lethal dose (LD_{50}) of more than 200 milligrams per kilogram, but not more than 1000 milligrams per kilogram of body weight when administered by continuous contact for 24 hours (or less if death occurs within 24 hours) with the bare skin of albino rabbits weighing between two and three kilograms each.

(c) A chemical that has a median lethal concentration (LC_{50}) in air of more than 200 parts per million, but not more than 2000 parts per million by volume of gas or vapor, or more than two milligrams per liter but not more than 20 milligrams per liter of mist, fume, dust, when administered by continuous inhalation for one hour (or less if death occurs within one hour) to albino rats weighing between 200 and 300 grams each.

Under the IATA hazard class system, toxics are listed as hazard class 6.

As a general rule of thumb, all chemicals should be treated as toxic and proper procedures such as maintaining good housekeeping, use of proper PPE, good personal hygiene, etc., should be followed. When working with known poisons, it is very important to have thought an experiment through, addressing health and safety issues before working with the poison. Safety Data Sheets (SDSs) and other chemical references should be consulted before beginning the experiment. Some questions to ask before working with poisonous chemicals:

- Do I need to use the poisonous chemical or can a less toxic chemical be substituted?
- What are the routes of entry into the body for the poison (inhalation, ingestion, injection, or skin absorption)?
- What are the signs and symptoms of potential chemical exposure?
- What are the proper PPE required (type of glove, safety glasses vs. splash goggles, face shield, etc.)?
- Does the chemical require any special antidote?
- What are the emergency procedures to be followed?

When working with highly toxic chemicals, you should not work alone. Always wear proper PPE and always wash your hands with soap and water when finished, even if gloves were worn. Be aware that poisonous mixtures, vapors, and gases can be formed during an experiment. Be sure to research both the reactants and products of the chemicals you will be working with first.

If you think you may have received an exposure to a poisonous substance, or may have accidentally ingested a chemical, seek medical attention immediately. If possible, bring a copy of the SDS with you. Upon completion of seeking medical attention, complete an accident report using the online Report It System.

CORROSIVES

A corrosive is defined as “a chemical that causes visible destruction of, or irreversible alterations in living tissue by chemical action at the site of contact.” Under the IATA hazard class system, corrosives are listed as hazard class 8.

Corrosive chemicals can be further subdivided as acids and bases. Corrosives can be in the liquid, solid, or gaseous state. Corrosive chemicals can have a severe effect on eyes, skin, respiratory tract, and gastrointestinal tract if an exposure occurs. Corrosive solids and their dusts can react with moisture on the skin or in the respiratory tract and result in an exposure.

Whenever working with concentrated corrosive solutions (>4 liters), splash goggles should be worn instead of safety glasses. Splash goggles used in conjunction with a face shield provide better protection. Please note that a face shield alone does not provide adequate protection. Use of rubber gloves such as butyl rubber and a rubber apron may also be required. Corrosive chemicals should be handled in a fume hood to avoid breathing corrosive vapors and gases.

When mixing concentrated acids with water, always add acid slowly to the water (specifically, add the more concentrated acid to the dilute acid). Never add water to acid, this can result in a boiling effect and cause acid to splatter. Do not pour the acid directly into the water; it should be poured in a manner that allows it to run down the sides of the container. Never store corrosive chemicals above eye level and always use a protective bottle carrier when transporting corrosive chemicals.

Some chemicals can react with acids and liberate toxic and/or flammable vapors. When working with corrosive materials, ensure spill cleanup material is available for neutralization, such as sodium bicarbonate for acids (calcium carbonate for HF) and citric acid for bases.

Wherever acids and bases are used, an eyewash and emergency shower must be available. If any corrosive chemical gets splashed in the eyes, immediately go to an eyewash station and flush your eyes for at least 15 minutes. The importance of flushing for at least 15 minutes cannot be overstated! Once the eyewash has been activated, use your fingers to hold your eyelids open and roll your eyeballs in the stream of water so the entire eye can be flushed. After flushing for at least 15 minutes, seek medical attention immediately and complete an accident report using the online Report It System.

For small splashes of corrosives to the skin, remove any contaminated gloves, lab coats, etc., and wash the affected area with soap and water for at least 15 minutes. Seek medical attention afterward, especially if symptoms persist.

For large splashes of corrosives to the body, it is important to get to an emergency shower and start flushing for at least 15 minutes. Once under the shower, and after the shower has been activated, it is equally important to remove any contaminated clothing. Failure to remove contaminated clothing can result in the chemical being held against the skin and causing further chemical exposure and damage. After flushing for a minimum of 15 minutes, seek medical attention immediately and complete an accident report using the online Report It System.

Please note some chemicals, such as hydrofluoric acid, require the use of a special antidote (such as calcium gluconate gel) and special emergency procedures. Read the SDSs for any chemical(s) you work with to determine if a special antidote is needed if a chemical exposure occurs.

HYDROFLUORIC ACID

Hydrofluoric Acid (HF) is one of the most hazardous chemicals used at KAUST. Small exposures to HF can be fatal if not treated properly. The critical minutes immediately after an exposure can have a great effect on the chances of a victim's survival.

HF is a gas that is dissolved in water to form hydrofluoric acid. The concentration can vary from very low such as in store bought products up to the most concentrated 70% form, with the most common lab use around 48%. The liquid is colorless, non-flammable and has a pungent odor. HF is actually a weak acid by definition and not as corrosive as strong acids such as hydrochloric acid (HCl), however, corrosivity is the least hazardous aspect of HF. The toxicity of HF is the main concern.

HF is absorbed through the skin quickly and is a severe systemic toxin. The fluoride ion binds calcium in the blood, bones and other organs and causes damage to tissues that is very painful and can be lethal. At the emergency room, the victim is often given calcium injections, but pain medication is not generally given since the pain subsiding is the only indication that the calcium injections are working.

Due to the serious hazard of working with HF, the following requirements and guidelines are provided:

- All users of HF must attend the HSE Hydrofluoric Acid Safety training as well as training by their supervisor. Dates for upcoming training sessions can be found on the Lab Safety Training Calendar.
- A Standard Operating Procedure (SOP) must be written for the process in which HF is used. This SOP should be posted or readily available near the designated area where HF use will occur.
- HF should only be used in a designated fume hood and the fume hood should be identified by posting a HF Designated Area sign. An example sign can be found on the Lab Safety Signs and Labels webpage.
- First Aid - A HF first aid kit must be available that includes 2.5% calcium gluconate gel. The calcium gluconate gel can be purchased from the Chemical Warehouse. Calcium gluconate gel should be located in the immediate area where HF is used.
- Spill Kits - An HF spill kit must be available with calcium compounds such as calcium carbonate. Sodium bicarbonate can be used but is discouraged since the product of neutralization (sodium fluoride) is water soluble and toxic. Calcium carbonate neutralizes HF to create an insoluble salt that is not water soluble.
- Prior approval - Before anyone uses HF they must have prior approval from their Principal Investigator. The Principal Investigator should ensure anyone working with HF is familiar with the following:
    - Has read the SDS for HF and the Guidelines for Use of HF, and any SOPs developed by the lab.
    - Has read the hydrofluoric acid section in this Lab Safety Manual.
    - Is aware of the designated area for HF use.
    - Knows the first aid procedure in case of an HF exposure.
    - Knows what to do in case of an HF spill.
- Personal Protective Equipment (PPE) and lab attire – The following is required for HF use:
    - Rubber or plastic apron.

- Plastic arm coverings.
- Gloves
    - Incidental use - double glove with heavy nitrile exam gloves and re-glove if any exposure to the gloves.
    - Extended use – heavy neoprene or butyl over nitrile or silver shield gloves.
- Splash goggles in conjunction with a fume hood sash.
- Closed toe shoes.
- Long pants and a long sleeve shirt with a reasonably high neck (no low cut).

The following are safe practice guidelines when working with HF:

- Never work alone with HF, always have a buddy system in place.
- Use a plastic tray while working with HF for containment in case of a spill.
- Keep containers of HF closed. HF can etch the glass sash and make it hard to see through (if the hood sash becomes fogged and hard to see though due to etching, then please contact the Help Desk at 959 about installing a polycarbonate sash).
- Safety Data Sheet (SDS) – An SDS for HF must be available.
- All containers of HF must be clearly labeled.
- The stock HF should be stored in plastic secondary containment and the cabinet should be labeled. HF should be stored in lower cabinets near the floor.
- Wash gloves off with water before removing them.

Additional information on the safe use and handling of hydrofluoric acid (HF) can be found on the Honeywell website - the world's largest producer of hydrofluoric Acid. This website contains useful information on HF such as:

- Safety Data Sheets
- Technical Data Sheets
- Recommended Medical Treatment for HF exposure
- HF Properties charts
- Online Training

PERCHLORIC ACID

Perchloric acid is a strong oxidizing acid that can react violently with organic materials. Perchloric acid can also explode if concentrated above 72%. For any work involving heated perchloric acid (such as in perchloric acid digestions), the work must be conducted in a special perchloric acid fume hood with a wash down function. If heated perchloric acid is used in a standard fume hood, the hot perchloric acid vapors can react with the metal in the hood ductwork to form shock sensitive metallic perchlorates. When working with perchloric acid, be sure to remove all organic materials, such as solvents, from the immediate work area. Due to the potential danger of perchloric acid, if possible, try to use alternate techniques that do not involve the use of perchloric acid. If you must use perchloric acid in your experiments, only purchase the smallest size container necessary.

Because perchloric acid is so reactive, it is important to keep it stored separate from other chemicals, particularly organics and bases (caustics). All containers of perchloric acid should be inspected regularly for container integrity and the acid should be checked for discoloration. Discolored perchloric acid should be discarded as hazardous waste. Perchloric acid should be used and stored away from combustible materials, and away from wooden furniture. Like all acids, but particularly with perchloric acid, secondary containment should be used for storage.

CHAPTER TEN: PARTICULARLY HAZARDOUS SUBSTANCES

Some classes of chemicals are considered to be “particularly hazardous substances”. These substances include “select carcinogens”, reproductive toxins, and substances that have a high degree of acute toxicity.

For researchers using particularly hazardous substances, specific consideration should be given to the following provisions where appropriate:

- Establishment of a designated area.
- Use of containment devices such as fume hoods or glove boxes.
- Procedures for safe removal of contaminated waste.
- Decontamination procedures.

HSE can assist researchers by providing information on working with particularly hazardous substances. General guidelines and recommendations for the safe handling, use, and control of hazardous chemicals and particularly hazardous substances can be found in MSDSs and other references such as Prudent Practices in the Laboratory and Safety in Academic Chemical Laboratories. All users of Particularly hazardous substances should review the HSE Particularly hazardous substance material as well as training by their supervisor.

For work involving particularly hazardous substances, laboratories should establish a designated area where particularly hazardous substances can only be used. In some cases, a designated area could be an entire room out of a suite of rooms, or could mean one particular fume hood within a laboratory. The idea is to designate one area that everyone in the laboratory is aware of where the particularly hazardous substances can only be used.

In certain cases of establishing designated areas, Principal Investigators and laboratory managers may want to restrict use of a particularly hazardous substance to a fume hood, glove box or other containment device. This information should be included as part of the laboratory's SOPs and covered during in-lab training.

Establishing a designated area not only provides better employee protection, but can help minimize the area where potential contamination of particularly hazardous substances could occur. If a designated area is established, a sign should be hung up (on a fume hood for example) indicating the area is designated for use with particularly hazardous substances. Most designated areas will have special PPE requirements and/or special waste and spill cleanup procedures as well. These and other special precautions should be included within the lab's SOPs.

SAFE REMOVAL OF CONTAMINATED MATERIALS AND WASTE

Some particularly hazardous substances may require special procedures for safe disposal of both waste and/or contaminated materials. When in doubt, contact HSE at researchsafety@kaust.edu.sa to determine proper disposal procedures. Once these disposal procedures have been identified, they should be included as part of the laboratory's SOPs and everyone working in the lab should be trained on those procedures.

DECONTAMINATION PROCEDURES

Some particularly hazardous substances may require special decontamination or deactivation procedures (such as diaminobenzidine waste or ethidium bromide) for safe handling. Review SDSs and other reference materials when working with particularly hazardous substances to identify if special decontamination procedures are required. If they are required, then this information should be included in the laboratory's SOPs and appropriate training needs to be provided to laboratory personnel who work with these chemicals.

GUIDELINES FOR WORKING WITH PARTICULARLY HAZARDOUS SUBSTANCES

Laboratory staff should always practice good housekeeping, use engineering controls, wear proper PPE, develop and follow SOPs, and receive appropriate training when working with any chemicals. The following special guidelines should be adhered to when working with particularly hazardous substances:

- Substitute less hazardous chemicals if possible to avoid working with particularly hazardous substances and keep exposures to a minimum.

- Always obtain prior approval from the Principal Investigator before ordering any particularly hazardous substances.

- Plan your experiment out in advance, including layout of apparatus and chemical and waste containers that are necessary. Ensure information related to the experiment is included within any SOPs.

- Before working with any particularly hazardous substance, review chemical resources for any special decontamination/deactivation procedures and ensure you have the appropriate spill cleanup materials and absorbent on hand.

- Ensure that you have the appropriate PPE, particularly gloves (check glove selection charts) or contact HSE at researchsafety@kaust.edu.sa.

- Always use the minimum quantities of chemicals necessary for the experiment. If possible, try adding buffer directly to the original container and making dilutions directly.

- If possible, purchase premade solutions to avoid handling powders. If possible, use a fume hood when weighing powders. If it is necessary to weigh outside of a fume hood (because some particles may be too light and would pose more of a hazard due to turbulent airflow) then use good analytical chemistry techniques to reduce exposure..

- As a measure of coworker protection when weighing out dusty materials or powders, consider waiting until other coworkers have left the room to prevent possible exposure and thoroughly clean up and decontaminate working surfaces.

- Whenever possible, use secondary containment, such as trays, to conduct your experiment in and for storage of particularly hazardous substances.

- Particularly hazardous substances should be stored by themselves in clearly marked trays or containers indicating what the hazard is i.e. "Carcinogens," Reproductive Toxins", etc.

- Always practice good personal hygiene, especially frequent hand washing, even if wearing gloves.

- If it is necessary to use a vacuum, only use a High Efficiency Particulate Air (HEPA) filters for the best capture and protection. Ensure the vacuum bag and its contents are disposed of as hazardous waste.

PRIOR APPROVAL

Prior approval ensures that laboratory workers have received the proper training on the hazards of particularly hazardous substances or with new equipment, and that safety considerations have been taken into account BEFORE a new experiment begins.

While HSE can provide assistance in identifying circumstances when there should be prior approval before implementation of a particular laboratory operation, the ultimate responsibility of establishing prior approval procedures lies with the Principal Investigator or

laboratory manager.

Principal Investigators or laboratory managers must identify operations or experiments that involve particularly hazardous substances (such as "select carcinogens," reproductive toxins, and substances which have a high degree of acute toxicity) and highly hazardous operations or equipment that require prior approval. They must establish the guidelines, procedures, and approval process that would be required. This information should be documented in the laboratory's or center's SOPs.

Examples where Principal Investigators or laboratory managers should consider requiring their laboratory workers to obtain prior approval include:

- Experiments that require the use of particularly hazardous substances such as "select carcinogens," reproductive toxins, and substances that have a high degree of acute toxicity, highly toxic gases, cryogenic materials and other highly hazardous chemicals or experiments involving radioactive materials, high-powered lasers, etc.

- Where a significant change is planned for the amount of chemicals to be used for a routine experiment such as an increase of 10% or greater in the quantity of chemicals normally used.

- When a new piece of equipment is brought into the lab that requires special training in addition to the normal training provided to laboratory workers.

- When a laboratory worker is planning on working alone on an experiment that involves highly hazardous chemicals or operations. See the Working Alone Section this manual for more information.

SELECT CARCINOGENS

A carcinogen is any substance or agent that is capable of causing cancer – the abnormal or uncontrolled growth of new cells in any part of the body in humans or animals. Most carcinogens are chronic toxins with long latency periods that can cause damage after repeated or long duration exposures and often do not have immediate or apparent harmful effects.

A “select carcinogen” is defined as any substance that meets one of the following criteria:

(i) It is listed under the category, "known to be carcinogens," in the Annual Report on Carcinogens published by the National Toxicology Program (NTP) (latest edition); or

(ii) It is listed under Group 1 ("carcinogenic to humans") by the International Agency for Research on Cancer Monographs (IARC) (latest editions); or

(iii) It is listed in either Group 2A or 2B by IARC or under the category, "reasonably anticipated to be carcinogens" by NTP, and causes statistically significant tumor incidence in experimental animals in accordance with any of the following criteria:

  i. After inhalation exposure of 6-7 hours per day, 5 days per week, for a significant portion of a lifetime to dosages of less than 10 mg/m(3);

  ii. After repeated skin application of less than 300 (mg/kg of body weight) per week; or

  iii. After oral dosages of less than 50 mg/kg of body weight per day.

A mixture “shall be assumed to present a carcinogenic hazard if it contains a component in concentrations of **0.1% or greater**, which is considered to be carcinogenic.” When working with carcinogens, laboratory staff should adhere to Guidelines for Working with Particularly Hazardous Substances.

Note that the potential for carcinogens to result in cancer can also be dependent on other “lifestyle” factors such as:

- Cigarette smoking
- Alcohol / drug consumption
- Consumption of high fat diet
- Geographic location – industrial areas and UV light exposure
- Therapeutic drugs
- Inherited conditions

More information on carcinogens, including numerous useful web links such as a listing of OSHA regulated carcinogens, can be found on the OSHA Safety and Health Topics for Carcinogens webpage.

REPRODUCTIVE TOXINS

A reproductive toxin is defined as a chemical "which affects the reproductive capabilities including chromosomal damage (mutations) and effects on fetuses (teratogenesis)".

A number of reproductive toxins are chronic toxins that cause damage after repeated or long duration exposures and can have long latency periods. Women of childbearing potential should be especially careful when handling reproductive toxins. Pregnant women and women intending to become pregnant, or men seeking to have children, should seek the advice of their physician before working with known or suspected reproductive toxins.

It is important to be aware of the threats to reproductive health and prevent potential reproductive hazard exposures for male and female employees and students who work with known and suspected reproductive toxins including chemical, biological, radiological, and physical agents. HSE is available to respond to concerns or questions on reproductive hazards, conduct workplace hazard assessments, and provide recommendations to address or eliminate specific reproductive risks. This service can be requested by completing the confidential Reproductive Hazard Assessment Form. As with any particularly hazardous substance, work involving the use of reproductive toxins should adhere to the Guidelines for Working with Particularly Hazardous Substances.

ACUTE TOXINS

A chemical is defined as being highly toxic if it falls within any of the following categories:

(a) A chemical that has a median lethal dose (LD_{50}) of 50 milligrams or less per kilogram of body weight when administered orally to albino rats weighing between 200 and 300 grams each.

(b) A chemical that has a median lethal dose (LD_{50}) of 200 milligrams or less per kilogram of body weight when administered by continuous contact for 24 hours (or less if death occurs within 24 hours) with the bare skin of albino rabbits weighing between two and three kilograms each.

(c) A chemical that has a median lethal concentration (LC_{50}) in air of 200 parts per million by volume or less of gas or vapor, or 2 milligrams per liter or less of mist, fume, or dust, when administered by continuous inhalation for one hour (or less if death occurs within one hour) to albino rats weighing between 200 and 300 grams each.

Information on determining whether or not a chemical meets one of these definitions can be found in SDSs and other chemical references.

As with any particularly hazardous substance, work involving the use of acute toxins should adhere to the Guidelines for Working with Particularly Hazardous Substances. When working with acute toxins, also follow these additional guidelines:

- Consider storing highly toxic materials in a locked storage cabinet.
- Be aware of any special antidotes that may be required in case of accidental exposure (hydrofluoric acid and inorganic cyanides for example).
- Give particular attention to the selection of gloves and other personal protective equipment.
- Do not work with highly toxic chemicals outside of a fume hood, glove box or ventilated enclosure.

More information on acute toxins, including numerous useful web links, can be found on the OSHA Safety and Health Topics for Hazardous and Toxic Substances webpage.

CHAPTER ELEVEN: HAZARDOUS CHEMICAL WASTE

A hazardous waste is broadly defined as "any unwanted or discarded chemical material that has properties that make it dangerous to health or the environment when improperly treated, stored, transported, used, or disposed of. Generally, a waste must exhibit at least one of the following characteristics to be considered hazardous:

- Ignitability (flash point below 60C (140F)
- Corrosivity (pH ≤5 or≥12)
- Reactivity (water reactive, shock sensitive, generates toxic gas)
- Toxicity (acutely toxic, carcinogenic, reproductive toxin, etc.)

It is KAUST policy that hazardous wastes shall be properly managed from point of generation to ultimate disposal. KAUST has a Hazardous Waste Collection Program to collect hazardous waste directly from your laboratory. You must utilize the Hazardous Waste Collection Program to dispose of all hazardous waste generated by your laboratory.

- Do not pour hazardous wastes down the sink.
- Do not dispose of hazardous wastes by evaporation in fume hoods, safety cabinets, etc.

- Do not put hazardous waste in regular trash.

WASTE AVOIDANCE

Waste avoidance benefits everyone. Generating less waste means less risk of harm to people or to the environment. It saves money and resources. It leads to a safer workplace by lessening risk of employee exposure to harmful chemicals and reduces the chance of accidents associated with handling waste. All laboratory employees are responsible for actively taking steps to eliminate the generation of hazardous waste where possible using techniques such as:

- Substitute with less hazardous materials.
- Reduce volumes by scaling down experiments.
- Avoid co-mingling hazardous and non-hazardous wastes – the combined volume must be considered hazardous waste.
- Purchase only the quantity of material that is actually needed.
- Reduce hazards – chemically neutralize corrosives.

WASTE CONTAINERS

Waste chemicals shall be collected in individual, leak proof, sealed containers. Be sure that the chemical contents are compatible with the container-material selected. Acid wastes should not be placed in metal containers. Glass containers should not be used for hydrofluoric acid or very strong bases (alkalis). A wide variety of waste containers are available through the KAUST service provider.

- Do not store incompatible wastes in the same container. If there is any suspicion that mixed waste materials could react, or are incompatible in any way, the wastes should not be combined and should be kept in separate containers.
- Do not fill waste containers more than 80% full. Leave adequate headspace above the liquid level to allow for expansion.
- Ensure that the container has a tight-fitting screw cap lid or seal for transportation – unsuitable lids/seals: parafilm, foil, corks, stoppers, etc. Therefore, containers with these kinds of tops will not be picked up for disposal.
- Hazardous waste containers shall remain closed except during filling. Do not leave funnels in waste containers.

It is the responsibility of the Principal Investigator and laboratory managers to ensure that personnel working in laboratories under their supervision are familiar with and follow KAUST hazardous chemical waste requirements as defined in the KAUST Hazardous Waste Manual.

CHAPTER TWELVE: GAS CYLINDER SAFETY

Compressed gases are commonly used in laboratories for a number of different operations. While compressed gases are very useful, they have the potential for creating hazardous working environments for these reasons:

- Gas cylinders may contain gases that are flammable, toxic, corrosive, asphyxiants, or oxidizers.
- Unsecured cylinders can be easily knocked over, causing serious injury and damage. The impact can shear the valve from an uncapped cylinder, causing a catastrophic release of pressure leading to personal injury and extensive damage.
- Mechanical failure of the cylinder, cylinder valve, or regulator can result in rapid diffusion of the pressurized contents of the cylinder into the atmosphere; leading to explosion, fire, runaway reactions, or burst reaction vessels.

The KAUST Compressed Gas Standard outlines required safety measures for the safe use of all types of compressed gases, liquefied gases and cryogenic gases in KAUST research laboratories. The standard specifies the needed operational controls (administrative and procedural) as well as engineering and design requirements to ensure safe gas use. All compressed gas usage shall be conducted in accordance with the requirements of the standards.

Compressed gas cylinders must be handled only by experienced and properly instructed personnel.

For additional information on the handling, use, and storage of compressed gases - see the KAUST Compressed Gas Standard.

STORAGE REQUIREMENTS

The following storage requirements apply to all gas cylinders:

- Gas cylinders shall not be stored in exits or egress routes.
- Always store gas cylinders in well-ventilated areas.

- Do not store gas cylinders in damp areas, near salt or corrosive chemicals, fumes, heat or where exposed to the weather.

- Always store gas cylinders in an upright condition and properly secured.

- Secure gas cylinders with a chain or appropriate belt above the midpoint, but below the shoulder of the cylinder. Laboratory cylinders less than 45 cm (18 inches) tall may be secured by approved stands or wall brackets.

- Cylinders must be capped when not in use or attached to a system (if the cylinder will accept a cap).

- Keep all cylinders at least 7 meters (20 feet) away from all flammable, combustible or incompatible substances.

- All cylinders of oxygen must be stored at least 7 meters (20 feet) away from cylinders of hydrogen or other flammable gas, or the storage areas must be separated by a firewall five feet high with a fire rating of 1/2 hour.

- Keep cylinders away from locations where they might form part of an electrical circuit, such as next to electric power panels or electric wiring.

- Cylinders should be stored such that cylinders are used in the order in which they are received.

- Store cylinders so that gases with the same hazard class are stored in the same area. Inert gases are compatible with all other gases and may be stored together.

- Do not store cylinders for longer than one year without use.

- Keep full cylinders separated from empty cylinders and properly labeled with a Full / In Use/ Empty tag.

STORAGE QUANTITY AND VOLUME

The storage of flammable or toxic compressed gases within a laboratory work area is defined within NFPA 45:

- Cylinders, except for nominal 0.5 kg (1 lb) propane cylinders, that are not necessary for current laboratory requirements, shall be stored outside of the laboratory.

- Lecture bottles of the following gases shall be kept in a continuously mechanically ventilated hood or enclosure:

  - All gases that have a health hazard rating of 3 or 4. See Appendix 11 for more information.
  - All gases that have a health hazard rating of 2 without physiological warning properties.
  - Pyrophoric gases.

COMPRESSED GAS CYLINDER HANDLING

The following requirements shall apply to the handling of gas cylinders:

- Compressed gases shall be handled only by properly trained persons.
- The contents of any compressed gas cylinder must be clearly identified.
- Do not move compressed gas cylinders by carrying, rolling, sliding, or dragging them across the floor.
- Transport cylinders with a hand truck designed for the transport of cylinders. Cylinder caps shall be secured during transport. Never transport a cylinder while a regulator is attached.
- Prevent damage to cylinders - locate cylinders where they will be protected from physical damage by striking or falling objects, corrosion, or damage from public tampering.
- No person other than the gas supplier shall attempt to mix gases in a cylinder.
- Do not transport oxygen and combustible gases at the same time.
- Cylinders shall not be subjected to artificially created low temperatures without approval from the supplier.
- Containers shall not be used for any other purpose than holding the contents as received.
- Damaged or leaking cylinders must be reported to HSE immediately.

GOOD PRACTICE GUIDELINES

Listed below are general “good practice” guidelines to follow when using gas cylinders and compressed gases.

- Make sure that the cylinder is secured.

- Attach the proper regulator to the cylinder. If the regulator does not fit, it may not be suitable for the gas you are using.

- Use a regulator only with gas for which it is intended. The use of adaptors or homemade connectors has caused serious and even fatal accidents.

- Ensure that regulator pressure control valve is relieved (i.e., closed) before attaching to tanks.

- When using more than one gas, be sure to install one-way flow valves from each cylinder to prevent mixing, otherwise accidental mixing can cause contamination of a cylinder.

- Close valves on gas cylinders when a system is not in use.

- Remove all pressure from regulators not currently used (by opening equipment valves downstream **after** the regulators are closed).

- Shut-off valves must not be installed between pressure relief devices and the equipment they are to protect.

- Use pressure relief valves in downstream lines to prevent high pressure buildup in the event that a regulator valve does not seat properly and a tank valve is left on.

- Relief valves should be vented to prevent potential buildup of explosive or toxic gases.

- Never allow flames or concentrated heat sources to come in contact with a gas cylinder.

- Never allow a gas cylinder to become part of an electrical circuit.

- Never partially open a tank valve to remove dust or debris from the cylinder inlet.

- Never use cylinder gas as compressed air.

- Pressurize regulators slowly and ensure that valve outlets and regulators are pointed away from all personnel when cylinder valves are opened.

- Cylinders which require a wrench to open the main valve shall have the wrench left in place on the cylinder valve while it is open. Use adequately sized wrenches to minimize ergonomic stress when turning tight tank valves. Never apply excessive force when trying to open valves. Cylinders with “stuck” valves should be returned to suppliers to have valves repaired.

- Do not attempt to open a corroded valve; it may be impossible to reseal.

- Valves should only be opened to the point where gas can flow into the system at the necessary pressure. This will allow for quicker shutoff in the event of a failure or emergency.
- Use a cylinder cap hook to loosen tight cylinder caps. Never apply excessive force or pry off caps. Return the cylinder to the supplier to remove “stuck” caps.
- Keep piping, regulators and other apparatus gas tight to prevent gas leakage.
- Confirm gas tightness by using compatible leak test solutions (e.g., soap and water) or leak test instruments.
- Release pressure from systems before connections are tightened or loosened and before any repairs.
- Never use adapters or exchange fittings between tanks and regulators.
- Fluorescent light can be used to check for grease or oil in regulators and valves.
- After an experiment is completed, turn the cylinder valve off first, and then allow gas to bleed from the regulator. When both gauges read “zero”, remove the regulator and replace the protective cap on the cylinder head.
- Do not allow a cylinder to become completely empty. Leave at least 25 psi of residual gas to avoid contamination of the cylinder by reverse flow.
- When the cylinder is empty, mark it as “Empty”, and store empty cylinders separate from full cylinders.

LABELING

The following labeling requirements shall apply to all gas cylinders:

- Know the contents of each cylinder you are using.
- Use only the vendor label for positive identification of contents of the cylinder. Be aware that color coding may be inconsistent from vendor to vendor.
- Mixed gases shall be clearly labeled with the contents of the cylinder.
- Empty cylinders shall be labeled with the word “empty” or the abbreviation MT.

MANIFOLDS, VALVES, AND REGULATORS

The following information applies to the use of manifolds, valves and/or regulators:

- Where compressed gas containers are connected to a manifold, the manifold and its related equipment, such as regulators, shall be of proper design for the product(s) they are to contain at the appropriate temperatures, pressures, and flows.

- Use only approved valves, regulators, manifolds, piping and other associated equipment in any system that requires compressed gas. Care must be taken to ensure that pressure gauges on regulators are correct for the pressure of the gas cylinder used. With the exception of lecture bottles, threads, configurations and valve outlets are different for each class of gases to prevent mixing of incompatible gases.

- Valves and regulators should undergo periodic maintenance and repair. A visual inspection should be performed before each usage to detect any damage, cracks, corrosion or other defects. Long term maintenance or replacement periods vary with the types of gases used, the length of use, and conditions of usage. Consult the cylinder, regulator or gas supplier for recommended valve and regulator maintenance schedules.

- Valves and regulator maintenance histories should be known before usage. Valves that pass visual inspection are still subject to failure, therefore it is critical that toxic or poisonous gases are used only in ventilated enclosures and have local exhaust ventilation in place for downstream pressure relief valves, etc.

- Valves and regulators should only be repaired by qualified individuals. Valve and regulator manufacturers, gas supply companies, or valve and regulator specialty shops should be consulted for any repair needs.

GASES WITH SPECIFIC HAZARDS

The following information regarding specific classes of gases is offered as additional guidance to be used in conjunction with the general usage requirements.

CORROSIVE GASES

The following information is provided for corrosive gases. Examples include chlorine, hydrogen chloride, fluorine, and hydrogen fluoride.

- There can be an accelerated corrosion of materials in the presence of moisture.

- Metals become brittle when used in corrosive gas service. So check equipment and lines frequently for leaks.

- A diaphragm gauge should be used with corrosive gases that would destroy a steel or bronze gauge. So, check with gas suppliers for recommended equipment.

- Remove regulators after use and flush with dry air or nitrogen.

- Due to the corrosive nature of the gases, corrosive cylinders should only be kept on hand for 6 months (up to one year maximum). Only order the smallest size needed for your experiments.

CRYOGENIC LIQUIDS AND GASES

Cryogenic liquids and their boil-off vapors rapidly freeze human tissue and cause embrittlement of many common materials which may crack or fracture under stress. Boiling and splashing will occur when the cryogen contacts warm objects.

All cryogenic liquids produce large volumes of gas when they vaporize and may create oxygen-deficient conditions and therefore dispensing areas need to be well ventilated. Avoid storing cryogenics in cold rooms, environmental chambers, and other areas with poor ventilation. If necessary, install an oxygen monitor/oxygen deficiency alarm and/or toxic gas monitor before working these materials in confined areas. Examples of common cryogenic liquids include liquid nitrogen, oxygen, hydrogen, and helium.

The following information applies to the use and handling of cryogenics:

- Use appropriate personal protective equipment (PPE) including insulated gloves and eye protection (goggles and a face shield) during any transfer of cryogenic liquid.

- Shirt sleeves should be rolled down and buttoned over glove cuffs, or an equivalent protection such as a lab coat, should be worn in order to prevent liquid from spraying or spilling inside the gloves. Trousers without cuffs should be worn.

- In the event of skin contact with a cryogenic liquid, do not rub skin; place the affected part of the body under warm (not hot) water. Never use dry heat to treat cryogenic burns. For any accidents or injuries, and complete an accident report using the online Report It System.

- If clothing becomes soaked with cryogenic liquid, it should be removed as quickly as possible and the affected area should be flooded with water as above. Where clothing has frozen to the underlying skin, cold water should be poured on the area, but no attempt should be made to remove the clothing until it is completely free.

- Use the buddy system when filling and transporting cryogenic liquids. Never transport cryogenic liquid using a passenger elevator.

- Vessels being filled must not be left unattended.

- Use only equipment, valves and containers designed for the intended product and service pressure and temperature.

- Do not use or store cryogenic liquids in poorly ventilated spaces such as cold rooms.

- Transfer operations involving open cryogenic containers such as dewars must be conducted slowly to minimize boiling and splashing of the cryogenic fluid.

- All cryogenic systems including piping must be equipped with pressure relief devices to prevent excessive pressure build-up. Pressure reliefs must be directed to a safe location.

- The caps of liquid nitrogen dewars are designed to fit snugly to contain the liquid nitrogen, but also allow the periodic venting that will occur to prevent an over-pressurization of the vessel. Do not ever attempt to seal the caps of liquid nitrogen dewars.

- Do not tamper with pressure relief valves or the settings for the valves.

See the Guidelines for Working with Cryogens on the Lab Safety webpage for more information.

FLAMMABLE GASES

The following information applies to the use and handling of flammable gases. Common examples of flammable gases include acetylene, hydrogen, methane, propane and iso-butane.

- Flammable gases, except for protected fuel gases, shall not be used near ignition sources. Ignition sources include open flames and sparks, sources of heat, oxidizing agents and ungrounded or non-intrinsically safe electrical or electronic equipment.

- Vapors from liquefied gas often are heavier than air, and may spread along the ground and travel to a source of ignition and result in a flashback fire.

- Portable fire extinguishers shall be available for fire emergencies. The fire extinguisher must be compatible with the apparatus and the materials in use.

- Flames shall not be used for detecting leaks. A compatible leak detection solution shall be used for leak detection. Spark proof tools shall be used when working with or on a flammable compressed gas cylinder or system.

- Access doors to areas which use or store flammable gases shall be posted "No Open Flames."

- Manifold systems shall be designed and constructed by competent personnel who are thoroughly familiar with the requirements for piping of flammable gases.

- Cylinders containing acetylene should never be stored on their side.

FUEL, HIGH PRESSURE AND OXIDIZING GASES

The following information applies to the use and handling of fuel, high pressure and oxidizing gases:

- Fuel gases often use a combination of flammable and oxidizing gases.

- High pressure gases can be rated up to 3000 pounds per square inch (psi). Typical uses include MIG welding gas mixtures, cryogenics, non-toxic gas distribution, medical gas distribution, and emergency oxygen services. In addition to any gas specific hazards, high pressure gases should carry the following hazard label: "CAUTION: HIGH PRESSURE GAS".

- Oxidizing gases are non-flammable gases (e.g., oxygen, chlorine, fluorine and nitrous oxide), but in the presence of an ignition source and fuel can support and vigorously accelerate combustion. Do not use oil in any apparatus where oxygen will be used. Gauges and regulators for oxygen shall bear the warning "OXYGEN - USE NO OIL."

TOXIC AND HIGHLY TOXIC GASES

The following information applies to the use of toxic and highly toxic gases.

- All gases with a NFPA Health Hazard rating of 3 or 4 must be considered as toxic or highly toxic. See Appendix 11 for more information.

- Unless otherwise indicated, all gases must be stored in a continuously mechanically ventilated gas cabinet, fume hood or other enclosure.

- Audible alarms should be utilized in ventilated hoods that are dedicated to toxic gas usage or storage.

- Standard Operating Procedures (SOPs) for processes or procedures which use corrosive, toxic or highly toxic gases shall be developed that include emergency response actions. All affected employees shall be trained on the contents of these procedures.

COMPRESSED GAS LEAKS AND EMERGENCIES

The following sections provide information on dealing with compressed gas leaks and emergencies.

PREPLANNING

Despite strict adherence to laboratory safety practices, accidents involving gases may occur in the laboratory. The amount of damage sustained by personnel and property from these accidents will be directly related to the quality of the laboratory's emergency plan and procedures. Users of compressed gas cylinders must be familiar with necessary safety precautions. Standard Operating Procedures (SOPs) for experiments using compressed gases shall include a discussion of possible accident scenarios, appropriate employee responses and should take into account the following factors:

- The nature of the operation (e.g., experimental design, equipment used, etc.).
- The potential location of a release or spill (e.g., outdoors versus indoors, in a laboratory, corridor or storage area, on a table, in a hood or on the floor).
- The quantities of material that might be released and the type of containment (i.e., compressed gas tank size, manifold systems, etc.).
- The chemical and physical properties of the compressed gas (e.g., its physical state, vapor pressure and air or water reactivity).
- The hazardous properties of the compressed gas (e.g., its toxicity, corrosivity and flammability).
- The availability and locations of emergency supplies and equipment.
- A contingency plan which identifies building evacuation routes, emergency telephone numbers, chemical containment procedures, fire extinguisher usage, etc., should be posted in the lab.

MINOR LEAKS

- Occasionally a gas cylinder or one of its component parts may develop a leak. Most of these leaks occur at the top of the cylinder in areas such as the valve threads, pressure safety device, valve stem and valve outlet. The following information applies to the remediation of minor leaks:
- If possible, verify suspected leaks using a flammable gas detector or soapy water solution (a flame should not be used for detection). If the leak cannot be stopped by tightening a valve gland or packing nut, emergency action procedures should be initiated by calling 911 from a campus phone or 012-808-0911 from a mobile phone.
    - For flammable, inert or oxidizing gases, move the cylinder to an isolated, well-ventilated area (e.g., within a fume hood) away from combustible materials. Post signs that describe the hazard.
    - For corrosive and toxic gases, move the cylinder to an isolated, well-ventilated area (e.g., within a fume hood or gas cabinet) and use suitable means to direct the gas into an appropriate chemical neutralizer. Post signs that describe the hazards.

MAJOR LEAKS

- In the event of a large gas release or if an accident takes place in which readily available personal protective equipment (PPE) is inadequate to ensure worker safety, activate the following Emergency Procedures:
    - Immediately call 911 from a KAUST landline or 012-808-0911 from a mobile phone and report the incident.
    - Activate building and area fire alarms (or chemical safety alarms if applicable).
    - Evacuate the area, securing entrances and providing assistance to others on the way out.
    - Provide emergency response officials with details of the problem upon their arrival. The KAUST Fire Department will respond to gas emergencies.

CHAPTER THIRTEEN: SAFE USE OF LABORATORY EQUIPMENT

In addition to the chemical hazards found in laboratories, there are also numerous physical hazards associated with laboratory equipment encountered by laboratory staff on a day-to-day basis. As with chemical hazards, having good awareness of these hazards, good preplanning, performing regular preventive maintenance, use of personal protective equipment and following basic safety rules can go a long way in preventing accidents involving laboratory equipment. Further, KAUST laboratories have access to LEM (Lab Equipment Maintenance) services.

It is the responsibility of the Principal Investigator and laboratory managers to ensure that staff and students in laboratories under their supervision are provided with adequate training and information specific to the physical hazards associated with equipment found within their laboratories under their supervision.

GENERAL EQUIPMENT SET UP

The following recommended laboratory techniques for general equipment set up were taken from the American Chemical Society's booklet – Safety in Academic Chemistry Laboratories. Following these recommendations will help make apparatus assembly easier and equipment safer:

- Keep work spaces free of clutter and practice good housekeeping.
- Set up clean and dry apparatus, firmly clamped and well back from the edge of the lab bench making adequate space between your apparatus and others work. Choose sizes that can

- properly accommodate the operation to be performed. As a rule, leave about 20% free space around your work.

- Use only equipment that is free from flaws such as cracks, chips, frayed wire, and obvious defects. Glassware can be examined in polarized light for strains. Even the smallest crack or chip can render glassware unusable. Cracked or chipped glassware should be repaired or discarded.

- A properly placed pan under a reaction vessel or container will act as secondary containment to confine spilled liquids in the event of glass breakage.

- When working with flammable gases or liquids, do not allow burners or other ignition sources in the vicinity. Use appropriate traps, condensers, or scrubbers to minimize release of material to the environment. If a hot plate is used, ensure the temperatures of all exposed surfaces are less than the autoignition temperature of the chemicals likely to be released and the temperature control device and the stirring / ventilation motor (if present) do not spark.

- Whenever possible, use controlled electrical heaters or steam in place of gas burners.

- Addition and separatory funnels should be properly supported and oriented so that the stopcock will not be loosened by gravity. A retainer ring should be used on the stopcock plug. Glass stopcocks should be freshly lubricated. Teflon stopcocks should not be lubricated.

- Condensers should be properly supported with securely positioned clamps and the attached water hoses secured with wire or clamps.

- Stirrer motors and vessels should be secured to maintain proper alignment. Magnetic stirring is preferable. Only non-sparking motors should be used in chemical laboratories. Air motors may be an option.

- Apparatus attached to a ring stand should be positioned so that the center of gravity of the system is over the base and not to one side. There should be adequate provision for removing burners or baths quickly. Standards bearing heavy loads should be firmly attached to the bench top. Equipment racks should be securely anchored at the top and bottom.

- Apparatus, equipment, or chemical bottles should not be placed on the floor. If necessary, keep these items under tables and out of aisleways to prevent creating a tripping hazard.

- Never heat a closed container. Provide a vent as part of the apparatus for chemicals that are to be heated. Prior to heating a liquid, place boiling stones in unstirred vessels (except test tubes). If a burner is used, distribute the heat with a ceramic-centered wire gauze. Use the thermometer with its bulb in the boiling liquid if there is the possibility of a dangerous exothermic decomposition as in some distillations. This will provide a warning and may

- allow time to remove the heat and apply external cooling. The setup should allow for fast removal of heat.

- Whenever hazardous gases or fumes are likely to be evolved, an appropriate gas trap should be used and the operation confined to a fume hood.

- Fume hoods are recommended for all operations in which toxic or flammable vapors are evolved as is the case with many distillations. Most vapors have a density greater than air and will settle on a bench top or floor where they may diffuse to a distant burner or ignition source. These vapors can roll out over long distances and, if flammable, an ignition can cause a flashback to the source of vapors. Once diluted with significant amounts of air, vapors move in air essentially as air itself.

- Use a hood when working with a system under reduced pressure (which may implode). Close the sash to provide a shield. If a hood is not available, use a standing shield. Shields that can be knocked over must be stabilized with weights or fasteners. Standing shields are preferably secured near the top. Proper eye and face protection must be worn even when using safety shields or fume hoods.

REFRIGERATORS AND FREEZERS

The potential hazards posed by laboratory refrigerators and freezers involve vapors from the contents, the possible presence of incompatible chemicals and spillage.

Only refrigerators and freezers specified for laboratory use should be utilized for the storage of chemicals. These refrigerators have been constructed with special design factors, such as heavy- duty cords and corrosion resistant interiors to help reduce the risk of fire or explosions in the lab.

Standard refrigerators have electrical fans and motors that make them potential ignition sources for flammable vapors. Do not store flammable liquids in a refrigerator unless it is approved for such storage. Flammable liquid-approved refrigerators are designed with spark-producing parts on the outside to avoid accidental ignition. If refrigeration is needed inside a flammable-storage room, you should use an explosion-proof refrigerator.

Frost-free refrigerators should also be avoided. Many of them have a drain or tube or hole that carries water and possibly any spilled materials to an area near the compressor, which may spark. Electric heaters used to defrost the freezing coils can also spark.

Only chemicals should be stored in chemical storage refrigerators; lab refrigerators should not be used for food storage or preparation. Refrigerators should be labeled for their intended purpose (example labels reads “No Food or Drink to be Stored in this Refrigerator”). Labels are available on the Lab Safety Signs and Labels webpage.

All materials in refrigerators or freezers should be labeled with the contents, owner, date of acquisition or preparation and nature of any potential hazard. Since refrigerators are often used for storage of large quantities of small vials and test tubes, a reference to a list outside of the refrigerator should be used. Labels and ink used to identify materials in the refrigerators should be water-resistant.

All containers should be sealed, preferably with a cap. Containers should be placed in secondary containers, or catch pans should be used.

Loss of electrical power can produce extremely hazardous situations. Flammable or toxic vapors may be released from refrigerators and freezers as chemicals warm up and/or certain reactive materials may decompose energetically upon warming. Proactive planning can avoid product loss and hazardous situations in event of an extended power outage. Dry ice or alternate power sources can be used to prevent refrigerator and freezer contents from warming.

STIRRING AND MIXING DEVICES

The stirring and mixing devices commonly found in laboratories include stirring motors, magnetic stirrers, shakers, small pumps for fluids, and rotary evaporators for solvent removal. These devices are typically used in laboratory operations that are performed in a hood, and it is important that they be operated in a way that precludes the generation of electrical sparks.

Only spark-free induction motors should be used in power stirring and mixing devices or any other rotating equipment used for laboratory operations. While the motors in most of the currently marketed stirring and mixing devices meet this criterion, their on-off switches and rheostat-type speed controls can produce an electrical spark because they have exposed electrical conductors. The speed of an induction motor operating under a load should not be controlled by a variable autotransformer.

Because stirring and mixing devices (especially stirring motors and magnetic stirrers) are often operated for fairly long periods without constant attention; the consequences of stirrer failure, electrical overload or blockage of the motion of the stirring impeller should be considered.

HEATING DEVICES

Most labs use at least one type of heating device, such as ovens, hot plates, heating mantles and tapes, oil baths, salt baths, sand baths, air baths, hot-tube furnaces, hot-air guns and microwave ovens. Steam-heated devices are generally preferred whenever temperatures of 100^{o} C or less are required because they do not present shock or spark risks and can be left unattended with assurance that their temperature will never exceed 100^{o} C. Ensure the supply of water for steam generation is sufficient prior to leaving the reaction for any extended period of time.

A number of general precautions need to be taken when working with heating devices in the laboratory. When working with heating devices, consider the following:

- Heating devices should be set up on a sturdy fixture and away from any ignitable materials (such as flammable solvents, paper products and other combustibles). Do not leave open flames (from Bunsen burners) unattended.

- Heating devices should not be installed near drench showers or other water spraying apparatus due to electrical shock concerns and potential splattering of hot water.

- The actual heating element in any laboratory heating device should be enclosed in such a fashion as to prevent a laboratory worker or any metallic conductor from accidentally touching the wire carrying the electric current.

- Heating device sometimes become so worn or damaged that its heating element is exposed; if this occurs, then the device should be either discarded or repaired before it is used again.

- Laboratory heating devices should be used with a variable autotransformer to control the input voltage by supplying some fraction of the total line voltage.

- The external cases of all variable autotransformers have perforations for cooling by ventilation and, therefore, should be located where water and other chemicals cannot be spilled onto them and where they will not be exposed to flammable liquids or vapors.

- Heating devices should have a backup power cutoff or temperature controllers to prevent overheating. If a backup controller is used, an alarm should notify the user that the main controller has failed.

- Hot plate/stirrers with lab/scissor jacks while being used in chemical fume hoods. This technique allows flammable vapors to be more easily removed (via fume hood air flow) while working with electrical equipment that may cause an ignition source for heavier than air flammable vapors.

- Provisions should be included in processes to make sure reaction temperatures do not cause violent reactions and a means to cool the dangerous reactions should be available.

- Post signs to warn people of the heat hazard to prevent burns.

Fail-safe devices can prevent fires or explosions that may arise if the temperature of a reaction increases significantly because of a change in line voltage, the accidental loss of reaction solvent or loss of cooling. Some devices will turn off the electric power if the temperature of the heating device exceeds some preset limit or if the flow of cooling water through a condenser is stopped owing to the loss of water pressure or loosening of the water supply hose to a condenser.

OVENS

Electrically heated ovens are commonly used in the laboratory to remove water or other solvents from chemical samples and to dry laboratory glassware. *Never use laboratory ovens for human food preparation*.

- Laboratory ovens should be constructed such that their heating elements and their temperature controls are physically separated from their interior atmospheres.

- Laboratory ovens rarely have a provision for preventing the discharge of the substances volatilized in them. Connecting the oven vent directly to an exhaust system can reduce the possibility of substances escaping into the lab or an explosive concentration developing within the oven.

- Ovens should not be used to dry any chemical sample that might pose a hazard because of acute or chronic toxicity unless special precautions have been taken to ensure continuous venting of the atmosphere inside the oven.

- To avoid explosion, glassware that has been rinsed with an organic solvent should be rinsed again with distilled water before being dried in an oven. Allowing the organic solvent rinsed glassware to dry for hours before placing in an oven is another option.

- Bimetallic strip thermometers are preferred for monitoring oven temperatures. Mercury thermometers should not be mounted through holes in the top of ovens so that the bulb hangs into the oven. Should a mercury thermometer break in an oven of any type, the oven should be closed and turned off immediately, and it should remain closed until cool. All mercury should be removed from the cold oven with the use of appropriate cleaning equipment and procedures in order to avoid mercury exposure.

- If toxic, flammable, or otherwise hazardous chemicals are evolved from the oven, then only use ovens with a single pass through design where air is ventilated out of the lab and the exhausted air is not allowed to come into contact with electrical components or heating elements.

- Heating flammables should only be done with a heating mantle, rotary evaporator, oil or steam bath.

HOT PLATES

Laboratory hot plates are normally used for heating solutions to 100°C or above when inherently safer steam baths cannot be used. Any newly purchased hot plates should be designed in a way that avoids electrical sparks. However, many older hot plates pose an electrical spark hazard arising from either the on-off switch located on the hot plate, the bimetallic thermostat used to regulate the temperature or both. Laboratory workers should be warned of the spark hazard associated with older hot plates.

In addition to the spark hazard, old and corroded bimetallic thermostats in these devices can eventually fuse shut and deliver full, continuous current to a hot plate.

- Do not store volatile flammable materials near a hot plate.
- Limit use of older hot plates for flammable materials.
- Check for corrosion of thermostats. Corroded bimetallic thermostats can be repaired or reconfigured to avoid spark hazards.

HEATING MANTLES

Heating mantles are commonly used for heating round-bottomed flasks, reaction kettles and related reaction vessels. These mantles enclose a heating element in a series of layers of fiberglass cloth. As long as the fiberglass coating is not worn or broken, and as long as no water or other chemicals are spilled into the mantle, heating mantles pose no shock hazard.

- Always use a heating mantle with a variable autotransformer to control the input voltage.
- Be sure to plug the heating mantle into the variable transformer and NOT directly into an outlet.
- Be careful not to exceed the input voltage recommended by the mantle manufacturer. Higher voltages will cause it to overheat, melt the fiberglass insulation and expose the bare heating element.
- If the heating mantle has an outer metal case that provides physical protection against damage to the fiberglass, it is good practice to ground the outer metal case to protect against an electric shock if the heating element inside the mantle shorts against the metal case.

OIL, SALT AND SAND BATHS

Electrically heated oil baths are often used to heat small or irregularly-shaped vessels or when a stable heat source that can be maintained at a constant temperature is desired. Molten salt baths (like hot oil baths) offer the advantages of good heat transfer, higher operating range (e.g., 200^{o}C to 425^{o}C) and high thermal stability (e.g., 540^{o}C). But these last two advantages don’t always occur.

There are several precautions to take when working with these types of heating devices:

- Heating baths should be durable and set up with firm support.
- Take care with hot oil baths so as not to generate smoke or have the oil burst into flames from overheating. Check the oil’s flash point.
- Always monitor oil baths by using a thermometer or other thermal sensing device to ensure that its temperature does not exceed the flash point of the oil being used.
- Fit oil baths left unattended with thermal sensing devices that will turn off the electric power if the bath overheats.

- Mix oil baths well to ensure that there are no “hot spots” around the elements that take the surrounding oil to unacceptable temperatures. The use of a small magnetic stirrer or a steel paper clip in the oil bath works well.

- Contain heated oil in a vessel that can withstand an accidental strike by a hard object.

- Mount baths carefully on a stable horizontal support such as a laboratory jack that can be raised or lowered without danger of the bath tipping over. Iron rings are not acceptable supports for hot baths.

- Clamp equipment high enough above a hot bath that if the reaction begins to overheat, the bath can be lowered immediately and replaced with a cooling bath without having to readjust the equipment setup.

- Provide secondary containment in the event of a spill of hot oil.

- Wear heat-resistant gloves when handling a hot bath.

- The reaction container used in a molten salt bath must be able to withstand a very rapid heat-up to a temperature above the melting point of salt.

- Since combustible liquids are often used in heat baths, the thermostat should be set so the temperature never rises above the flash point of the liquid. Check the SDS for the chemical to determine the flashpoint. Compare that flashpoint with the expected temperature of the reaction to gauge risk of starting a fire.

See the Guidelines for Working with Hot Oil Baths and Other Heating Sources on the Lab Safety webpage for more information.

HOT AIR BATHS AND TUBE FURNACES

Hot air baths are used in the lab as heating devices. Nitrogen is preferred for reactions involving flammable materials. Electrically heated air baths are frequently used to heat small or irregularly-shaped vessels. One drawback of the hot air bath is that they have a low heat capacity. As a result, these baths normally have to be heated to 100^{o}C or more above the target temperature. Tube furnaces are often used for high-temperature reactions under pressure. Consider the following tips when working with either apparatus:

- Ensure that the heating element is completely enclosed.

- For air baths constructed of glass, wrap the vessel with heat resistant tape to contain the glass if it should break.

- Sand baths are generally preferable to air baths.

- For tube furnaces, carefully select glassware and metal tubes and joints to ensure they are able to withstand the pressure.

- Follow safe practices outlined for both electrical safety and pressure and vacuum systems.

HEAT GUNS

Laboratory heat guns are constructed with a motor-driven fan that blows air over an electrically heated filament. They are frequently used to dry glassware or to heat the upper parts of a distillation apparatus during distillation of high-boiling materials.

The heating element in a heat gun typically becomes red-hot during use and the on-off switches and fan motors are **not** usually spark-free. For these reasons, heat guns almost always pose a serious spark hazard. Household hair dryers may not be substituted for laboratory heat guns.

Any hand-held heating device of this type that will be used in a laboratory should have ground-fault circuit interrupter (GFCI) protection to ensure against electric shock.

Never use a heat gun near flammable materials including open containers of flammable liquids, flammable vapors or hoods used to control flammable vapors.

MICROWAVE OVENS

Microwave ovens used in the laboratory may pose several different types of hazards.

- As with most electrical apparatus, there is the risk of generating sparks that can ignite flammable vapors.
- Metals placed inside the microwave oven may produce an arc that can ignite flammable materials.
- Materials placed inside the oven may overheat and ignite.
- Sealed containers, even if loosely sealed, can build pressure upon expansion during heating, creating a risk of container rupture.

To minimize the risk of the hazards associated with microwave ovens, the guidelines below should be followed:

- In order to avoid exposure to microwaves, never operate microwave ovens with doors open.
- Do not place wires and other objects between the sealing surface and the door on the oven's front face. The sealing surfaces must be kept absolutely clean.
- Never use a microwave oven for both laboratory use and food preparation.

- Electrically ground the microwave. If use of an extension cord is necessary, only a three- wire cord with a rating equal to or greater than that for the oven should be used.

- Do not use metal containers and metal-containing objects (e.g. stir bars) in the microwave - as they can cause arcing.

- Do not use heat sealed containers in the microwave oven. Even heating a container with a loosened cap or lid poses a significant risk since microwave ovens can heat material so quickly that the lid can slip upward against the threads and containers can explode.

- Remove screw caps from containers being microwaved. If the sterility of the contents must be preserved, use cotton or foam plugs. Otherwise plug the container with kimwipes to reduce splash potential.

ULTRASONICATORS

Human exposure to ultrasound with frequencies between 16 and 100 kilohertz (kHz) can be divided into three distinct categories: airborne conduction, direct contact through a liquid coupling medium, and direct contact with a vibrating solid.

Ultrasound through airborne conduction does not appear to pose a significant health hazard to humans. However, exposure to the associated high volumes of audible sound can produce a variety of effects - including fatigue, headaches, nausea and tinnitus. When ultrasonic equipment is operated in the laboratory for extended periods of time (>10 minutes), the apparatus should be enclosed in a 2-cm thick wooden box or in a box lined with acoustically absorbing foam or tiles to substantially reduce acoustic emissions (most of which are inaudible).

Direct contact of the body with liquids or solids subjected to high-intensity ultrasound of the sort used to promote chemical reactions should be avoided. Under sono-chemical conditions, cavitation is created in liquids, and it can induce high-energy chemistry in liquids and tissues. Cell death from membrane disruption can occur even at relatively low acoustic intensities.

Exposure to ultrasonically vibrating solids, such as an acoustic horn, can lead to rapid frictional heating and potentially severe burns.

CENTRIFUGES

Centrifuges should be properly installed and must be operated only by trained personnel.

Each employee using the centrifuge must become familiar with requirements for operation of this instrument. Assistance is available upon request from HSE. Each operator shall be instructed on proper operating procedures before being allowed to use the centrifuge. These proper operating procedures should be documented in a lab specific SOP.

Instructions should include requirements for balancing loads, using the proper centrifuge head, and using accessory equipment. Conditions for loading and operating an ultra-centrifuge and preparative centrifuge vary considerably. Therefore, even experienced investigators should review procedures before operating an unfamiliar instrument.

Each employee who uses a centrifuge is responsible for the condition of the machine at the end of the procedure. This includes entering data in the log books, turning off the power, and cleaning up spills, broken glass, etc. Detailed records of operation should be made for most high-speed centrifuges and rotors. The safe speed that rotors can be operated is determined by a rating formula which is based on numbers of starts and stops, R.P.M., and total "G" loads. Also, warranty coverage and service procedures for the machine are determined by hours of operation. These records should be kept in log books placed near each machine.

It is important that the load is balanced each time the centrifuge is used and that the lid is closed while the rotor is in motion. The disconnect switch must be working properly to shut off the equipment when the top is opened, and the manufacturer's instructions for safe operating speeds must be followed.

For flammable and/or hazardous materials, the centrifuge should be under negative pressure to a suitable exhaust system.

Some general safety guidelines to follow when using centrifuges:

- Be familiar with the operating procedures written by the manufacturer. Keep the operating manual near the unit for easy reference. If necessary, contact the manufacturer to replace lost manuals.

- Handle, load, clean, and inspect rotors as recommended by the manufacturer.

- Pay careful attention to instructions on balancing samples -- tolerances for balancing are often very restricted. Check the condition of tubes and bottles. Make sure you have secured the lid to the rotor and the rotor to the centrifuge.

- Maintain a log book of rotor use for each rotor, recording the speed and length of time for each use.

- To avoid catastrophic rotor failure, many types of rotors must be "de-rated" (limited to a maximum rotation speed that is less than the maximum rotation speed specified for the rotor when it is new) after a specified amount of use, and eventually taken out of service and discarded.

- Use only the types of rotors that are specifically approved for use in a given centrifuge unit.

- Maintain the centrifuge in good condition. Broken door latches and other problems should be repaired before using the centrifuge.

- Whenever centrifuging biohazardous materials, always load and unload the centrifuge rotor in a biosafety cabinet.

Basic centrifuge rotor care includes:

- Keep the rotor clean and dry, to prevent corrosion.
- Remove adapters after use and inspect for corrosion.
- Store the rotor upside down, in a warm, dry place to prevent condensation in the tubes.
- Read and follow the recommendations in the owner's manual regarding:
    - Regular cleaning
    - Routine inspections
    - Regular polishing and lubrication of O-rings
    - Decontaminating the rotor after use with radioactive or biological materials
- Remove any rotor from use that has been dropped or shows any sign of defect, and report it to a manufacturer's representative for inspection. Always follow the manufacturer's recommendations for operating procedures and maintenance schedules.

ROTARY EVAPORATORS

A rotary evaporator is a device used in chemical laboratories for the efficient and gentle removal of solvents from samples by evaporation. The solvent is evaporated in a reduced pressure environment with the application of heat and constant rotation. The reduced pressure increases the evaporation process by decreasing the boiling point of the solvent, allowing the evaporation to be conducted at lower temperatures. Rotation of the evaporation process maintains even heating of the solvent, while increasing the surface area of the evaporating solvent. Rotation also reduces the effect of 'bumping', which is the sudden burst of solvent vaporization that can scatter liquid exposed to reduced pressure.

Hazards of rotary evaporation include risks of implosion with potential hazards of flying glass, spattering chemicals and fire. Although glass vessels are frequently used in vacuum systems, they can implode or explode violently, either spontaneously from the strain or from an accidental blow. The properties of compounds used (such as peroxide forming chemicals) must be investigated prior to evaporation or reaction because some compounds are explosive upon dryness.

The following safety precautions should be followed whenever using rotary evaporators:

- Always read the owner's manual to ensure equipment specific safety information is being followed.

- Always wear Personal Protective Equipment (PPE) which includes safety glasses, face shield, laboratory coat, and the appropriate chemically resistant gloves.

- The rotation speed and application of vacuum should be done gradually when using a rotary evaporator.

- Only use quality, heavy walled glass or pyrex round bottom flasks or specially manufactured accessory flasks (e.g. beaker flask) for evaporation.

- Only use glassware that is free from cracks, scratches, etching marks and other imperfections.

- The condenser and receiving flask should be plastic coated to restrain fragments in case of implosion. The use of plastic safety netting may also be placed around the condenser.

- Ensure all tubing is checked regularly and replaced when brittle.

- Because large volumes of organic solvent vapor can be generated through rotary evaporation, it is best to conduct the process in a fume hood or at a minimum under a local exhaust (i.e. “snorkel”).

See the Guidelines for Working With Rotary Evaporators on the Lab Safety webpage for more information.

AUTOCLAVES

The use of an autoclave is a very effective way to decontaminate infectious waste. Autoclaves work by killing microbes with superheated steam. However, autoclaves have the following potential hazards:

- Heat, steam, and pressure.

- Thermal burns from steam and hot liquids.

- Cuts from exploding glass.

The following are recommended guidelines when using an autoclave:

- All users must be given training in proper operating procedures for using the autoclave.

- Read the owner’s manual before using the autoclave for the first time and always follow the manufacturer’s directions for loading the autoclave. Operating instructions should be posted near the autoclave.

- Do not put sharp or pointed contaminated objects into an autoclave bag. Place them in an appropriate rigid sharps disposal container.

- Use caution when handling an infectious waste autoclave bag, in case sharp objects were inadvertently placed in the bag. Never lift a bag from the bottom to load it into the chamber. Always handle the bag from the top.

- Do not overfill an autoclave bag. Steam and heat cannot penetrate as easily to the interior of a densely packed autoclave bag. Frequently the outer contents of the bag will be treated but the innermost part will be unaffected.

- Do not overload the autoclave compartment but instead allow for enough space between items for the steam to circulate. An overpacked autoclave chamber does not allow efficient steam distribution. Considerably longer sterilization times may be required to achieve decontamination if an autoclave is tightly packed.

- Always wear personal protective equipment, including heat-resistant gloves, safety glasses and a lab coat when operating an autoclave. Use caution when opening the autoclave door. Allow superheated steam to exit before attempting to remove autoclave contents.

- Be on the alert when handling pressurized containers. Superheated liquids may spurt from closed containers. Jarring them may cause sudden boiling, and result in burns. Never seal a liquid container with a cork or stopper. This could cause an explosion inside the autoclave.

- Some kinds of bottles containing liquids can crack either in the autoclave or when they are removed from the autoclave. Use a tray to provide secondary containment in case of a spill, and add a little water to the tray to ensure even-heating.

- Only fill bottles half way to allow for liquid expansion and loosen screw caps on bottles and tubes of liquid before autoclaving - to prevent them from shattering.

- At the end of the run, open the autoclave slowly: first open the door only a crack to let any steam escape slowly for several minutes, and then open all the way. Opening the door suddenly can scald a bare hand, arm, or face.

- Wait at least five minutes after opening the door before removing items.

- Wear appropriate PPE, including eye protection and insulating heat-resistant gloves before handling any items from the autoclave at the end of a cycle.

- Agar plates will melt and the agar will become liquefied when autoclaved. Avoid contact with molten agar. Use a secondary tray to catch any potential leakage from an autoclave bag rather than allowing it to leak onto the floor of the autoclave chamber.

- If there is a spill inside the autoclave chamber, allow the unit to cool before attempting to clean up the spill. If glass breaks in the autoclave; use tongs, forceps or other mechanical means to recover fragments. Do not use bare or gloved hands to pick up broken glassware.

- Do not leave an autoclave operating unattended for a long period of time. Always be sure someone is in the vicinity while an autoclave is cycling in case there is a problem.

- Autoclaves should be included in preventive maintenance contracts to ensure they are operating properly.

See the Guidelines for Using An Autoclave on the Lab Safety webpage for more information.

COLD TRAPS

The following are general guidelines for use of cold traps:

- Because many chemicals captured in cold traps are hazardous, care should be taken and appropriate protective equipment should be worn when handling these chemicals. Hazards include flammability, toxicity, and cryogenic temperatures, which can burn the skin.

- If liquid nitrogen is used, the chamber should be evacuated before charging the system with coolant. Since argon and oxygen have higher boiling points than nitrogen, liquid argon and oxygen can be produced and cause an explosion hazard.

- Boiling and splashing generally occur when charging (cooling) a warm container, so stand clear and wear appropriate protective equipment. Items should be added slowly and in small amounts to minimize splash.

- A blue tint to liquid nitrogen indicates contamination with oxygen and represents an explosion hazard. Contaminated liquid nitrogen should be disposed of appropriately.

- If working under vacuum see the Vacuums Section in this manual.

See the Guidelines for Working with Cryogens on the Lab Safety webpage for more information.

ELECTROPHORESIS DEVICES

Electrophoresis units present several possible hazards including electrical, chemical, and radiological hazards. Electrophoresis units use very high voltage (approximately 2000 volts) and potentially hazardous current (80 milliamps or more). This high power output has the potential to cause a fatal electrical shock if not properly handled. All of these hazards need to be addressed before using the units. Precautions to prevent electric shock must be followed when conducting procedures involving electrophoresis. Lethal electric shock can result when operating at high voltages such as in DNA sequencing or low voltages such as in agarose gel electrophoresis (e.g., 100 volts at 25 milliamps).

Principal Investigators are responsible for providing instruction on the safe use of electrophoresis units to those in the laboratory who work with them. The instruction should cover the operating procedures written by the manufacturer or laboratory, as well as the associated hazards, the correct personal protective equipment, and applicable emergency procedures.

The following are guidelines to assist researchers in safely operating electrophoresis units:

- Place electrophoresis units and their power supplies so that the on/off switch is easy to reach and the power-indicator lights are easily seen. Locate the equipment where it will not be easy to knock or trip over.

- Routinely inspect electrophoresis units and their power supplies to ensure they are working properly. Power supplies should be inspected to ensure that all switches and lights are in proper working condition, that power cords and leads are undamaged and properly insulated. Power supplies for electrophoresis units should be protected by Ground Fault Circuit Interrupters (GFCIs).

- Inspect the buffer tanks for cracks or leaks, exposed connectors, or missing covers.

- Turn the power off before connecting the electrical leads. Do not override safety devices. Connect one lead at a time, using one hand only. Ensure that hands are dry while connecting leads.

- Keep the apparatus away from sinks or other water sources.

- Turn off power before opening the lid or reaching inside the chamber.

- Do not leave electrophoresis units unattended for long periods of time since unauthorized persons may accidentally come in contact with the unit, or the buffer tank liquid may evaporate, resulting in risk of fire.

- Laboratories that perform electrophoresis work during off hours should consider using a "buddy system" to ensure that emergency services can be notified if someone is injured or exposed.

- If using acrylamide, purchase premixed solutions or pre-weighed quantities whenever possible.

- If using ethidium bromide, have a hand-held UV light source available in the laboratory. Check working surfaces after each use.

- Mix all stock solutions in a chemical fume hood.

- Provide spill containment by mixing gels on a plastic tray.

- Decontaminate surfaces with ethanol. Dispose of all cleanup materials as hazardous waste.

It is the responsibility of the Principal Investigator and laboratory managers to ensure that personnel working in laboratories under their supervision have been properly trained when working with any electrical equipment.

GLASSWARE

Although glass vessels are frequently used in low-vacuum operations, evacuated glass vessels may collapse violently, either spontaneously from strain or from an accidental blow. Therefore, pressure and vacuum operations in glass vessels should be conducted behind adequate shielding. It is advisable to check for flaws such as star cracks, scratches and etching marks each time a vacuum apparatus is used. Only round-bottomed or thick-walled (e.g., Pyrex) evacuated reaction vessels specifically designed for operations at reduced pressure should be used. Repaired glassware is subject to thermal shock and should be avoided. Thin-walled, Erlenmeyer or round-bottomed flasks larger than 1 L should never be evacuated unless designed for such operation.

The following are guidelines for use of glassware:

- Borosilicate glassware (i.e., pyrex) is recommended for all lab glassware, except for special experiments using UV or other light sources. Soft glass should only be used for things such as reagent bottles, measuring equipment, stirring rods, and tubing.

- Inspect glassware that will be used for reduced pressure to make sure there are no defects such as chips or cracks that may compromise its integrity.

- Any glass equipment being evacuated, such as filtering flasks, should be specially designed with heavy walls. Dewar flasks and large vacuum vessels should be taped or guarded in case of flying glass from an implosion. Household thermos bottles have thin walls and are not acceptable substitutes for lab dewar flasks.

- Use a shield between the user and any glass under vacuum or wrap the glass with tape to contain any glass in the event of an implosion.

- Glass containers containing hazardous chemicals should be transported in rubber bottle carriers or buckets to protect them from breakage and contain any spills or leaks. It is recommended to transport plastic containers this way as well since they also can break or leak.

See the Guidelines for Working with Glassware on the Lab Safety webpage for more information.

PREPARATION OF GLASS TUBING AND STOPPERS

The following are guidelines for preparation of glass tubing and stoppers.

To cut glass tubing:

- Clean the glass surface with a kim wipe and water or methanol. Cleaning the glass surface ensures a cleaner cut and will result in less errors.

- Hold the tube against a firm support and make one firm, quick stroke with a sharp triangular file or glass cutter to score the glass long enough to extend approximately one third around the circumference.

- Cover the tubing with cloth and hold the tubing in both hands away from the body. Place thumbs on the tubing opposite the nick by 2 to 3 cm and extended toward each other.

- Push out on the tubing with the thumbs as you pull the sections apart, but do not deliberately bend the glass with the hands. If the tubing does not break, re-score the tube in the same place and try again. Be careful to not contact anyone nearby with your motion or with long pieces of tubing.

- All glass tubing, including stir rods, should be fire polished before use. Unpolished tubing can cut skin as well as inhibit insertion into stoppers. After polishing or bending glass, give ample time for it to cool before grasping it.

When drilling a stopper:

- Use only a sharp borer one size smaller than that which will just slip over the tube to be inserted. For rubber stoppers, lubricate with water or glycerol. Holes should be bored by slicing through the stopper, twisting with moderate forward pressure, grasping the stopper only with the fingers, and keeping the hand away from the back of the stopper.

- Keep the index finger of the drilling hand against the barrel of the borer and close to the stopper to stop the borer when it breaks through. Preferably, drill only part way through and then finish by drilling from the opposite side.

- Discard a stopper (1) if a hole is irregular or does not fit the inserted tube snugly, (2) if it is cracked, or (3) if it leaks.

- Corks should have been previously softened by rolling and kneading. Rubber or cork stoppers should fit into a joint so that one-third to one–half of the stopper is inserted.

- When available, glassware with ground joints is preferable. Glass stoppers and joints should be clean, dry, and lightly lubricated.

INSERTION OF GLASS TUBES OR RODS INTO STOPPERS

The following practices will help prevent accidents during insertion of glass tubes or rods into stoppers:

- Make sure the diameter of the tube or rod is compatible with the diameter of the hose or stopper.
- If not already fire polished, fire polish the end of the glass to be inserted and then let it cool.
- Lubricate the glass - water may be sufficient, but glycerol is a better lubricant.
- Wear heavy gloves or wrap layers of cloth around the glass and protect the other hand by holding the hose or stopper with a layered cloth pad.
- Hold the glass not more than 5 cm from the end to be inserted.
- Insert the glass with a slight twisting motion, avoiding too much pressure and torque.
- When helpful, use a cork borer as a sleeve for insertion of glass tubes.
- If appropriate, substitute a piece of metal tubing for glass tubing.
- Remove stuck tubes by slitting the hose or stopper with a sharp knife.

GLASSWARE WASHING

In most cases laboratory glassware can be cleaned effectively by using detergents and water. In some cases it may be necessary to use chemicals for cleaning glassware. Strong acids should be avoided unless necessary. In particular, chromic acid should not be used due to its toxicity and disposal concerns. One product that may be substituted for chromic acid is “Nochromix Reagent”. The Fisher catalog describes this material as: “Nochromix Reagent. Inorganic oxidizer chemically cleans glassware. Contains no metal ions. Rinses freely—leaving no metal residue, making this product valuable for trace analysis, enzymology, and tissue culture work. (Mix with sulfuric acid).”

Unused Nochromix Reagent can be neutralized to a pH between 5.5 and 9.5 and drain disposed. Acid/base baths should have appropriate labeling and secondary containment. Additionally a Standard Operating Procedure (SOP), proper personal protective equipment (PPE), and spill materials should be available. Proper disposal for spent acid/base bath contents is neutralization and drain disposal, if the solution does not contain any heavy metals or other toxic materials.

When handling glassware, check for cracks and chips before washing, autoclaving or using it. Dispose of chipped and broken glassware immediately in a dedicated and clearly labeled broken glass container. DO NOT put broken glassware in the regular trash. Handle glassware with care –

avoid impacts, scratches or intense heating of glassware. A “Broken Glass” sign can be found on the Lab Safety Signs and Labels webpage.

VACUUMS

Vacuum pumps are used in the lab to remove air and other vapors from a vessel or manifold. The most common usages are on rotary evaporators, drying manifolds, centrifugal concentrators (“speedvacs”), acrylamide gel dryers, freeze dryers, vacuum ovens, tissue culture filter flasks and aspirators, desiccators, filtration apparatus and filter/degassing apparatus.

Consider these critical factors when selecting a vacuum pump:

- Application the pump will be used on;
- Nature of the sample (air, chemical, moisture);
- Size of the sample(s).

When using a vacuum pump on a rotary evaporator, a dry ice alcohol slurry cold trap or a refrigerated trap is recommended. A cold trap should be used in line with the pump when high vapor loads from drying samples will occur. Consult with the manufacturer for specific situations. These recommendations are based on keeping evaporating flasks on rotary evaporator at 400 C. Operating at a higher temperature allows the Dry Vacuum System to strip boiling point solvents with acceptable evaporation rates.

Vacuum pumps can pump vapors from air and water to toxic and corrosive materials like trifluoracetic acid and methylene chloride. Oil seal pumps are susceptible to excessive amounts of solvent, corrosive acids and bases and excessive water vapors. Pump oil can be contaminated quite rapidly by solvent vapors and mists. Condensed solvents will thin the oil and diminish its lubricating properties, possibly seizing the pump motor. Corrosives can create sludge by breaking down the oil and cause overheating. Excess water can coagulate the oil and promote corrosion within the pump. Proper trapping (cold trap, acid trap) and routine oil changes greatly extend the life of an oil seal vacuum pump. Pump oil should be changed when it begins to turn a dark brown color.

Diaphragm pumps are virtually impervious to attack from laboratory chemical vapors. They are susceptible to physical wearing of the membrane if excessive chemical vapors are allowed to condense and crystallize in the pumping chambers. A five minute air purge, either as part of the procedure or at day’s end, will drive off condensed water vapors and further prolong pump life.

Hazardous chemicals can escape from the vacuum pump so the pump should be vented into the hood. Cold traps and acid traps can be helpful, but if allowed to thaw or saturate, they can lose their effectiveness.

Follow these general guidelines when using vacuum pumps:

- Cold traps should be used to prevent pump oil from being contaminated which can create a hazardous waste.
- Pump exhaust should be vented into a hood when possible.
- Ensure all belts and other moving parts are properly guarded.
- Whenever working on or servicing vacuum pumps, be sure to follow appropriate lock-out procedures.

EXTRACTIONS AND DISTILLATIONS

The following are guidelines for working with extractions and distillations:

Extractions

- Do not attempt to extract a solution until it is cooler than the boiling point of the extractant due to the risk of over-pressurization, which could cause the vessel to burst.
- When a volatile solvent is used, the solution should be swirled and vented repeatedly to reduce pressure before separation.
- When opening the stopcock, your hand should keep the plug firmly in place.
- Ensure the stopcock is lubricated.
- Vent funnels away from ignition sources and people, preferably into a hood.
- Keep volumes small to reduce the risk of overpressure and if large volumes are needed, break them up into smaller batches.

Distillations

- Avoid bumping (which may cause sudden boiling) since the force can break apart the apparatus and result in splashes. Bumping can be avoided by even heating, such as using a heat mantle. Also, stirring can prevent bumping. Boiling stones can be used only if the process is at atmospheric pressure.
- Do not add solid items such as boiling stones to a liquid that is near boiling since it may result in the liquid boiling over spontaneously.

- Organic compounds should never be allowed to boil to dryness unless they are known to be free of peroxides, because peroxides can result in an explosion hazard.

Reduced pressure distillation

- Do not overheat the liquid. Superheating can result in decomposition and uncontrolled reactions.

- Superheating and bumping often occur at reduced pressures so it is especially important to abide by the previous point on bumping and to ensure even, controlled heating. Inserting a nitrogen bleed tube may help alleviate this issue.

- Evacuate the assembly gradually to minimize bumping.

- Allow the system to cool and then slowly bleed in the air. Air can cause an explosion in a hot system (pure nitrogen is preferable to air for cooling).

See the Guidelines for Working with Solvent Stills on the Lab Safety webpage for more information.

ELECTRICAL HAZARDS

Electrically powered equipment, such as hot plates, stirrers, vacuum pumps, electrophoresis apparatus, lasers, heating mantles, ultrasonicators, power supplies, and microwave ovens are essential elements of many laboratories. These devices can pose a significant hazard to laboratory workers, particularly when mishandled or not maintained. Many laboratory electrical devices have high voltage or high power requirements, carrying even more risk. Large capacitors found in many laser flash lamps and other systems are capable of storing lethal amounts of electrical energy and pose a serious danger even if the power source has been disconnected.

Electricity travels in closed circuits, and its normal route is through a conductor. Shock occurs when the body becomes a part of the electric circuit. Electric shock can cause direct injuries such as electrical burns, arc burns, and thermal contact burns. It can also cause injuries of an indirect or secondary nature in which involuntary muscle reaction from the electric shock can cause bruises, bone fractures, and even death resulting from collisions or falls. Shock normally occurs in one of three ways. The person must be in contact with ground and must contact with:

- Both wires of the electric circuit, or

- One wire of the energized circuit and the ground, or

- A metallic part that has become energized by being in contact with the energized wire.

Although there are no absolute limits or even known values that show the exact injury from any given amperage, the table below shows the general relationship between the degree of injury and the amount of amperage for a 60-cycle hand-to-foot path of one second's duration of shock.

EFFECTS OF ELECTRIC CURRENT IN THE BODY

Current	Reaction
1 milliampere	Perception level. Just a faint tingle.
5 milliamperes	Slight shock felt. Average individual can let go. However, strong involuntary reactions to shocks in this range can lead to injuries.
6-30 milliamperes	Painful shock. Muscular control lost.
50-150 milliamperes	Extreme pain, respiratory arrest, severe muscular contractions. Individual cannot let go. Death is possible.
1,000-4,300 milliamperes	Ventricular fibrillation. Muscular contraction and nerve damage occur. Death is most likely.
10,000-milliamperes	Cardiac arrest, severe burns and probable death.

The so-called low voltages can be extremely dangerous because, with all other factors being equal, the degree of injury is proportional to the length of time the body is in the circuit - low voltage does not mean low hazard.

PREVENTING ELECTRICAL HAZARDS

There are various ways of protecting people from the hazards caused by electricity, including insulation, guarding, grounding, and electrical protective devices. Laboratory workers can significantly reduce electrical hazards by following some basic precautions:

- Read and follow all equipment operating instructions for proper use.
- Remove all jewelry before working with electricity. This includes rings, watches, bracelets, and necklaces.
- Inspect wiring of equipment before each use. Replace damaged or frayed electrical cords immediately.
- Use guarding around exposed circuits and sources of live electricity (i.e., electrophoresis devices). Plexiglass shields may be used to protect against exposed live parts.

- Know the location and how to operate shut-off switches and/or circuit breaker panels.

- When it is necessary to handle equipment that is plugged in, be sure hands are dry and (when possible) wear nonconductive gloves and shoes with insulated soles.

- Extension cords should only be used on a temporary basis; they are not intended as permanent wiring. Do not use extension cords for fixed equipment such as computers, refrigerators/freezers, etc. Avoid extension cords and/or power strips to become a tripping hazard.

- Power strips are <u>preferred</u> over use of extension cords. In all other cases, request installation of a new electrical outlet.

- Power strips must have a built-in overload protection (circuit breaker) and must <u>not</u> be connected to another power strip or extension cord (commonly referred to as daisy chained or piggy-backed).

- Multi-plug adapters must have circuit breakers or fuses.

- Safe power strips, adapters and other appliances are available through procurement. Locally purchased power strips and adapters should not be used.

- Only equipment with properly grounded plugs should be used in the laboratory.

- Electrical outlets must not be overloaded and should be protected from possible spills of water or chemicals.

- Try to minimize power strips or electrical equipment on the floor to prevent electric issues during a flood situation. Try to elevate all electrical above the floor at least 3 cm (1 inch).

- Never store flammable liquids near electrical equipment, even temporarily. Always minimize the potential for water or chemical spills on or near electrical equipment and keep work areas clean and dry.

- Minimize the use of electrical equipment in cold rooms or other areas where condensation is likely. If equipment must be used in such areas, mount the equipment on a wall or vertical panel.

- If water or a chemical is spilled onto equipment, shut off power at the main switch or circuit breaker and unplug the equipment.

- If an individual comes in contact with a live electrical conductor, do not touch the equipment, cord or person. Disconnect the power source from the circuit breaker or pull out the plug using a leather belt.

- Disconnect the power source before servicing or repairing electrical equipment.

- Repairs of high voltage or high current equipment may be performed only by highly trained electricians.

For additional information, see the Electrical Safety – Safety Bulletins.

CIRCUIT PROTECTION DEVICES

Circuit protection devices are designed to automatically limit or shut off the flow of electricity in the event of a ground-fault, overload or short circuit in the wiring system. Ground-fault circuit interrupters, circuit breakers and fuses are three well-known examples of such devices.

The ground-fault circuit interrupter, or GFCI, is designed to shutoff electric power if a ground fault is detected, protecting the user from a potential electrical shock. The GFCI is particularly useful near sinks and wet locations. Since GFCIs can cause equipment to shutdown unexpectedly, they may not be appropriate for certain apparatus. Portable GFCI adapters (available in most safety supply catalogs) may be used with a non-GFCI outlet.

Fuses and circuit breakers prevent over-heating of wires and components that might otherwise create fire hazards. They disconnect the circuit when it becomes overloaded. This overload protection is very useful for equipment that is left on for extended periods of time, such as stirrers, vacuum pumps, drying ovens, variacs and other electrical equipment.

MOTORS

In laboratories where volatile flammable materials are used, motor-driven electrical equipment should be equipped with non-sparking induction motors or air motors. These motors must meet National Electric Safety Code (US DOC, 1993) Class 1, Division 2, Group C-D explosion resistance specifications. Many stirrers, variacs, outlet strips, ovens, heat tape, hot plates and heat guns **do not** conform to these code requirements.

Avoid series-wound motors, such as those generally found in some vacuum pumps, rotary evaporators and stirrers. Series-wound motors are also usually found in household appliances such as blenders, mixers, vacuum cleaners and power drills. These appliances should not be used unless flammable vapors are adequately controlled.

Although some newer equipment has spark-free induction motors, the on-off switches and speed controls may be able to produce a spark when they are adjusted because they have exposed contacts. One solution is to remove any switches located on the device and insert a switch on the cord near the plug end.

MERCURY CONTAINING EQUIPMENT

Elemental mercury (Hg) or liquid mercury is commonly seen in thermometers, barometers, diffusion pumps, sphygmomanometers, thermostats, high intensity microscope bulbs, fluorescent bulbs, UV lamps, batteries, Coulter Counter, boilers, ovens, welding machines, etc.

Most of these items can be substituted with equipment without mercury, thus greatly decreasing the hazard potential. Larger laboratory equipment may be more difficult to identify as "Mercury containing" due to the fact that mercury can be hidden inside inner components such as switches or gauges. For new equipment purchases, please attempt to procure instruments with no or little mercury.

The concerns surrounding mercury containing equipment are:

- It is difficult to identify exposures or cross-contamination due to mercury leaks or spills.
- The amount of mercury used is usually much greater than reportable quantities for releases to the environment.
- People may be unaware of the mercury and thus may not be properly trained for use, maintenance, spills, transport or disposal or may not use the appropriate engineering controls or Personal Protective Equipment (PPE).
- There is legal liability if human health and the environment are not properly protected.

To minimize the potential for mercury spills and possible exposures, laboratory personnel are strongly encouraged to follow these recommendations:

- Identify and label "Mercury Containing Equipment".
- Write a Standard Operating Procedure (SOP).
- Train personnel on proper use, maintenance, transport and disposal.
- Conduct periodic inspections of equipment to ensure no leaks or spills have occurred.
- Consider replacing mercury with electronic or other replacement components.
- Have available proper PPE such as nitrile gloves.
- Use secondary containment (such as trays) as a precaution for spills.
- Plan for an emergency such as a spill or release of mercury.
- Decontaminate and remove mercury before long-term storage, transport or disposal.

CHAPTER FOURTEEN: LASER SAFETY

KAUST has a Laser Safety Program designed to establish guidelines to protect faculty, staff, students, and employees from the potential hazards associated with laser devices and systems used to conduct laboratory, educational, and research activities at KAUST laboratories. To achieve this goal, HSE recognizes the American National Standard for the Safe Use of Lasers, ANSI Z136.1-2007.

ANSI Z136.1-2007 requires that all class 3b and 4 laser users must attend laser safety training. HSE offers training to meet this requirement, which includes topics such as laser hazards, laser classifications, signage/labeling, medical monitoring, safety guidelines, and what to do in case of an exposure incident. Upcoming dates for Laser Safety Training classes can be found on the Lab Safety Training Calendar webpage.

Additionally, any class 3b and 4 lasers that are in use must be registered with HSE. If your user group has not completed this process, please complete the LASER use and inventory forms found on the Laser Safety webpage. Laser safety reviews, control recommendations, and medical monitoring are also available upon request.

For additional information regarding laser safety please contact the HSE Laser Safety Officer at researchsafety@kaust.edu.sa. Additional information can be found on the OSHA Safety and Health topics webpage for laser hazards.

It is the responsibility of the Principal Investigator or laboratory manager with class 3b or 4 LASERs in laboratories under their supervision to ensure the class 3b or 4 LASERs have been registered with HSE and employees using these LASERs have received the appropriate training.

CHAPTER FIFTEEN: RADIATION SAFETY

All users of radioactive materials and radiation producing equipment are required to attend Radiation Safety Training. Upcoming dates for Radiation Safety Training classes can be found on the Lab Safety Training Calendar webpage.

Additionally, all radiation producing equipment (RPE) must be registered with HSE. If your user group has not completed this process, please complete the RPE use and inventory forms found on the Radiation Safety webpage.

For additional information regarding radiation safety please contact HSE Radiation Safety Officer at researchsafety@kaust.edu.sa.

KAUST has a Radiation Safety Program designed to establish guidelines to protect faculty, staff, students, and employees from the potential hazards associated with use of radioactive materials and radiation producing equipment used to conduct laboratory, educational, and research activities at KAUST laboratories.

It is the responsibility of the Principal Investigator or laboratory manager who using radioactive materials and radiation-producing equipment in laboratories under their supervision to ensure the equipment and users have been registered with HSE and employees have received the appropriate training.

Failure to Comply

Members of KAUST have a responsibility to understand and follow this Manual and are expected to comply with it. A violation of this Manual may result in appropriate disciplinary action, including the possible termination from KAUST.
Please refer to the Disciplinary Policy and Procedure.

APPENDICES

APPENDIX 1 – COMPILED LAB SAFETY RESPONSIBILITIES

The following is a compiled list of lab safety responsibilities for Principal Investigators and laboratory managers. The item after the statements in bold and parentheses correspond to the section header within this Laboratory Safety Manual.

1) It is the responsibility of the Principal Investigator to ensure a Laboratory Safety Plan is written and that all personnel working in laboratories under their supervision have reviewed and understood the plan. ***(Laboratory Safety Plan)***

2) It is the responsibility of Principal Investigators and laboratory managers to ensure that all persons in the laboratory are familiar with this Laboratory Safety Manual, the Laboratory Safety Plan, and are properly trained and competent to safely carry out their job duties and research. ***(Laboratory Safety Responsibilities)***

3) It is the responsibility of the Principal Investigator and laboratory manager to ensure that personnel working in laboratories under their supervision are informed and follow laboratory-specific, research center-specific, and campus-wide policies and procedures related to laboratory safety – such as the guidelines and requirements covered in this Laboratory Safety Manual. ***(Laboratory Safety Policies)***

4) It is the responsibility of Principal Investigators and laboratory managers to ensure personnel working in laboratories under their supervision have been provided with the proper training, have received information about the hazards in the laboratory they may encounter, and have been informed about ways they can protect themselves. ***(Employee Training)***

5) It is the responsibility of the Principal Investigator and laboratory manager to ensure written SOPs incorporating health and safety considerations are developed for work involving the use of hazardous chemicals in laboratories under their supervision and that PPE and engineering controls are adequate to prevent overexposure. In addition, Principal Investigators and laboratory managers must ensure that personnel working in laboratories under their supervision have been trained on those SOPs. ***(Standard Operating Procedures)***

6) It is the responsibility of Principal Investigators and laboratory managers to ensure procedures for working alone are developed and followed by personnel working in laboratories under their supervision. ***(Working Alone Policy)***

7) It is the responsibility of Principal Investigators and laboratory managers to ensure laboratories under their supervision are maintained in a clean and orderly manner and personnel working in the lab practice good housekeeping. ***(Laboratory Housekeeping)***

procedures for unattended operations are developed and followed by personnel working in laboratories under their supervision. ***(Unattended Operations)***

9) If a Principal Investigator or laboratory manager authorizes visitors or children to enter hazardous work areas, then that Principal Investigator or laboratory manager is responsible for the health and safety of those individuals. ***(Visitors and Children in Labs)***

10) It is the responsibility of the center directors, Principal Investigators, and laboratory managers to ensure visiting scientists and other similar users have been properly trained and made aware of any potential health and physical hazards that may exist in their labs. ***(Visiting Scientists and Other Similar Users)***

11) Principal Investigators, laboratory managers, and centers are free to set policies that establish minimum PPE requirements for personnel working in and entering their laboratories above the KAUST minimum standards. ***(Personal Protective Equipment)***

12) It is the responsibility of Principal Investigators and laboratory managers to ensure laboratory staff and students have received the appropriate training on the selection and use of proper PPE, that proper PPE is available and in good condition, and laboratory personnel use proper PPE when working in laboratories under their supervision. ***(PPE Training)***

13) HSE strongly encourages Principal Investigators and laboratory managers to ensure the use of eye protection is a mandatory requirement for all laboratory personnel, including visitors, working in or entering laboratories under their control. ***(Eye Protection)***

14) Please note: shorts or short skirts (and similar clothing) and open toed shoes (sandals, flip flops, etc.) are not permitted in KAUST laboratories. See the **PPE Standard for KAUST Laboratories** for more information. ***(Protective Clothing)***

15) It is the responsibility of the Principal Investigator to determine the hazards associated with all of the chemicals used in laboratories under their supervision. ***(Working Safely With Hazardous Chemicals)***

16) It is the responsibility of the Principal Investigator and laboratory manager to ensure staff and students under their supervision are provided with adequate training and information specific to the hazards found within their laboratories. ***(Chemical Hazard Information)***

17) All chemical containers (both hazardous and non-hazardous) must be properly labeled with clear indication of its contents and an appropriate warning of its physical and health hazards. ***(Chemical Container Labeling Requirements)***

18) *It is the responsibility Principal Investigators and laboratory managers to ensure* that staff and students working in laboratories under their supervision have obtained required health and safety training and have access to SDSs (and other sources of information) for all hazardous chemicals used in laboratories under their supervision. ***(Safety Data Sheets)***

19) While HSE can provide assistance in identifying circumstances when there should be prior approval before implementation of a particular laboratory operation, the ultimate responsibility of establishing prior approval procedures lies with the Principal Investigator or laboratory manager. ***(Prior Approval)***

20) It is the responsibility of the Principal Investigator and laboratory managers to ensure that personnel working in laboratories under their supervision are familiar with and follow KAUST hazardous chemical waste requirements as defined in the KAUST Hazardous Waste Manual. ***(Waste Containers)***

21) It is the responsibility of the Principal Investigator and laboratory managers to ensure that staff and students in laboratories under their supervision are provided with adequate training and information specific to the physical hazards associated with equipment found within their laboratories under their supervision. ***(Safe Use Of Laboratory Equipment)***

22) It is the responsibility of the Principal Investigator and laboratory managers to ensure that personnel working in laboratories under their supervision have been properly trained when working with any electrical equipment. ***(Electrophoresis Devices)***

23) It is the responsibility of the Principal Investigator or laboratory manager with class 3b or 4 LASERs in laboratories under their supervision to ensure the class 3b or 4 LASERs have been registered with HSE and employees using these LASERs have received the appropriate training. ***(Laser Safety)***

24) It is the responsibility of the Principal Investigator or laboratory manager who is using radioactive materials and radiation producing equipment in laboratories under their supervision to ensure the equipment and users have been registered with HSE and employees have received the appropriate training. ***(Radiation Safety)***

APPENDIX 2 – STANDARD OPERATING PROCEUDRE EXAMPLES

Examples of SOPs and guidelines can be found on the Lab Safety Standard Operating Procedures webpage.

A Standard Operating Procedure template can be used or researchers can create Standard Operation Procedures using other resources.

The following links are examples of SOPs from other university websites:

- A list of SOP examples and resources on the web from the University of Maryland.
- The SOP library (with numerous examples) from the University of California - Irvine.
- The Michigan State University SOP webpage (with a number of examples).
- Example of a chemical specific information sheet type SOP (generic – not lab specific) – University of California, Irvine.
- A blank template for chemical specific or chemical group SOP - University of California, Irvine.

*DISCLAIMER: HSE has not verified the accuracy of the information contained within these links and SOPs. It is the responsibility of the laboratory personnel to ensure the accuracy of these non-HSE SOPs. These links are being provided only as examples and each lab should write an SOP that is specific to their processes and procedures.

APPENDIX 3 – LAB MOVE GUIDE

This appendix provides general guidance to those laboratory personnel preparing to move their laboratory work to another technical facility or new facility. Moving a research laboratory can be a complex process, especially if hazardous materials are involved. However, the steps outlined below can help to ensure a safe and smooth transition. If you are moving your laboratory and have specific questions, contact HSE at researchsafety@kaust.edu.sa.

NOTE: All laboratory personnel who are leaving KAUST must go through the Departure Clearance procedure before departing.

GENERAL CONSIDERATIONS

- Once you have made the decision to move your lab, start planning well in advance of the move.
- When cleaning up your old lab, please be considerate of the next occupants (custodial staff, maintenance workers, and new laboratory staff) and ensure all items are removed from the lab (or scheduled to be removed), including items in drawers, cabinets, fume hoods, refrigerators, freezers, etc.
- Keep in mind the value of limited laboratory space when cleaning out your old lab. Now is the time to discard old equipment, paper, boxes, and other materials that have not been used in a long time (and will not be used in the foreseeable future). For any surplus equipment, tables, cabinets, etc. that you plan on discarding, check with Campus Support to see if these items should remain in the lab you are leaving or if they could be donated to someone else in your unit or if you would like to donate them to the campus, contact HSE at researchsafety@kaust.edu.sa.
- Before the actual move occurs, visit the new facility and identify where equipment from the old facility will be located. Check to see if the correct electrical, water, gas, and space requirements are available for your new equipment and processes. Conducting this type of preplanning will greatly facilitate the moving process and occupation of your new facility.
- When moving equipment and materials to the new facility, keep in mind that no equipment, boxes, or other materials may be stored in hallways, stairwells, or other egress points used in the event of fire or other emergency. If you do need to temporarily store these items in the hallway, please contact HSE at researchsafety@kaust.edu.sa so proper arrangements can be made. No items may be allowed to accumulate in the hallway or service corridors and they must be removed by the end of each day. No hazardous materials (chemical, biological, or radiological) may be left in the hallways unattended at any time.
- When you arrive at the new facility, identify the location of emergency eyewashes and safety showers, fire extinguishers, and other safety equipment before bringing hazardous materials

to the new lab. Do not block access to emergency eyewashes and safety showers at any time. Do not stack boxes under or around emergency eyewashes or safety showers, even on a temporary basis.

- If fire extinguishers are not present in the new facility, contact the Help Desk at 959 to have fire extinguishers installed. If you have not been trained in the use of fire extinguishers, you can obtain this training from the Health, Safety, and Environmental Department.

- As part of your move, update your standard operating procedures and lab door signage.

CHEMICALS

- Before preparing to move chemicals to your new lab, now is the time to inventory all of your chemicals or update your current chemical inventory form.

- Only move those chemicals that will be needed for your research at the new facility or those chemicals you expect to use in the near future. Before your move, now is the time to get rid of old, outdated chemicals or chemicals that do not have any foreseeable use in the new facility. For those chemicals that are in good condition, contact your unit manager to see if anyone in your unit could use the chemicals, and then contact HSE at researchsafety@kaust.edu.sa to see if the chemicals could be included in the campus chemical recycling program. All other chemicals that cannot or will not be used in the new facility should be disposed of properly.

- Do not move full containers of chemical wastes to your new facility. Contact the Chemical Warehouse for proper disposal of any hazardous wastes. HSE can provide assistance with making waste determinations (i.e.: hazardous waste, universal waste, biomedical waste, radioactive waste, oil waste, etc.) and laboratory cleanouts.

- Only trained laboratory workers may move chemicals. Any highly toxic, highly hazardous, or reactive chemicals should only be moved by staff who have received special training. When moving highly toxic or highly hazardous chemicals, HSE recommends a "buddy system" be used in the event of a spill or other emergency.

- When moving chemicals, be sure all containers are properly labeled and all are securely closed. When packaging chemicals, use a packing material (such as vermiculite, ground corn cobs, shipping peanuts, cardboard, absorbent clay, etc.) that is compatible with the chemicals to prevent bottle breakage during transport. Only place chemicals that are compatible with each other in the same container and do not overload containers with chemical bottles.

- When transporting chemicals, it is best to use carts with lips or trays to prevent containers from being knocked off. Other items that are useful for transport include rubber bottle carriers, five gallon pails, or other forms of secondary containment.

- When moving chemicals, wear appropriate personal protective equipment such as safety glasses (splash goggles for corrosives), lab coat, and gloves. Remember to remove gloves when touching door knobs and latches, and elevator buttons. If possible, avoid using passenger elevators. If you must use a passenger elevator, request that no passengers ride along with you.

- After removing all chemicals and waste from your old lab facility, ensure all spills have been cleaned up and all potentially contaminated surfaces have been cleaned with water and detergent thoroughly. This includes bench tops, fume hoods, storage cabinets and drawers (both inside and outside), shelving, and the outside of large equipment that is scheduled to be moved by a moving company. Remember to clean out refrigerators and freezers thoroughly and defrost freezers. Please keep in mind the next immediate occupants of your old lab will be custodians and maintenance workers. Please be considerate of their health and safety by thoroughly cleaning up any potentially hazardous (chemical, biological, and radiological) contamination.

- When storing chemicals in your new lab, remember to segregate and store chemicals according to hazard class. HSE recommends using secondary containment such as trays, buckets, or bottle carriers when storing chemicals to help prevent spills.

COMPRESSED GAS CYLINDERS

- Before moving to your new facility, be sure to make arrangements for the removal of any compressed gas cylinders that will no longer be used or for any empty cylinders. If you need assistance having the cylinders removed, contact the Chemical Warehouse (WHSOrder@kaust.edu.sa).

- Before moving any compressed gas cylinders, remove the regulator and replace the safety cap over the cylinder valve. Only use an appropriate cylinder handcart to move compressed gas cylinders. Do not attempt to "roll" cylinders from one area to another.

- Any compressed cylinders containing highly toxic or highly reactive gases should only be moved by staff with special training in the use and hazards of these materials.

- After moving compressed gas cylinders, secure them with a strap or chain at once (chains are preferred). Do not leave compressed gas cylinders unsecured for any period of time, even temporarily. Any new gas distribution systems, using metal or plastic tubing, must be pressure tested (leak tested) before use. All cylinders must either have a regulator or a cap depending on if it is in use or stored.

BIOHAZARDOUS MATERIALS

- All biohazardous materials must be properly packaged and only moved by properly trained laboratory staff. Non-laboratory personnel (including moving company staff) or untrained laboratory personnel are not permitted to move biohazardous materials.

- All potentially contaminated equipment and surfaces such as bench tops, fume hoods, storage cabinets and drawers (both inside and outside), shelving, refrigerators, freezers, incubators, and the outside of large equipment that is scheduled to be moved by a moving company, must be thoroughly decontaminated. Please be considerate of the health and safety of future occupants by thoroughly cleaning up any potentially hazardous (chemical, biological, and radiological) contamination.

- Before moving to the new facility, dispose of all biohazardous waste properly.

- If you are having your Biosafety Cabinet (BSC) moved to your new location, thoroughly decontaminate both the inside and outside of the cabinet. You will also need to have the BSC recertified by a third party. Check with the manufacturers guidelines before moving your BSC.

RADIOACTIVE MATERIALS

- NOTE: All of the following steps must be coordinated through HSE. Please keep in mind that advance notification of your planned move is required.

- Please remember that no space may be occupied for the use of radioisotopes until the area has been setup by HSE. Contact HSE at researchsafety@kaust.edu.sa for more information.

- Any equipment to be handled by movers and not by laboratory staff must be certified as contamination free before the equipment is moved.

- Only properly trained staff may move radioactive materials and small equipment used with radioactive materials. All materials must be properly packaged and shielded.

- Before your planned move, properly dispose of any radioactive waste. Do not bring full containers of radioactive waste to your new lab.

- All vacated rooms must be certified as contamination free before they are turned over to custodians, maintenance workers, or new lab occupants. Contact HSE at researchsafety@kaust.edu.sa for more information.

DECOMMISSIONING FACILITIES AND EQUIPMENT

Laboratory renovations may require more formal decommissioning procedures of both facilities and equipment depending on the extent of renovation and the past use of the room and/or facility.

The purpose of decommissioning procedures includes:

- Decommissioning labs require standardized processes, strategies, and validation methods for screening and characterization of hazardous debris and other regulated waste streams and for compliance with hazardous waste regulations.

- Strategies to minimize generation of regulated wastes, to encourage on-site treatment, and decontamination technologies and to maximize recycling/recovery of materials from biological/chemical must also be considered.

- Cost-benefit analysis of decontamination and recycling versus disposal without decontamination.

Areas and materials of concern for decommissioning of facilities and equipment include:

- Chemical and biological contamination and/or spills
- Fluorescent light bulbs
- Fume hoods
- Gas cylinders and lecture bottles
- Lead shielding
- Mercury sources – sink traps, thermometers, switches, etc.
- Reaction chambers
- Unknown chemicals
- Vacuum pumps
- and other materials and equipment

SPECIFIC ROLES AND RESPONSIBILITIES FOR DECOMMISSIONING ACTIVITIES INCLUDE:

HSE roles/responsibilities

- Provide the initial HSE assessment.
- Provide HSE technical guidance and advice.
- Advise on decontamination and hazardous chemical waste disposal.
- Ensure compliance with HSE laws, regulations, policies and guidelines.
- Provide continuous HSE-related updates of the plan or project on the basis of new evidence, findings, or information.
- Provide continual review of project decommissioning as new information is obtained.
- Perform or review appropriate risk assessment.

Research staff member's roles/responsibilities

- Departure Clearance form from HSE if you are leaving KAUST
- Provide advice on needs, concerns and issues with lab decommissioning to HSE.
- Provide HSE with historical use of biohazardous materials, radioactive materials, and hazardous chemical usage for decontamination analysis.
- Identify and label materials (both biological and chemical) and create an inventory to be submitted to HSE.
- Segregate chemicals in accordance to the compatibility. HSE can provide research groups

with information and assistance with segregation and proper packaging of hazardous chemicals.

- Clean work and storage surfaces with soap and water, with special attention given to areas with visible decontamination.
- Identify biological/chemical contaminated area(s) that cannot be cleaned by researchers and work with HSE to facilitate decontamination of the area(s).

Additional guidance on decommissioning procedures can be found in the ANSI standard – Z9.11-2008 – Laboratory Decommissioning. If you have additional questions or would like more information, then please contact HSE at researchsafety@kaust.edu.sa.

SUMMARY

In conclusion, the above steps are ways laboratory staff can ensure a planned move to a new facility goes smoothly. The guidelines mentioned above and the following key points will help to provide a safe and successful transition to your new laboratory facility:

- Plan the move well in advance, including providing proper notification where required.

- Pre-plan where items and equipment in your new lab will be placed before you begin the move.

- Take advantage of the move to dispose of old or discontinued items, equipment, and chemicals.

- Once in your new lab, check with your new building coordinator to find out about any building-specific procedures.

- Please be courteous to the new occupants of your old lab – leave your old lab in the condition you want your new lab to be in when you arrive.

- Contact HSE at researchsafety@kaust.edu.sa if you have any questions.

APPENDIX 4 – GLOVE SELECTION FOR SPECIFIC CHEMICALS

Chemical	Incidental Contact	Extended Contact
Acetic acid	Nitrile	Neoprene, Butyl rubber
Acetic anhydride	Nitrile (8 mil), double glove	Butyl rubber, Neoprene
Acetone	[1]Natural rubber (Latex) (8 mil)	Butyl rubber
Acetonitrile	Nitrile	Butyl rubber, Polyvinyl acetate (PVA)
Acrylamide	Nitrile, or double Nitrile	Butyl rubber
bis-Acrylamide	Nitrile	
Alkali metals	Nitrile	
Ammonium hydroxide	Nitrile	Neoprene, Butyl rubber
Arsenic salts	Nitrile	
Benzotriazole, 1,2,3-	Nitrile	
Bismuth salts	Nitrile	
Butanol	Nitrile	Nitrile, Butyl rubber
Butyric acid	Nitrile	Butyl rubber, Neoprene
Cadmium salts	Nitrile	
Carbon disulfide	Nitrile (8 mil), double glove, or 15 mil or heavier	Viton, Polyvinyl acetate (PVA)
Carbon tetrachloride	Nitrile (8 mil), double glove, or 15 mil or heavier	Viton
Catechol	Nitrile	
Chloroform	Nitrile (8 mil), double glove, or 15 mil or heavier	Viton, Polyvinyl acetate (PVA)
Chlorosulfuron	Nitrile	

Chromium salts	Nitrile	
Cobalt chloride	Nitrile	Nitrile
Cobalt salts	Nitrile	
Copper (Cupric) sulfate	Nitrile	
Cyrogenic liquids	Cryogloves	
3,3’-Diaminobenzidine (DAB)	Nitrile	Nitrile, double glove
Diazomethane in Ether	Nitrile (8 mil), double glove, or 15 mil or heavier	Norfoil
Dichloromethane	Nitrile (8 mil), double glove	Polyvinyl acetate (PVA) or Viton
2,4-Dichlorophenoxy acetic acid	Nitrile	
Diethyl pyrocarbonate	Nitrile	Nitrile, double glove
Dimethyl sulfoxide	[1]Natural rubber (15-18mil)	Butyl rubber
1,4-Dioxane	Nitrile (8 mil), double glove, or 15 mil or heavier	Butyl rubber
Dithiothreitol	Nitrile	
Ethanol	Nitrile	
Ethidium bromide (EtBr)	Nitrile	Nitrile, double glove
Ethyl acetate	Nitrile (8 mil), double glove	Butyl rubber, PVA
Ethyl ether	Nitrile (8 mil), double glove, or 15 mil or heavier	Polyvinyl acetate (PVA)
Formaldehyde	Nitrile	
Formamide	Nitrile	Butyl rubber
Formic acid	Nitrile (8 mil), double glove	Butyl rubber, Neoprene (.28-.33mm)
Gallic acid	Nitrile	
Geneticin	Nitrile	
Glutaraldehyde	Nitrile	
Heavy metal salts	Nitrile	Nitrile, double glove

Heptane	Nitrile (8 mil), double glove, or 15 mil or heavier	Nitrile (35 mils or thicker), Viton, PVA
Hexamethylenediamine (1,6-Diaminohexane)	Nitrile (8 mil)	Neoprene
Hexane	Nitrile (8 mil), double glove, or 15 mil or heavier	Nitrile (35 mils or thicker), Viton, PVA
Hydrochloric acid	Nitrile	Neoprene, Butyl rubber
Hydrofluoric acid (HF)	Nitrile (8 mil), double glove, or 15 mil or heavier	Nitrile or Rubber sleeves
Hypophosphorous acid	Nitrile (4mil), double glove or 8 mil or heavier	
Isoamyl alcohol	Nitrile	
Isoctane	Nitrile	Heavy weight Nitrile
Isopropanol	Nitrile	
Kananmycin	Nitrile	
Lactic acid	Nitrile	Nitrile (double glove), or Neoprene or Butyl rubber
Laser dyes	Nitrile	
Lead acetate	Nitrile	Nitrile, double glove
Lead salts	Nitrile	
Mercuric chloride	Nitrile	Nitrile, double glove
Mercury	Nitrile	
Mercury salts	Nitrile	
Methanol (Methyl alcohol)	Nitrile	
Methylene chloride	Nitrile (8 mil), double glove	Polyvinyl acetate, Viton
Methylphosphonic acid	Nitrile (4 mil), double glove	8 mil or heavier Nitrile
Methyl sulfonic acid, Ethyl ester (EMS) (Ethyl methanesulfonate)	Nitrile	Nitrile, double glove

Monoethanolamine	Nitrile	
Nickel chloride	Nitrile	Nitrile, double glove
Nickel salts	Nitrile	Nitrile, double glove
Nitric acid	Nitrile (8 mil), double glove	Heavy weight (.28-.33mm) Butyl rubber or Neoprene
N-Methylethanolamine	Nitrile (8 mil), double glove	Viton, Neoprene, Butyl rubber
Octane	Nitrile	Heavy weight Nitrile or Viton
Organophosphorous compounds	Nitrile (8 mil), double glove, or 15 mil or heavier	
Osmium salts	Nitrile	
Osmium tetroxide	Nitrile	Nitrile, double glove
Paraformaldehyde	Nitrile	
Pentane	Nitrile (8mil), double glove	Heavy weight Neoprene, or Viton
Perchloroethylene (tetrachloroethylene)	Nitrile (8 mil), double glove	Nitrile (22mil or heavier)
Pesticides	heavy weight, unlined Nitrile (8-20 mils), or glove specified by pesticide label.	
Petroleum ether	Nitrile	Heavy weight Nitrile or Viton
Phenol	Nitrile (8 mil), double glove	Neoprene, Butyl rubber
Phenol-Chloroform mixtures	Nitrile (8 mil), double glove, or 15 mil or heavier	Viton
Phenylmethylsulfonyl fluoride (PMSF)	Nitrile	Nitrile, double glove
Phosphonic acid	Nitrile (4 mil), double glove, or 8 mil or heavier single	
Phosphoric acid	Nitrile (4 mil), double glove, or 8 mil or heavier	
Picloram (4-amino-3,5,6-	Nitrile	

trichloropicolinic acid)		
Polychlorinated Biphenyls (PCB's)	Nitrile (8 mil) glove over a Neoprene glove	Neoprene (20 mil)
Polyoxyethylene-sorbital-n-monolaurate (Tween 20)	Nitrile	
Potassium ferricyanide	Nitrile	
Potassium ferrocyanide	Nitrile	
Potassium permanganate	Nitrile	
Propanol	Nitrile	
Propionic acid	Nitrile	Neoprene or Butyl rubber
Propylene oxide	heavier weight (17 mil or greater) Butyl rubber or Neoprene	Norfoil
Psoralen	Nitrile	Nitrile, double glove
Pump oil	Butyl rubber	
Silane based silanization or derivatization compounds	Nitrile (8 mil), double glove, or 15 mil or heavier single	
Silver nitrate	Nitrile	Nitrile, double glove
Silver salts	Nitrile	
Sodium dodecyl sulfate (SDS)	Nitrile	
Sodium azide	Nitrile, or double glove	
Spermidine	Nitrile	
Sulfuric acid	Nitrile (8 mil)	Neoprene, Butyl rubber (20 mil or greater)
Tetrahydrofuran (THF)	Nitrile (8 mil), double glove, or 15 mil or heavier	Norfoil
3,3',5,5'-Tetramethyl-benzidine (TMB)	Nitrile	Nitrile, double glove

N,N,N',N'-Tetramethyl-ethylenediamine (TEMED)	Nitrile	Nitrile, double glove
Timetin	Nitrile	
Toluene	Nitrile (8 mil), double glove, or 15 mil or heavier	Viton, Polyvinyl acetate (PVA)
Trichloroethylene	Nitrile (8 mil), double glove	Viton, Polyvinyl acetate (PVA)
Trichloromethyl chloroformate (diphosgene)	Nitrile (8 mil) over Butyl rubber glove	This material must be used in a glove box.
Triton-X100	Nitrile	
Uranium salts	Nitrile	
Valeric acid	Nitrile	Nitrile, double gloves, or Neoprene or Butyl rubber
Xylene	Nitrile	Polyvinyl acetate (PVA), Viton

[1] If you are allergic to natural rubber products, you may double glove with 8 mil Nitrile gloves.

Glove Selection Guides

All Safety Products, Inc – Glove Selection Chart

Ansell Protective Products – See Ansell Chemical Resistance Guide

Argonne National Laboratory – Glove Selection Guideline

Best Gloves - Comprehensive Guide to Chemical Resistant Best Gloves

Microflex – Chemical Resistance Guide

North Safety - Chemical Resistance Guide

APPENDIX 5 – HOW TO UNDERSTAND SDSs

Chemical manufacturers are required by law to supply "Safety Data Sheets" (OSHA Form 174 or its equivalent) upon request by their customers. These sheets have nine sections giving a variety of information about the chemical. Following is a section-by-section reproduction and explanation of a Safety Data Sheet (SDS).

U.S. DEPARTMENT OF LABOR
Occupational Safety and Health Administration
SAFETY DATA SHEET
Required For compliance with OSHA Act of 1970
Public Law 91-596 (CFR 1910)

SECTION I	
Product Name	Size
Chemical Name	
Formula	
Manufacturer	
Address	
For Information on Health Hazards Call	
For Other Information Call	
Signature and date	

This section gives the name and address of the manufacturer and an emergency phone number where questions about toxicity and chemical hazards can be directed. Large chemical manufacturers have 24-hour hotlines manned by chemical safety professionals who can answer questions regarding spills, leaks, chemical exposure, fire hazard, etc. Other information that may be contained in Section I include:

Trade Name: This is the manufacturer's name for the product.

Chemical Name and Synonyms: This refers to the generic or standard names for the chemical.

Chemical Family: This classification allows one to group the substance along with a class of similar substances, such as mineral dusts, acids, caustics, etc. The potential hazards of a substance can sometimes be gauged by experience with other chemicals of that hazard class.

SECTION II - HAZARDOUS INGREDIENTS OF MIXTURES		
Principal Hazardous component(s)	%	TVL (Units)

This section describes the percent composition of the substance, listing chemicals present in the mixture. It lists Threshold Limit Values for the different chemicals that are present. Threshold Limit values (TLV's) are values for airborne toxic materials that are used as guides in the control of health hazards. They represent concentrations to which nearly all workers (workers without special sensitivities) can be exposed to for long periods of time without harmful effect. TLV's are usually expressed as parts per million (ppm), the parts of gas or vapor in each million parts of air. TLV's are also expressed as mg/m^3, the milligrams of dust or vapor per cubic meter of air.

SECTION III - PHYSICAL DATA			
Boiling Point (^{o}F)		Specific Gravity (H_2O=1)	
Vapor Pressure (mm Hg)		Percent Volatile By Volume (%)	
Vapor Density (Air=1)		Evaporation Rate (Butyl Acetate=1)	
Solubility in Water			
Appearance and Odor			

This section gives information about the physical characteristics of the chemical. This information can be very useful in determining how a chemical will behave in a spill situation and what appropriate steps should be taken.

Vapor Pressure: Vapor pressure (VP) can be used as a measure of how volatile a substance is…how quickly it evaporates. VP is measured in units of millimeters of mercury (mm Hg). For comparison, the VP of water (at 20^o Centigrade) is 17.5 mm Hg. The VP of Vaseline (a nonvolatile substance) would be close to zero mm Hg, while the VP of diethyl ether (a very volatile substance) is 440 mm Hg.

Vapor Density: Vapor density describes whether the vapor is lighter or heavier than air. The density of air is 1.0. A density greater than 1.0 indicates a heavier vapor, a density less than 1.0 indicates a lighter vapor. Vapors heavier than air (gasoline vapor for instance) can flow along just above the ground and can collect in depressions where they may pose a fire and explosion hazard.

Specific Gravity: Specific gravity describes whether the liquid is lighter or heavier than water. Water has a specific gravity of 1.0.

Percent Volatile by Volume: Describes how much of the substance will evaporate.

<table>
<tr><th colspan="5">SECTION IV - FIRE AND EXPLOSION HAZARD DATA</th></tr>
<tr><td>Flash Point (°F)</td><td colspan="2">Flammable Limits in Air (% by Vol.)</td><td>Lower</td><td>Upper</td></tr>
<tr><td colspan="2">Extinguisher Media</td><td colspan="3">Autoignition Temperature (°F)</td></tr>
<tr><td colspan="5">Special Fire Fighting Procedures</td></tr>
<tr><td colspan="5">Explosion Hazards</td></tr>
</table>

This section gives information, which is important for preventing and extinguishing fires and explosions. If a fire does occur, this information should be made available to fire fighters.

Flash Point: Flash point is the lowest temperature at which a liquid gives off enough vapor to ignite when a source of ignition is present. A fire or explosion hazard may exist if the substance is at or above this temperature and used in the presence of spark or flame.

Flammable Limits: In order to be flammable, a substance must be mixed with a certain amount of air (as in an automobile carburetor). A mixture that is too "lean" (not enough chemical) or too "rich" (not enough air) will not ignite. The Lower Explosive Limit (LEL) and the Upper Explosive Limit (UEL) define the range of concentration in which combustion can occur. The wider the range between the LEL and UEL, the more flammable the substance is.

SECTION V - HEALTH HAZARD DATA
Threshold Limit Value
Effects of Overexposure
Acute Overexposure
Chronic Overexposure
Emergency and First Aid Procedures
Inhalation
Eyes
Skin
Ingestion

This section describes the potential health effects resulting from overexposure to the chemical and gives emergency and first aid procedures. The symptoms and effects listed are the effects of exposure at hazardous levels. Most chemicals are safe in normal use and the vast majority of workers never suffer toxic effects. However, any chemical can be toxic in high concentrations, and the precautions outlined in the SDS should be followed.

The health hazards section often contains information on the toxicity of the substance. The data most often presented are the results of animal experiments. For example, "LD_{50} (mouse) = 250 mg/kg." The usual measure of toxicity is a dose level expressed as weight of chemical per unit body weight of the animal-usually milligrams of chemical per kilogram of body weight (mg/kg). The LD_{50} describes the amount of chemical ingested or absorbed by the skin in test animals that causes death in 50% of test animals used during a toxicity test study. Another common term is LC_{50}, which describes the amount of chemical inhaled by test animals that causes death in 50% of test animals used during a toxicity test study. The LD_{50} and LC_{50} values are then used to infer what dose is required to show a toxic effect on humans.

As a general rule of thumb, the <u>lower</u> the LD_{50} or LC_{50} number, the more toxic the chemical. Note there are other factors (concentration of the chemical, frequency of exposure, etc.) that contribute to the toxicity of a chemical, including other hazards the chemical may possess.

Health hazard information may also distinguish the effects of acute and chronic exposure. Acute toxicity is generally thought of as a single, short-term exposure where effects appear immediately and the effects are often reversible. Chronic toxicity is generally thought of as frequent exposures where effects may be delayed (even for years), and the effects are generally irreversible. Chronic toxicity can also result in acute exposures, with long term chronic effects.

<table>
<tr><th colspan="5">SECTION VI - REACTIVITY DATA</th></tr>
<tr><td colspan="2">Stability</td><td colspan="2">Unstable</td><td>Conditions to avoid</td></tr>
<tr><td colspan="2"></td><td colspan="2">Stable</td><td></td></tr>
<tr><td colspan="5">Incompatibility (Materials to Avoid)</td></tr>
<tr><td colspan="5">Hazardous Decomposition Products</td></tr>
<tr><td colspan="3">Hazardous Polymerization</td><td colspan="2">Conditions to Avoid</td></tr>
<tr><td>May Occur</td><td colspan="2">Will Not Occur</td><td colspan="2"></td></tr>
</table>

This section gives information on the reactivity of the chemical – with other chemicals, air, or water which is important when responding to a spill or fire. Chemical substances may be not only hazardous by themselves, but may also be hazardous when they decompose (break down into other substances) or when they react with other chemicals.

Stability: Unstable indicates that a chemical can decompose spontaneously under normal temperatures, pressures, and mechanical shocks. Rapid decomposition may be hazardous because it produces heat and may cause a fire or explosion. **Stable** compounds do not decompose under normal conditions.

Incompatibility: Certain chemicals should never be mixed because the mixture creates hazardous conditions. Incompatible chemicals should not be stored together where an accident could cause them to mix.

Hazardous Decomposition Products: Other chemical substances may be created when a chemical burns or decomposes.

Hazardous Polymerization: Some chemicals can undergo a type of chemical reaction (rapid polymerization) which may produce enough heat to cause containers to explode. Conditions to avoid are listed in this section.

SECTION VII - SPILL OR LEAK PROCEDURES
Steps to be Taken in Case Material is Released or Spilled
Waste Disposal Method

This section can provide specific information about how to clean up a spill of the chemical and how the chemical should be properly disposed.

SECTION VIII - SPECIAL PROTECTION INFORMATION		
Respiratory Protection (Specify type)		
Ventilation	Local Exhaust	Special
	Mechanical (general)	Other
Protective Gloves	Eye protection	
Other Protective clothing or Equipment		

This section gives information for any special protection that needs to be taken when handling this chemical including ventilation requirements and the type of personal protective equipment that should be worn.

SECTION IX - SPECIAL PRECAUTIONS
Precautions to be Taken in Handling and Storing
Other Precautions

This section describes other precautionary measures that may need to be taken. Some of the precautions presented are intended for large-scale users and may not be necessary for use with small quantities of the chemical. If you have any questions about precautions or health effects, then contact HSE at researchsafety@kaust.edu.sa.

APPENDIX 6 – NFPA HEALTH HAZARD RATING

Hazard	Exposure	LD_{50}	LC_{50}
4	**Health Hazard 4 usually includes: Materials that, under emergency conditions, can be lethal.**	Materials whose $LD_{50}$for acute dermal toxicity is ≤ 40 mg/kg. Materials whose LD_{50} for acute oral toxicity ≤ 5 mg/kg.	Gases whose LC_{50} for acute inhalation toxicity is ≤ 1000 ppm. Any liquid whose saturated vapor concentration at 20 C is equal to or 10 times its LC_{50} for acute inhalation toxicity, if its LC_{50} is ≤1000 ppm. Dusts and mists whose LC_{50} for acute inhalation toxicity is ≤ 0.5 mg/L.
3	**Health Hazard 3 usually includes: Materials that under emergency conditions, can cause serious or permanent injury.** Materials that are corrosive to the respiratory tract; Materials that are corrosive to the eye or cause irreversible corneal opacity; Materials that are severely irritating and/or corrosive to the skin.	Materials whose LD_{50} for acute dermal toxicity is > 40 mg/kg but ≤ 200mg/kg. Materials whose LD_{50} for acute oral toxicity is > 5 mg/kg but ≤ 50 mg/kg.	Gases whose LC_{50} for acute inhalation toxicity is > 1000 ppm but ≤ 3000 ppm. Any liquid whose saturated vapor concentration at 20 C is equal to or greater than its LC_{50} for acute inhalation toxicity, if its LC_{50} is ≤ 3000 ppm and that does not meet the criteria for degree of hazard 4. Dusts and mists whose LC_{50} for acute inhalation toxicity is > 0.5 mg/L but ≤ 2 mg/L
2	**Health Hazard 2 usually includes: Materials that, under emergency conditions, can cause temporary incapacitation or residual injury.** Materials that are respiratory irritants; Materials that cause irritating by reversible injury to the eyes; Materials that are primary skin irritants or sensitizers.	Materials whose LD_{50} for acute dermal toxicity is > 200 mg/kg but ≤ 1000 mg/kg. Materials whose LD_{50} for acute oral toxicity is > 50 mg/kg but ≤ 500 mg/kg.	Gases whose LC_{50} for acute inhalation toxicity is > 3000 ppm but ≤ 5000ppm. Any liquid whose saturated vapor concentration at 20 C is equal to or greater than ⅕ its LC_{50} for acute inhalation toxicity, if its LC_{50} is ≤ 5000 ppm and that does not meet the criteria for either degree of hazard 3 or degree of hazard 4. Dusts and mists whose LC_{50} for acute inhalation toxicity is > 2 mg/L but ≤10

			mg/L.
1	**Health Hazard 1 usually includes: Materials that, under** **emergency conditions, can cause significant irritation.** Materials that are slightly irritating to the respiratory tract, eyes and skin.	Materials whose LD_{50} for acute dermal toxicity is > 1000 mg/kg but ≤ 2000 mg/kg. Materials whose LD_{50} for acute oral toxicity is > 500 mg/kg but ≤ 2000 mg/kg.	Gases and vapors whose LC_{50} for acute inhalation toxicity is > 5000 ppm but ≤10,000 ppm. Dusts and mists whose LC_{50} for acute inhalation toxicity is > 10 mg/L but ≤ 200 mg/L.
0	**Health Hazard 0 usually includes: Materials that, under emergency conditions, would offer no hazard beyond ordinary combustible materials.** Essentially non-irritating to the respiratory tract, eyes and skin.	Materials whose LD_{50} for acute dermal toxicity is > 2000 mg/kg. Materials whose LD_{50} for acute oral toxicity is > 2000 mg/kg.	Gases and vapors whose LC_{50} for acute inhalation toxicity is > 10,000 ppm. Dusts and mists whose LC_{50} for acute inhalation toxicity is > 200 mg/L.

- LD_{50} Quantity of toxic material necessary to cause death in 50% of test subjects (usually mouse or rat). This value is usually associated with a dose received through injection, ingestion or dermal contact and is quantified by body weight of a specific animal.
- LC_{50} Quantity of toxic material in air which is necessary to cause death in 50% of the test subjects (usually mouse or rat). This value is associated with inhalation risks.

APPENDIX 7 – HAZARDS OF FUNCTIONAL GROUPS

The following information gives a basic overview of the hazards of functional groups. This information is not meant to replace safety data sheets for the specific chemical(s) used in your experiments. While these functional groups are listed alphabetically for convenience, chemicals should be segregated and stored by hazard classes.

ALCOHOLS

- The lower aliphatic alcohols are low to moderately toxic and usually have low vapor pressures, therefore inhalation toxicity is low.
- Vapors may be an irritant to the eyes and mucous membranes.
- Ingestion and absorption of the liquids through the skin can be a major health hazard.
- Lower alcohols containing double or triple bonds exhibit a greater degree of toxicity and irritation.
- Fatty alcohols (derived from oils, fats, and waxes) are almost nontoxic.
- Lower alcohols are flammable or combustible liquids.
- Flammability decreases with an increase in the carbon number.
- Solubility of alcohols decrease with increase in carbon chain length.
- Toxicity tends to decrease with an increase in carbon number.

Examples:

Allyl alcohol
1-Butanol
Cyclohexanol
1,2-Ethanediol
Ethanol
Methanol
1-Propanol
2-Propyn 1-ol

ALDEHYDES

- Aldehydes are intermediate products in the conversion of primary alcohols to carboxylic acids or vice versa.
- The low molecular weight aldehydes are more toxic than the higher ones.
- Toxicity decreases with increase in the carbon chain length.
- Aromatic aldehydes are less toxic than low molecular weight aliphatic aldehydes.
- Low molecular weight aldehydes are highly flammable, with flammability decreasing with increasing carbon chain length.
- Low aromatic aldehydes are combustible or nonflammable liquids.

Examples:

Acetaldehyde
Acrolein
Benzaldehyde
Formaldehyde
Glutaraldehyde
1-Hexanal
Isobutyraldehyde
Propenal

ALIPHATIC AMINES

- The toxicity of most aliphatic amines may fall in the low to moderate category.
- The health hazard from amines arises primarily from their caustic nature.
- All lower aliphatic amines are severe irritants to the skin, eyes, and mucous membranes.
- All of these compounds have a strong to mild odor of ammonia and their vapors produce irritation of the nose and throat.
- Aliphatic amines, especially the lower ones, are highly flammable liquids, many which have flashpoints below 0^0 Celsius.
- The vapors are heavier than air.
- They react vigorously with concentrated mineral acids.
- The flammability decreases with an increase in the carbon number.
- The reactivity of amines in general, is low.

Examples:
Aminocyclohexane
Ethyleneimine
Methylamine
2-Propylamine

ALIPHATIC and ALICYCLIC HYDROCARBONS

- Organic compounds composed solely of carbon and hydrogen.
- Hydrocarbons may be classified into 3 broad categories:
    - Open-chain aliphatic compounds
    - Cyclic or alicyclic compounds of naphthalene type
    - Aromatic ring compounds
- Open chain aliphatic hydrocarbons constitute alkanes, alkenes, alkynes, and their isomers. Alkenes or olefins are unsaturated compounds, characterized by one or more double bonds between the carbon atoms. Alkynes or acetylenic hydrocarbons contain a triple bond in the molecule and are highly unsaturated. An alicyclic hydrocarbon is a cyclic ring compound of 3 or more carbon atoms. Aromatics are ring compounds too, but are characterized by a 6 carbon atom unsaturated benzenoid ring.
- The toxicities of aliphatic and alicyclic hydrocarbons in humans and animals are very low.
- The gaseous compounds are all nontoxic and are simple asphyxiants.
- Lower hydrocarbons are highly flammable substances, an increase in the carbon number causes a decrease in flammability.
- It is the flammable properties that make hydrocarbons hazardous.
- The reactivity of alkanes and cycloalkanes is very low.
- Alkenes and alkynes containing double and triple bonds are reactive.

Examples:
Butane
Cyclohexene
Cyclopentane
Methane
n-Pentane

ALKALI and OTHER REACTIVE METALS

- Alkali metals constitute Group IA of the periodic table.
- Alkaline-earth metals constitute Group IIA and are less active than the alkali metals.
- These can be water and/or air reactive.
- Several of these metals are flammable, too, but only in a finely divided state.
- Reactions with water produce strong bases.

Examples:
Aluminum
Calcium
Lithium
Magnesium
Potassium
Sodium

ALKALIES

- Water-soluble bases, mostly the hydroxides of alkali- and alkaline-earth metals.
- Certain carbonates and bicarbonates also exhibit basic properties but are weak bases.
- These compounds react with acids to form salts and water.
- The health hazard from concentrated solutions of alkalies arises from their severe corrosive actions on tissues.
- These compounds are bitter to taste, corrosive to skin and a severe irritant to the eyes.
- The toxicity of alkalies is governed by the metal ions.
- Hydroxides and carbonates of alkali-and alkaline-earth are noncombustible.
- Strong caustic alkalies react exothermically with many substances, including water and concentrated acids, generating heat that can ignite flammable materials.

Examples:
Lithium hydroxide
Potassium hydroxide
Potassium carbonate
Sodium hydroxide

AROMATIC AMINES

- Compounds that contain one or more amino groups attached to an aromatic ring.
- These amines are similar in many respects to aliphatic amines.
- These amines are basic, but the basicity is lower to aliphatic amines.
- The health hazard from aromatic amines may arise in two ways:
  - Moderate to severe poisoning, with symptoms ranging from headache, dizziness, and ataxia to anemia, cyanosis, and reticulocytosis.
  - Carcinogenic, especially cancer of the bladder.
- Many aromatic amines are proven or suspected human carcinogens, among aromatic amines, ortho- isomers generally exhibit stronger carcinogenic properties than those of the para- and meta-isomers.
- Unlike aliphatic amines, the aromatic amines do not cause severe skin burn or corneal injury.
- The pure liquids (or solids) may produce mild to moderate irritation on the skin.
- Lower aromatic amines are combustible liquids and form explosive mixtures with air.

- Amines may react violently with strong oxidizing compounds.

Examples:
Aniline
Benzidine
o-Toluidine

AROMATIC HYDROCARBONS

- Aromatics are a class of hydrocarbons having benzene-ring structures.
- Many polyaromatics are carcinogens.
- The acute toxicity of mononuclear aromatics is low.
- Inhalation of vapors at high concentrations in the air may cause narcosis with symptoms of hallucination, excitement, euphoria, distorted perception, and headache.
- Benzene is the only mononuclear aromatic with possible human carcinogenicity and other severe chronic effects.
- With a greater degree of substitutions in the benzene ring and/or increase in the carbon chain length of the alkyl substituents, the flammability decreases.

Examples:
Benzene
Benzolalpyrene
Pyrene
Toluene
Xylene

AZIDES, FULMINATES, ACETYLIDES, and RELATED COMPOUNDS

- These compounds form highly explosive shock- and heat-sensitive salts with many metals.
- Structurally they differ from each other, but have similar detonating characteristics.
- While alkali metal azides are inert to shock; the salts for copper, silver, lead, and mercury are dangerously shock sensitive.
- Fulminates of heavy metals are powerful explosives.
- These compounds are highly sensitive to impact and heat.
- Acetylides of heavy metals are extremely shock sensitive when dry, whereas, the salts of alkali metals are fairly stable.
- Most azides, fulminates, acetylides, nitrides and related compounds are highly unstable and constitute an explosion hazard.
- Salts of Group IB and IIB metals are especially explosive.
- Azides of nonmetals, such as those of halogens or organic azides such as that of cyanogen, are also extremely shock sensitive.
- Some of these compounds may even explode on exposure to light.

Examples:
Cuprous acetylide
Hydrazoic acid
Lead azide
Mercury fulminate
Silver fulminate
Silver nitride
Sodium azide

CARBOXYLIC ACIDS

- Weak organic acids, their strength is much weaker than mineral acids.
- Toxicity of monocarboxylic acids is moderate to low and decreases with carbon chain length.
- Some of lower dicarboxylic acids are moderate to high toxicity, becoming less toxic with increasing carbon chain length.
- Low molecular weight carboxylic acids are combustible liquids.
- Aromatic acids are of low toxicity.

Examples:

Acetic acid
Butyric acid
Formic acid
Methacrylic acid
Oxalic acid
Propionic acid
Succinic acid
Valeric acid

EPOXY COMPOUNDS

- Epoxides, also called oxiranes and 1,2-epoxides.
- Exposure to epoxides can cause irritation of the skin, eyes, and respiratory tract.
- Low molecular weight epoxides are strong irritants and more toxic than higher ones.
- Inhalation can produce pulmonary edema and affect the lungs, central nervous system and liver.
- Many epoxy compounds have been found to cause cancer in animals.
- Lower epoxides are highly flammable.
- They also polymerize readily in the presence of strong acids and active catalysts, this reaction generates heat and pressure that may rupture closed containers.
- Therefore contact with anhydrous metal halides, strong bases, and readily oxidizable substances should be avoided.

Examples:

Butylene oxide
Epichlorohydrin
Ethylene oxide
Glycidaldehyde
Glycidol
Isopropyl glycidyl ether

ESTERS

- Lower aliphatic esters have a pleasant fruity odor.
- The acute toxicity of esters is generally of low order, they are narcotic at high concentrations.
- Vapors are an irritant to the eyes and mucous membranes.
- Toxicity increases with an increase in the alkyl chain length.
- Lower aliphatic esters are flammable liquids, some have low flash points and may cause flashback to an open container.
- The vapors form explosive mixtures with air.
- The flash point increases with increase in the alkyl chain length.

- The reactivity of esters is low.
- Aromatic esters are similar in effects as aliphatic esters.

Examples:
Ethyl acetate
Ethyl formate
Methyl acrylate
Methyl formate
n-Propyl acetate

(Aromatics)
Methyl benzoate
Methyl salicyate

ETHERS

- Widely used as solvents.
- They have a high degree of flammability.
- They tend to form unstable peroxides, which can explode spontaneously or upon heating.
- The flash point decreases with increase in carbon chain.
- Lower aliphatic ethers are some of the most flammable organic compounds and can be ignited by static electricity or lightning.
- The vapor densities are heavier than air.
- They form explosive mixtures with air.
- Aromatic ethers are noncombustible liquids or solids and do not exhibit the flammable characteristics common to aliphatic ethers.
- Ethers react with oxygen to form unstable peroxides, this reaction is catalyzed by sunlight, when evaporated to dryness, the concentrations of such peroxides increase, resulting in violent explosions.
- The toxicity of ethers is low to very low, at high concentrations these compounds exhibit anesthetic effects.

Examples:
Butyl vinyl ether
Ethyl ether
Isopropyl ether
Methyl propyl ether
Vinyl ether

GLYCOL ETHERS

- Also known by the name Cellosolve.
- The toxic effects are mild; however, moderate to severe poisoning can occur from excessive dosage.
- The routes of exposure are inhalation, ingestion, and absorption through the skin.
- Compounds with high molecular weights and low vapor pressures do not manifest an inhalation hazard.
- Low molecular weight alkyl ethers are flammable or combustible liquids forming explosive mixtures with air.
- The reactivity of glycol ethers is low.
- There is no report of any violent explosive reactions.
- The high molecular weight compounds are noncombustible.

Examples: Ethylene glycol monobutyl ether
Ethylene glycol monomethyl ether
2-Isopropoxyethanol

HALOETHERS

- Haloethers are ethers containing hydrogen atoms.
- Halogen substitutions make ether molecules less flammable or nonflammable.
- The explosion hazards of low aliphatic ethers due to peroxide formation are not manifested by the haloethers. The halogens inhibit the ether oxidation to peroxides.
- Inhalation of Fluoroethers can produce anesthesia similar to that of the lower aliphatic ethers. Lower aliphatic chloro-and bromoethers can be injurious to the lungs.
- Many of these are cancer causing to lungs in animals or humans.
- Aromatic chloroethers are toxic by inhalation, ingestion, and skin absorption only at high doses. These effects can be attributed to the chlorine content and to a lesser extent on the aromaticity of the molecule.

Examples: Bis(chloromethyl)ether
2-Chloroethyl vinyl ether
Pentachlorodiphenyloxide

HALOGENATED HYDROCARBONS

- The flammability of these compounds shows a wide variation.
- Bromo compounds are less flammable than their Chloro- counterparts, the difference in flammability is not great though.
- An increase in the halosubstitutions in the molecule increases the flash point.
- The flammable hydrocarbons are stable compounds with low reactivity.
- These compounds, however, may react violently with alkali metals and their alloys or with finely divided metals.
- Violent reactions may occur with powerful oxidizers, especially upon heating.
- Volatile halocarbons may rupture glass containers due to simple pressure build up or to exothermic polymerization in a closed vessel.
- Halogenated hydrocarbons in general exhibit low acute toxicity.
- Inhalation toxicity is greater for gaseous or volatile liquid compounds.
- The health hazard from exposure to these compounds may be due to their anesthetic actions; damaging effects on liver and kidney; and in case of certain compounds, carcinogenicity.
- The toxic symptoms are drowsiness, lack of coordination, anesthesia, hepatitis, and necrosis of the liver.
- Vapors may cause irritation of the eyes and respiratory tract.
- Death may result from cardiac arrest due to prolonged exposure to high concentrations.
- Ingestion can produce nausea, vomiting, and liver injury.

- Fluorocarbons are less toxic than the chloro-, bromo-, and iodo- compounds, the toxicity increases with increase in the mass number of the halogen atoms.
- Some of the halogenated hydrocarbons cause cancer in humans.

Examples:
Benzyl chloride
Carbon tetrachloride
Chloroform
1,2-Dichlorobenzene
Ethyl bromide
Fluorobenzene
Methylene chloride

HYDRIDES

- The single most hazardous property of hydrides is their high reactivity toward water.
- The reaction with water is violent and can be explosive with liberation of hydrogen.
- Many hydrides are flammable solids that may ignite spontaneously on exposure to moist air.
- Many ionic hydrides are strongly basic; their reactions with acids are violent and exothermic, which can cause ignition.
- Hydrides are also powerful reducing agents, they react violently with strong oxidizing substances, causing explosions.
- Covalent volatile hydrides such as arsine, silane, or germane are highly toxic.
- Ionic alkali metal hydrides are corrosive to skin, as they form caustic alkalies readily with moisture.

Examples:
Decarborane
Lithium aluminum hydride
Potassium hydride
Sodium borohydride
Sodium hydride

COMMON SOLVENTS

- The toxic effects of most of the solvents are of low order, chronic exposures or large doses can produce moderate to severe poisoning.
- Most organic solvents are flammable or combustible liquids, the vapors of which can form explosive mixtures with air.
- Many of the common solvents can cause flashback of the vapors, and some form peroxide on prolonged storage, especially those compounds containing an ether functional group, some also can form shock-sensitive solvated complexes with metal perchlorates.

Examples:
Acetamide
Acetone
Benzene
Carbon tetrachloride
Chloroform
Methyl acetate
Pyridine
Tetrahydrofuran

INORGANIC CYANIDES

- Inorganic cyanides are the metal salts of Hydrocyanic acid.
- Cyanides of alkali metals are extremely toxic.
- In addition to being extremely toxic by ingestion or skin absorption, most metal cyanides present a serious hazard of forming extremely toxic Hydrogen cyanide when they come into contact with acids.

Examples:
Barium cyanide
Cyanogen chloride
Cyanamide cyanogen
Hydrogen cyanate
Potassium cyanide
Sodium cyanide

KETONES

- Similar to aldehydes.
- In general, the toxicity is much lower than that of other functional groups, such as cyanides or amines.
- Unlike aldehydes and alcohols, some of the simplest ketones are less toxic than the higher ones.
- Beyond 7 carbons, the higher ones are almost nontoxic.
- Substitution of other functional groups can alter toxicity significantly.
- The simplest ketones are highly flammable.
- The flammability decreases with increase in the carbon number.

Examples:
Acetophenone
Acetone
Ketene
Mesityl oxide
Methyl Ethyl Ketone

MINERAL ACIDS

- Acid strengths vary widely.
- Sour in taste.
- React with a base to form salt and water.
- Produce hydrogen when reacting with most common metals.
- Produce carbon dioxide when reacting with most carbonates.
- All mineral acids are corrosive.
- Noncombustible substances.
- Some are highly reactive to certain substances, causing fire and/or explosions.

Examples:
Hydrochloric acid
Hydrofluoric acid
Hydroiodic acid
Phosphoric acid
Nitric acid
Sulfuric acid

ORGANIC CYANIDES (NITRILES)

- These are organic derivatives of Hydrocyanic acid or the cyano-substituted organic compounds.
- The CN group reacts with a large number of reactants to form a wide variety of products, such as amides, amines, carboxylic acids, aldehydes, ketones, esters, thioamides, and other compounds.
- Nitriles are highly toxic compounds, some of them are as toxic as alkali metal cyanides.
- Lower aliphatic nitriles are flammable and form explosive mixtures with air. The explosive range narrows down with an increase in the carbon chain length.

Examples:
Acrylonitrile
Acetonitrile
Butyronitrile
Cyanohydrin

ORGANIC ISOCYANATES

- Organic groups attached to the isocyanate group.
- These compounds are highly reactive due to the high unsaturation in the isocyanate functional group.
- Isocyanates in general are highly reactive toward compounds containing active hydrogen atoms.
- Most isocyanates are hazardous to health.
- They are lachrymators and irritants to the skin and mucous membranes.
- Skin contact can cause itching, eczema, and mild tanning.
- Inhalation if isocyanate vapors can produce asthma-like allergic reaction, with symptoms from difficulty in breathing to acute attacks and sudden loss of consciousness.
- Toxicities of isocyanates vary widely, in addition, health hazards differ significantly on the route of exposure but occur primarily via inhalation exposure.
- Most isocyanates have high flash points, therefore the fire hazard is low.
- However, closed containers can rupture due to the pressure built up from carbon dioxide, which is formed from reaction with moisture.

Examples:
n-Butyl isocyanate
Hexamethylene diisocyanate
Methyl isocyanate
Phenyl isocyanate

ORGANIC PEROXIDES

- Compounds containing the peroxide group bound to organic groups.
- In general the toxicity is low to moderate.
- Peroxides are a hazardous class of compounds, some of which are extremely dangerous to handle.
- The dangerous ones are highly reactive, powerful oxidizers, highly flammable and often form decomposition products, which are more flammable.

- Many organic peroxides can explode violently due to one or a combination of the following factors:
  - Mechanical shock (such as impact, jarring, or friction)
  - Heat
  - Chemical contact
- Short chain alkyl and acyl peroxides, hydroperoxides, peroxyesters, and peroxydicarbonates with low carbon numbers are a much greater hazard than the long chain peroxy compounds.
- The active oxygen content of peroxides is measured as the amount of active oxygen (from peroxide functional group) per 100 gm of the substance. The greater the percentage of active oxygen in formulation, the higher is its reactivity. An active oxygen content exceeding 9% is too dangerous for handling and shipping.

Examples:
Benzoyl peroxide
Cumene hydroperoxide
Diacetyl peroxide
Diisopropyl peroxydicarbonate
Hydroperoxyenthanol

OXIDIZERS

- Include certain classes of inorganic compounds that are strong oxidizing agents, evolving oxygen on decomposition.
- These substances are rich in oxygen and decompose violently on heating.
- The explosion hazard arises when these substances come into contact with easily oxidizable compounds such as organics, metals, or metal hydrides.
- When the solid substances are finely divided and combined, the risk of explosion is enhanced.
- The unstable intermediate products, so formed, are sensitive to heat, shock, and percussion.
- The health hazard from the substances arises due to their strong corrosive action on the skin and eyes.
- The toxicity depends on the metal ions in these molecules.

Examples:
Bromates
Chlorites
Dichromates
Hypochlorites
Iodates
Inorganic peroxides
Nitrates
Perchlorates
Periodates
Permanganates

PEROXY ACIDS

- There are 2 types: Peroxycarboxylic acids and Peroxysulfonic acids.
- Peroxycarboxylic acids are weaker acids than the corresponding carboxylic acids.
- Lower peroxy acids are volatile liquids, soluble in water.
- Higher acids with greater than 7 carbons are solids and insoluble in water.
- These compounds are highly unstable and can decompose violently on heating.

- May react dangerously with organic matter and readily oxidizable compounds.
- Among organic peroxides, peroxy acids are the most powerful oxidizing compounds.
- The lower acids are also shock sensitive, but less than some organic peroxides.
- Health hazard primarily due to their irritant actions.

Examples: Peroxyacetic acid Peroxyformic acid
Peroxybenzoic acid

PHENOLS

- Phenols are a class of organic compounds containing hydroxyl groups attached to aromatic rings.
- The hydroxyl group exhibits properties that are different from an alcoholic hydroxyl group.
- Phenols are weakly acidic, forming metal salts on reactions with caustic alkalies.
- In comparison, acid strengths of alcohols are negligibly small or several orders of magnitude lower than those of phenols.
- In comparison with many other classes of organic compounds, phenols show relatively greater toxicity.

Examples: Cresol Phenols
2-Naphthol Resorcinol
Pentachlorophenol

PHTHALATE ESTERS

- These are esters of Phthalic acid.
- They are noncombustible liquids.
- Some are EPA-listed priority pollutants.
- The acute toxicity is very low.
- High doses may produce somnolence, weight loss, dyspnea, and cyanosis.
- The pure liquids are mild irritants to the skin.
- These are relatively harmless and are among the least toxic organic industrial products.

Examples: Dibutyl phthalate Diethylhexyl Phthalate (DEHP)

Reference:

Patnaik, Pradyot, *A Comprehensive Guide to the Hazardous Properties of Chemical Substances*, Van Nostrand Reinhold, 1992.

APPENDIX 8 – PEROXIDE FORMING CHEMICALS

SAFE STORAGE PERIODS FOR PEROXIDE FORMERS	
Unopened chemicals from manufacturer	18 months or (expiration date)
Opened containers:	
Chemicals in Table A	3 months
Chemicals in Tables B and D	12 months
Uninhibited chemicals in Table C	24 hours
Inhibited chemicals in Table C (Store under an inert atmosphere)	12 months

A. Chemicals that form explosive levels of peroxides without concentration		
Butadiene[a]	Diisopropyl ether	Sodium amide (sodamide)
Chloroprene[a]	Potassium metal	Tetrafluoroethylene[a]
Divinylacetylene	Potassium amide	Vinylidene chloride
B. Chemicals that form explosive levels of peroxides on concentration		
Acetal	Diethyl ether	4-Methyl-2-pentanol
Acetaldehyde	Diethylene glycol dimethyl ether (diglyme)	2-Pentanol
Benzyl alcohol	Dioxanes	4-Penten-1-ol
2-Butanol	Ethylene glycol dimethyl ether (glyme)	1-Phenylethanol
Cumene	4-Heptanol	2-Phenylethanol
2-Cyclohexen-1-ol	2-Hexanol	2-Propanol
Cyclohexene	Methylacetylene	Tetrahydrofuran

Decahydronaphthalene	3-Methyl-1-butanol (*iso*-amyl alcohol)	Tetrahydronaphthalene
Diacetylene	Methylcyclopentane	Vinyl ethers
Dicyclopentadiene	Methyl isobutyl ketone	Other secondary alcohols
C. Chemicals that may autopolymerize as a result of peroxide accumulation		
Acrylic acid[b]	Methyl methacrylate[b]	Vinyl chloride
Acrylonitrile[b]	Styrene	Vinylpyridine
Butadiene[c]	Tetrafluoroethylene[c]	Vinyladiene chloride
Chloroprene[c]	Vinyl acetate	
Chlorotrifluoroethylene	Vinylacetylene	
D. Chemicals that may form peroxides but cannot clearly be placed in sections A-C		
Acrolein	p-Chlorophenetole	4,5-Hexadien-2-yn-1-ol
Allyl ether[d]	Cyclooctene[d]	*n*-Hexyl ether
Allyl ethyl ether	Cyclopropyl methyl ether	*o,p*-Iodophenetole
Allyl phenyl ether	Diallyl ether[d]	Isoamyl benzyl ether[d]
p-(*n*-Amyloxy)benzoyl chloride	*p*-Di-n-butoxybenzene	Isoamyl ether[d]
n-Amyl ether	1,2-Dibenzyloxyethane[d]	Isobutyl vinyl ether
Benzyl *n*-butyl ether[d]	*p*-Dibenzyloxybenzene[d]	Isophorone[d]
Benzyl ether[d]	1,2-Dichloroethyl ethyl Ether	*B*-Isopropoxypropionitrile[d]
Benzyl ethyl ether[d]	2,4-Dichlorophenetole	Isopropyl 2,4,5-trichloro-phenoxy- acetate
Benzyl methyl ether	Diethoxymethane[d]	Limonene
Benzyl 1-napthyl ether[d]	2,2-Diethoxypropane	1,5-*p*-Methadiene
1,2-Bis(2-chloroethoxy) Ethane	Diethyl ethoxymethylene-Malonate	Methyl *p*-(*n*-amyloxy)-benzoate
Bis(2 ethoxyethyl)ether	Diethyl fumarate[d]	4-Methyl-2-pentanone

Bis(2-(methoxyethoxy)-ethyl) ether	Diethyl acetal[d]	*n*-Methylphenetole
Bis(2-chloroethyl)ether	Diethyketene[f]	2-Methyltetrahydrofuran
Bis(2-ethoxyethyl)adipate	*m,o,p*-diethoxybenzene	3-Methoxy-1-butyl acetate
Bis(2-ethoxyethyl)phthalate	1,2-Diethoxyethane	2-Methoxyethanol
Bis(2-methoxyethyl)-Carbonate	Dimethoxymethane[d]	3-Methoxyethyl acetate
Bis(2-methoxyethyl) ether	1,1-Dimethoxyethane[d]	2-Methoxyethyl vinyl ether
Bis(2-methoxyethyl) Phthalate	Dimethylketene[f]	Methonxy-1,3,5,7-cyclo-octa-tetraene
Bis(2-methoxymethyl) Adipate	3,3-Dimethoxypropene	B-Methoxypropionitrile
Bis(2-n-butoxyethyl) Phthalate	2,4-Dinitrophenetole	m-Nitrophenetole
Bis(2-phenoxyethyl) ether	1,3-Dioxepane[d]	1-Octene
Bis(4-chlorobutyl) ether	Di(1-propynyl)ether[f]	Oxybis(2-ethyl acetate)
Bis(chloromethyl) ether[e]	Di(2-propynyl)ether	Oxybis(2-ethyl benzoate)
2-Bromomethyl ethyl ether	Di-*n*-propoxymethane[d]	*B,B*-oxydipropionitrile
B-Bromophenetole	1,2-Epoxy-3-isopropoxy-propane[d]	1-Pentene
o-Bromophenetole	1,2-Epoxy-3-phenoxy-Propane	Phenoxyacetyl chloride
p-Bromophenetole	*p*-Ethoxyacethophenone	*a*-Phenoxypropionyl chloride
3-Bromopropyl phenyl ether	2-Ethoxyethyl acetate	Phenyl *o*-propyl ether
1,3-Butadiyne	(2-Ethoxyethyl)-o-benzoyl Benzoate	*p*-Phenylphenetone
Buten-3-yne	1-(2-Ethoxyethoxy)ethyl Acetate	*n*-Propyl ether
tert-Butyl ethyl ether	1-Ethoxynaphthalene	*n*-Propyl isopropyl ether
tert-Butyl methyl ether	o,p-Ethoxyphenyl isocyanate	Sodium 8,11,14-eicosa-tetraenoate
n-Butyl phenyl ether	1-Ethoxy-2-propyne	Sodium ethoxyacetylide[f]
n-Butyl vinyl ether	3-Ethoxyopropionitrile	Tetrahydropyran

Chloroacetaldehyde diethylacetal[d]	2-Ethylacrylaldehyde oxime	Triethylene glycol diacetate
2-Chlorobutadiene	2-Ethylbutanol	Triethylene glycol dipropionate
1-(2-Chloroethoxy)-2-phen-oxyethane	Ethyl *B*-ethoxypropionate	1,3,3-Trimethoxypropene[d]
Chloroethylene	2-Ethylhexanal	1,1,2,3-Tetrachloro-1,3-butadiene
Chloromethyl methyl ether[e]	Ethyl vinyl ether	4-Vinyl cyclohexene
β-Chlorophenetole	Furan	Vinylene carbonate
o-Chlorophenetole	2,5-Hexadiyn-1-ol	Vinylidene chloride[d]

NOTES:

[a] When stored as a liquid monomer.

[b] Although these chemicals form peroxides, no explosions involving these monomers have been reported.

[c] When stored in liquid form, these chemicals form explosive levels of peroxides without concentration. They may also be stored as a gas in gas cylinders. When stored as a gas, these chemicals may autopolymerize as a result of peroxide accumulation.

[d] These chemicals easily form peroxides and should probably be considered under Part B.

[e] OSHA - regulated carcinogen.

[f] Extremely reactive and unstable compound.

References:

Prudent Practices in the Laboratory, National Research Council, 1995.
"Review of Safety Guidelines for Peroxidizable Organic Chemicals," *Chemical Health and Safety*, September/October 1996.

APPENDIX 9 – INCOMPATIBLE CHEMICALS

Substances in the left-hand column should be stored and handled so they cannot contact corresponding substances in the right-hand column. The following list contains some of the chemicals commonly found in laboratories, but it should not be considered exhaustive. Information for the specific chemical you are using can usually be found in the "REACTIVITY" or "INCOMPATIBILITIES" section of the Safety Data Sheet.

Alkaline and alkaline earth metals, such as Sodium, Potassium, Cesium, Lithium, Magnesium, Calcium	Carbon dioxide, Carbon tetrachloride and other chlorinated hydrocarbons, any free acid or halogen. Do not use water, foam or dry chemical on fires involving these metals.
Acetic acid	Chromic acid, Nitric acid, hydroxyl compounds, Ethylene glycol, Perchloric acid, peroxides, permanganates
Acetic anhydride	Chromic acid, Nitric acid, hydroxyl-containing compounds, Ethylene glycol, Perchloric acid, peroxides and permanganates
Acetone	Concentrated Nitric and Sulfuric acid mixtures
Acetylene	Copper, Silver, Mercury and halogens, Fluorine, Chlorine, Bromine
Alkali & alkaline earth metals (such as powdered Aluminum or Magnesium, Calcium, Lithium, Sodium, Potassium)	Water, Carbon tetrachloride or other chlorinated hydrocarbons, Carbon dioxide, and halogens
Aluminum alkyls	Halogenated hydrocarbons, water
Ammonia (anhydrous)	Silver, Mercury, Chlorine, Calcium hypochlorite, Iodine, Bromine, Hydrogen fluoride, Chlorine dioxide, Hydrofluoric acid (anhydrous)
Ammonium nitrate	Acids, metal powders, flammable liquids, chlorates, nitrites, Sulfur, finely divided organics or combustibles
Aniline	Nitric acid, Hydrogen peroxide
Arsenical materials	Any reducing agent
Azides	Acids, halogenated solvents (e.g. chloroform, dichloromethane)
Benzoyl peroxide	Chloroform, organic materials

Bromine	Ammonia, Acetylene, Butadiene, Butane and other petroleum gases, Sodium carbide, Turpentine, Benzene and finely divided metals, Methane, Propane, Hydrogen
Calcium carbide	Water (see also Acetylene)
Calcium hypochlorite	Acids, Methyl carbitol, Phenol, Glycerol, Nitromethane, Iron oxide, Ammonia, activated carbon
Calcium oxide	Water
Carbon, activated	Calcium hypochlorite, all oxidizing agents
Carbon tetrachloride	Sodium
Chlorates	Ammonium salts, acids, metal powders, Sulfur, finely divided organics or combustibles
Chlorine	Ammonia, Acetylene, Butadiene, Butane, Propane, and other petroleum gases, Hydrogen, Sodium carbide, Turpentine, Benzene and finely divided metals, Methane
Chlorine dioxide	Ammonia, Methane, Phosphine and Hydrogen sulfide
Chlorosulfonic acid	Organic materials, water, powdered metals
Chromic acid & Chromium trioxide	Acetic acid, Naphthalene, Camphor, Glycerin, Turpentine, alcohol and other flammable liquids, paper or cellulose
Copper	Acetylene, Hydrogen peroxide, Ethylene oxide
Cumene hydroperoxide	Acids, organic or mineral
Cyanides	Acids
Ethylene oxide	Acids, bases, Copper, Magnesium perchlorate
Flammable liquids	Ammonium nitrate, Chromic acid, Hydrogen peroxide, Nitric acid, Sodium peroxide, halogens
Fluorine	Almost all oxidizable substances
Hydrocarbons (such as Bromine, Butane)	Fluorine, Chlorine, Chromic acid, Sodium peroxide
Hydrocyanic acid	Nitric acid, alkalis
Hydrofluoric acid (anhydrous)	Ammonia (aqueous or anhydrous)
Hydrogen peroxide	Copper, Chromium, Iron, most metals or their salts, any flammable liquid, combustible materials, Aniline,

	Nitromethane, alcohols, Acetone, organic materials, Aniline
Hydrides	Water, air, Carbon dioxide, chlorinated hydrocarbons
Hydrofluoric acid, anhydrous (Hydrogen fluoride)	Ammonia (anhydrous or aqueous), organic peroxides
Hydrogen sulfide	Fuming Nitric acid, oxidizing gases
Hydrocarbons (Benzene, Butane, Propane, Gasoline, Turpentine, etc.)	Fluorine, Chlorine, Bromine, Chromic acid, Sodium peroxide, fuming Nitric acid
Hydroxylamine	Barium oxide, Lead dioxide, Phosphorus pentachloride and trichloride, Zinc, Potassium dichromate
Hypochlorites	Acids, activated Carbon
Iodine	Acetylene, Ammonia (anhydrous or aqueous), Hydrogen
Maleic anhydride	Sodium hydroxide, Pyridine and other tertiary amines
Mercury	Acetylene, Fulminic acid, Ammonia, Oxalic acid
Nitrates	Acids, metal powders, flammable liquids, chlorates, sulfur, finely divided organics or combustibles, Sulfuric acid
Nitric acid (concentrated)	Acetic acid, Aniline, Chromic acid, Hydrocyanic acid, Hydrogen sulfide, flammable liquids, flammable gases, nitratable substances, organic peroxides, chlorates, Copper, brass, any heavy metals
Nitroparaffins	Inorganic bases, amines
Oxygen	Oil, grease, Hydrogen, flammable liquids, solids, or gases
Oxalic acid	Silver, mercury, organic peroxides
Perchlorates	Acids, organics
Perchloric acid	Acetic anhydride, Bismuth and its alloys, alcohol, paper, wood, grease, oil, organic amines or antioxidants
Peroxides, organic	Acids (organic or mineral); avoid friction, store cold
Phosphorus (white)	Air, Oxygen, alkalis, reducing agents
Phosphorus pentoxide	Propargyl alcohol

Potassium	Carbon tetrachloride, Carbon dioxide, water
Potassium chlorate	Acids, organics, sulfur, Sulfuric acid (see also chlorates)
Potassium perchlorate	Sulfuric & other acids (see also Perchloric acid, & chlorates)
Potassium permanganate	Glycerin, Ethylene glycol, Benzaldehyde, any free acid, Sulfuric acid
Selenides	Reducing agents
Silver	Acetylene, Oxalic acid, Tartaric acid, Fulminic acid, ammonium compounds
Sodium	Carbon tetrachloride, Carbon dioxide, water. See alkaline metals (above)
Sodium amide	Air, water
Sodium nitrate	Ammonium nitrate and other ammonium salts, organics
Sodium oxide	Water, any free acid
Sodium peroxide	Any oxidizable substance, such as Ethanol, Methanol, glacial Acetic acid, Acetic anhydride, Benzaldehyde, Carbon disulfide, Glycerine, Ethylene glycol, Ethyl acetate, Methyl acetate and Furfural
Sulfides	Acids
Sulfuric acid	Chlorates, perchlorates, permanganates, organic peroxides. Potassium chlorate, Potassium perchlorate, Potassium permanganate (similar compounds of light metals, such as Sodium, Lithium), methanol, carbohydrates
Tellurides	Reducing agents
UDMH (1,1-Dimethylhydrazine)	Oxidizing agents such as Hydrogen peroxide and fuming Nitric acid
Zirconium	Prohibit water, Carbon tetrachloride, foam and dry chemical on zirconium fires

APPENDIX 10 – HSE CHEMICAL SEGREGATION SCHEME

KEY

Hazard Class # – All Hazard Classes must be segregated from other **Hazard Classes**
- Class – must segregate from other Classes within **Hazard Class**
    - *Group – recommend to segregate from other groups within* Class

Hazard Class 1 - Explosives (potentially explosive)

Hazard Class 2 - Compressed Gases / Lecture Bottles
- Class 2.1 - Flammable gases
- Class 2.2 - Non-Flammable gases
- Class 2.3 - Poisonous gases
- Oxidizing gases (separate from everything)
- Corrosive – acids
- Corrosive – bases
- Cryogenics
- Pyrophorics

Hazard Class 3 - Flammable liquids
- Combustible liquids (that do not have another hazard)

Hazard Class 4 - Flammable solids
- Class 4.1 - Flammable solids
- Class 4.2 - Spontaneously combustible
- Class 4.3 - Dangerous When Wet

Hazard Class 5 - Oxidizers
- Class 5.1 – Oxidizers
    - *Liquids*
    - *Solids*

- Class 5.2 - Organic peroxides

Hazard Class 6 - Poisons
- Class 6.1 - Poisons
    - *Liquids*
    - *Solids*
    - *Carcinogens*
    - *Reproductive hazards (Teratogens, Mutagens)*
    - *Irritants*
    - *Organic acids, solid*

  - *Nonhazardous chemicals*

- Poison Inhalation Hazards (PIH)
- Cyanides
- Controlled substances
- Class 6.2 - Biohazards – Infectious agents
  - *CDC Select agents*

Hazard Class 7 - Radioactives

Hazard Class 8 - Corrosives

- Inorganic acids
- Oxidizing acids (Nitric acid and Perchloric acid)
- Hydrofluoric acid
- Organic acids, liquid (can store in flammable cabinet)
- Bases
  - *Liquids*
  - *Solids*

Hazard Class 9 – Miscellaneous

- *For KAUST segregation purposes, these materials can be stored with* **Hazard Class 6 - Poisons**

APPENDIX 11 – FLAMMABLE AND TOXIC GAS CYLINDERS

COMMON COMPRESSED AND LIQUEFIED GASES WHICH ARE FLAMMABLE OR TOXIC (HEALTH 3 OR 4)

Gas	State	Flammable	Health
Acetylene	gas	y	
Allene (propadiene)	liquid	y	
Ammonia	liquid	y	3
Arsine	liquid	y	4
Boron Trichloride	gas	n	3
Boron Trifluoride	gas	n	3
1,3-Butadiene	liquid	y	
n-Butane	liquid	y	
iso-Butane	liquid	y	
1-Butene	liquid	y	
2-Butene	liquid	y	
Carbon Monoxide	gas	y	3
Carbonyl Chloride (phosgene)	gas	n	4
Carbonyl Fluoride	gas	n	4
Carbonyl Sulfide	liquid	y	3
Chlorine	gas	n	3
Chlorine Dioxide	gas	n	4
Chlorine Monoxide	gas	y	3
Chlorine Trifluoride	gas	n	4
1-Chloro-1,1-difluoroethane	liquid	y	
Chlorotrifluoroethylene	liquid	y	
Cyanogen	liquid	n	4
Cyanogen Chloride	liquid	n	4
Cyclobutane	gas	y	
Cyclopropane	liquid	y	
Deuterium	gas	y	
Diazomethane	gas	y	4
Diborane	gas	spontaneously ignitible	3
1,1-Difluoroethane	liquid	y	
1,1-Difluoroethylene	liquid	y	3
Dimethylamine	gas	y	3
Dimethyl Ether	liquid	y	
2,2-Dimethylpropane	liquid	y	
Ethane	gas	y	
Ethylacetylene	liquid	y	
Ethylamine	liquid	y	3
Ethyl Chloride	liquid	y	
Ethylene	gas	y	
Ethylene Oxide	liquid	y	3
Fluorine	gas	n	4
Formaldehyde	gas	y	3
Germane	gas	y	
Hexafluoroacetone	gas	n	3
Hydrogen	gas	y	
Hydrogen Bromide	gas	n	3
Hydrogen Chloride	gas	n	3
Hydrogen Cyanide	liquid	y	4
Hydrogen Fluoride	gas	n	4
Hydrogen Selenide	liquid	y	3
Hydrogen Sulfide	liquid	y	4
Ketene	gas	y	
Methane	gas	y	
Methylacetylene (propyne)	liquid	y	
Methylamine	liquid	y	3
Methylbromide	liquid	y	3
3-Methyl-1-butene	liquid	y	
Methyl Chloride	liquid	y	
Methyl Ether	gas	y	
Methyl Fluoride	liquid	y	
Methyl Mercaptan	liquid	y	4
2-Methylpropene	gas	y	
Natural Gas	gas	y	
Nitric Oxide	gas	n	3
Nitrogen Dioxide	gas	n	3
Nitrogen Trioxide	gas	n	3
Nitrogen Trifluoride	gas	n	3
Nitrosyl Chloride	gas	n	3
Oxygen Difluoride	gas	n	4
Ozone	gas	n	4
Pentaborane	liquid	spontaneously ignitible	4
iso-Pentane	liquid	y	
Phosphine	gas	spontaneously flammable	4
Propane	liquid	y	
Propylene	liquid	y	
Selenium Hexafluoride	gas	n	3
Silane	gas	spontaneously flammable	
Silicon Tetrafluoride	gas	n	4
Stibine	gas	y	4
Sulfur Tetrafluoride	gas	n	4
Sulfuryl Fluoride	gas	n	
Tetrafluoroethylene, monomer	liquid	y	
Tetrafluorohydrazine	liquid	y	
Trimethylamine	liquid	y	3
Vinyl Bromide	liquid	y	
Vinyl Chloride	liquid	y	
Vinyl Fluoride	liquid	y	
Vinyl Methyl Ether	liquid	y	