DEPARTMENT OF CHEMISTRY
NATIONAL UNIVERSITY OF SINGAPORE

Safety Manual

2016-2017

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CONTENTS

Safety, Health and Environmental Policy

The Department of Chemistry is committed to the provision of a safe and healthy working, training and learning environment for all its faculty members, nonacademic staff members, students and visitors. The Department aims to prevent any accidents from occurring and will take all possible steps to make the Department a safe workplace. Where reasonably and practically possible, the Department is committed to:

1. Safety and Health

Making every effort to ensure health and safety in all phases of teaching, research, and in the development and commissioning of equipment/experiments and facilities. In this respect, we will identify all safety and health hazards and review constantly safety and health policies, rules and guidelines to reduce, if not eliminate, any hazards present. We will ensure that all faculty members, nonacademic staff members, students, contractors and visitors take it as a personal responsibility to prevent injury to themselves and/or their colleagues.

2. No Accidents and Injuries

Making every effort to achieve a safe and healthy working environment.

3. Environmental Protection

Making every effort to minimize and defuse wastes and emissions so as to preserve the local environment and also to save energy and natural resources in order to ensure that the global environment can be protected.

4. Conformance with Laws and Regulations

Complying with all relevant University and legal requirements in relation to safety, health and environmental policies.

5. Education and Training

Establishing and promoting safety and health awareness by offering both in-house or external training courses, and communicating the importance of such awareness to prevent accidents and injuries.

6. Continual Improvement

Establishing and implementing a management system to ensure health and safety in our activities as well as to protect the environment, and continually improving this system at all levels of our organization.

Health and Safety Procedures in the Department of Chemistry

If your time is to be spent in Office or Computing work solely, the information that you need to absorb will not be great, but for those working in workshops and laboratories, there is much more, in keeping with the greater potential hazards in those areas, hence it is important that you spend some time to read the Safety Manual.

Risk Assessments

Risk Assessments are procedures to estimate the risks to Health and Safety associated with any work activities you perform and to devise rules and methods of work to minimise these risks. The Workplace Safety & Health Act requires that Risk Assessments be carried out for all work that you do and that you are informed of the outcome of the assessment and are trained to carry out your duties safely. The Risk Assessment procedure applies to all kinds of work activities from the use of computer equipment to the manual handling of heavy items. "Standard Assessment" implies that the application of good laboratory practice is sufficient for the safe handling of materials but in the case of a "Special Assessment" the risks associated with the particular substance **as it is to be used**, the precautions to be taken in handling, measures for adequate control, the action to be taken in an emergency (for example a spillage) and the procedures for safe disposal all should be recorded.

If you are working in a Laboratory

Risk Assessments: Before proceeding with your research work, risk assessment has to be carried out. There are Prepared Risk Assessments for a number of common activities that may be relevant to your work. You must read these and record the fact that you have read these Assessments, so you should go to the section below entitled "**Forms you need to complete**". In addition you should also complete a comprehensive activity-based risk assessment for your work. The completed forms must be signed by your supervisor and should be kept by you in the lab.

Who makes the Assessment?

Involving students in preliminary assessment work for their own projects (i.e. researching information on substances and how they are used, identifying the measures necessary for adequate control *etc*.) is useful training. It is important to note that it remains the responsibility of the Supervisor to validate such Assessments and that the Regulations call for the Assessment to be made by a "competent person" who may not be the student. Category 1 and Category 2 Carcinogens require special consideration.

Review of Assessments

As projects develop, the nature of the work and experimental techniques may change. Procedures not included in the initial Assessment should not be started without being assessed in the same way; regular review of Assessments is therefore required. In any case, all Assessments should be reviewed annually at the beginning of each Academic year.

It is the responsibility of the Supervisor to see that all relevant Risk Assessments have been carried out for every research worker under his/her care and that all the appropriate safety documentation **has been completed irrespective of the nature of the research work.**

If you are not working in a Laboratory or Workshop

If your workplace is not a laboratory or workshop, e.g., if you are a member of the office staff or a researcher carrying out a project which is purely computational, then the only Prepared Risk Assessments you need to read are those concerning ***General Office Work***, ***Visual Display Equipment*** and ***Standard Electrical Equipmentl***

You need to record the fact that you have read these Assessments and so you should go to the Section Below entitled "**Forms you need to complete**".

Teaching Laboratory Technical Staff

There are specially prepared Risk Assessment documents and forms for Teaching Laboratory Technical Staff.

If you are working in a Workshop or Stores

Local specific rules and Risk Assessments apply if you are working in Stores or Workshops.

Forms you must Complete

If you are carrying out research work in the Department of Chemistry, once you have read the appropriate **Prepared Risk Assessments**, then you must:-

- Complete the **Risk Assessment Record Form for Graduates and Research Workers** remembering to indicate your status (Undergraduate, Graduate, etc.) and giving a brief description of your Research project.
- Sign the form and have it signed by your Supervisor.
- Keep the hardcopy in your laboratory.
- **This form must be renewed if the nature of your research project changes substantially.**
- You must carry out a detailed step-by-step risk assessment for each procedure using the Excel file risk assessment.

Personnel Responsibilities

1. **The Head of Department** has ultimate responsibility for the provision of a safe working environment within the Department of Chemistry.
2. **All Members of the Department including all Students, Research Workers, Postdoctoral Researchers and Visitors** have a duty to co-operate with the Head of Department or representative in any matters relating to health and safety.
3. **Academic Staff Members**, as Supervisors or as Teaching Laboratory, Organisers and Academic Demonstrators of students, are responsible for all matters relating to the health and safety at work of students in their care.
4. **Lab Officers and Technologists in charge of Labs, Stores and Workshops** are responsible for all matters relating to the health and safety at work of persons employed in their Labs, Stores or Workshops and under their care.

5. **All Employees, including Undergraduate and Graduate Students, Postdoctoral Researchers, Research Workers and Visitors** have a duty to take care of their own Health and Safety and that of others who may be affected by their activities.

Research Supervisors/Principal Investigators

The primary responsibility of the supervisor/principal investigator is to implement the safety plan.

Student Research Projects (UROPS and Honours)
Students are required to undergo the Faculty of Science's safety orientation training before undertaking their projects. Where student projects are concerned, effective or adequate supervision does not necessarily (or even usually) mean constant attendance. Also, where attendance is necessary, this can be carried out by the Supervisor or his/her nominee, providing that nominee is competent to carry out such supervision and agrees to do so. The day to day supervision appropriate to any particular set of circumstances is difficult to quantify but there are fundamental elements about which the Supervisor must satisfy themselves. **It is the responsibility of the Supervisor to ensure that**:
the project is properly assessed for:

- compliance with existing Departmental procedures;
- general risks to health and safety. A written Risk Assessment is required unless the risks are not significant;
- compliance with any University local rules.

In all but the most elementary circumstances, the results of such an Assessment are committed to writing and made clear to the student, any precautions which are necessary are agreed between the Supervisor and student and again committed to writing and that, at the same time, students are made aware of their legal duty not to behave in a way that is likely to cause harm to themselves or to others;

Regular checks are carried out by the Supervisor to see that the student is actually following the agreed procedures;

It has been made clear to the student that alterations in method must be documented and discussed rather than introduced without the Supervisor's approval.

Supervisors should identify areas of work and classify them in the following risk categories:

A	Those in which work may **not be undertaken without close senior supervision i.e. the presence of the Supervisor or of a Senior Post-Doctoral nominated by the Supervisor**
Bp	Those in which work may **not be started without Supervisor's advice**. (Graduate)
Bu	Those in which work may **not be started without Supervisor's advice**.(Undergraduate)
C	Those with some risks (other than A and B) where care must be observed but it is considered that workers are adequately trained and competent in the procedures involved.
D	General laboratory practice.
E	Those which, even without training, have very low levels of risk.

- **Tasks in category A** should **never** be assigned to Undergraduates. Post-doctoral Fellows and Academic Visitors **may** be considered to be senior **if they themselves are carrying out the work**.
- **Those in category B** are subdivided depending on the experience of the researcher.
- **Tasks C** require a small amount of training but form a large part of the "background" of

daily business and fall outside of Category D. **Note that the use of Visual Display Equipment falls within Category C**.

- **Tasks D**, *i.e*. General Laboratory Practice, includes the procedures covered in Undergraduate Teaching Laboratories and in which all persons due to carry out research work are reasonably expected to be competent.
- **Tasks E** are associated with projects that are purely theoretical or computational and which require no written risk assessment **except if the use of VDU equipment plays a large part in that project in which case Category C applies**.

For all but the lowest categories of work (D and E), Supervisors are required to complete a Risk Assessment, or validate one prepared by the research worker, *before work begins*. The Assessment needs to consider and identify:

1. The hazards associated with the activity, the likelihood that these hazards will be realised, the severity of any consequences, the frequency of exposure and the identity of those at risk.
2. The control measure to be employed, the precautions to be taken by the researcher to reduce the level of risk as far as reasonably possible including any training to be undertaken, protective clothing to be worn and the actions to be taken in the event of an emergency (what, for example, should be done if the alarm bells ring part way through a procedure?), loss of services *etc.* Note that it may not be sufficient, for example, to say simply "wear gloves"; the glove material, thickness *etc*. may need to be specified.
3. The residual risks associated with the activity when all reasonable control measures are in place and hence its risk category as defined above.

Supervisor Absences

In the Department of Chemistry, arrangements must be made for a temporary, alternative Supervisor during absences of the regular Supervisor for any significant period. The written form, signed by both parties, must be given to the Departmental Secretary. What constitutes a "significant period" will depend upon the nature of the project, *e.g*. computational versus experimental, and the experience of the students; however, Supervisors are recommended to be conservative in their estimate and, for laboratory based projects, two to three days absence should be considered as significant. It is the responsibility of the regular Supervisor to ensure that the deputy is capable of acting as an alternate Supervisor, that the deputy has been informed of the absence and that the students involved know the identity of the deputy.

Safe Working Environment

The responsibility of a research Supervisor to maintain a safe working environment for research students extends to the physical fabric of the laboratory, *i.e*., to the state of housekeeping in the laboratory, the safety and testing of electrical equipment, the operation of safety equipment such as fume-hoods, glove-boxes *etc*., the level of lighting, the state of floors and so on. Although other people within the Department and University have the brief to maintain and repair much of this fabric, it remains the ultimate responsibility of the Supervisor to see that that students are not working in unsafe conditions or with unsafe equipment and that the appropriate people are informed when repairs are needed.

Emergency Equipment

The Supervisor (PI) of the lab should ensure that all emergency equipment i.e. fire extinguishers, fire blankets, eye wash stations etc. are maintained in good working order and that new workers are informed of the location and means of operation of this equipment.

Inspections

The Supervisor should carry out regular inspections of his/her laboratory (ies) to ensure that they are in a safe and acceptable state and that procedures recommended as a result of Risk Assessments are being followed.

Discipline

Where those being supervised show a persistent disregard for matters of safety, the Supervisor is advised to use University disciplinary procedures to ensure that the safety of the person concerned, and anyone else who might be adversely affected, is maintained.

Academic Visitors, Post-doctoral Fellows, Research Workers

Whilst these people may be expected to show a higher degree of skill and ability than an Undergraduate or Graduate student, it should be noted that they assume the status of employees and as such have the responsibility to obey all appropriate Regulations and to adhere to Departmental Safety Policies. Irrespective of competence or status, the appropriate activity Risk Assessments must be made and, for example, even very experienced laser users must be registered as users within the Department.

It is the responsibility of the Academic member of staff who invites an Academic Visitor or who engages a Post-doctoral Fellow to ensure that they are informed of their duties in these respects.

It is also the responsibility of the Academic member of staff who invites an Academic Visitor or who engages a Post-doctoral Assistant to ensure that the Head and the Departmental Safety Committee is informed of their presence in the Department especially if they arrive at times other than the normal start of Session.

Accidents and Incidents

It is the responsibility of the Supervisor in charge of a laboratory to report in writing any accidents or dangerous incidents, of which they are aware, occurring within that laboratory or involving any student for whom they are the Supervisor. In the first instance any such accidents or dangerous incidents should be reported to the Departmental Safety Committee and the online form to OSHE submitted. For accidents/incidents that occur after hours, students and workers should report to their Supervisor who in turn, will inform the Department Safety Officer and the Safety Chair. Accident reporting is mandatory under the Workplace Safety & Health Act.

Safety Inspections/Audits

From time to time, areas within the Department of Chemistry are subject to inspections in respect of health and safety carried out by the Departmental Safety Committee or the Faculty Safety Officer. The aim of these inspections is to check the completeness of any Risk Assessments, for that area, to check that work procedures recommended as a result of such Assessments and Department safety policies are being adhered to and that the area is free of obvious avoidable hazards and constitutes a safe working environment. Written reports outlining the findings of such inspections and recommendations for improvement are sent to Supervisors responsible for those areas, who are then required to implement those recommendations.

Supervised Practical Teaching

It is assumed that undergraduate experiments have been approved by the Teaching Committee.

Risk Assessments

The student should read the prepared risk assessments relevant to his/her work and verify that he/she has done so. Undergraduates working in the teaching lab should read the Undergraduate Safety Note, and pass the "undergraduate safety test" (as a part of assessments for each lab module) and also complete the respective pre-lab assignments of experiments before he or she perform them in the teaching labs. In addition, risk assessments forms for each experiments can be found online.

Other Assessments

A number of simple Risk Assessments and operating procedures are made available to all students including the use of Fume-hoods, the use of Glassware (one of the major causes of injury in the teaching laboratory), use of standard Electrical Equipment, use of Laboratory Heating Equipment (Bunsen burners and steam-baths) and use of Reduced Pressure Equipment (water pumps and rotary evaporators).

If other items of equipment are used or procedures followed which carry more than minimal risks, Assessments must be made and information and instruction passed to the students. This is the responsibility of the Academic-in-charge.

Review Period

Safety information and Assessments should be reviewed annually and revised as necessary.

Academic-in-Charge of Teaching Lab

The main duty of the Academic-in-charge is to provide immediate supervision of the Teaching Laboratory **at all times when students are present** and to ensure that:

- local rules and work practices are followed and that the well-being of all students in the Laboratory is protected;
- students are taught to carry out procedures in a safe way and that any perceived unsafe practices are corrected;
- accidents or dangerous incidents are reported in writing to the Chemistry Safety Committee
- in the case of emergency alarms all students are ushered from the Laboratory via the normal exit to the appropriate assembly point;
- any student who shows persistent disregard for matters of safety is warned that this is a disciplinary offence and the matter is reported in writing to the Chemistry Safety Committee.

Local Rules and Introductory Talks

In the course of introductory talks to Laboratory sessions, students should be informed about detailed rules operating in the Teaching Laboratories (e.g. no eating or drinking, long hair to be tied back *etc.*). It does not convey a consistent message if some laboratories allow students to enter without wearing safety glasses and others insist on them. The hard and fast rule should be that students are not allowed into the laboratory area without wearing safety glasses. In the course of introduction to Laboratories, students should be shown the normal route of exit when the emergency alarm sounds, the position of fire extinguishers, blankets and any other emergency equipment.

Discipline

Academic-in-charge of Teaching Laboratories aided by Teaching Assistants must ensure that local safety rules such as those requiring wearing of Safety Glasses and Lab-Coats are obeyed at all times. Any student who, despite warnings, show a persistent disregard for matters of safety should be warned that this is a disciplinary offence and, if repeated, must be required to leave the laboratory in order to ensure that their own safety, and that of anyone else who might be adversely affected, is maintained.

Accidents and Incidents

It is the duty of the Academic-in-charge to report in writing any accidents or dangerous incidents, of which they are aware, occurring within that laboratory or involving any student for whom they are responsible. **In the first instance any such accidents or dangerous incidents should be reported to the Chemistry Safety Committee before informing OSHE via the online accident/incident website (https://staffweb.nus.edu.sg/oshe/submit_airs.htm).**

Teaching Assistants

Teaching assistants are normally employed to assist the Academic Demonstrator in the running of Teaching Laboratories. As such they have considerable responsibility for ensuring the Safety of Undergraduates in these laboratories and, in order to be able fulfill there responsibilities,
Teaching Assistants should prepare themselves by becoming familiar with:-

- experiments,
- the local Safety Rules of the Teaching Laboratory in question by attending any introductory talks which include Safety Information and by reading the Department of Chemistry Undergraduate Safety Note document. Demonstrators must themselves obey all local Safety Rules including, for example, the wearing of Safety Glasses and fastened Lab coats,
- the Emergency Evacuation Procedure including the Evacuation Route from the Laboratory,
- the location of Emergency Equipment i.e. fire extinguishers, fire blankets and safety showers serving the Laboratory,
- any Risk Assessments relevant to procedures or substances used in the Teaching Laboratory so that they are aware of any particular hazards associated with the experiments and the steps to take in the event of an accident.

When laboratories are in progress, the Teaching Assistant must ensure that:

- students in the laboratory obey all the local Safety Rules. Repeated breach of these Rules must be reported to the Academic-in-charge of the Laboratory,
- students are taught to carry out procedures in a safe way and that any perceived unsafe practices are corrected,
- in the event of an Emergency Alarm, students are assisted in making their work safe and are directed to the proper exits as soon as possible. All Teaching Assistants should assist in ushering students out of the Building,
- all accidents and dangerous incidents are reported immediately to the Academic-in-charge.

Coping with an Emergency

Normal Working Hours: **These are from 8:30 a.m. to 6:00 p.m. Monday to Thursday and 8:30 am to 5:30 pm on Friday.**

Precautions

Know at least *two* routes from your workplace to an Exit.
Know the locations of: **Telephones**, **Fire Extinguishers and Blankets**, **Fire Alarm Points, Safety Showers, Eye Wash Stations** and **First Aid Boxes.**
Know how to contact Campus Security.
Know how to switch off electricity, gas, water etc. in and around *your* workplace.

Evacuation Procedure

All tests sounding of the alarms will be notified in advance. **In the event of an evacuation, follow the route given in the Dept of Chemistry Emergency Evacuation Route map. Never use a lift.** Assemble away from danger and clear of the building. Do not re-enter the building until you are told that it is safe to do so.

Fire	If the fire is clearly minor, tackle it with an extinguisher **but do not endanger yourself.** Normally the sensors will detect any fire and the Alarm will operate automatically. Otherwise, operate the nearest Alarm Point and call Campus Security at 6874 1616.
Escape of Toxic Material	Leave the area immediately. Close all doors on exit. **Operate the nearest Fire Alarm Point**. Warn people to avoid the affected area and inform Campus Security at 6874 1616.
Aiding an Injured Person	Either phone for a First Aider or if more serious call Campus Security at 6874 1616 first, then a First Aider. **Even if the Alarms sound, do not attempt to move the injured person out of the building unless there is imminent danger.** Stay with the injured person until help arrives. If the injury is slight they should be taken by taxi with a First Aider in attendance or, if the injury is more serious, by Ambulance.
Flood	If it is obvious, stop the leak; phone Campus Security at 6874 1616. Warn people in labs below to safeguard papers and equipment. **Do not attempt to move wet electrical equipment until it is disconnected from the mains.**
Failure of Mains Service	Failure of fume-hood, gas, water, electricity or lift during working hours, call Maintenance Response Centre at 61515. **Out of hours, call Campus Security at 6874 1616.**

Emergency Telephone Numbers	**Departmental Safety Office**	**62691**
	Security	**6874 1616**
	Maintenance Response Centre	61515
	Police	999
	Fire/Ambulance	995
	Nearest hospital (NUH)	

Basic First Aid

**If anyone becomes unconscious following an injury,
call 6874 1616 (security) if after office hours**

Cuts

Control the bleeding by applying pressure over the wound with a pad of paper tissue or towel roll.
Do not attempt to remove any broken glass etc.
Seek medical attention.

Avoid contact with blood

Burns

Douse the burn with copious amounts of cold water e.g. under a running tap.
Do not attempt to remove anything sticking to the burn.
Seek medical attention.

Chemicals

On Skin: Wash off with copious amounts of water. Seek medical attention if necessary.

In Eyes: If available use an eye-wash spray with the eyelids held open. Otherwise use a cold running tap. Seek medical attention if necessary.

Inhaled: If possible, move to fresh air. Seek medical attention.

Swallowed: Seek medical attention. Identify the chemical.

Electricity
Switch off power. Call 6874 1616 for help.

Other injuries - falls, blows
Call for medical attention.

First Aiders

In the event of a serious injury, use the emergency number 6874 1616 which accesses University Security on a 24 hour line.

For minor injuries, First Aiders may be called.

Jiang Xiaohui	68990	FST Lab, S14-05-02C
Lee, Adrian Michael	65130	S7-04-13
Lee Chooi Lan	68990	FST Lab, S14-05-02C
Leng Zhi Jin	62691	Lab Supplies, S5-B1
Lew Huey Lee	68990	FST Lab, S14-05-02C
Lin Hansheng	62690	Physical Lab, S5-01-05
Ong Bee Hoon	62685	Analytical Lab, S8-04
Linda Janti Oei	66318	General Office, S8-03

IN CASE OF SEVERE ACCIDENT, RING 6874 1616 FIRST.

First Aid Boxes

First Aid Boxes should be kept stocked according to the list posted on the front or within the box. If the plastic lock is broken, the items taken need to be replaced.
All First Aid material is available from the Chemistry Store and Staff in charge of laboratories should nominate a member of that laboratory to see that the stock of the First Aid box is regularly maintained.

Emergency (Fire) Alarms

The buildings in the Chemistry Department are equipped with a fire detection system that will sound the alarms if a sensor detects flame, heat or smoke or if the break-glass alarm button is activated.

There is unfortunately a high incidence of false alarms on campus due to ageing and defective fire detectors. **In the event of an alarm, spend a few seconds** only in turning off heating equipment or making your experiment safe before leaving the building by the route that has been described to you. Do not use the lifts. Assemble at the designated area – **multipurpose field** - for a roll-call.

Do not attempt to enter the building until you have been told it is safe to do so.

Preventing Fires and Floods

A laboratory door signage must be clearly posted outside each lab. The form gives details on the person(s) to contact in case of emergency and the type of hazards to be expected in the lab. The form can be downloaded from https://wws.nus.edu.sg/osh/labsign/default.aspx.

Fire: Apart from the obvious dangers of horrendous injury and even death, fires are enormously destructive. **Remember, after a fire, you may have lost all of your work and your equipment will be gone.**

The Fire Detection System: All parts of the Department of Chemistry are fitted with fire detectors that are on alert at all times. A red light appears when a detector is activated, the alarms sound and you must leave the building until the alarm is over.

Take great care to avoid causing "false" alarms. However if you think that something you have done has caused the alarm, inform Campus Security at 6874 1616 immediately.

Solvents in Laboratories: You should store only a working minimum of flammable solvents in your laboratory since, in the event of fire, excess amounts of solvent could endanger life and the fabric of the building. **In any case, for legal purposes no more than the quantity permitted under the Petroleum and Flammable Licence is allowed (1.6 L/m^2). For an average lab size of 60 m^2, this works out to 96 L of flammable or highly flammable liquids that may be stored in any one laboratory or workshop**. As far as possible, and certainly overnight, solvents should be stored in the ventilated safety cabinet provided for the purpose.

Leaving a Laboratory or Workshop: When you leave your workplace in the evening or during the day if you are to be away for long, you have the responsibility to check that:

- there are no obvious problems with reactions or equipment left running (these should be properly labelled).
- unnecessary electrical equipment, e.g. ovens, are turned off and **no naked flame or flammable gas is left on**;
- flammable solvents are properly stored in closed storage cupboards;
- fume-hoods are closed;
- lights are turned off ;
- fire doors and other doors are closed.

Floods: Apart from the damage they can cause to equipment and paperwork and the considerable inconvenience to victims, floods can be dangerous, for example, by bringing down ceiling boards and wetting live electrical equipment. The greatest care must be taken to avoid floods.

Water Cooling Connections. Plastic tubing carrying cooling water to rotary evaporators, diffusion pumps or any other semi-permanent or temporary systems **must be fastened on to the apparatus and the water taps with wire, plastic tags or screw clips.** The exit tube must pass the water properly down a drain which is able to cope with the flow and be anchored to prevent splashing or ejection if the water pressure rises.

APPLICABLE LEGISLATIONS

OSHE's website gives a comprehensive list of the legal requirements applicable to the purchase, use and storage of chemicals (http://www.nus.edu.sg/osh/legalreg.htm).

Fire Safety (Petroleum & Flammable Material) Regulations 2005

Administered by Singapore Civil Defence Force.

Summary of the Act

A licence is required for purchase and storage of PFM in the workplace. Suppliers are not permitted to sell PFM to users without PFM licence or in quantities exceeding storage limit of PFM.

NUS is currently having an extension of the PFM waiver until the buildings comply with the requirements for storage of PFM.

Please note that all our labs do not have sprinklers and therefore the following maximum allowable quantity (MAQ) applies.

Requirements

- Secondary containment tray for all flammable liquids should be made of metal and not plastic.
- Minimal capture of these trays must be 20 %.
- The volume of flammable liquid wastes must also be part of the total licensed PFM volume stored in the laboratory.
- Waste container size cannot exceed 20 L.
- Wherever possible, activities involving flammable liquids should be performed in a fume cupboard, to prevent the build up of a flammable mixture in the room.
- Flammable liquid containers for Class I and Class II (flash point between 37.8 °C – 60 °C) cannot exceed 4 L.

NUS has adopted a more stringent limit for all flammable liquids in the laboratories. All flammable liquids are classified as Class 1 (flash point < 37.8 °C) and the storage limit is as follows:

Liquid in Laboratory			
Excluding Qty in Cabinet		Including Qty in Cabinet	
Max Qty (L/m^2)	Max Qty (L/m^2)	Max Qty (L/m^2)	Max Qty (L/m^2)
0.8	250	1.6	500

Gases

- Spacing of 6 m apart is required for each group categorized below.
- Only two 4.5 kg LPG cylinders allowed in lab.
- Flammable gases must be in use in the lab.
- Labs cannot be used for storage of flammable gases.

Flammable gases

Labs < 50 m^2: 85 L

Labs > 50 m^2: Allowed quantity = 3.4 x lab work area (m^2)

Oxidizing gases

Labs < 50 m^2: 85 L

Labs > 50 m^2: Allowed quantity = 3.4 x lab work area (m^2)

Liquefied flammable gases
Labs < 50 m^2: 30 L
Labs > 50 m^2: Allowed quantity = 0.6 x lab work area (m^2)

Toxic gases
Labs < 50 m^2: 8 L
Labs > 50 m^2: Allowed quantity = 0.16 x lab work area (m^2)

Workplace Safety & Health Act

Administered by Ministry of Manpower (MOM).

Summary of the Act

The Workplace Safety and Health Act (WSHA) is an essential part of the new framework to cultivate good safety habits in all individuals so as to engender a strong safety culture in our workplace. It provides general requirements on safety and health issues related to the workplace such as

- Use of hazardous materials
- Use of pressure vessels - autoclaves and pressure vessels must be inspected frequently by a professional engineer.

WSH (Risk Management) Regulation 2006
The principal investigator or lab-in-charge shall conduct a risk assessment in relation to the safety and health risks posed to any person who may be affected by his undertaking in the workplace.

- The principal investigator or lab-in-charge shall conduct a risk assessment in relation to the safety and health risks posed to any person who may be affected by his undertaking in the workplace.
- The principal shall take all reasonably practicable steps to eliminate any foreseeable risk to any person who may be affected by his under taking in the workplace.
- Every principal shall maintain a record of any risk assessment conducted, any measure or safe work procedure implemented, submit the record when required and shall be kept for a period of no less than 3 years.
- Every principal shall review the risk assessment at least once every 3 years, upon the occurrence of any bodily injury to any person as a result of exposure to a hazard or when there is significant change in work practices.
-

WSH (Incident Reporting) Regulation 2006
Incidents involving the following must be reported as soon as reasonably practicable, to OSHE at http://www.nus.edu.sg/osh/services/airs.htm

- All workplace accidents/dangerous incidents must be reported to department and faculty safety officers before reporting online to OSHE.
- Mandatory reporting for workplace accident resulting in the death of an employee
- Mandatory reporting for workplace accident resulting in the injury of an employee who is unfit for work for more than 3 days, regardless of whether these were consecutive days of medical leave; or hospitalized for at least 24 hours. The reporting shall be done not later than 10 days after the 3rd day of the sick leave.
- Mandatory reporting for a subsequent death of an employee as a result of an injury at the workplace
- Mandatory reporting for a workplace accident which involves a self-employed person or member of public and results in his or her death or treatment in hospital for the injury

WSH (First Aid) Regulations 2006
Provides requirements of first-aid facilities (first-aid box, first-aiders) in the workplace

Environmental Protection and Management Act

Administered by National Environmental Agency.

Summary of the Act
- Regulates purchase and use of toxic and environmentally hazardous chemicals.
- All hazardous chemicals must not be bought or used without approval and license applied for through Faculty Safety and Health Officers

Details
- Required to keep a record of the quantity of the hazardous substances. A softcopy version is allowed. This can be generated by using the Online Chemical Store Inventory system to update the weight after use by the user.

Storage of the hazardous substances
- for the approved purpose
- in the approved container
- in an area entry restricted to authorized personnel
- with labeling stated in the code of labeling

Personnel are to receive adequate instruction and training to understand the nature of all the hazardous chemicals being stored and the emergency response plan to be implemented in the event of any emergency involving any hazardous substances stored.

Establish and keep up-to-date adequate emergency response plan to deal with any spillage.

Poisons Act
Administered by HSA-CDA.

Summary of the Act
- Regulates substances classified under Poisons (potent medical substances).
- All poisons must be kept under lock and key in a designated poison cupboard.
- Records of toxins and flammable chemicals must be kept. Alternatively, a softcopy version can be kept. This can be generated by using the Online Chemical Store Inventory system to update the weight after use by the user.

Details
The poison must be kept:
- in a bottle or other vessel tied over, capped, locked or otherwise safely secured in a manner different from that in which bottles or vessels containing non-poisonous substances are secured in the same warehouse.
- in a bottle or other vessel readily distinguishable by touch from the bottles or vessels in which non-poisonous substances are kept in the same warehouse.
- in a bottle, vessel, box or package kept in a room or cupboard under lock and key set apart for the keeping or storage of dangerous substances.

Arms and Explosives (Amendment) Act, Chap 13SPF
Administered by Singapore Police Force.

From 1 July 2007, the Singapore Police Force (SPF) has instituted a new regulatory regime under the Arms & Explosives (Amendment) Act, Cap 13 to control the use of a select group of 15 chemicals, which are explosive precursors (i.e. ingredients which can be used to make improvised explosive devices or IEDs).

Summary of the Act

- Regulate the use of 15 chemicals that are classified as explosive precursors.
- The applicant will be the one directly involved in the handling of the explosive precursors.
- It is a requirement that the holder of the license has relevant experience and knowledge in handling the explosive precursors and a register book shall be kept and maintained on the user, user identification (IC/passport/FIN), amount used, amount remaining, date of usage.
- The EP register book shall be kept for a period of not less than 3 years from the date the record is made, and any person who contravenes this shall be guilty of an offence and shall be liable on conviction to a fine or imprisonment. Alternatively, a softcopy version can be kept.
- Appropriate security measures shall be taken as to prevent any loss or theft of EP. In NUS, the minimal security measure is to store EP under lock and key to prevent unauthorised access.
- Any loss of EP shall immediately be reported to Faculty Safety Unit.
- Licence is held at the faculty level.

  - Ammonium Nitrate
  - Ammonium Perchlorate
  - Barium Nitrate
  - Guanidine Nitrate
  - Hydrogen Peroxide
  - Potassium Chlorate
  - Potassium Nitrate
  - Perchloric Acid
  - Potassium Nitrite
  - Potassium Perchlorate
  - Sodium Chlorate
  - Sodium Nitrate
  - Sodium Nitrite
  - Sodium Perchlorate
  - Tetranitromethane

Environmental Public Health Act
Administered by NEA.

Summary of the Act

- Regulates disposal of toxic and environmentally hazardous chemicals
- Only licensed waste collector must be engaged to collect hazardous waste generated.
- All generated toxic & hazardous waste must be treated & properly packed in specified containers with appropriate labeling.

Sewerage & Drainage Act
Administered by PUB.

Summary of the Act

- Regulates the discharge of waste water into public sewers.
- The regulations specify allowable limits for trade effluent discharge into the public sewer.
- NUS staff and students not to dispose hazardous materials into the sewer.

Chemical Weapons Convention
Administered by the Singapore National Authority for the Chemical Weapons Convention.

Summary of the Act

- Check if chemical falls under CWC at PSSO or OSHE website.
- The Principal Investigator (PI) has to seek approval by OSHE prior to the purchase of any chemicals listed under the Chemical Weapons (Prohibition) Act. Online application at https://wws.nus.edu.sg/rci/default.aspx
- PI must inform OSHE if he or she intends to use the chemicals of purposes either than those stipulated in the initial application
- A copy of the MSDS provided by the supplier must be made available in hardcopy in the laboratory at all times.
- The Principal Investigator must inform OSHE of the transfer of ownership of the scheduled chemicals. The Principal Investigator must inform OSHE of the loss of any scheduled chemicals within 24 hours.
- These chemicals must be kept in a storage cabinet or fridge under lock and key. The key shall be kept by the Principal Investigator. Only personnel authorized by the Principal Investigator will be allowed to use the chemical weapon.

Inventory Control of Scheduled Chemicals

- The logbook system is implemented for each chemical weapon that is used in the laboratory.
- Inventory records shall be regularly updated
- The Chemical Weapon Logbook must contain the following information:
- Name of chemical weapon in both common name and scientific name
- Chemical weapon formula or composition
- Date of purchase
- Original quantity of chemical weapon purchased
- Date of usage of the chemical weapon
- Quantity of usage of the chemical weapon
- Name of personnel using the chemical weapon
- Activity level of the chemical weapon (radioactive source) and date of measurement if applicable
- Location where the chemical weapon is kept
- Name of person responsible of the chemical weapon
- Name of person responsible for the key to where the chemical weapon is kept
- Transfer of ownership or location record
- Alternatively, a softcopy version can be kept. This can be generated by using the Online Chemical Store Inventory system to update the weight after use by the user.

Biological Agent & Toxins Act

Administered by Ministry of Health.

The Biological Agents and Toxins Act came into force on 3rd January 2006. Under this Act, approval is required for the possession, import, handling and transportation of scheduled biological agents and toxins.

<u>Summary of the Act</u>

- Regulate the possession, use, import, transfer and transportation of biological agents (BAs) and toxins that are known to be hazardous to human health in Singapore.
- Approval is required for the possession, import, handling and transportation of scheduled biological agents and toxins.
- Proper decontamination is required for all waste prior to disposal.
- Agent-specific license issued by MOH to PIs.

IMPORT ADVISORY TO IMPORTERS OF BIOLOGICAL AGENTS AND/OR TOXINS

Under sections 8, 17, 25, 28 and 32 of the Biological Agents and Toxins Act (BATA), importation of biological agents, toxins including proficiency test items and inactivated agents are required to have an import permit granted by the MOH. Any importation of these items without a proper import permit[1] is considered a breach of the Act and is punishable by fine, imprisonment or both.

Note that in the event that sections 8, 17, 25, 28 and 32 have been breached, the importer will be held liable.

The importer[2] shall be responsible in providing the correct information to the permit declarant[3]. This information referred to includes the following:

1. Item description
2. HS Code
3. MOH product code (and corresponding AVA code, if required)

As such, the importer has to ensure that all these information for the biological agent or toxin with the proper corresponding product code are correctly stated in the import permit and the approved permit was indeed granted by the Biosafety Legislation Branch of the Ministry of Health.

It is advised, that importers should be vigilant in ensuring and verifying that the couriers get the correct permit prior to clearing the item in the customs.

[1] A proper import permit refers to a permit with the correct item description and the corresponding correct MOH product code (and AVA code, if applicable), HS code and approved by the Biosafety legislation Branch of MOH.

[2] Importer usually refer to the laboratory/end user who had been granted with the "Approval to Possess" (if applicable) of the item being imported but may also refer to a distributor depending on the case.

[3] Permit declarant or declaring agent may be the courier service provider which was contracted by the exporter/importer to clear and deliver the goods to the importer.

Ministry of Health, Singapore
College of Medicine Building
16 College Road
Singapore 169854
TEL (65) 6325 9220
FAX (65) 6224 1677
WEB www.moh.gov.sg

Chemical Hazards

Chemicals are classified according to their hazards and are labelled with hazard symbols and plain-text warnings, with the inclusion of risk and safety (R and S) information. Under the Safety Management System (SMS) of each lab, you must do a Semiquantitative Risk Assessment of the hazardous chemicals to see if you need to have a medical examination before usage. This is an Excel form with the hazards of the chemical, amount to be used and duration of exposure.

Hazard symbols

Explosive, **E** (Chemicals that explode**)** • Unstable explosives • Self-reactive substances and mixtures • Organic peroxides	
Oxidising, **O** (Chemicals that react exothermally with other chemicals**)**	
Acute toxicity (Chemicals that at very low levels cause damage to health OR Chemicals that at low levels cause damage to health)	

Harmful (Chemicals that may cause damage to health) • Respiratory sensitization, • Germ cell mutagenicity • Carcinogenicity • Reproductive toxicity • Specific target organ toxicity following single exposure • Specific target organ toxicity following repeated exposure • Aspiration hazard	
Corrosive , **C** (Chemicals that may destroy living tissue on contact)	
Irritant (Chemicals that may cause inflammation to the skin or other mucous membranes) • Acute toxicity (oral, dermal, inhalation), • Skin irritation • Eye irritation • Skin sensitization • Specific target organ toxicity following single exposure • Respiratory tract irritation • Narcotic effects	
Compressed gases Liquefied gases Refrigerated liquefied gases Dissolved gases	
Dangerous for the Environment (Chemicals that may present an immediate or delayed danger to one or more components of the environment) • Acute hazards to the aquatic environment • Chronic hazards to the aquatic environment,	

Risk phrases (R)

Information on hazards of chemicals

R1 Explosive when dry
R2 Risk of explosion by shock, friction, fire or other sources ofigniotn.
R10 Flammable
R11 Highly flammable
R12 Extremely flammable
R14 Reacts violently with water
R15 Contact with water liberates extremely flammable gases
R16 Explosive when mixed with oxidizing substances
R26 Very toxic by inhalation

R27 Very toxic in contact with skin
R30 Can become highly flammable in use
R31 Contact with acids liberates toxic gases
R32 Contact with acids liberates very toxic gases

Safety phrases (S)

Information on storage, usage and other precautionary measures.

S1 Keep locked up
S2 Keep out of reach of children
S3 Keep in a cool place
S6.1 Keep under nitrogen
S7 Keep container tightly closed
S8 Keep container dry
S9 Keep container in a well-ventilated place.
S37 Wear suitable gloves
S62 If swallowed, do not induce vomiting, seek medical advice immediately and show this container or label.

Flammable Hazards

Extremely Flammable F+ and Highly Flammable F

The most common fire hazard in the laboratory is a flammable liquid or the vapour produced from such a liquid. For a fire to occur requires:

- an oxidising atmosphere (usually air),
- flammable gas or vapour at a concentration within the flammability limits of the substance and
- a source of ignition.

Under normal circumstances, oxygen or air will always be present and the best way to prevent a fire is to keep the vapour or gas away from sources of ignition. Some specific properties of flammable materials are**:-**

Flammable Gases

Leakage or escape of flammable gases can produce a serious explosive hazard in a laboratory. Acetylene, hydrogen, ammonia, hydrogen sulphide, propane and carbon monoxide are especially dangerous. Hydrogen leaking from a high-pressure cylinder can ignite spontaneously and the resulting flame can be almost invisible and so extremely dangerous.

Pyrophoric materials

Pyrophoric materials are those that ignite spontaneously in air below about 45 °C. Consequently the main hazards arising from the use of such materials involve fire, either from direct contact with the pyrophoric material or as a result of secondary fires following ignition.

The most commonly used materials are alkyl lithiums, trialkylaluminium reagents and alkylboranes. t-BuLi is the most pyrophoric of the Li reagents but n-BuLi is also pyrophoric as a concentrated solution i.e.~ 10 M.

These reagents are supplied in solution, in alkane, arene or ether solvents, the pyrophoric hazard increasing with concentration.

Spontaneous Combustion

Some materials are prone to inflame spontaneously with no source of ignition. Normally this is the result of exothermic autoxidation within a large mass where heat cannot escape.

Flash Point

The flash point is the lowest temperature at which a liquid has a sufficient vapour pressure to form an ignitable mixture with air near the surface of the liquid. Many common organic liquids have flash points below room temperature e.g. acetone (-18° C) or diethyl ether (-45° C).

A Flammable Liquid is classified as one with a flash point of less than 55°C, a Highly Flammable Liquid (F) is one with a flash point of less than 21°C (a Highly Flammable solid is one which is spontaneously combustible in air at ambient temperature or one which readily ignites after brief contact with a flame or one which evolves highly flammable gases in contact with water or moist air) and an Extremely Flammable Liquid (F+) is one with a flash point less than 0°C and a boiling point of 35°C or less.

Ignition Temperature

The ignition (sometimes called auto-ignition) temperature of a substance is the minimum temperature required to initiate or to cause self-sustained combustion independent of the heat source. A spark or flame is not necessary for ignition when a flammable vapour reaches its auto-ignition temperature. For diethyl ether this is 160° C and the material can be ignited by a hot plate.

Lower and Upper Explosion Limits

These limits define the range of concentrations in mixtures with air (or oxygen depending on definition) that will propagate a flame and cause an explosion. The lower values of these limits are normally well above levels legally allowed as ambient in laboratories and workplaces but can easily be exceeded following a spill.

Sources of Ignition

The most common sources of ignition in the laboratory are flames and heating elements but there are a number of less obvious electrical sources such as refrigerators, heat-guns, stirrers etc. It also must be remembered that vapours from a flammable liquid may be denser than air and may spread over bench and floor surfaces to sources of ignition which are apparently remote.

Carcinogens

Cancer is a disorder of cells in the body. It begins with a group of cells that fail to respond to the normal control mechanism and continue to divide without need. The new growths are called tumours or neoplasia and may be either "benign" or "malignant". A "benign" tumour is one that remains localised whereas "malignant" tumours invade neighbouring tissues, enter blood vessels, lymphatic vessels and other spaces and can be carried to other areas of the body to form new tumours called "secondaries" or "metastases".

Cancer carries with it a high risk of premature death.

Cancer may arise from various causes, one of which is the adverse effects of certain substances on the cells of the body either directly or via their metabolites. While it is often difficult to prove a causal link between exposure to a certain chemical and subsequent cancer, there exists evidence to incriminate a number of compounds and other are under more or less strong suspicion. Several organisations and bodies provide lists of known or "suspect" **carcinogens**, classified into different categories and some of these are covered here.

COSHH

Under the UK Control of Substances Hazardous to Health (COSHH) Regulations, a **carcinogen** is defined as:

- Any substance or preparation is labelled with the Risk Phrases R45 "may cause cancer" or R49 "may cause cancer by inhalation".

Carcinogens are divided into three categories:

Category 1 - substances known to be carcinogenic to humans. There is sufficient evidence to establish a causal association between human exposure to the substance and the development of cancer.

Category 2 - substances that should be regarded as if they are carcinogenic to humans, for which there is sufficient evidence, based on long-term animal studies and other relevant information, to provide a strong presumption that human exposure may result in the development of cancer.

Category 3 - substances that cause concern owing to possible carcinogenic effects but for which available information is not adequate to make satisfactory assessments.

Categories 1 and 2, if purchased from a supplier will carry the "toxic" (**T**) symbol and the Risk Phrase R45 (may cause cancer) or R49 (may cause cancer by inhalation).

Category 3, if purchased from a supplier carries the "harmful" (**Xn**) symbol and the Risk Phrase R40 (limited evidence of carcinogenic effect).

Acute Toxicity

- **LC_n** This abbreviation is used for the exposure concentration of a toxicant lethal to n% of a test population e.g. LC_{50}
- **LD_n** This abbreviation is used for the dose of a toxicant lethal to n% of a test population.
- **Evident Toxicity** - this concept is used to designate toxic effects after exposure to a substance tested, which are so severe that exposure to the next highest fixed dose would probably lead to death.

Very Toxic (T+)
Acute lethal effects:

R28 "Very Toxic if swallowed" : LD_{50} oral, rat < or = 25mg/kg : less than 100% survival at 5mg/kg oral, rat.
R27 "Very Toxic in contact with skin" : LD_{50} dermal, rat or rabbit: < or = 50mg/kg.
R26 "Very Toxic by inhalation" : LC_{50} inhalation, rat, for aerosols or particulates < or = 0.25mg/litre/4h,
LC_{50} inhalation, rat, for gases and vapours < or = 0.5mg/litre/4h

Non-lethal irreversible effects after a single exposure:

R39 "Danger of very serious irreversible effects" : Irreversible damage is likely to be caused by a single exposure by an appropriate route, generally in the above dose ranges.
In order to indicate the route of exposure, combinations of Risk Phrases may be used e.g. R39/23 i.e. "**Danger of very serious irreversible effects by inhalation".**

Toxic (T)

Acute lethal effects

R25 "Toxic if swallowed" : LD_{50} oral, rat 25 < LD_{50} < or = 200mg/kg: At 5mg/kg, oral, rat. less than 100% survival but evident toxicicty.

R24 "Toxic in contact with skin" : LD_{50} dermal, rat or rabbit: 50 < LD_{50} < or = 400mg/kg.

R23 "Toxic by inhalation" : LC_{50} inhalation, rat, for aerosols or particulates: 0.25 < LD_{50}< or = 1mg/litre/4h
LC_{50} inhalation, rat, for gases and vapours < or = 0.5 < LD_{50} < 2mg/litre/4h

Non-lethal irreversible effects after a single exposure

R39 "Danger of very serious irreversible effects": Irreversible damage is likely to be caused by a single exposure by an appropriate route, generally in the above dose ranges. In order to indicate the route of exposure, combinations of Risk Phrases may be used e.g. R39/23 i.e. "**Danger of very serious irreversible effects by inhalation".**

Severe effects after repeated or prolonged exposure

R48 "Danger of serious damage to health by prolonged exposure": Serious damage is likely to be caused by repeated or prolonged exposure by an appropriate route. "Toxic with R48" is used when effects are observed at levels of the order of:

Oral, rat	< or = 5mg/kg(bodyweight)/day
Dermal, rat or rabbit	< or = 10mg/kg(bodyweight)/day
Inhalation, rat	< or = 0.025mg/l, 6h/day

In order to indicate the route of exposure, combinations of Risk Phrases may be used e.g. R48/23 i.e. "**Danger of serious damage to health by prolonged exposure by inhalation".**

Reactive Hazards

Oxidising Agents

Oxidizing agents are chemicals that bring about an oxidation reaction. The oxidizing agent may provide oxygen to the substance being oxidized (in which case the agent has to be oxygen or contain oxygen) or receive electrons being transferred from the substance undergoing oxidation (chlorine is a good oxidizing agent for electron-transfer purposes, even though it does not contain oxygen). The intensity of the oxidation reaction depends on the oxidizing-reducing potential of the material involved. Fire or explosion is possible when strong oxidizing agents come into contact with easily oxidizable compounds, such as metals, metal hydrides or organics. Because oxidizing agents possess varying degrees of instability, they can be explosively unpredictable.

Examples of Oxidizing Agents

Gases	Fluorine, chlorine, ozone, nitrous oxide, oxygen
Liquids	Hydrogen peroxide, nitric acid, perchloric acid, bromine, sulphuric acid
Solids	Nitrites, nitrates, perchlorates, chromates, dichromates, picrates, permanganates, hypochlorites, bromates, iodates, chlorites, chlorates, persulphates.

Explosives

Explosives cause sudden, almost instantaneous release of pressure, gas, and heat when subjected to sudden adverse conditions. Heat, light, mechanical shock, detonation, and certain catalysts can initiate explosive reactions. Compounds containing the functional groups azide, acetylide, diazo, nitroso, haloamine, peroxide, and ozonide are sensitive to shock and heat and can explode violently.

Peroxide-Forming Compounds

Generally, organic peroxides are low-powered explosives that are sensitive to shock, sparks, and heat.

Some organic compounds such as ethers, tetrahydrofuran, and dioxane can react with oxygen from the air forming unstable peroxides. Peroxide formation can occur slowly under normal storage conditions -limited access to air and exposure to light. These accumulated peroxides can violently explode when exposed to shock, friction, or heat especially when concentrated and heated by distillation.

Bretherick ("Hazards in the Chemistry Laboratory") points out the particular danger from peroxide formation by di-isopropyl ether.

Water-Reactive Compounds

These compounds react with water or moisture in the air releasing heat or flammable, toxic gas. Examples include alkali metals, alkaline earth metals, carbides, hydrides, inorganic chlorides, nitrides, peroxides, and phosphides.

Toxic Hazards from Mixtures

Toxic gases may be evolved following the mixture of some chemicals e.g.

Chemical A	Chemical B	Product
Arsenical materials	Any reducing agent	Arsine
Azides	Acids	Hydrogen Azide
Cyanides	Acids	Hydrogen Cyanide
Hypochlorites	Acids	Chlorine or hypochlorous acid
Nitrates	Sulphuric Acid	Nitrogen Dioxide
Nitric Acid	Copper, brass, any heavy metals	Nitrogen Dioxide
Nitrites	Acids	Nitrous fumes
Phosphorus	Caustic alkalis or reducing agents	Phosphine
Selenides	Reducing agents	Hydrogen Selenide
Sulphides	Acids	Hydrogen Sulphide
Tellurides	Reducing agents	Hydrogen Telluride

Reactive Hazards from Mixtures

Many chemicals may react violently on mixing accidentally or intentionally.

Corrosive Hazards

Corrosives (liquids, solids, and gases) are chemicals that cause visible destruction of, or irreversible alterations in, living tissue by chemical action at the site of contact. Corrosive effects can occur not only to the skin and eyes, but also to the respiratory tract through inhalation and to the gastrointestinal tract through ingestion. Corrosive liquids have a high potential to cause external injury to the body, while corrosive gases are readily absorbed into the body through skin contact and inhalation. Corrosive solids and their dusts can damage tissue by dissolving rapidly in moisture on the skin or within the respiratory tract when inhaled.

Specific corrosive chemicals include strong acids and bases, dehydrating agents, non-metal chlorides, halogens and other compounds that hydrolyse to acids.

Chemicals Harmful to Health other than Reactive, Corrosive or Flammable

Injury can be caused by chemicals only if they reach sensitive parts of the body at a sufficiently high concentration and for a sufficiently long time (high enough **exposure**).

Exposure: is a function of the amount (or concentration) of the chemical involved and the time of it interaction. Effects may vary depending upon the nature of exposure - continuous or repeated short intervals- and may depend on the substance's ability to accumulate in the body and on the "victim's" age and/or state of health.

The potential to cause damage or toxicity can vary enormously from substance to substance e.g. LD_{50} values (the single dose that can be expected to kill 50% of a population) can vary from 7000 mg/kg of body weight for Ethanol to 0.02 mg/kg for Dioxins.

The injury depends on the properties of the potentially toxic substance, the exact nature of the exposure circumstances and the health of the person at risk.

Entry or Exposure Routes

Major **routes** of exposure are through the skin (topical), through the lung (inhalation) or through the gastrointestinal tract (ingestion). In general, inhalation is likely to cause more damage than ingestion, which, in turn, is more harmful than skin exposure.

Skin Absorption

This is the least likely route of penetration since the natural thickness of the skin plus its natural coating of grease and sweat provide some protection against chemicals. However, some materials are capable of penetrating intact, healthy skin e.g. aniline, hydrogen cyanide, some steroid hormones, organic mercury compounds, nitrobenzene, organophosphate compounds and phenol. Phenol itself can be lethal if absorbed for a sufficient time through a few square centimeters of skin and inappropriate protective clothing e.g. incorrect gloves may cause absorption rate to increase.
The natural protection of the skin may also be bypassed through cuts, abrasion or puncture wounds e.g. needle-stick injury.

Inhalation

Gases and vapours, aerosols and fumes are readily inhaled and may cause harm (including asphyxiation) anywhere in the respiratory system and may also be absorbed into the bloodstream but inhalation of particles depends upon their size and shape -the smaller the particle, the further into the respiratory tract it can go.

Large particles are filtered off in the nose.

Smaller particles, or those breathed in by mouth, settle on the walls of the upper respiratory tract or throat and are coughed up and either ejected or swallowed. If swallowed, they may enter the gut and cause damage as if they had been ingested.

The smallest particles of dust and fibres can be inhaled down into the lungs where they can cause local damage, sometimes by interaction with the cells in the lungs which normally remove bacteria. These particles may also be absorbed into the bloodstream.

Ingestion

Airborne particles that are eventually swallowed are the most likely source of ingested chemical. Otherwise, ingestion of potentially toxic substances is likely to be accidental on contaminated food, drink or make-up. Once absorbed through the stomach or intestine, the route to excretion may be complex and damaging.

Adverse Effects

Adverse Effects may be local or systemic.

Local Effects occur at the site of exposure e.g. corrosives and often irritants.

Systemic Effects occur at a target organ or at site remote from the point of contact following absorption and distribution around the body.

Some substances produce both effects e.g. lead tetraethyl damages the skin on contact and is the absorbed and transported to the central nervous system where it may cause further damage.

Adverse Effects may also be **acute** or **chronic.**
Acute Effects are immediate such as the effect from inhaling chlorine.
Chronic Effects are much slower, often cumulative following repeated exposures. Chronic effects can be the most difficult to avoid because damage may not become evident for many years.

Adverse Effects may also be **reversible** or **irreversible.**
Reversible Effects: damage can be repaired by the body's natural processes.
Irreversible Effects: cannot be repaired e.g. dead nerve cells cannot be replaced.

Adverse Effects may be **psychological** as well as purely **physical**.

Response of the Body

Irritation

- **Respiratory:** Chemicals can irritate the nose and upper respiratory tract causing sneezing, coughing and, in some cases, bronchitis. They may also damage lung tissue.
- **Skin and Eyes:** Chemicals on skin often cause dermatitis (a rash). Solvents can de-grease the skin causing it to become red and sore. Corrosive material such as strong acids and bases can be irritants in dilute form but cause severe burns when concentrated. Eyes are particularly vulnerable and damage can be permanent.

Sensitisation

- **Respiratory:** Some chemicals can cause sensitisation leading to asthma. Once sensitised, even minimal exposure can cause a severe allergic response.
- **Skin:** Sensitisation can occur through contact with a chemical and the skin. As before, once sensitised, minimal contact can cause an allergic response causing severe itching and other discomfort.

Long-term Effects

- The most serious of long-term effects is cancer, a disorder of cell growth. Here the effect of exposure may not be evident for many years.

Reproductive Disorders

Possible effects are loss of fertility in both men and women, heritable genetic damage or harm to the unborn child.

Laboratory Chemical Storage

The usage and storage of chemicals in Singapore are subjected to a number of regulations. Please view http://www.nus.edu.sg/osh/legalreg.htm to know legislative requirements. Some of regulations are:

- Fire Safety (Petroleum & Flammable Material) Regulations 2005
- Environmental Pollution Control Act (Hazardous Substances)
- Arms & Explosives (Amendment) Act
- Poisons Act
- Chemical Weapons Convention
- Biological Agent & Toxins Act

Safe practice in chemical storage

1. Store all chemicals by their hazards class and not in their alphabetical order. The Merck system or that following Fred Hutchinson Cancer Research Centre are two good examples that you can follow.
2. Do not store chemicals in direct sunlight or near heat sources such as ovens
3. Date chemicals when first opened. If a particular chemical can become unsafe or deteriorate while in storage, an expiration date should also be included
4. Do not use the lab bench for permanent storage of chemicals.
5. Inspect your chemicals routinely for any signs of deterioration and for integrity of the label.
6. Do not store chemicals above eye levels. If the container breaks, the contents can fall onto the face and upper body.

1. Merck System

Chemicals must be stored according to their **storage class**. Each chemical is allocated one storage class only; those with more than one hazard characteristic are allocated according to the ranking of their hazard characteristics. This ensures that in the case of chemicals with similar or identical hazard characteristics, the same safety measures can be taken, especially against fire and explosion. Liquids or solid substances as well as preparations and products that do not fulfill the criteria of classes 1-8 are characterized as being of classes 10-13. No further differentiation in class is made between classes 10, 11, 12 and 13 as these are all substance-orientated.

LGK	Designation
1	Explosion material
2A	Compressed, liquefied, or pressure-dissolved gases
2B	Pressurized gas packages (aerosol containers)
3A	Flammable liquid materials (Flashpoint < 55 °C)
3B	Flammable liquids
4.1A	Flammable solid materials

4.1B	Flammable solid materials
4.2	Spontaneously combustible materials
4.3	Materials that form flammable gases in contact with water
5.1A	Oxidizing agents
5.1B	Organic pesticides
6.1A	Flammable toxic materials
6.1B	Non-flammable toxic materials
6.2	Infectious materials
7	Radioactive materials
8A	Flammable corrosive materials
8B	Non-flammable corrosive materials
10	Flammable liquids if not LGK 3A or 3B
11	Flammable solids
12	Non-flammable liquids in non-flammable packages
13	Non-flammable solids in non-flammable packages

2. Fred Hutchinson Cancer Research Center "Hazard Awareness and Management Manual"

In this plan there are nine storage groups. Seven of these groups cover storage of liquids because of the wide variety of hazards posed by these chemicals. Specific instructions must be followed for metal hydrides (Group VIII) and certain individual compounds, but otherwise, dry solids are in Group IX.

Many liquid chemicals pose hazards that correspond to more than one storage group. These chemicals should be stored in the lowest group number.

Group I	Flammable Liquids
Group II	Poisons - volatile
Group III	Acids - Oxidizing
Group IV	Acids - Organic and Mineral
Group V	Bases - Liquid
Group VI	Oxidizer - Liquid
Group VII	Poisons - Non-volatile
Group VIII	Reactives
Group IX	Solids

Group I: Flammable Liquids

Includes liquids with flashpoints < 55 °C. Examples: all alcohols, acetone, acetaldehyde, acetonitrile, amyl acetate, benzene, cyclohexane, dimethyldichlorosilane, dioxane, ether, ethyl acetate, hexane, hydrazine, methylbutane, picolene, piperidine, propanol, pyridine, scintillation liquids, all silanes, tetrahydrofuran, toluene, triethylamine, xylene

Primary Storage Concern: To protect from ignition Recommended

Facilities/Measures:

1. Flammable cabinet
2. Refrigerator: for containers less than 1 liter.

Compatible Storage Groups: Volatile poisons may be in the same compartment of the flammable cabinet as flammables if bases are not present.

Group II: Volatile Poisons

Includes poisons, toxics and known and suspected carcinogens with strong odor or evaporation rate greater than 1 (butyl acetate = 1): Examples: carbon tetrachloride, chloroform, dimethyl formamide, dimethyl sulfate, formamide, formal dehyde, halothane, mercaptoethanol, methylene chloride, phenol.

Primary Storage Concern: To prevent inhalation exposures.

Recommended Facilities/Measures:

1. Flammable cabinet
2. Refrigerator: for containers less than 1 liter.

Compatible Storage Groups: Volatile poisons may be in the same compartment of the flammable cabinet as flammable if bases are not present.

Group III: Oxidizing Acids

All oxidizing acids are highly reactive with most substances and each other. Examples: nitric, sulfuric, perchloric, phosphoric acids, and chromic acids. For example, the inadvertent mixing of nitric acid with organic materials even in small or residual amounts, have led to explosions and detonations after a short lag time. This is due to simultaneous oxidation and nitration of the organics.

Primary Storage Concern: Preventing contact and reaction with each other and other substances and corrosive action on surfaces.

Recommended Facilities/Measures:

1. Safety Cabinet. Each oxidizing acid must be <u>double-contained</u>, i.e., the primary container must be kept inside canister, tray or tub.

Compatible Storage Groups:

Oxidizing acids must be double-contained and should be segregated in their own compartment in a safety cabinet. When quantities are small (e.g., 1 or 2 bottles) they do not warrant a separate compartment. Small quantities may be double-contained and stored with Group 4. Store oxidizing acids on bottom shelf below Group 4.

Group IV: Organic and Mineral Acids

Examples: acetic, butyric, formic, glacial acetic, hydrochloric, isobutyric, mercaptoproprionic, proprionic, trifluoroacetic acids.

Primary Storage Concern: To prevent contact and reaction with bases and oxidizing acids and corrosive action on surfaces.

Recommended Facilities/Measures:

1. Safety cabinet - vented corrosive cabinet if possible. Otherwise organic acids can safely be stored with flammable and combustible liquids, but should not be stored with oxidizing mineral acids, which could react more or less violently with organic acids.

Compatible Storage Groups: Small amount of double-contained oxidizing acids can be stored in the same compartment with organic acids if the oxidizing acids are stored on the bottom shelf.

Exceptions: acetic anhydride and trichloroacetic anhydride are corrosive. These acids are very reactive with other acids and should not be stored in this group. It is better to store these with organic compounds as in Group 7 Non-volatile Liquid Poisons.

Group V: Liquid Bases

Examples: sodium hydroxide, ammonium hydroxide, calcium hydroxide, glutaraldehyde

Primary Storage Concern: Preventing contact and reaction with acids.

Recommended Facilities/Measures:

1. Safety cabinet;
2. In tubs or trays in normal cabinet.

Compatible Storage Groups: Liquid bases may be stored with flammables in the flammable cabinet if volatile poisons are not also stored there.

Group VI: Oxidizing Liquids

Oxidizing liquids react with everything potentially causing explosions or corrosion of surfaces.

Examples: ammonium persulfate, hydrogen peroxide (if greater than or equal to 30%)

Primary Storage Concern: To isolate from other materials.

Recommended Facilities/Measures:

1. Total quantities exceeding 3 liters should be kept in a cabinet housing no other chemicals.
2. Smaller quantities must be double-contained if kept near other chemicals, e.g., in a refrigerator.

Compatible Storage Groups: None

Group VII: Non-Volatile Liquid Poisons

Includes highly toxic (LD50 oral rat < 50 mg/kg) and toxic chemicals (LD50 oral rat < 500 mg/kg), known carcinogens, suspected carcinogens and mutagens Examples: acrylamide solutions;

diethylpyrocarbonate; diisopropyl fluorophosphate; uncured epoxy resins; ethidium bromide; triethanolamine

Primary Storage Concern: To prevent contact and reaction with other substances.

Recommended Facilities/Measures:

Cabinet or refrigerator (i.e., must be enclosed)

Do not store on open shelves in the lab or cold room.

Liquid poisons in containers larger than 1 liter must be stored below bench level on shelves closest to the floor. Smaller container of liquid poison can be stored above bench level only if behind sliding (non-swinging) doors.

Compatible Storage Groups: Non-hazardous liquids (e.g., buffer solutions).

Exceptions: Anhydrides, e.g., acetic and trichloroacetic, are organic acids, however it is better to store with this group than with Group 4 Organic Acids, since they are highly reactive with other organic or mineral acids.

Group VIII: Reactives Metal Hydrides and Pyrophorics

Most metal hydrides react violently with water, some ignite spontaneously in air (pyrophoric). Examples of metal hydrides, are sodium borohydride, calcium hydride, lithium aluminum hydride. Other pyrophorics are boron, diborane, dichloroborane, 2-furaldehyde, diethyl aluminum chloride, lithium, white or yellow phosphorus and trimethyl aluminum. Other water reactives include aluminum chloride-anhydrous, calcium carbide, acetyl chloride, chlorosulonic acid, sodium, potassium, phosphorous pentachloride, calcium, aluminum tribromide, calcium oxide, and acid anhydrides.

Primary Storage Concern: To prevent contact and reaction with liquids and, in some cases, air.

Recommended Facilities/Measures:

1. Secure, water-proof double-containment according to label instructions.
2. Isolation from other storage groups.

Compatible Storage Groups: If securely double-contained to prevent contact with water and/or air, metal hydrides may be stored in the same area as Group 9 Dry Solids.

Group IX: Dry Solids

Includes all powders, hazardous and non-hazardous. Examples: benzidine, cyanogen bromide, ethylmaleimide, oxalic acid, potassium cyanide, sodium cyanide

Primary Storage Concern: To prevent contact and potential reaction with liquids.

Recommended Facilities/Measures:

1. Cabinets are recommended, but if not available, open shelves are acceptable.
2. Store above liquids.
3. Warning labels on highly toxic powders should be inspected and highlighted or amended if they do not cause the containers to stand out against less toxic substances in this group.
4. It is recommended that the most hazardous substances in this group be segregated.
5. It is particularly important to keep liquid poisons below cyanide-or sulfide-containing poisons (solids). A spill of aqueous liquid onto cyanide - or sulfide - containing poisons would cause a reaction that would release poisonous gas.

   Compatible Storage Groups: Metal hydrides, if properly double-contained may be stored in the same area.

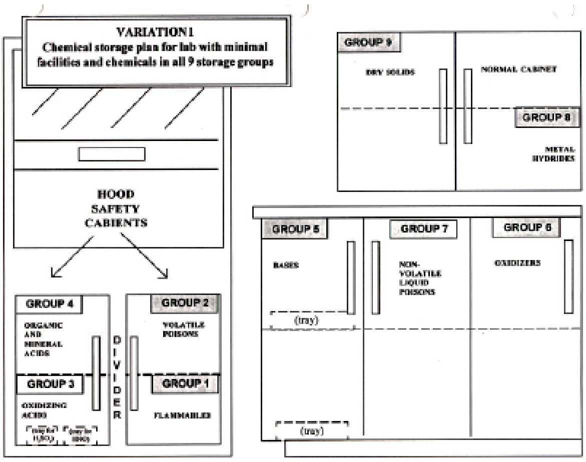
   Exceptions: Solid picric or picric sulfonic acid can be stored with this group, but should be checked regularly for dryness. When completely dry, picric acid is explosive and may detonate upon shock or friction. Picric acid in contact with some metals may form explosive metal picrates. Use non-metal caps.

Storage Plan Variations for Different Lab Facilities

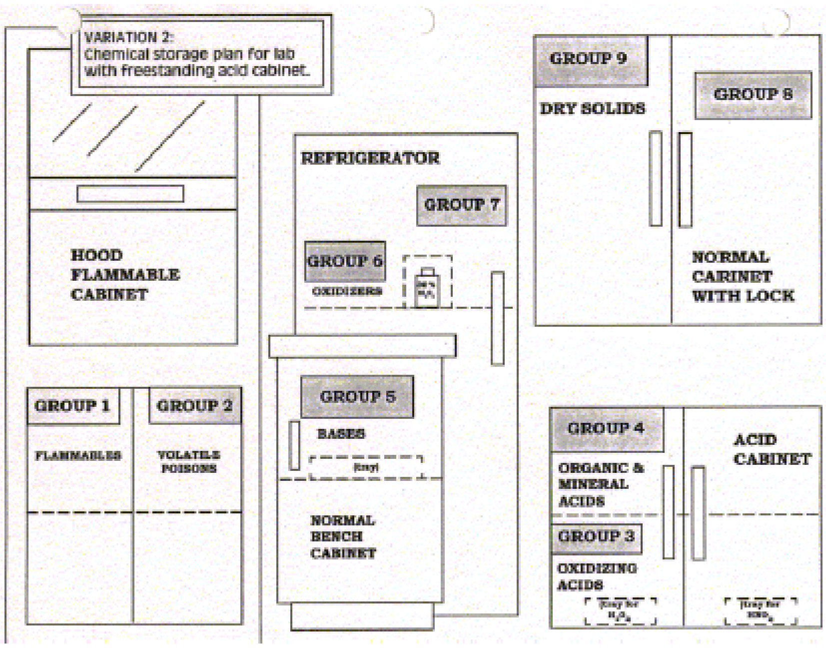
Below are illustrations of possible chemical storage arrangements for two types of lab facilities. They are provided merely as examples of arrangements which satisfy the recommendations of the chemical storage plan. They are not intended to restrict storage designers to the particular arrangements and facilities depicted.

Variation 1:

Chemical storage plan for lab with minimal facilities and chemicals in all 9 storage groups.



Variation 2:
Chemical storage plan for lab with freestanding acid cabinet.



Material Safety Data Sheets

Material Safety Data Sheets contain information under the following specific headings:

- Identification of the substance or preparation (a preparation is a mixture of substances) and the name of the supplying company.
- Composition/information on ingredients.
- Hazards Identification.
- First-aid measures.
- Fire-fighting measures.
- Accidental release measures.
- Handling and storage
- Physical and Chemical properties
- Stability and reactivity
- Toxicological Information.
- Ecological Information.
- Disposal considerations.
- Transport information
- Regulatory Information
- Other Information.

- Exposure controls/ personal protection.

The relevant safety data sheets must be read before you carry out your experiments. It is advisable to keep a hardcopy at hand when you are carrying out your experiment, in case of any emergencies. Check for incompatible chemicals at Bretherick's Handbook of Reactive Chemical Hazards available as an e-book at the Library.

Partial list of incompatible chemicals (Reactive Hazards) adapted from Prudent Practices in the Laboratory: Handling and Disposal of Chemicals (1995) available from NUS library electronic copy (http://www.netlibrary.com.libproxy1.nus.edu.sg/Reader/)

Partial List of Incompatible Chemicals

CHEMICAL	INCOMPATIBILITIES: SHOULD NOT BE STORED OR MIXED WITH
Acetic acid	Chromic acid, nitric acid, peroxides, permanganates
Acetic anhydride	Hydroxyl-containing compounds such as ethylene glycol, perchloric acid
Acetone	Concentrated nitric and sulfuric acid mixtures, hydrogen peroxide
Acetylene	Chlorine, bromine, copper, silver, fluorine, mercury
Alkali and alkaline earth metals, such as sodium, potassium, lithium, magnesium, calcium, powdered aluminum	Carbon dioxide, carbon tetrachloride, other chlorinated hydrocarbons (also prohibit the use of water, foam, and dry chemical extinguishers on fires involving these metals - dry sand should be employed)
Ammonia (anhydrous)	Mercury, chlorine, calcium hypochlorite, iodine, bromine, hydrogen fluoride
Ammonium nitrate	Acids, metal powders, flammable liquids, chlorates, nitrites, sulfur, finely divided organics, combustibles
Aniline	Nitric acid, hydrogen peroxide
Bromine	Ammonia, acetylene, butadiene, butane, other petroleum gases, sodium carbide, turpentine, benzene, finely divided metals
Calcium oxide	Water
Carbon, activated	Calcium hypochlorite, other oxidants
Chlorates	Ammonium salts, acids, metal powders, sulfur, finely divided organics, combustibles
Chromic acid and chromium trioxide	Acetic acid, naphthalene, camphor, glycerol, turpentine, alcohol, other flammable liquids
Chlorine	Ammonia, acetylene, butadiene, butane, other petroleum gases, hydrogen, sodium carbide, turpentine, benzene, finely divided metals
Chlorine dioxide	Ammonia, methane, phosphine, hydrogen sulfide
Copper	Acetylene, hydrogen peroxide
Fluorine	Isolate from everything
Hydrazine	Hydrogen peroxide, nitric acid, any other oxidant

Hydrocarbons (benzene, butane, propane, gasoline, turpentine, etc.)	Fluorine, chlorine, bromine, chromic acid, peroxides
Hydrocyanic acid	Nitric acid, alkalis
Hydrofluoric acid (anhydrous), Hydrogen Fluoride	Ammonia (aqueous or anhydrous)
Hydrogen peroxide	Copper, chromium, iron, most metals or their salts, any flammable liquid, combustible materials, aniline, nitromethane
Hydrogen sulfide	Fuming nitric acid, oxidizing gases
Iodine	Acetylene, ammonia (anhydrous or aqueous)
Mercury	Acetylene, fulminic acid*, ammonia
Nitric acid (concentrated)	Acetic acid, acetone, alcohol, aniline, chromic acid, hydrocyanic acid, hydrogen sulfide, flammable liquids, flammable gases, nitratable substances
Nitroparaffins	Inorganic bases, amines
Oxalic acid	Silver and mercury and their salts
Oxygen	Oils, grease, hydrogen, flammable liquids, solids, gases
Perchloric acid	Acetic anhydride, bismuth and its alloys, alcohol, paper, wood, grease, oils (all organics)
Peroxides, organic	Acids (organic or mineral), (also avoid friction, store cold)
Phosphorus (white)	Air, oxygen
Phosphorus pentoxide	Alcohols, strong bases, water
Potassium chlorate	Acids (see also chlorates)
Potassium perchlorate	Acids (see also perchloric acid)
Potassium permanganate	Glycerol, ethylene glycol, benzaldehyde, sulfuric acid
Silver and silver salts	Acetylene, oxalic acid, tartaric acid, fulminic acid*, ammonium compounds
Sodium	See alkali metals (above)
Sodium nitrite	Ammonium nitrate and other ammonium salts
Sodium peroxide	Any oxidizable substance, such as ethanol, methanol, glacial acetic acid, acetic anhydride, benzaldehyde, carbon disulfide, glycerol, ethylene glycol, ethyl acetate, methyl acetate, furfural
Sulfuric acid	Chlorates, perchlorates, permanganates

Potentially Explosive Combinations of Common Reagents
Acetone + chloroform in the presence of base
Acetylene + copper, silver, mercury or their salts
Ammonia (including aqueous solutions) + Cl_2, Br_2, or I_2
Carbon disulfide + sodium azide
Chlorine + an alcohol
Chloroform or carbon tetrachloride + powdered Al or Mg
Decolorizing carbon + an oxidizing agent
Diethyl ether + chlorine (including a chlorine atmosphere)
Dimethyl sulfoxide + CrO_3

Ethanol + calcium hypochlorite
Ethanol + silver nitrate
Nitric acid + acetic anhydride or acetic acid

Personal Safety

General principles-

- Think before you start a piece of work.
- Never work alone.
- Wear the proper protective equipment.
- Keep your workplace tidy

Eating, Drinking or Smoking

Eating or drinking is forbidden in laboratories and workshops and smoking is forbidden in all parts of the Building. Eating or drinking is only permitted in designated student areas where there is no contact with chemicals.

Protective Clothing

Safety Glasses

Safety Glasses are available from Lab Supplies – payable from your supervisor's grant for the first pair but you must pay for replacement of losses. Safety Glasses must be worn in all designated areas and whenever you are handling chemicals, glass vacuum or pressure apparatus and equipment with moving parts.
Contact Lenses: There is an ongoing debate as to whether it is safe to wear contact lenses in a Chemistry Laboratory. The most important advice remains: **wear Safety Glasses**.

Laboratory Coats

Wearing a lab-coat can give considerable protection against splashed chemicals and flash burns. Lab-coats must be worn in areas where wet chemistry is carried out. **This is the case in all synthetic chemistry laboratories.** Remove lab coats, gloves or other personal protective clothing before leaving the lab. This clothing may have been contaminated and you could spread the contamination.

Protective Gloves

Disposable gloves give short-term protection against some chemicals but some solvents may attack them. Many grades of gloves can be obtained which offer more or less protection.
See http://www.aps.anl.gov/Safety_and_Training/User_Safety/gloveselection.html for full details of available gloves and guidance for their use. Even if you have been wearing gloves, wash your hands frequently when working.
Never wear rubber or plastic gloves when working with a naked flame.
<u>Never wear gloves outside the lab. Gloves should not be worn for handling computer terminals, any equipment or door knobs.</u>

Shoes

Shoes which **fully** cover the feet and toes and not slip-ons should always be worn in a lab to protect against chemicals and glass cuts. Sandals, flip-flops, clogs, backless shoes, cloth shoes, open-toed shoes, high heeled shoes and stiletto-heeled shoes are **strictly** not allowed. In the laboratory, wear shoes with uppers made of leather or polymeric leather substitute.

Personal Attire

Clothing must offer good protection against chemical spills and splashes. Tank tops, off-shoulder tops, halter-necks and shorts are not allowed. Legs and waists must be covered by your clothing. Excessively loose and flowing clothing should not be worn to labs.

Fume-hood Safety

Fume-hoods in the Department of Chemistry are of the built-in ducted type that vent to the outside through outlets on the roof. The sashes should be kept down as far as possible for maximum efficiency in coping with the removal of vapours. Proper work practices for fume hood users include:

- Set your work up at least six inches behind the plane of the sash.
- Never put your head inside an operating fume hood to check an experiment. The plane of the sash is the barrier between contaminated and uncontaminated air. Work with the sash in the lowest position possible, especially when working with explosive materials. The sash will then act as a physical barrier in the event of a mishap in the hood.
- Do not clutter your hood with bottles or equipment. Keep it clean. Only materials actively in use should be in the fume hood.
- No apparatus should be protruding from the fume hood. This would make it difficult to close the sash fully in an emergency.
- Do not use a fume hood as a storage cabinet for chemicals.

Chemical Safety

It is necessary to make an Assessment of the health risks to you in handling chemicals **before the materials are used.**

The following points are worth emphasising:

Common Solvents Many common solvents, e.g., CH_2Cl_2, are toxic and in handling (or spilling them) in the open laboratory you may exceed danger limits for the vapour concentration. Use an effective fume-hood whenever possible. Dusty substances can be as dangerous as highly volatile substances both in toxicity and in explosion risks.

Spills Absorbent granules to mop up spilled solvent are available at Lab Supplies or in the teaching laboratories. **If you are using large amounts of acid or base or any amount of strongly smelling material you must keep a neutralising agent at hand.**

Carcinogenic Materials The handling and storage of carcinogenic materials are classified into the following categories:

Category 1 - substances known to be carcinogenic to humans. There is sufficient evidence to establish a causal association between human exposure to the substance and the development of cancer. **Category 2 -** substances that should be regarded as if they are carcinogenic to humans, for which there is sufficient evidence, based on long-term animal studies and other relevant information, to provide a strong presumption that human exposure may result in the development of cancer. **Category 3 -** substances that cause concern owing to possible carcinogenic effects but for which available information is not adequate to make satisfactory assessments.

Categories 1 and 2, if purchased from a supplier will carry the "toxic" (**T**) symbol and the Risk Phrase R45 (**May cause cancer**) or R49 (**May cause cancer by inhalation**). **Category 3,** if purchased from a supplier carries the "harmful" (**Xn**) symbol and the Risk Phrase R40 (**Limited evidence of a carcinogenic effect**).

In the Department of Chemistry, the following rules apply for Category 1 and 2 carcinogens:

- The worker should be fully informed of the carcinogenic nature of the chemicals and the procedures for proper handling and disposal.
- **A record must be kept by the PI** of all user exposure to such material

(a suitable form is provided).

- Carcinogenic materials must be disposed of carefully and **not via the waste solvents. Arrangements must be made by the PI with the chemical waste disposal company.**

Mercury — **Mercury is very toxic**. Although mercury is no longer in use in all our labs, there may be still some apparatus containing mercury. All glass apparatus containing mercury **must** have secondary containment to catch mercury in the event of a breakage. Spilt mercury should be collected up immediately.

Cyanides — **Great care must be taken when working with cyanides**. **The use of cyanides outside of normal working hours is forbidden**.

Hydrofluoric acid — **Great care must be taken when working with HF**. **The use of HF outside of normal working hours is forbidden.** At concentrations above 1M (2%) in water, HF can cause very painful burns that may not be apparent for some hours. Always wear gloves, a lab-coat and safety glasses when using this acid. Have available a tube of "**HF Antidote Gel**" which should be applied if concentrated acid contacts the skin.
In the event of HF accidents, contact Safety Officer, Junaidi (61760) or A/P G. K. Chuah (62839).

Important Safety Practices

General Housekeeping

1. Glassware (including glass chemical containers) should not be left on the floor
2. All chemical containers in the lab should be labeled, especially in the fridge and fume hood
3. Avoid using round bottom flasks for storage of compounds. This is especially important where the fridge is concerned. Upon opening the door, they may roll out and break on the floor resulting in the release of toxic chemicals that may be stored in them.
4. Keep all aisles, walkway and exits clear to provide a safe walking surface and an unobstructed exit.
5. Do not block access to emergency equipment and utility controls e.g. main switches, gas valves, etc.
6. Keep the work surface as uncluttered as possible.

Handling Mercury Spills

1. Clean up all mercury spills promptly.
2. If a large area is involved, obtain sulphur from Laboratory Supplies and spread it over the area. After 24 hours sweep up the sulphur. Place mercury and sweepings in a container and arrange for disposal.
3. When a mercury spill is not cleaned up promptly it may be ground into the floor, fracturing into extremely small particles with a large total surface area (6.4 ft^3 for 1 ml as 10 micron spheres). From such large areas, mercury may vaporize at a rate faster than the room's ventilation can safely dilute it.
4. The rate of mercury volatilization is directly related to temperature. Whenever elevated temperatures are involved, special care must be exercised to provide adequate ventilation. A common occurrence is the breaking of thermometers due to bumping or raising the temperature above the thermometer's capacity.

In addition to handling mercury spills, all staff and students are reminded to **exercise extreme caution** when handling organomercury compounds. Karen E. Wetterhahn, Professor of Chemistry and Albert Bradley Third Century Professor in the Sciences at Dartmouth College, died on June 8, 1997 at the age of 48 from mercury poisoning. The cause of the poisoning was traced to several drops of dimethylmercury which seeped through latex gloves. More details can be found at the links below:

http://www.organik.uni-erlangen.de/bauer/mercury.html
http://www.dartmouth.edu/~toxmetal/HMKW.shtml
http://www.udel.edu/OHS/dartmouth/drtmtharticle.html

Read ACS Chemical & Engineering News: Safety Letters on
Safety Standards
Hazardous References
Handling of dimethylmercury
More on working with dimethylmercury
All staff and students are advised to read the Prepared Risk assessment on Handling Acutely Toxic Compounds as well as the above links.

Liquid Nitrogen

1. Liquid nitrogen is frequently used in chemical research laboratories for the purpose of cooling because of its low boiling point (bp -196 °C), inexpensive price, and low toxicity.
2. Cryogenic liquids such as liquid nitrogen can cause very severe burns upon eye or skin contact.
3. Splashes are common when handling liquid nitrogen and safety goggles and gloves must therefore be worn at all times when working with this material.
4. Do not use household thermos bottles as a substitute for laboratory Dewar flasks. Their walls are too thin and they are not designed to withstand the low temperature.
5. ***Extreme care must be employed when using liquid nitrogen as a cold trap coolant.*** Systems including liquid nitrogen traps must never be opened to the atmosphere until the trap is removed from the coolant. Oxygen has a higher boiling point (-183 °C) than nitrogen (-196 °C), and will condense out of the atmosphere and collect in a liquid-nitrogen cooled vessel open to the air. Liquid oxygen forms highly explosive mixtures with many organic materials.
6. **Never cool an apparatus that is under an argon atmosphere using liquid nitrogen**. Argon will condense at liquid nitrogen temperature and when the apparatus is removed from the coolant, liquid argon will instantly vaporize, expanding in volume by a factor of 847! Even if the vessel is vented (e.g. to an inert gas line), an explosion is very likely due to the rapid increase in pressure in the vessel.

Quenching of Reactives

Refer to the section on Special Disposal or for a more complete list, the book by Margaret-Ann Armour on Hazardous Laboratory Chemicals Disposal Guide, Third Edition (QA64 Arm) which is available online at NUS Library.

Use of Hazardous Chemicals

Flammable solvents

E.g. acetone, ethyl acetate, ethanol, hexane, etc.
1. Flammable solvents that are not in active use must be stored in safe containers inside cabinets designed for flammables.
2. Minimise the amount of flammable liquids stored in the lab.
3. Use flammables only in areas free of ignition sources.
4. Never heat flammables with an open flame.
5. Never store flammable chemicals in a standard household fridge.
6. Always use a fume hood while working with flammable liquids.

Oxidizers

E.g. Peroxides, nitrates, nitrites, perchlorates, chlorates, chlorites, hypochlorites, dichlorates.

1. Store oxidizers away from flammables, organic compounds and combustible materials
2. Strong oxidizing agents like chromic acid should be stored in glass or other inert containers, preferably unbreakable. Corks and rubber stoppers should not be used.
3. Reaction vessels containing appreciable amount of oxidizing materials should never be heated in oil baths but rather on a heating mantle or sand bath.
4. Do not attempt to heat perchloric acid if you do not have access to a fume hood designed for perchloric acid.
5. Do not allow perchloric acid to come in contact with strong dehydrating agents e.g. sulphuric acid.
6. Do not order or use anhydrous perchloric acid. It is unstable at room temperature and can decompose spontaneously with a severe explosion.

Corrosives

E.g. Sulphuric acid, chromic acid, stannic acid, hydrofluoric acid, ammonium hydroxide

1. Always store acids separately from bases and flammables. Many acids are also strong oxidizers, e.g., nitric acid, perchloric acid.
2. Add acid to water but never water to acid.
3. Never store corrosives above eye level.
4. Store corrosives in a tray or bucket to contain any leakages
5. Store corrosives in a wooden cabinet or one that has a corrosion-resistant lining.
6. Nitric acid should be stored in a separate cabinet or compartment.
7. Only personnel fully trained in the hazards of hydrofluoric acid should use it. Inhalation of anhydrous hydrogen fluoride can be fatal. Initial skin contact with HF may not produce any symptoms.
8. Always use HF in a properly functioning fume hood.

Aqua Regia

Aqua regia is a highly corrosive solution made up of 3 parts of concentrated hydrochloric acid to 1 part concentrated nitric acid. It is used for cleaning as it can dissolve metals such as gold, platinum and palladium. Improper handling of the solution may result in skin burns and the presence of organics such as acetone, ethanol, isopropanol, detergents, will result in explosions, hence do not use it unless it is absolutely necessary. **You must inform your PI before you use aqua regia.**

1. Wear chemical splash goggles (eye protection) or face shield mask, lab coat and acid-resistant gloves. Make the solution in an uncluttered fumehood with the sash between you and the solution.
2. Always use glass containers (free of organics) as aqua regia will melt some plastics and corrode/dissolve most metals.
3. **Always** add the nitric acid to the hydrochloric acid **slowly**. Leave hot aqua regia solution in an open container in the hood until it is cool (it should not be bubbling if ready for quenching).
4. Never prepare or manipulate aqua regia while alone. If you leave something to soak overnight, the container must be clearly labeled as "Aqua Regia, Extremely Corrosive!"
5. Do not add other acids or (especially!) bases to aqua regia.
6. Mix up only what you need, then destroy after each use. **Never** store or leave aqua regia in a closed container. It will oxidize over time to form nitrosyl chloride, nitrogen dioxide and chlorine gases. This will pressurize the container, and can lead to an explosion.

$$HNO_3\ (aq) + 3HCl\ (aq) \rightarrow NOCl\ (g) + 2H_2O\ (l) + Cl_2\ (g)$$
$$2NOCl\ (g) \rightarrow 2NO\ (g) + Cl_2\ (g)$$
$$2NO\ (g) + O_2\ (g) \rightarrow 2NO_2(g)$$

Disposal of aqua regia
The spent solution should be left to cool. For small volumes (< 5 mL), dilute by pouring very slowly into a large excess of cold water (as a guideline, at least a 20-fold larger volume). The diluted solution can be carefully neutralized by adding small portions of sodium or potassium carbonate or bicarbonate with stirring (careful of foaming!!!). The use of a (bi)carbonate solution allows you to gauge that the acid is neutralized when there are no more bubbles formed. When the solution no longer foams upon addition of carbonate, check the pH. If it is between 6 – 8, you can dispose of it down the sink drain, followed by flushing with copious amounts of water. **If the solution is contaminated with heavy metals (e.g., silver, lead, chromium), the neutralized solution must be stored in the approved waste carboy for disposal as hazardous waste. It is advisable to rinse out the carboy with water first to remove any trace organics.** Use the white label for Acids/Bases and label the waste as neutralized aqua regia with heavy metals.
For larger volumes of aqua regia, dilute and send for waste disposal.

Reactives

Water-reactives: sodium, lithium, potassium, magnesium, zinc, aluminium, silanes, alkylaluminiums
Pyrophorics: diethylzinc, triethylaluminium, metal hydrides
Peroxide-forming: Diisopropyl ether, sodium amide, dioxane, tetrahydrofuran, butadiene, acrylonitrile, divinylacetylene, potassium amide, diethyl ether, vinyl ethers, vinylpyridine,
Shock-sensitive materials: chemicals containing nitro groups, fulminates, hydrogen peroxide (30%+), ammonium perchlorate, dry benzoyl peroxide, compounds containing the following functional groups: acetylide, azide, diazo, halamine, nitroso and ozonide.

1. Minimise the amount of reactives used in the experiment.
2. Always substitute a less hazardous chemical whenever possible.
3. Store water-reactive material in an isolated part of the lab away from any water sources.
4. Store pyrophorics in an isolated part of the lab and in a clearly marked cabinet.
5. Do not open any chemical containers if peroxide formation is suspected. The act of opening the container could be sufficient to cause an explosion. Visually inspect for crystals and unusual viscosity before opening.
6. Date all peroxide-forming material with the date received and expected shelf life.
7. Chemicals like diisopropyl ether, divinyl acetylene, sodium amide and vinylidene chloride should be discarded after three months
8. Chemicals such as dioxane, diethyl ether and tetrahydrofuran should be discarded after one year.
9. Store all peroxide-forming material away from heat, sunlight and sources of ignition
10. Never store peroxide-forming material in clear glass bottles where they can be exposed to light
11. Secure the lids and caps of the containers to discourage the evaporation and concentration of these chemicals
12. Never store peroxide-forming material in glass containers with screw cap lids or glass stoppers - friction and grinding must be avoided.
13. Never distill an ether unless it is known to be free of peroxides.
14. Store shock sensitive materials separately from other chemicals and in a clearly marked cabinet.

Electrical Safety

Notice the danger signs On all electrical equipment you use, watch for signs of wear on the cable and insulation problems where it connects to the plug or equipment. Replace or rectify as necessary.

Plugs and Fuses If you put a mains plug on a piece of equipment, follow the wiring colour code:

BROWN	LIVE
BLUE	NEUTRAL
GREEN-YELLOW	EARTH

Use the correct fuse for the equipment.

Water and electricity Wet electrical equipment is very dangerous. Disconnect from the mains before touching it. **Beware of wet heating mantles.**

Safety Testing All portable electrical equipment (i.e. equipment that can be unplugged) must be tested regularly.
New, second-hand and old equipment must be tested before being brought into use.
Equipment that carries a “Failed” sticker must never be used.

Mechanical Safety

Carrying solvents Winchester bottles of solvents may be carried in the corridors or lifts only in carriers (maximum load per person, two carriers) or on appropriate trolleys

Rotary equipment Equipment with rotating parts, e.g. stirrers, rotary evaporators, rotary pumps must not be allowed to catch hair or clothing or any trailing wires or tubing.

Gas cylinders Large cylinders of compressed gases must be moved only in proper trolleys (which are designed to be pushed, not pulled) and transferred carefully to positions where they can be securely strapped. Only the minimum number of cylinders should be kept at any station. If a cylinder trolley is showing signs of wear or is giving any trouble, inform Lab Supplies.
There are a number of types of regulators in use with different pressure scales: mark on your regulators the maximum safe pressure for routine work in your laboratory.
Never attempt to fit compressed gas cylinders if in doubt.

Laser Safety

The major health risk for personnel working with lasers is the potential for eye injury. Electromagnetic radiation above X-ray spectrum penetrates the ocular structures to varying degrees, depending on wavelength, maximizing in the visible spectrum:

<315 nm (far UV) -cornea
315-400 nm (near UV) -lens
400-1400 nm (visible and near IR) -retina
1400-3000 nm (far IR and microwave) -lens
>3000 nm - cornea
The risk also depends on the power of the laser, and for lasers of medium power or greater, on the potential for possible reflections of surrounding surfaces. Lasers are classified as Class 1, 2, 3a, 3b, or 4 according to output (beam intensity in Watts/cm^2 or radiation dose in joule/cm^2 at specific wavelengths). High power lasers may produce additional risk to skin and associated

hazards primarily related to the generating equipment, such as electrical shock and ionizing radiation.

Laser radiation should be discharged in a non-reflective and fire resistant background. All personnel should be cleared for a reasonable distance on all sides of the laser beam. A warning sign should be attached to the laser device in a conspicuous location to indicate the potential eye hazard associated with the laser. The correct safety goggles for the Laser class should be used in order to filter out the specific laser wavelength. All workers should have a pre-employment eye examination as well as a final eye examination. Information on licence application is given below and at the PSSO website.

Radiation Safety

It is particularly important that workers proposing to use sealed or open sources (e.g. radioactive labelling experiments) seek advice from OSHE at an early stage (e.g. before submitting a grant application). This is necessary to ensure that the proposed work can be safely carried out in the department and that sufficient overheads are included in the grant application to cover the costs of handling the radioactive materials involved. Information on licence application is given below and at the PSSO website.

Users of X-ray diffractometers

Training for the X-ray generators is provided by the respective CMMAC facility. Users should have a R1 licence.

Users of sealed or open sources of ionising radiation

Contact the Faculty Safety Officer for advice and licence requirements. This category includes all sealed radioactive sources that might for example be used to calibrate equipment.

Unsealed radiation sources typically consist of small volumes of organic or inorganic chemicals or carrier-free solutions containing radionuclides. The contents of these unsealed sources are readily accessible to the user. Most come in liquid form, with potential for spills, splashes, aerosolization, and vaporization.

From a safety standpoint, controlling contamination imposes the most stringent requirements on handling the majority of unsealed sources. Some high-energy beta emitters and some gamma emitters need to be handled cautiously to prevent unnecessary dose as well as prevent contamination. A good starting point is general housekeeping in the laboratory including proper organization and storage of chemicals and tools, adequate space in which to work, a clutter-free environment, and ease of access to sinks, eyewash stations and safety showers. Keep fumehoods free of clutter, especially at the face and floor of the hood where the air flow may be disrupted. Work well inside the hood--not right at the hood face--and keep your face out of the hood.

Good personal hygiene can protect you from unnecessary dose. Wash hands thoroughly after every procedure and before leaving the laboratory.

Always wear protective clothing and equipment. Gloves shall be worn every time you handle vessels containing radioactive material (and those that may be contaminated). Select gloves which are most appropriate for the chemical hazard. Never wear disposable gloves outside of the lab. Lab coats shall always be worn when there is a potential for exposure to hazardous materials. Lab coats shall be removed upon leaving the lab when there is a potential of contamination from a hazardous material on the lab coat. Keep lab coats buttoned up. Approved eye protection shall be worn when there is a potential exposure to the eyes from any hazardous material.

Double containers shall always be used to transport radioactive materials. A second, outer container with absorbent material will cushion a dropped sample or broken vessel. Establish a designated radiation work area and make sure that vessels, tools, and equipment used for radioactive materials work are labeled and stay in that area. Protect the work area with plastic-backed absorbent paper. Work on a tray that is also lined with absorbent paper.

Label all containers that hold or are contaminated with radioactive material.

Step-by-Step Procedure for Licence Application

Types of licences

Ionising Radiation

- L3 - Application for a licence to keep or possess an irradiating apparatus for use other than sale (for individual equipment owner)
- L4 - Application for a licence to keep or possess radioactive materials for use other than sale (licence under Faculty)
- L5 - Application for a licence to use irradiating apparatus (other than sale) (for individual PI)
- L6 - Application for a licence to use, handle and transport radioactive materials (other than sale) (for individual PI)
- L6A - Application for a licence to handle and transport radioactive materials (for transport company)
- L7 - Application for a licence to import/export a consignment of irradiating apparatus
- L8 - Application for a licence to import/export a consignment of radioactive materials
- R1 - Registration as a radiation worker (students and workers based on L5 or L6 of PI)

Non-ionising Radiation

- N1 - Application for a licence to manufacture or deal in the apparatus specified in Parts I, II and III of the NIR regulations
- N2 - Application for a licence to keep or possess for use the irradiating apparatus specified in Parts II and III of the NIR Regulations (to possess laser or sonicator)
- N3 - Application for a licence to use the irradiating apparatus specified in Part III of the NIR regulations (each individual person operating laser need to apply for this license. No need N3 to operate sonicator.)
- N4A - Application for a licence to import the irradiating apparatus specified in Parts I, II and III of the NIR regulations
- N4B - Application for a licence to export the irradiating apparatus specified in Parts II and III of the NIR regulations

Procedure

L3 license (L3 for possessing an ionizing irradiating apparatus, e.g., XRD)

1. Download the application form for L3 from NEA website http://www.nea.gov.sg/services-forms/licences-permits-building-plan-clearances/radiation
2. Complete the application form. Obtain the equipment brochure.
3. Submit the completed NEA license application form, equipment brochure and cheque to Mdm Lim Nyoon Keow. Remember to keep a copy of these documents.
4. Mdm Lim will submit the documents to FOS Safety (Syam/Alicia) who submit the documents to NEA for processing. A copy of these documents will be kept by them.
5. Wait for approval from NEA (about 1 month).
6. Install the equipment and ensure it is in operating conditions.
7. NEA will conduct a site inspection for the equipment to measure the radiation level. FOS Safety will assist to make appointment with NEA officer, Mr Chai Chiang Yap (email: chai_chiang_yap@nea.gov.sg; phone: 6731 9543) for inspection.

8. NEA will issue the L3 licence when the inspection is passed.
9. Once NEA issued the license, they will mail to FOS Safety and the mail will be forwarded to you via Mdm Lim. A copy of the license will be kept by FOS Safety Officer.

L5 for using the XRD and also as a supervisor for R1 license holder

1. Download the application form for L5 from NEA website http://www.nea.gov.sg/services-forms/licences-permits-building-plan-clearances/radiation
2. Complete the application form.
3 a) Complete the attach Authorization form for Occupational Health Services
b) Submit the complete form to Mdm Lim Nyoon Keow who will submit to FOS Safety (Syam/ /Alicia) for approval. The approved form will be returned to you.
c) With the approved form, make an appointment with Occupational Health Clinic in OSHE. Contact person: Nurse Kim @ nursekim@nus.edu.sg, 6516 7333 or Goh Sha Wee @ oshgsw@nus.edu.sg, 6601 1781. Upon receipt of the completed request form, they will contact you via phone or e-mail for further arrangements.
d) Go for the medical examination and obtain the medical report.
4. Submit the completed NEA license application form, medical report and cheque to Mdm Lim. Remember to keep a copy of these documents.
5. Mdm Lim will submit the documents to FOS Safety who will submit the documents to NEA for processing. They will also keep a copy of these documents.
6. Attend the written test in NEA upon receive the notification from NEA.
7. Wait for approval from NEA.
8. Once NEA issued the license, they will mail to FOS Safety and the license will be forwarded to you via Mdm Lim, then she will pass to you. A copy of the license will be kept by FOS Safety Officer.

R1 license holder for radiation worker (work under supervisor of L5 license holder, no written test required)

1. Download the application form for R1 from NEA website http://www.nea.gov.sg/services-forms/licences-permits-building-plan-clearances/radiation
2. Complete the application form.
3 a) Complete the attached Authorization form for Occupational Health Services
b) Submit the completed form to Mdm Lim who will forward to FOS Safety for approval. The approved form will be returned to you.
c) With the approved form, make appointment with Occupational Health Clinic in OSHE. Contact person: Nurse Kim @ nursekim@nus.edu.sg, 6516 7333 or Goh Sha Wee @ oshgsw@nus.edu.sg, 6601 1781.Upon receipt of the completed request form, they will contact you via phone or e-mail for further arrangements.
d) Go for medical examination and obtain the medical report.
4. Submit the completed NEA license application form, medical report and cheque to Mdm Lim. Remember to keep a copy of these documents.
5. Mdm Lim will submit the documents to FOS Safety who will forward the documents to NEA for processing. They will also keep a copy of these documents.
6. Wait for approval from NEA.
7. Once NEA issued the licence, they will mail to FOS Safety Officer and the license will be forwarded to you via Mdm Lim, then she will pass to you. A copy of the license will be kept by FOS Safety Officer.

License renewal for L3, L5 and R1

1. Take note of the licence expiry date. You should receive the renewal notice about 2 months before the expiry date. If you do not receive the renewal notice 1 month before the expiry date, highlight to Mdm Lim /Syam/Alicia. They will request the renewal notice from NEA.

2. Start the renewal process when you received the renewal notice.
a) Complete the renewal form.
b) Prepare the cheque.
c) Submit the completed license renewal form and cheque to Mdm Lim /finance. Remember to keep a copy of these documents.

d) Mdm Lim/finance will submit the documents to finance/FOS Safety (Syam/Alicia). Finance/FOS Safety will submit the documents to NEA for processing.

3. Once NEA issues the new license, they will mail to Syam/Alicia who will forward to Mdm Lim for transmission to you. FOS will keep a copy of the license.

TLD badge

1. With the L5 and R1 licenses, the NEA will issue you a TLD badge to you. The TLD badge from NEA will be given to FOS Safety Officer who will forward to Mdm Lim to pass to you.
2. NEA will issue TLD badges to you every month. It is a one-to-one exchange exercise. Therefore, you need to return the used TLD badge to get a new badge.
3. NEA will send FOS Safety Officer the dose report for the TLD badge. You will receive the report from Mdm Lim.

Glassware Safety

Broken glass and empty bottles

Broken glass or used disposable pipettes and other items, may be put only in waste bins labelled **Sharps** - this is for the safety of cleaning staff who empty waste bins.

Before they leave your laboratory it is vital that all bottles for disposal are treated in the following way:-

- Any sodium residues in bottles must be carefully destroyed and the bottles washed with water;
- All bottles should be completely emptied of solvents and chemicals then washed and dried to the extent that there is no residual odour from them;
- **Cleaned** bottles can be put **unstoppered** into the waste bins.

Glassware for repairs

- All glassware sent to the glassblower for repairs must be thoroughly cleaned first. For perfluorinated grease like Krytox, use ethyl acetate to degrease followed by soaking in a base bath.
- For the silicone or hydrocarbon grease like Apiezon, use pentane for degreasing.

Cryogenic Safety

Refrigerators and freezers

An **explosion-proof fridge** must be used for chemicals. Do not use your refrigerator or freezer as a dump. Make sure everything you put in is tightly sealed in a way that will not leak when cold. Check the contents frequently and discard unwanted samples. **Food must never be stored in a refrigerator used for chemicals.**

Liquid N_2/ Solid CO_2

These substances can freeze-burn you. Equipment cooled outside by liquid N_2 but open to air will allow liquid O_2 to form **inside** which can create a dangerous pressure rise on warming or an explosion with flammable material. Use liquid nitrogen to cool sealed or evacuated systems only.

In closed environments, these chemicals can cause **asphyxiation**. Therefore, be aware of the dangers when transporting in lifts. To avoid in possible risks from nitrogen boil off during, for example, a prolonged period of lift breakdown, Dewars of liquid nitrogen must not be accompanied in lifts. Rather, two people should be assigned to transport the Dewars, one to load and one to receive at the destination floor. To prevent others from entering the lift, fitted straps should be pulled across the entrance. Dry ice should be transported in a thermally insulated container with a loose-fitting lid. Do not use am airtight container as the gaseous CO_2 is likely to cause the container to explode. A block of dry ice (~ 1 kg) when completely sublimed is enough to reduce the oxygen level in a stalled lift to suffocation level. Use the stairs whenever possible.

Working with Sealed Tubes or High Pressure

Working with hazardous chemicals at high pressure and temperatures requires special precautions. It is imperative that you carry out these procedures with protection against explosion by selecting the appropriate equipment. Never carry out reactions in, or apply heat to, an apparatus that is a closed system unless it has been designed and tested to withstand pressure.

Maximum pressure

The maximum pressure expected in the vessel should be calculated from the amount of reactants/products, temperature and volume of free space. In a closed vessel, you will have gas/liquid equilibrium, with the pressure equal to the vapour pressure of the compound. You can check the Cox plot for the pressure or use the Antoine equation at: http://ddbonline.ddbst.com/AntoineCalculation/AntoineCalculationCGI.exe

Only above the critical point will you have a single phase. Take note that the density at the critical point is about 1/3 of the liquid density. Therefore NEVER fill the autoclave more than 1/3 full. An expanding liquid exerts much higher pressure than corresponding to its vapour pressure. Above the critical point, you can use the ideal gas law to determine the pressure from the known number of moles that you put into the autoclave. Take care that the maximum allowable pressure is not exceeded.

Types of apparatus

Reactions under pressure are typically carried out using sealed tubes or autoclaves. While it is sometimes convenient to run very small scale reactions at low pressures in a small sealed glass tube or in a thick-walled pressure bottle, you should be fully prepared for the significant possibility that the sealed vessel will burst. Every precaution to prevent injury from flying glass or from corrosive or toxic reactants should be taken by using suitable shielding.

Sealed tubes are usually rated for 5 – 6 bar maximum pressure only. Avoid glassware for work at high pressure whenever possible. Glass is a brittle material, subject to unexpected failures due to factors such as mechanical impact and assembly and tightening stresses. Poor annealing after glassblowing can leave severe strains. If glass is required because of material-of-construction concerns, use a metal reactor with a glass or Teflon liner instead of a glass vessel under pressure. Fill glass tubes under pressure no more than three-quarters full.

It is highly advisable that you carry out the reaction in an autoclave instead. Autoclaves are made of metal and may come with glass or plastic inserts. Autoclaves are designed for higher pressures than glass sealed tubes. All branded autoclaves are pressure-rated and come fitted with pressure relief valves which will be activated one the maximum allowable pressure is exceeded. Experiments involving highly reactive materials that might explode or undergo rapid decomposition with gas evolution will need special quick-acting pressure relief valves that can be operated at a fraction of the permissible working pressure of the system. Home-built ones commonly do not have pressure relief valves and should be used only for reactions using water as solvent and below its pressure limit. Take note that the pressure of water increased from ~ 2 bar to 16 bar for temperatures of 120 to 200 °C. For any reaction run on a large scale (>10 g total weight of reactants) or at a maximum pressure in excess of 690 kPa (100 psi), use only procedures involving a suitable high-pressure autoclave.

Pressure-relief devices

Examples of pressure-relief devices include the rupture-disk type used with closed-system vessels and the spring-loaded safety valves used with vessels for transferring liquefied gases.

- The temperature rating of the relief device must be sufficient. Heat conduction via tubing and fittings can cause the relief device to reach high temperatures, depending on the apparatus design.
- The pressure-relief devices should be placed with the vent side of the device directed away from the operator or other personnel. Also vent the relief device into an appropriate trap to catch flammable solvent, reaction solids, etc., avoiding spray into the workspace in the event of a release and minimizing the potential of a fire and aiding clean up. The relief device and trap must be supported so that they are not dislodged or thrown due the thrust resulting from sudden venting.
- The maximum setting of a pressure-relief device is the rated maximum allowable working pressure (MAWP) established for the vessel or for the weakest member of the pressure system at the operating temperature. The operating pressure should be less than the maximum setting of the pressure-relief device. In the case of a system protected by a spring-loaded relief device, the maximum operating pressure should be from 5 to 25% lower than the rated working pressure, depending on the type of safety valve and the importance of leak-free operation. In a system protected by a rupture-disk device, the maximum operating pressure should be approximately two-thirds of the rated MAWP; the exact figure is governed by the fatigue life of the disk used, the temperature, and load pulsations.
- Vent pressure-relief devices that may discharge toxic, corrosive, flammable, or otherwise hazardous or noxious materials in a safe and environmentally acceptable manner such as scrubbing or diluting with nonflammable streams.

- Do not install valves or other shutoff devices between pressure-relief devices and the equipment they are to protect. Similarly, do not install shutoff valves downstream of the relief device and take care to ensure that the relief vent is not blocked or restricted. Tubing and piping downstream of such devices must be at least the same diameter as the fitting on the vent side of the relief device.
- Only qualified persons should perform maintenance work on pressure-relief devices.
- Inspect and replace pressure-relief devices periodically.

Heating

Use a heating jacket or an oil bath. Ovens or furnaces **should not be used** for heating the autoclaves when the reaction involved organic solvents. In case of overpressurization, the pressure relief valve may open and the discharged organics may come into contact with heating elements, causing a fire or explosion. Carry out any reaction of this type in a fume hood, labeled with signs that indicate the contents of the reaction vessel and the explosion risk.

Cooling down

When the required heating has been completed, allow the sealed tube or bottle to cool to room temperature before opening.

Noise and Safety

Changes in sounds are often a first indication that something is wrong with equipment or machinery. Try to keep background noises from pumps, shakers, compressed air jets, etc. at as low a level as possible for the comfort of everyone and so that you can hear when something is going wrong. **Noisy radios are not permitted in laboratories**.

The use of personal audio equipment which include earphones is forbidden in the research areas and teaching laboratories of the Department of Chemistry.

Out of Hours Working

There are special risks from working in a laboratory in the Department outside normal working hours (8:30 a.m. – 6:00 p.m. Monday to Thursday and 8:30 a.m. – 5:30 p.m. on Friday) as help may not be available in the event of an accident. **It is the duty of all Research Supervisors to be aware of the work being undertaken by their students and to ensure that out of hours work is properly regulated**. The following rules apply out of normal hours:-

- **Undergraduates are forbidden to be in laboratories unless a member of the academic staff of the Department or designate is present with them.**
- **Lone working is forbidden**. Make sure there is always someone within calling distance.
- Experiments that involve any measure of risk must be left to normal working hours. **No work involving Cyanides or HF may be carried out outside normal working hours.**

Unattended Experiments

Experimental work left running unattended poses special risks in terms of fires and floods and must be carefully controlled. The following rules apply:

- Unattended running of experiments may be carried out **only when absolutely necessary.**
- Experiments involving overnight refluxing of solvents **must be within a ducted fume-hood**. All water lines must be fixed securely.

- All experiments left on must have a notice on
  - stating **Experiment in Progress Please Leave On**
  - and indicating **potential hazards in plain English** e.g., "*Flammable solvent*", "*Contains Toxic Material*"
  - and the **name and telephone number** of the person who is responsible for it:- This must be **a realistic telephone number where you can be contacted at all times** because **you** may be called out at any time to deal with **your** experiment.
  - If at all possible, this information should also be posted in a prominent position external to the laboratory.
  - If an unattended experiment is set up in a fume hood, the **lighting for that fume hood should be turned on**.
  - Electrical equipment left on should carry a **Do Not Switch Off** notice in yellow card giving the name of the person leaving the equipment and a contact phone number**.** For **large permanent equipment** like Electron Microscopes, NMR equipment etc. contact numbers should also be posted external to the laboratory and **Emergency Electrical OFF** switches clearly identified within the laboratory.

Pregnancy

Certain chemicals, radiation and physical tasks pose a greater than normal danger to an expectant woman and to her unborn child. If you become pregnant, you should inform your Supervisor **in writing** - they may then be able to help you to avoid exposure to such agents and to any problematic tasks.

Tidiness

The prospect that you and your co-workers stay safe will be increased if you all keep your **working environment reasonably tidy and free of obstacles**.

Reporting Accidents and Incidents

In event of a dangerous incident or an accident in the Department, it must be **first** reported to Department Safety Office. **Do not clean up** the site of the incident/accident until the safety personnel has inspected it.
Dangerous incidents are defined as unplanned events in which no one was hurt but which either had the potential to cause injury or did cause damage to apparatus, equipment or the building. **Accidents** are defined as events in which someone gets hurt.

Contact numbers
Office hours: 61760 (Junaidi), 62659 (Department secretary), 62922 (Department General Office, 62839 (GK Chuah).
After office hours: inform your PI first who will then call the Safety officer or Safety chairperson.

Following the inspection of the accident site by department and faculty safety personnel, an Incident Form must be submitted online to OSHE within 24 hours. It is compulsory under the Workplace Safety & Health Act to report any dangerous event and accident.

An Incident Form for reporting Dangerous Incidents or Accidents to OSHE is available here (https://wws.nus.edu.sg/airs/report.aspx). **The completed form must be sent online. Please note that the aim is not to apportion blame for an Accident/Incident but rather to see that it does not occur again. No one should be afraid to report such an event.**

Regulations on Purchase of Chemicals and Inventory

1. All deliveries of chemicals and solvents to the Department of Chemistry must have purchase orders originating from Lab Supplies, Department of Chemistry. The ES Online Chemstore System is used for generating purchase orders to buy chemicals and other non-chemical items. You must pass the Chemistry Safety test before you are allowed to login to the ES system (https://www.chemistry.nus.edu.sg/chemstore/userlogin.wp). Read the instructions at the site to know how to use. If chemicals fall under CWC, you need to apply online to OSHE for the licence to purchase the chemicals (https://wws.nus.edu.sg/rci/default.aspx).

2. Strictly no Cash-On-Delivery is allowed for purchase of chemicals and solvents.

3. Irrespective of the source of the grant, purchases involving excessive amounts of solvents and/or chemicals to be stored in the Department of Chemistry will not be approved. Should it be necessary that large amounts of solvents and/or chemicals be purchased, arrangements should be made with the supplier for storage at their site and partial delivery be made on an as-and-when-needed basis. Written verification from the supplier is necessary.

4. No chemicals/solvents are to be sent directly to any individuals. All chemicals and solvents must be delivered to Lab Supplies, Dept of Chemistry, Science Drive 2, Blk S5 Basement Office, Singapore 117543.

5. All chemicals and solvents not purchased and delivered in accordance with the above procedures will be considered illegal. When buying chemicals from chemical companies not in Singapore, you must inform them that **proper declaration** of the chemicals is required. Deliveries made without proper declaration of the contents will be returned to the sender at your cost and a report will be made to customs.

6. All chemicals and solvents must be properly stored in the appropriate safety cabinets.

7. All chemicals and solvents must be updated regularly after use using the weighing balance and scanner provided in each lab. Keeping an inventory is required for **all regulated** chemicals. A softcopy version is allowed.

7. Lab Supplies sells technical solvents, acids, alkalis and some common lab chemicals. To purchase these, the Letter of Authorisation for Collection of Solvents & Chemicals must be signed by the PI and submitted to Lab Supplies before 11:30 am. The solvents can then be collected at 2:45 pm (on Tuesdays and Fridays) or 3:00 pm (on Mondays, Wednesdays, and Thursdays) at the Technical Solvents store. For flammable solvents, the maximum volume that you can purchase each time is 60 L (12 x 5L). You MUST return the empty canisters before you can buy new stock. If you do not return the empty canisters, the solvents you bought will remain under your lab's inventory and your lab may exceed the maximum allowable quantity (MAQ) for flammables. If that happens, your lab will not be allowed to purchase any more PFM-regulated chemicals.

Regulations on Import of Biological Agents/Toxins

An import permit granted by the Ministry of Health is required for the importation of biological agents, toxins including proficiency test items and inactivated agents. If you are the importer, then you must have an Approval to Possess for that item. Refer to Import of Biological Agents/Toxins under Applicable Legislations for more information.

Chemical Waste Disposal

For safety and environmental reasons, regulations make the disposal of chemical waste difficult and costly. It is a matter of sensible economics as well as good practice to generate as little waste as possible and, wherever practicable, substances should be recovered and recycled.

At the end of research projects it is necessary to dispose of all unwanted products or other chemicals and researchers are required to follow the instruction for laboratory clearance described in the Safety Manual.

Waste Chemicals

The PI of the individual research project is to make arrangements with a chemical waste disposal company for disposal of unwanted chemicals. A list of such companies can be obtained from the Chemistry Safety Office.

All substances to be disposed of should, if possible, be identified by chemical name and molecular formula. If this is very difficult because there is a mixed waste, then the character of the mixture must be accurately defined, *e.g.* categorizations such as *a mixture of organic amines and their salts but with no compound boiling below 100 °C; some are suspect carcinogens* would be helpful and acceptable (provided it is true) but a categorization such as *mixture of organic liquids, smells of nitrobenzene* will not be acceptable and some work will have to be done by the originators of the waste to determine what else is with the nitrobenzene before it can be accepted. **It is very important that if there are known hazards associated with the waste, these should be stated on the label (see below) including for example the inclusion of hazardous drying agents.**

All substances to be disposed of must be put into leak-proof containers that are clearly labelled with the **identity or categorization of the contents, any known hazards, and some indication of boiling point range.** Substances identified only by a trade name will also not be accepted - there has to be some indication of the chemical nature.

General: If material is packed into used boxes, ensure that old labels are obliterated and the container is marked "**this way up**". The total weight should not exceed 5 kg and the dimensions should be about one foot cube. Organic or aqueous liquids should be in glass or plastic containers, solids in metal drums or plastic tubs.

Twice Weekly Disposal of Wastes

The Department has a twice weekly arrangement to dispose of waste solvents, corrosives, silica and sharps. Prior to disposal, you are to go to Lab Supplies and register the type and quantity of waste to be disposed. At present, the wastes are categorized into “chlorinated/halogenated” and “non-chlorinated/non-halogenated” waste solvents, corrosives – acids and bases, silica gels and sharps. **Waste containers are not dumps** and may contain only the approved wastes. For organic waste solvents, only limited amounts of solute are allowed. Reaction mixtures containing **drying agents, oxidants or solutions of oxidants, acids or bases** must **never** be put into the waste solvent containers. A list of incompatible chemicals is given in the tables below. Please observe the incompatibility strictly and **never** place the incompatible chemicals in the **same** waste container. Serious accidents have resulted from this. It is your duty to use the correct labels for the waste containers: green tag for non-chlorinated/non-halogenated solvents, yellow for chlorinated/halogenated solvents, and white for acid/base (cross out to show the correct content). The date of first waste generation and the contents of the wastes must be written on the labels.

Discharge of toxic and environmentally hazardous chemicals into public sewers is forbidden under the Sewerage and Drainage Act. Under the Environmental Public Health Act, only licensed waste collector must be engaged to collect hazardous waste generated.

No substances that are category 1 or 2 carcinogens may be put in the waste solvents in any form.

Organic liquids acceptable as Waste Solvents

Non-chlorinated

- Mixed solvents - acetone, ethanol, ethyl acetate, ethylene glycol, hexane, isopropyl alcohol, kerosene, 1 -methyl-2-pyrrolidinone (NMP), methanol, methyl ethyl ketone, methyl isobutyl ketone, propylene glycol, thinner, toluene, xylene

Chlorinated (halogenated)

- C_1: dichloromethane, chloroform, carbon tetrachloride
- C_2: trichloroethylene, tetrachloroethylene, 1,2-dichloroethane, 1,1,1-trichloroethane,
- C_3: 1-chlorobutane plus small amounts of non-chlorinated materials but no water.

No chlorinated aromatic wastes should be mixed with the chlorinated wastes as they need separate incineration. Contact the waste vendor if you have such wastes.

Acids/Bases

Organic acids must be kept in separate containers from mineral acids**. Wherever possible, dilute first before disposing**. If you are disposing of concentrated acids or bases, rinse the waste carboy with water first to ensure that it is cleaned of any trace organics.

Be aware that concentrated acids especially nitric acid, being an oxidizer, can react violently with organic matter and should not be mixed with other organic acids. It can attack plastics over time, therefore, do timely disposal.

Containers: The accepted container for transfer of waste solvent to the Lab Supplies is a screw-capped 5 L polythene bottle. No other containers are acceptable. **Before use, the chlorinated (yellow), non-chlorinated (green), acid/base (white) label must be pasted on the canister with the date of first use and intended wastes listed. The containers must be filled only to the 80 % level with approved solvents, sealed with their original caps, not leaking vapour or liquid or contaminated on the outside.** Stores staff are not allowed to accept over-full, leaking or externally contaminated containers.

Registration: Prior to collection every Monday and Thursday, information about the solvent to be disposed must be recorded in the log book at Lab Supplies. The cut-off time for registering disposal is 1:00 pm on the day of disposal. **You will be given the Waste Vendor label to be pasted on the container.** Do not paste over the yellow/green/white hazard label. The name of the PI and date must be filled in.

Storage: Separate containers for Chlorinated/Halogenated and non-Chlorinated/non-Halogenated solvents should ideally be kept in a fume-hood. Large polythene containers of flammable solvents are extremely vulnerable in case of fire and must be kept in a closed cupboard when not being used to receive waste solvent. Secondary containers are required for the waste canisters.

Transport: Waste solvents should be transported only in designated lifts. These lifts are closed to the general public for the exclusive transport of wastes from 2:30 – 2:35 pm. No one should enter the designated lifts when waste transportation is being carried out. Two persons should do the waste disposal. One person should push in the trolley, pull the sash across the lift to prevent others from getting in and press the button for the ground floor. The second person should wait at the ground level for the waste trolley to arrive.

Collection: Waste solvent is to be disposed every Monday and Thursday between 2:45 p.m. – 3:00 p.m. outside the Solvent Store. Lab Supplies Staff are not allowed to accept containers which do not meet the criteria described under "Containers" above.
The waste containers must be checked by Lab Supplies staff before unloading or placing into the big bin of waste vendor.

Special disposal

For disposal of other chemicals such as waste HF, waste pump oils, please store them separately with appropriate hazard label and arrange via Lab Supplies for disposal by the waste vendor.

If you have small quantities of acids or bases that are free of heavy metals (copper, zinc, silver, etc), you should dilute and neutralize the solution before drain disposal.

Drain disposal of small quantities of acids and bases

Acids and bases must be rendered **neutral** before being disposed down a lab sink with copious amounts of water. Neutralization should be done in small quantities (i.e., no larger than 5 ml). You should not collect a quantity of the acid/base wastes from different experiments and do a batch neutralization. Do neutralization in a fume hood as fumes and heat may be generated. PPE must be donned before carrying out the dilution and neutralization. Do your calculations for the dilution and neutralization.

1. Choose a container with a volume at least twice that of your final volume after neutralization. Slowly add the acid to the cold water to dilute to about 5 %.
2. For acid neutralization, prepare a 5 % basic solution of sodium carbonate, calcium hydroxide or sodium hydroxide. The use of a carbonate solution allows you to gauge that the acid is neutralized when there are no more bubbles formed. (For base neutralization, add 5 % hydrochloric acid solution.)
3. Slowly add the base solution to the diluted acid from (1).
4. Check that the pH is between 6 to 8 before turning on the tap.
5. Pour the solution down the drain keeping the tap on. Let the tap run for another few minutes after the container has been emptied.

Chromic acid and dichromate solutions

Chromic acid solution is a mixture of concentrated sulfuric acid and potassium dichromate, Chromerge (chromic acid), or chromium anhydride (chromium trioxide). It is used to clean laboratory glassware because it oxidizes most residues and eats away a very thin layer of the glass surface, leaving a new, clean surface. The Safety Committee recommends that you try to avoid using such cleaning solutions due to the following considerations.

1. The hexavalent chromium present in the above solutions is considered a human carcinogen.
2. It is a strong oxidizer that has been known to react violently and explode when combined with oxidizable materials.

3. The addition of chloride or halogens to chromic acid cleaning solutions can generate the highly toxic and volatile carcinogen, chromyl chloride. The formation of volatile chromyl chloride necessitates that these cleaning solutions be used inside chemical fume hoods.
4. Used chromic acid cleaning solutions cannot be neutralized and flushed into the sanitary sewer because the chromium metal remains.
5. There are many non-toxic biodegradable cleaning solutions that can be used instead of chromic acid. See the alternative cleaning solutions listed below.

Suggested alternatives to chromic acid cleaning solutions are

1. Non hazardous cleaning solutions (safest; try these first)

   * Ultrasonic baths (these work well for many labs)
   * Alconox or similar detergents
   * Pierce RBS-35 or similar detergents
   * Biodegradable surfactants

2. Strong corrosive solutions (hazardous due their corrosivity)

   * Potassium hydroxide/ethanol solutions (also flammable)
   * Dilute hydrochloric acid

Stop using chromic acid solution unless you have tried the alternatives and found them to be unsatisfactory.

Waste disposal guide for chromic acid cleaning solution:

1. The amount of solution should be less than 100 ml. All work should be done in a fume hood.
2. Wear nitrile rubber gloves, laboratory coat and eye protection.
3. Do a 1:1 dilution by slowly adding the solution to a container of water.
4. Adjust the pH to 1 by the addition of 3 M sulfuric acid or sodium carbonate.
5. With stirring, slowly add solid sodium thiosulfate (~13.5 g) until the solution becomes cloudy and blue in color.
6. Neutralize the solution with sodium carbonate and wait till a blue-gray flocculent precipitate is formed.
7. Let the mixture stand for 1 week until much of the supernatant can be decanted.
8. The remaining liquid is allowed to evaporate or the slid filtered through Celite.
9. The liquid may be washed into the drain with 50 times its volume of water.
10. The solid residue should be washed with hot water to remove sodium sulfate, then dried, packaged, labeled and lastly sent for disposal.

$$Cr_2O_7^{2-} + 3S_2O_3^{2-} + 2H_3O^+ \rightarrow 2Cr(OH)_3 \downarrow + 3SO_4^{2-} + 3S$$

Drying agents and water reactive substances

In research laboratories it is common practice to add drying agents to organic solvents to remove trace quantities of water. Caution must be used when choosing a suitable drying agent because many drying agents are extremely water reactive. Some of these reactive materials generate highly flammable gases on contact with water and careless handling could cause a serious fire or explosion. Such chemicals are: sodium metal, sodium hydride, potassium metal, potassium hydride, calcium metal, calcium hydride, lithium aluminum hydride. Another reason to avoid using water reactive drying agents is the hazard the agent presents when the material is disposed. If the drying agent has not been removed from the solvent there is a potential for explosion, because all flammable solvent wastes are consolidated into drums. If a water reactive material is accidentally poured into one of these drums, someone could be severely burned or killed by the resulting

explosion.
Dehydrite is a drying agent which contains magnesium perchlorate. Magnesium perchlorate is a strong oxidizer which may cause fires or explosions on contact with organic materials. The safest and most common drying agents are calcium chloride, silica gel, molecular sieves, and calcium sulfate (Drierite). It is highly recommended that you use these materials because of their lower toxicity and stability.

Waste disposal guide for sodium

1. For small quantities of sodium only. Wear eye protection, laboratory coat, and nitrile rubber gloves and work in the fume hood.
2. Place small pieces of solid sodium in a three-necked, round-bottom flask equipped with a stirrer, dropping funnel, condenser, and heating mantle.
3. Flush the flask with nitrogen. Add 95% ethanol (13 mL per gram of sodium) dropwise at a rate to cause rapid reflux. Stirring is started as soon as enough ethanol has been added to make it feasible.
4. Stir the mixture and heat under reflux until the sodium is dissolved.
5. Turn off the heat and add an equal volume of water at a rate that causes no more than mild refluxing.
6. Cool the solution and neutralize with 6 N sulfuric acid (prepared by cautiously adding 15 mL of concentrated acid to 75 mL of cold water) or hydrochloric acid (prepared by adding concentrated acid to an equal volume of cold water).
7. Wash into the drain with at least 50 times its volume of water.

$$2Na + 2C_2H_5OH \rightarrow 2C_2H_5ONa \text{ (sodium ethoxide)} + H_2$$

$$C_2H_5ONa + H_2O \rightarrow NaOH + C_2H_5OH$$

Waste disposal guide for sodium hydride and potassium hydride

1. The amount should be less than 10 g. All work should be done in a fume hood.
2. Wear Nitrile rubber gloves, laboratory coat and eye protection. (For KH, face shield is necessary)
3. Mix the hydride with a 1:1:1 mixture by weight of sodium carbonate or calcium carbonate, clay cat litter (bentonite) and sand.
4. Slowly add butanol (~38 mL/g NaH, ~22 mL/g KH) until the reaction ceases.
5. Add water very carefully until all the hydride is destroyed.
6. Let the mixture stand until solids settle.
7. Decant the liquid into drain with at least 50 times its volume of water.
8. The solid residue may be discarded with normal procedure.

$$NaH + n-butanol \rightarrow NaOC_4H_9 + H_2$$

$$NaOC_4H_9 + H_2O \rightarrow NaOH + n-butanol$$

Waste disposal guide for calcium hydride

1. The amount should be less than 20 g. All work should be done in a fume hood.
2. Wear Nitrile rubber gloves, laboratory coat and eye protection.
3. Place the hydride in a 3-necked round-bottom flask equipped with nitrogen inlet dropping funnel and condenser.
4. Under N_2 and with stirring, add methanol (25 mL/g of hydride) dropwise.
5. When the reaction is complete, slowly add an equal volume of water to the slurry of calcium methoxide.
6. Wash the solution into the drain with at least 50 times its volume of water.

$$CaH_2 + 2CH_3OH \rightarrow Ca(OCH_3)_2 + 2H_2$$

$$Ca(OCH_3)_2 + H_2O \rightarrow Ca(OH)_2 + 2CH_3OH$$

Waste disposal guide for lithium aluminium hydride

1. Wear butyl rubber gloves, laboratory coat, face shield and eye protection.
2. All work should be done in a fume hood.

When the amount is less than 10 g

3. Slowly add the hydride to a large excess of butanol in a pail (~24 mL/g of hydride).
4. When the reaction is complete, dilute the mixture with water and allow the solids to settle.
5. Flush the liquid to the drain with at least 50 times its volume of water.
6. The solid residue may be discarded with normal procedure.
   When it is a reaction mixture of < 100 mL
7. The stirred reaction mixture from n grams of $LiAlH_4$ is treated by successive dropwise addition of n mL of water, n mL of 15% NaOH solution and 3n mL of water.
8. This produces a granular precipitate with is filtered and disposed as normal procedure.
9. Flush the filtrate down the drain with at least 50 times its volume of water.

$$LiAlH_4 + 4C_4H_9OH \rightarrow C_4H_9OLi + Al(OC_4H_9)_3 + 4H_2$$

$$C_4H_9OLi + 2H_2O \rightarrow LiOH + C_4H_9OH$$

$$Al(OC_4H_9)_3 + 3H_2O \rightarrow Al(OH)_3 + 3C_4H_9OH$$

If you need further information on how to dispose a specific chemical, check out the following references:
1. Prudent Practices in the Laboratory: Handling and Disposal of Chemicals (T55.3 Haz.Pr)
2. Hazardous Laboratory Chemicals Disposal Guide, Second Edition by Margaret-Ann Armour (QA64 Arm)

Safety Inspections

Regular and random safety inspections of laboratories, workshops, stores, offices and other rooms and spaces are carried out in order to maintain as high a level of Safety as is practicable, to comply with legal requirements. Demerit points will be meted out for safety violations.

In order to inspect all areas of the Department of Chemistry on a regular, frequent basis, Inspections are divided into three principle formats:-

Self Assessments by the PI in charge of Research Laboratories

The PI of the lab is requested to complete a Safety Assessment of the laboratories for which they have responsibility on a regular basis, e.g. monthly. This Assessment, as far as possible, is conducted with the assistance of the researchers who work in those laboratories and assigned lab technologists (whilst remaining the responsibility of the PI) at the same time. A standard Lab Self Assessment Form is used to complete the Assessment and a copy should be kept in the lab. Any necessary remedial work identified by the Assessment should be arranged at this time.

Spot Inspections

From time to time unannounced, Spot Inspections are carried out. The purposes of this type of Inspection are to ensure that all parts of the Building are visited regularly to see that obvious failings, identified to the Academic in charge, are dealt with quickly and to allow a basis for the prioritisation of more in-depth inspections.

Full Safety Inspections

"Problem" areas identified in the course of "blanket" Inspections or by having generated an accident/incident may be inspected more frequently. These Inspections **may be** notified in advance by standard letter in order to enable the Academic to be present to provide information and any paperwork requested. Serious problems are reported verbally, for immediate attention, at the time of Inspection and a written report sent to the Academic in charge within a few days. These written reports point out any faults that have been found and indicate a time scale for their remedy. **They may be made public within the Department and posted (for internal use only)**. In cases where significant faults have been found, a follow up re-inspection takes place, usually within two weeks.

Serious Faults

If, in the course of these Inspections, or by any other means, the Inspection Team, or any of its members, identifies a situation in a laboratory, workshop or other area which, in their opinion, constitutes a serious danger to workers in that area or to any member of the School of Chemistry, the Departmental Safety Committee will recommend to the Head of Department that that laboratory, workshop or area be closed until such time as the situation has been remedied to the satisfaction of the Inspection Team.

Security in the Department

All doors should be locked when no one is in the lab or office. Also be alert if a stranger pops into your lab. Ask what he/she wants. You should contact security at extension 6874 1616 or 62365 if you are unsure what the person wants.

All corridor doors should be locked after office-hours. **When you enter/exit a corridor, make sure that you have locked the door after you**. Report any faults to Lab Supplies.

The roll call form listing the persons authorized to work in your lab should be updated regularly whenever there is a change.

Vacating a Laboratory: Clearance Procedures

The Department of Chemistry requires that when researchers leave, all chemicals or other potentially hazardous material or equipment, not to accompany them, be disposed of properly by them.

Graduate Students: The Head of Department will not allow Theses to be processed to viva without a completed and fully signed copy of the Clearance Form

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Laboratory Clearance: Chemicals

Ensure that all containers of chemicals are labelled with their chemical name (not just a sample code) and are securely closed.

Check refrigerators, freezers, fume hoods and bench tops as well as cupboards for chemicals. Give particular attention to shared storage areas.

Clean and tidy up your work area.

Complete the **Clearance Check List** including the appropriate signatures.

Inform your Research Supervisor when the laboratory has been cleared and record his/her approval.

Laboratory Clearance: Micro-organisms and Cultures

Ensure that all containers of micro-organisms are properly labelled and secure.

Decontaminate waste material by autoclaving and dispose of properly.

Clean glassware, incubators, drying or curing ovens, refrigerators and freezers.

If samples are to be saved then responsibility for them can be transferred to another person who is willing to accept the responsibility and who has indicated such willingness in writing. If no such person can be found, dispose of the material in the proper way.

Clean and tidy up your work area including the removal of any redundant biohazard signs.

Complete the Clearance Check List including the appropriate signatures.

Inform your Research Supervisor when the laboratory has been cleared and record his/her approval.

Laboratory Clearance: Radioactive Material

In normal operation, radioactive materials are carefully recorded and disposed of regularly. Carefully label and make secure any remaining material *e.g*. stock vials, sealed sources etc. Ensure that each item has an associated Stock Card. If it does not, start one.

If samples are to be saved then responsibility for them can be transferred to another person who is willing to accept the responsibility and who has indicated such willingness in writing. If no such person can be found, dispose of the material in the proper way. Record such transfers and disposals on the appropriate Stock Card.

Check for contamination and if necessary decontaminate, clean and tidy up the work area. Where significant activities have been held and used and the laboratory is to revert to non-radioactive use, OSHE must confirm **in writing** that the laboratory has been adequately cleared and decontaminated.

Complete the Clearance Check List including the appropriate signatures.

Inform your Research Supervisor when the laboratory has been cleared and record his/her approval.

GUIDELINES FOR THE DISPOSAL OF RADIOACTIVE WASTE

1. Radioactive Waste Management

Only radioactive waste that have been left to decay to negligible proportions as required by Centre of Radiation Protection of Health Sciences Authority (CRP,HSA) in its licenses to various Departments are allowed to be disposed of by landfill or controlled discharge into sewer. All other radioactive waste must be kept in designated secured waste storage areas or returned to original suppliers.

Only Radiation Workers who have been licensed to be engaged in radiation work are allowed to handle radioactive waste resulting from radioactive materials they have used. They are to ensure proper control, safe packaging and identification of the waste before the waste are packed into containers for safe handling by nonradiation workers.

2. Dry Solid Radioactive Waste

(a) All dry wastes must be deposited into red plastic waste disposal bags with NUS logo and radioactivity hazard symbol. Each disposal bag should contain waste only contaminated with a single radionuclide and should not have radioactivity quantities exceeding one Licensing Exemption Limit (LEL) given in the First Schedule to the Radiation Protection Regulations, 1974. The Licensing Exemption Limits for commonly used radionuclides are:

Radionuclide	Licensing Exemption Limit (in µCi)
Carbon 14	100
Hydrogen 3	1000
Iodine 125	10
Phosphorus 32	10
Sulphur 35	10

(b) Waste contaminated with more than one radionuclide must satisfy the following condition before it can be accepted for disposal :

($A_1/M_1 + A_2/M_2 + A_3/M_3 \leq$ LEL of the most active nuclide) where A_1, A_2, A_3, etc. are the quantities of the radionuclides involved and M_1, M_2, M_3, etc. are the licensing exemption limit for each of the radionuclides.

(c) Each bag when full shall be closed and securely sealed with masking tape. The activity, content and isotope shall be entered on the waste disposal form (Form RAD01-1) and on the radioactive waste container label (yellow form) which is to be adhered on to the waste disposal bag. The exposure rate on the surface of each bag must not be greater than 0.1 mRem/hr (1 µSv/hr).

(d) Glassware and sharps such as vials and syringes are to be packed separately in bins or multiple layers of bags suitably padded before they are placed in cartons. Animal carcasses for disposal should be refrigerated and/or chemically preserved. They are subject to the same disposal criteria as dry solid waste and to be packed in separate containers. All container surfaces are to be free from radioactive contamination. (e) All bags must be packed and deposited at secured area in the Department. They are to be checked by the NUS safety officers and inspectors of the Centre of Radiation Protection and the Pollution Control Department before they are certified safe for disposal. No compaction of radioactive waste is permitted.

3. Solvent Radioactive Waste

Contaminated solvents should be solidified by absorption into vermiculite (an absorbent material) at point of use and disposed of as dry solid radioactive waste.

4. Aqueous Radioactive Waste

(a) Rinse water from 3rd and subsequent rinsings of apparatus should be discharged into the sewer directly at point of use.

(b) First and 2nd rinsings and other aqueous waste should be collected in containers and disposed of centrally to the sewer, making use of storage and dilution to render it safe. Aqueous wastes are to be transferred first to one gallon reagent bottles or other approved containers. Full bottles are to be capped with moulded resin screw caps and the caps sealed.

(c) No aqueous and solvent type radioactive waste are to be mixed in the same container. Whenever

possible each container should contain waste only contaminated with a single radionuclide.
(d) The activity, isotopes, type of liquid and quantity shall be entered on the waste disposal form (Form RAD01-1) and on the radioactive waste container label (yellow form). The containers should be delivered to designated secured waste area within the Department for storage and checking prior to dilution and controlled discharge into the sewer. The waste disposal form must be certified safe for disposal by the Safety Office and relevant authorities before the waste is discharged into the sewer.
(e) All aqueous waste must be neutralized to a pH of approximately 7.0. The level of radioactivity allowed in the sewer should be controlled to 1/10 the Maximum Allowable Concentration (MAC) as shown in 3rd Schedule to Radiation Protection Regulations, 1974. The period of storage and the amount of water used for dilution should be sufficient to ensure that: (Radioactivity after decay/Total amount of water used) ≤ 0.1 MAC for the combination of radionuclides.

Complete the **REQUEST FOR DISPOSAL OF RADIOACTIVE WASTE** form**.**

Laboratory Clearance: Mixed Hazard

For mixed hazard *i.e.* involving more than one of chemical, radioactive or biological materials apply all of the appropriate procedures.

Complete the Clearance Check List including the appropriate signatures.

Inform your Research Supervisor when the laboratory has been cleared and record his/her approval.

Laboratory Clearance: Equipment

Clean and decontaminate any equipment that is to be left (glassware, vacuum lines, exhaust lines, pump oil, filters, centrifuges, IR, UV *etc*). Supply custom built equipment with precise operating instructions and an operating risk assessment.

Return gas cylinders to the Store.

Clean and tidy up the laboratory.

Complete the Clearance Check List including the appropriate signatures.

Inform your Research Supervisor when the laboratory has been cleared and record his/her approval.

Laboratory Clearance: Entire Lab

For clearance of the entire laboratory, the following applies:

Chemicals

If chemicals are useful, then responsibility for them can be transferred to another person **who is willing to accept the responsibility and who has indicated such willingness in writing**. If no such person can be found, dispose of the material in the proper way.

Prepare for disposal all chemicals that are not to be removed or that are not accepted by another person. Contact Lab Supplies for a list of vendors dealing with chemical waste disposal. The process of disposal can take some time so begin the procedure some weeks before departure from the laboratory. Complete the actual removal of the chemicals before the laboratory is vacated.

Equipment

When equipment is left, responsibility must be transferred to another person who is willing to accept the responsibility and has indicated such willingness in writing. Otherwise dispose of the equipment by “condemning” it. A form for condemning the unwanted equipment may be obtained from Lab Supplies.

Arrange for a handover inspection with the Safety Committee and FOS Safety Officer before leaving. Fill up OSHE’s Lab Decommissioning & Verification Form beforehand.

Bring the completed Lab Decommissioning & Verification Form to the handover inspection. Upon completion of the verification exercise, a confirmation email will be sent to the Head of Department, and cc to PI.

Personnel Connected with Safety in the Department of Chemistry

Prof. Richard Wong Ming Wah (Chair)	62659
A/P Chuah Gaik Khuan (Co-Chair)	62839
Asst/Prof Chi Chunyan	65375
Dr Chui Sin Yin, Stephen	63699
Mdm Han Yanhui	64406
Mr Junaidi bin Aminuddin (Deputy Chair, Safety Officer)	61760
Mdm Lee Chooi Lan	68990
Ms Leng Zhi Jin	62691
Mdm Lim Nyoon Keow (Safety Officer)	61672
Mr. Gideon Lin Hansheng	63658
Dr. Liu Qiping	68991
Mdm Low Eng Hah	62841
Mdm Ong Bee Hoon	62685
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