LABORATORY SAFETY COURSE – MONDAY 18th
FEBRUARY 2019

You are enrolled in a one day laboratory safety course from 9.00 am until 4.45 pm on Monday 18th February in the Wilsmore Lecture Theatre Adjacent to the Bayliss (Molecular & Chemical Sciences) Building (see map following).

The course is intended to provide staff, post graduate and honours students who are required to work in research laboratories with important laboratory safety principles and practices.

The course comprises demonstrations, lectures and case study discussions. The presenters will be Professor Allan McKinley (School of Molecular Sciences), Mr Lyall Munslow-Davies (UWA Safety, Health, and Wellbeing), Dr Laurton McGurk (UWA Safety, Health, and Wellbeing), and Dr Caixia Li (UWA Biosafety.) There are no laboratory sessions.

This comprehensive set of notes is provided to each person attending the course. These notes are a good source of information and you should keep them for your future reference. Not all of the topics included in the notes will be covered by the lectures.

For further information, contact Ms Rebecca Joel (6488 3938, safety@uwa.edu.au) in UWA Safety, Health and Wellbeing.

Yours sincerely

Mr Sean Ashton
Acting Manager, Safety Health & Wellbeing
# UWA LABORATORY SAFETY COURSE

<table>
<thead>
<tr>
<th>Times</th>
<th>Topics</th>
</tr>
</thead>
<tbody>
<tr>
<td>09:00 – 09:30</td>
<td>Demonstration 1</td>
</tr>
<tr>
<td>09:50 – 10:30</td>
<td>Safety and Emergency Procedures – general laboratory safety rules, working in isolation, general emergency procedures, laboratory emergency procedures, personal protective equipment (particularly gloves), fire protection and safety, case studies.</td>
</tr>
<tr>
<td>10:30 – 10:45</td>
<td>Morning Tea</td>
</tr>
<tr>
<td>10:45 – 11:30</td>
<td>Laboratory and Engineering Safety – laboratory construction, access and egress, fire and emergency alarms, safety equipment, reticulated services, hydraulic services, electrical services and safety, ventilation, fume cupboards and their safe use, out-of-service tags for maintenance. Hazards, Risks and Toxicology – identification of hazards, risk assessment and control, hierarchy of controls, toxicology, routes of entry, exposure standards, monitoring</td>
</tr>
<tr>
<td>11:30 – 12:00</td>
<td>Hazardous Substances – regulations, management systems (labels, registers, SDS, health surveillance, carcinogenic substances), dangerous goods, poisons</td>
</tr>
<tr>
<td>12:00 – 13:00</td>
<td>Lunch</td>
</tr>
<tr>
<td>13:00 – 13:30</td>
<td>Chemical Safety – chemical hazards in laboratories, use, storage, spillage, disposal, case studies Cryogens and Gases – cryogenics, operation under vacuum, compressed and liquefied gases</td>
</tr>
<tr>
<td>13:30 – 14:00</td>
<td>Demonstration 2</td>
</tr>
<tr>
<td>14:00 – 15:15</td>
<td>Biological Safety – classification of hazards, classification of laboratories, OGTR requirements, blood and products of human origin, disinfection and decontamination methods, AQIS requirements, laminar flow and biosafety cabinets, autoclaving.</td>
</tr>
<tr>
<td>15:15 – 15:30</td>
<td>Afternoon Tea</td>
</tr>
<tr>
<td>15:30 – 16:30</td>
<td>Test Login and Instructions.</td>
</tr>
<tr>
<td>16:30 – 16:45</td>
<td>Closure</td>
</tr>
</tbody>
</table>
Figure 1. Location of Wilsmore Lecture Theatre.
# CONTENTS

**LABORATORY SAFETY COURSE – MONDAY 18th FEBRUARY 2019**

## Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>LABORATORY SAFETY COURSE – MONDAY 18th FEBRUARY 2019</td>
<td>ii</td>
</tr>
<tr>
<td>UWA LABORATORY SAFETY COURSE</td>
<td>ii</td>
</tr>
<tr>
<td>CONTENTS</td>
<td>iv</td>
</tr>
<tr>
<td>LABORATORY SAFETY COURSE – MONDAY 18th FEBRUARY 2019</td>
<td>iv</td>
</tr>
<tr>
<td><strong>CHAPTER 1</strong> INTRODUCTION TO SAFETY</td>
<td>1</td>
</tr>
<tr>
<td>INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>SYSTEMS OF WORK</td>
<td>1</td>
</tr>
<tr>
<td>LEGISLATIVE FRAMEWORK IN WESTERN AUSTRALIA</td>
<td>1</td>
</tr>
<tr>
<td>THE GENERAL DUTIES AN OVERVIEW</td>
<td>2</td>
</tr>
<tr>
<td>DUTY OF CARE</td>
<td>3</td>
</tr>
<tr>
<td>PROVISION OF INFORMATION, INSTRUCTION, TRAINING AND SUPERVISION</td>
<td>3</td>
</tr>
<tr>
<td>SUPERVISORS</td>
<td>5</td>
</tr>
<tr>
<td>UNIVERSITY EMPLOYEES AND STUDENTS</td>
<td>5</td>
</tr>
<tr>
<td>WARDENS</td>
<td>5</td>
</tr>
<tr>
<td>RESOLUTION OF SAFETY AND HEALTH ISSUES</td>
<td>6</td>
</tr>
<tr>
<td>ACCIDENT AND INCIDENT REPORTING</td>
<td>6</td>
</tr>
<tr>
<td>NOTIFICATION AND REPORTING OF INJURIES INCIDENTS AND HAZARDS</td>
<td>7</td>
</tr>
<tr>
<td>CASE STUDIES</td>
<td>8</td>
</tr>
<tr>
<td>RESPONSIBILITIES AND ACCOUNTABILITY FOR SAFETY AND HEALTH AT UWA</td>
<td>11</td>
</tr>
<tr>
<td>LEARNING OBJECTIVES</td>
<td>11</td>
</tr>
<tr>
<td><strong>CHAPTER 2</strong> SAFETY AND EMERGENCY PRINCIPLES</td>
<td>12</td>
</tr>
<tr>
<td>LABORATORY CONDUCT CODE</td>
<td>12</td>
</tr>
<tr>
<td>FIRE PROTECTION</td>
<td>23</td>
</tr>
<tr>
<td>Implementation of Emergency Procedures</td>
<td>26</td>
</tr>
<tr>
<td>Emergency Control Organisation for a building (ECO)</td>
<td>27</td>
</tr>
<tr>
<td>LABORATORY EMERGENCY PROCEDURES</td>
<td>30</td>
</tr>
<tr>
<td>FIRST AID</td>
<td>32</td>
</tr>
<tr>
<td>CASE STUDIES</td>
<td>35</td>
</tr>
<tr>
<td>Laboratory Emergency Response Procedures</td>
<td>47</td>
</tr>
<tr>
<td><strong>CHAPTER 3</strong> LABORATORY AND ENGINEERING SAFETY</td>
<td>50</td>
</tr>
<tr>
<td>ELECTRICAL SAFETY</td>
<td>50</td>
</tr>
<tr>
<td>SAFE USE OF FUME CUPBOARDS</td>
<td>52</td>
</tr>
<tr>
<td>OUT OF SERVICE TAGS</td>
<td>53</td>
</tr>
<tr>
<td>CASE STUDIES</td>
<td>53</td>
</tr>
<tr>
<td>LEARNING OBJECTIVES</td>
<td>54</td>
</tr>
<tr>
<td><strong>CHAPTER 4</strong> HAZARDS AND RISKS</td>
<td>55</td>
</tr>
<tr>
<td>INTRODUCTION</td>
<td>55</td>
</tr>
<tr>
<td>IDENTIFICATION OF HAZARDS</td>
<td>55</td>
</tr>
<tr>
<td>ASSESSING RISK</td>
<td>55</td>
</tr>
<tr>
<td>IDENTIFYING HAZARDS</td>
<td>55</td>
</tr>
<tr>
<td>CONTROL THROUGH PPE</td>
<td>59</td>
</tr>
<tr>
<td>REVIEW OF CONTROL MEASURES</td>
<td>60</td>
</tr>
</tbody>
</table>


CHAPTER 10 - CASE STUDIES ................................................................. 116
LABORATORY ACCIDENTS AND INCIDENTS .............................................. 116
CASE STUDIES - EXPLOSIONS .................................................................. 118
CASE STUDIES - MECHANICAL ................................................................. 119
CASE STUDY - HYDROGEN EXPLOSION IN MICROBIOLOGICAL ANAEROBIC
CHAMBER .................................................................................................. 120
CASE STUDY - SOLVENT FIRE AND EXPLOSION WHAT HAPPENED .......... 120
CASE STUDY LABORATORY EXPLOSION INVOLVING CHEMICALS (FORMIC
ACID) .......................................................................................................... 122
CASE STUDY CAUSTIC BURNS ................................................................. 123
CASE STUDIES HYDROFLUORIC ACID ....................................................... 123
BIOSAFETY CASE STUDIES ........................................................................ 124
CASE STUDIES X-RAY ANALYSIS ............................................................. 124
CASE STUDY - LASERS .............................................................................. 125
LABORATORY CHECKLIST .......................................................................... 130
SCHOOL/DISCIPLINE CHEMICAL SAFETY CHECKLIST ............................... 132
INDIVIDUAL LABORATORY CHEMICAL SAFETY AUDIT ............................ 136
WORKSHOP CHECKLIST ........................................................................... 141
CHAPTER 1     INTRODUCTION TO SAFETY

INTRODUCTION
This laboratory safety course has been prepared for people who work in University laboratories. The course is intended to provide participants with important safety principles and practices:

- to protect the safety and health of laboratory users.
- to protect the equipment, facilities and intellectual property within the laboratory and building
- to ensure the University provides safe workplaces and safe working practices
- to enable the University to properly comply with legislative requirements and best safety practices.

The course is designed to provide research laboratory users with a greater awareness of the specific hazards in their workplace and to prioritise safety in UWA laboratories.

SYSTEMS OF WORK
The work system involves a number of discrete and interconnected components comprising people, plant, and equipment, procedures, management, materials and environment.

The failure of any of these can result in unplanned and adverse outcomes. The overall work environment is more than the physical aspects of the workplace, it includes but is not limited to the:

- skills, knowledge and interactions of employees and managers
- workplace attitudes, particularly towards productivity, quality and safety
- communication, issue resolution and reward systems

Workplace accidents are a failure of systems of work to identify, assess and effectively manage workplace hazards. Some organisations have superior safety records compared to their industry peers. Studies of these have identified a number of common factors, which help account for their superior performance. These include:

- Management Commitment – the management insists on practical safety at all levels
- Planning – Safety is included before and throughout the project
- Consultation – all levels are encouraged to critique safety and give feedback
- Hazard Management - safety ‘fixes’ are practical, are prompt and are assessed for effectiveness. People are commended for reporting hazards and encouraged to offer solutions
- Training – is competency based and reflects the needs of the worker’s environment

LEGISLATIVE FRAMEWORK IN WESTERN AUSTRALIA
The Occupational Safety and Health Act 1984 (OSH Act) sets objectives to promote and improve occupational safety and health standards. The Act sets out broad duties and is supported by more detailed requirements in the Occupational Safety and Health Regulations 1996. The legislation is further supported by guidance material such as approved codes of practice. This framework is delineated below.

- OCCUPATIONAL SAFETY AND HEALTH ACT 1984 encompasses general duties, resolution of issues and duties of Safety and Health representatives, and committees.
- OCCUPATIONAL SAFETY AND HEALTH REGULATIONS 1996 sets the minimum
requirements for specific hazards and work practices.

- The act and the regulations are supported by:
  - Approved Codes of Practice (Section 57 of the Act)
  - WorkSafe WA Guidance Notes
  - National Codes of Practice

Some of provisions in the Act and some requirements in the Regulations are qualified by the words "so far as is practicable". "Practicability" applies to general duties undertaken by yourself or by someone to whom you have a duty of care. We should also do what is reasonable to ensure our and other's safety.

Whether something is reasonable takes into account:

- the severity of any injury or harm to health that may occur;
- the degree of risk (or likelihood) of that injury or harm occurring;
- how much is known about the hazard and the ways of reducing, eliminating or controlling it; and
- the availability, suitability and cost of the safeguards.

The risk and severity of injury must be weighed up against the overall cost and feasibility of the safeguards needed to remove the risk. Common practice and knowledge throughout the relevant industry are taken into account when judging whether a safeguard is "reasonably practicable". Individual employers cannot claim that they do not know what to do about certain hazards if those hazards are widely known within industry, and safeguards are available. The cost of putting safeguards in place is measured against the consequences of failing to do so. It is not a measure of whether the employer can afford to put the necessary safeguards in place.

While cost is a factor, it is not an excuse for failing to provide appropriate safeguards, particularly where there is risk of either a serious, or a frequent but less severe, injury.

Where a regulation exists and is not qualified by the words "as far as is practicable", the regulation must be complied with as a minimum requirement.

Access to Act, Regulations and Other Relevant Documents

Employers are required to provide information to employees, to alert them to areas where hazards may exist and to improve their understanding of safe work practices.

Regulations specify documents, which must be made available upon request for perusal by employees at the workplace.

Copies of the Occupational Safety and Health Act, Occupational Safety and Health Regulations, codes of practice and guidance notes published by WorkSafe WA can be purchased from WorkSafe WA or accessed via the web at:


THE GENERAL DUTIES AN OVERVIEW

For Employers: We must, so far as is practicable, provide and maintain a working environment in which employees are not exposed to hazards. In particular employers shall (Section 19):

- provide a workplace and safe system of work so that, as far as practicable,
employees are not exposed to hazards;
- provide employees with information, instruction, training and supervision to enable them to work in a safe manner;
- consult and co-operate with safety and health representatives in matters related to safety and health at work;
- provide adequate protective clothing and equipment where hazards cannot be eliminated; and
- ensure that plant is installed or erected so it can be used safely.

An employer who contravenes the above commits an offence under the OSH Act and is liable to a fine of up to $250,000. Should the offence cause the death of, or serious harm to an employee then a maximum penalty of up to $500,000 applies.

**Employees** are required (Section 20) to take reasonable care to:
- ensure their own safety and health at work and
- avoid adversely affecting the safety and health of any other person.

In particular **employees shall**:
- comply with occupational safety and health instructions;
- use personal protective equipment;
- not misuse or damage equipment;
- report hazards and injuries; and
- co-operate with their employer.

An employee who contravenes the above commits an offence under the OSH Act and is liable to a fine of up to $10,000.

Should the offence cause the death of, or serious harm to any person then a maximum penalty of up to $25,000 applies.

Other sections of the Act explain the duty of care of:
- Self-employed persons (Section 21);
- Designers, manufacturers, importers and suppliers of plant (Section 23); and
- Designers or builders of a building or structure for use as a workplace (Section 23).

**DUTY OF CARE**
Supervisors owe a duty to take reasonable care of the safety and health of all persons under their control and supervision. Supervisors are not expected to ensure that no harm will ever occur but they must take reasonable care to avoid harm being suffered.

Employees and students owe a duty to take reasonable care of the safety and health of themselves and to avoid adversely affecting the safety and health of others.

What constitutes reasonable care depends on all the circumstances to determine whether the acts or omissions complained of fall below the standard of reasonableness. In general, the abilities, competencies and capabilities of the person being supervised, the magnitude of the risk, and the degree of probability of its occurrence and the difficulty and inconvenience involved in taking alleviating actions will be assessed to determine if reasonable was taken or given.

**PROVISION OF INFORMATION, INSTRUCTION, TRAINING AND SUPERVISION**
Employers must also provide employees with proper information, instruction and training to enable them to do their work safely.

The information, instruction and training could include:
• an induction which covers site instructions and policies;
• "on the job" training;
• "in house" training program; and
• Industry based or formal training (e.g. accredited or certificated courses).

**Training Programs**

An effective training program should:
• identify the tasks to be performed and the hazards associated with those tasks.
• ensure appropriate competency is achieved.
• encompass all levels of experience
• have clear objectives
• evaluation of results in relation to their usefulness to the industry
• recognition of skills attained where applicable (e.g. accreditation)
• equip trainees to assess risks and hazards in their work place

**Induction**

Induction programmes are essential for new employees and for those taking up new jobs or where work situations have changed.

Information given during an induction should include:
• how to carry out the job in a safe and healthy manner;
• use, fitting, storage and maintenance of personal protective equipment;
• emergency evacuation procedures.
• workplace policies and procedures;
• how to identify hazards;
• reporting of hazards;
• reporting of accidents or incidents;
• information on hazardous work practices;
• where to obtain occupational safety and health information; and

"On the job" training

Employee "on the job" training should include:
• demonstrating to the employee the skills to be mastered;
• explaining the reasons, steps and key points;
• having the person practice the skills;
• giving feedback on the practice; and
• correction of errors as they occur.

**Further training or re-training**

Persons may need further training where:
• new methods, equipment, policies or procedures are introduced;
• the type of operation or environment changes; and
• their particular job requirements change.

**Certification or accreditation**

There may be occasions when a person is required to obtain some formal accreditation or certificate. Employers must ensure that any required accreditation or certification is valid and current.
Supervision
Where this is necessary the supervisor must be competent. In some instances the supervisor may need to hold a recognised qualification. Supervision should include monitoring that appropriate work practices are adhered to.

SUPERVISORS
In addition to the general responsibilities, supervisors are also responsible for:
- ensuring that all within their area are aware of their responsibility to work and act safely;
- conducting regular safety inspections;
- completing incident, injury or near miss reports and/or investigations and ensuring corrective action is taken as necessary;
- making training recommendations, to the Faculty/School/Centre/Section heads;
- inductions of new supervisees;
- promoting rehabilitation of injured employees; and
- promoting the implementation and administration of UWA Safety, Health & Wellbeing policies, procedures and guidelines.

UNIVERSITY EMPLOYEES AND STUDENTS
All employees and students are responsible for working and acting safely. Specific responsibilities include:
- taking reasonable care of their safety and health and that of co-workers, students and visitors;
- cooperating with the implementation and administration of University safety policies, procedures and guidelines;
- observing all instructions and rules issued to protect their safety and health and that of others;
- using plant and equipment as instructed by their supervisor;
- making proper use of all safeguards, safety devices, personal protective equipment;
- using protective equipment and wearing personal protective clothing as instructed;
- seeking information or advice regarding hazards and procedures before carrying out new or unfamiliar work;
- being familiar with emergency and evacuation procedures and the location of first aid kits, personnel and emergency equipment, and if appropriately trained, using emergency equipment; and
- reporting all incidents, injuries, near misses and hazards to their supervisor.

WARDENS
Wardens are responsible for assisting in the planning of and the execution of building evacuations.
Wardens must be familiar with alarms. They must ensure the building is evacuated, that all personal can be accounted for and for liaising with emergency services who respond to the alarm. Each building should have a Building Warden and a number of Wardens for areas within the building. It is essential that there be deputy wardens to assist and in case of absences. In the case of an alarm directions from wardens must be obeyed immediately.
RESOLUTION OF SAFETY AND HEALTH ISSUES

All hazards, incidents and injuries must be reported, investigated and resolved. Any unresolved issues should be dealt with in accordance with the following:

1. Notify Immediate Supervisor
   
   Issue still unresolved
   
   2. Notify Safety and Health Representative or School / Section Safety Officer
      
      Issue still unresolved
      
      3. Notify Head or Manager of School, Unit or Centre
         
         Issue still unresolved
         
         4. Notify UWA Safety, Health and Wellbeing
            
            Issue still unresolved
            
            5. Refer to the University Safety Committee
               
               The above process should be followed at all times. WorkSafe WA can be notified if there is a risk of imminent and serious harm

Figure 2. Resolution of OHS issues.

ACCIDENT AND INCIDENT REPORTING

Definitions

An accident is commonly used to describe an incident which has resulted in an injury.

An incident is any unplanned event resulting in or having the potential for injury, ill health, damage or loss.

A hazard is a source or a situation with the potential for harm in terms of human injury or ill health.
NOTIFICATION AND REPORTING OF INJURIES INCIDENTS AND HAZARDS

All injuries, incidents and hazards involving staff, students, contractors or visitors must be reported. The report form and the accompanying guidance sheet can be accessed at http://www.safety.uwa.edu.au/incidents-injuries-emergency/notification. Part 1 of the form should reach UWA Safety, Health and Wellbeing within 24 hours of an incident. Injury/incident investigations do not seek to blame injured persons or supervisors. Our primary objection is to prevent further incidents and help the injured.

In the event of an injury or incident the person involved should

- promptly seek first aid or medical attention as required (NOTE: any medical certificate must be received by UWA Safety, Health and Wellbeing promptly as it must reach the University's Insurers within 3 days)
- inform their supervisor as soon as possible
- email an incident report form (found at http://www.safety.uwa.edu.au/incidents-injuries-emergency/notification) to safety@uwa.edu.au
- assist their supervisor in the investigation and reporting of the incident

The Supervisor of the person(s) involved in the injury or incident must

- ensure the hazard has been resolved and/or the area is secured to prevent further injury
- conduct an initial investigation into the cause of the event and enter findings and recommendations into RISKWARE to complement the report submitted by student/employee
- ensure that all serious injuries are reported to UWA Safety, Health and Wellbeing immediately by phone on 6488 3938

Notification and Reporting of Serious Injury

WorkSafe WA must be notified of any injury/incident at work resulting in the following any of the following:

- Death;
- Fracture of the skull, spine or pelvis;
- Fracture of a bone in:
  - The arm, (other than in the wrist or hand); and/or
  - In the leg, (other than a bone in the ankle or foot).
- Amputation of an arm, hand, finger, finger joint, leg, foot, toe or toe joint.
- Loss of sight of an eye.
- Any other injury that results in, or on the basis of medical advice, appears likely to result in the staff member being unable to work for 10 or more days from the day of the injury.

UWA Safety, Health and Wellbeing must be immediately notified of these incidents by telephone on extension 3938. Leave a message on voicemail if the telephone is unattended.

In every case an incident report and investigation must be submitted and completed within RISKWARE by the student/employee and their supervisor.
In an empirical study of a wide range of accidents across a number of US companies it was found that for every serious or disabling injury there were 10 with minor injuries, 30 incidents which resulted in property damage and 600 incidents with no visible injury or damage (near misses).

Whilst it is natural to focus on the relatively few events resulting in serious or disabling injury there is a need to provide effective controls to reduce the likelihood of all injuries and incidents.

**CASE STUDIES**

**Case Study One**
A cleaner feels ill when cleaning a particular laboratory. He has complained verbally to his supervisor who gave him a mask to wear. The mask is very uncomfortable and didn’t seem to work well so the cleaner didn’t wear it. Towards the end of the shift the cleaner collapsed and was rushed to hospital.

**What practicable steps should the supervisor have taken to prevent the incident?**
**What could the employee have reasonably done to avoid the exposure?**

**Case Study Two**
A postgraduate student uses some highly toxic substances in her research. She has some concerns regarding the procedure outlined by her supervisor and the safe storage of these chemicals.
What can or should she do?

Case Study Three
A student wearing headphones is pushing a trolley piled high with glassware. He collides with a staff member clutching a Winchester of hydrochloric acid. The resultant spill causes serious burns to both.
Who has failed to meet their ‘duty of care’? Why?

Case Study Four
A drilling machine in a workshop has been malfunctioning. In order to keep the machine operable a worker removed the guards. As a result, the machine operator was often struck by flying metal debris.
An apprentice fitter was required to operate this machine during her first week on the job. She was subsequently taken to hospital with a metal fragment lodged in her eye.
Who has failed to meet their duty of care? Why?

Case Study Five
A postgraduate student is processing rotten carcases in his laboratory. Several people have complained of a nauseating smell. The student and his supervisor have both been approached about the subject but nothing has been done.
What can or should the complainants do?

Case Study Six
A postgraduate student is required to manually log data every 5 minutes from an experiment over a 24 hour period. Whilst driving home the student fails to stop at a stop sign and is involved in a serious car accident.
Who has failed to meet their duty of care? Why?

Case Study Seven
A trainee technical officer was burned from acid splashes to the face, neck and chest. It arose from trying to make a solution of sulphuric, nitric and hydrochloric acids and water. Despite having been shown how to make the solution safely, it seems that the trainee used an inappropriate method, believing it to be faster. As a result the lid of the mixing cylinder blew off, splashing the acid. The Court considered that the trainee had received inadequate instruction and had no real understanding of why the mixture had to be prepared as shown. The employer was held to have been negligent.

Case Study Eight
In May 1995 a chemical explosion flooded a university laboratory with fumes. The incident occurred when a 2.5 litre glass container of waste chemicals left on a trolley overnight exploded. Fortunately, the students involved were unhurt. However, the security officer who proceeded to evacuate the building suffered a burning throat and tight chest that led to his treatment in hospital.
Under the State Occupational Health and Safety Act the university was found to have breached its duty of care to employees and others not in its employment and fined $25,000. The Industrial Court heard evidence that the university had failed to heed not only its own code of safe laboratory practices but advice from a WorkCover
safety assessment survey and a Dangerous Goods assessment. The court was also told that no formal training in the disposal of waste chemicals had been given to either laboratory technicians or to research students who were nevertheless given responsibility for disposal.

Case Study Nine
A worker received a needle stick injury after attempting to re-sheath a needle prior to disposal. The needle was contaminated with blood from a Hepatitis B patient and the worker subsequently contracted the disease. The institution had no Hepatitis B immunisation programme and no instructions or training had been provided on the disposal of sharps.

Case Study Ten
US Research Assistant Dies from Laboratory Fire Injuries
A 23 year old graduate chemist Research Assistant working at the University of California Los Angeles (UCLA) died in hospital on 16/01/09 from second and third degree burns to 43% of her body following a laboratory fire in the UCLA Molecular Sciences Building on 29/12/08. The staff member was working with a solution of t-butyl lithium in pentane which is a highly flammable liquid and spontaneously burns upon exposure to air. She was wearing safety glasses and nitrile gloves but was not wearing a laboratory coat. It is thought that molten residue from the synthetic cardigan she was wearing contributed to the seriousness of the burns she sustained. In addition, she ran away from the safety shower and her burning clothes were not extinguished immediately which is also thought to have contributed to the seriousness of her burns. Two months earlier, UCLA safety inspectors directed the Professor responsible for this laboratory and the head of the Chemistry and Biochemistry Department to fix more than a dozen deficiencies by 5 December 2008. The noted deficiencies included employees not wearing requisite laboratory coats and improper storage of flammable liquids and chemicals. The deficiencies were not rectified by 29 December 2008. UCLA was fined $31,000 for this Research Assistant’s death as she was not trained properly and was not wearing protective clothing.
A year before this in November 2007 a graduate student was seriously burned in a similar accident when ethanol he was handling splashed onto his hands and clothes and was ignited by a Bunsen burner. He was not wearing a laboratory coat and his polyester shirt melted causing serious burns on his chest. UCLA was fined $23,900 for not reporting this as legally required and in February 2010 was fined an additional $67,700 for deficiencies with safety gear, chemical storage, inspections and inadequate safety training.
RESPONSIBILITIES AND ACCOUNTABILITY FOR SAFETY AND HEALTH AT UWA

All staff and students are responsible for their own safety and health and for others whose activities they may influence or control. The degree of responsibility a person has will depend on his or her level of influence or control. This concept is recognised in law. This responsibility may be delegated, but in no way is it absolved.

LEARNING OBJECTIVES

On completion of Chapter 1 you should have understood and be able to:

1. List the components of a system of work and appreciate how these combine to promote both safe workplaces and safe work practices.
2. List the elements that have assisted superior safety performance in organisations.
3. Describe the legislative framework for occupational safety and health in Western Australia including the major provisions of the Occupational Safety and Health Act 1984:
   • The General Duties of the employer (section 19);
   • The General duties of the employee (section 20);
4. Describe the University’s
   • Safety and health roles and responsibilities.
   • Incident and accident reporting requirements.
CHAPTER 2    SAFETY AND EMERGENCY PRINCIPLES

LABORATORY CONDUCT CODE

UWA, Curtin, Murdoch and ECU have jointly prepared the following Code reproduced below.

Purpose of Code

This Code provides clear guidelines for all aspects of laboratory conduct. This practical advice should be followed unless an equally effective, alternative approach or practice achieves compliance. Advice should be sought from the UWA SH&W Office before any alternative approach is used.

Laboratories

Each laboratory should have either on or adjacent to its entry door a prominent placard containing at least the following information:-

- Supervisor’s name and contact details including an after hours contact number.
- Deputy supervisor’s name and contact details including an after hours contact number.
- Safety Hazards in this Area
- Precautionary Measures Required
- Access only for authorised persons

Offices, write up, and study areas shall be separated from areas where hazardous materials are used or potentially harmful processes undertaken to ensure that reading and writing materials do not become contaminated.

Laboratory Safety Manual

Each laboratory should have its own Laboratory Safety Manual. This should include:-

- Standard Operating Procedures for common shared equipment;
- Risk Assessments for commonly performed tasks;
- Register of Equipment and reagents within the laboratory;
- Safety Data Sheets for reagents within the laboratory;
- Working Rules appropriate to the particular laboratory including:
  - Statutory Obligations such as for OGTR/radioactive/dangerous goods/prescribed agents/AQIS etc. compliance;
  - Emergency Procedures for fire/smoke, personal injuries/spills including location of spill kits, first aid cabinet and officers, and of eye wash and emergency shower;
  - Transport Requirements for materials being brought into or taken out of the laboratory; and
  - Waste Management and Disposal procedures.

Each person within the laboratory needs to sign (with date) that they have read, understood and will abide by this manual before being permitted to commence work. This should also be countersigned (and dated) by the Laboratory Manager.

Responsibilities

The University and its representatives have a responsibility to provide a safe working environment. This encompasses, but is not limited to, safe premises, PPE, appropriate working practices and emergency preparedness.
Employees, students, volunteers and visitors must act to ensure their, and others’, safety by following safety procedures, reporting issues, and actively modelling good safety awareness and behaviours.

Risk Assessments

Risk Assessments for common procedures will be included in the Laboratory Safety Manual. Risk assessments are not necessary when ‘a risk is well known and the solution is obvious’ for example: if you see water/coffee spilled on the floor or stairwell – clean it up!

Risk assessments determine the level of hazard or risk associated with any procedure and assess whether current control methods are adequate or need to be improved. They should be performed when any or all of the following circumstances occur:

- it is the first time you are carrying out a procedure.
- there is only limited knowledge about a hazard or the risk or how the risk may result in injury or illness.
- there is uncertainty about whether all of the things that can go wrong have been found.
- the situation involves a number of different hazards, processes, equipment or site and there is a lack of understanding about how hazards may impact on each other to produce new or greater risks.
- there is to be a significant change of procedure/practice from the original assessment.
- The procedure is being scaled up significantly.

In research and educational environments documented risk assessments should be completed for the following:

- Laboratory projects – work is not to commence until a written risk assessment has been completed by you and your supervisor. It is to be signed off and recorded.
- Every hazardous chemical to be used –
- Use of specific equipment.

Planning

Take time to plan your project – from beginning to end – then discuss with your supervisor and staff that will be able to help you. Check your details because:

- some processes or equipment will have a lead time before they are operational.
- equipment or processes may need to be booked in advance.
- chemicals (particularly those from overseas) may have long delivery time.
- risk assessments need to be completed and approved. All required controls will have been identified and arrangements commenced for their implementation.

Planning must also include:

- Handling - Some chemicals may require special piping or equipment to be in place before you can use them,
- Storage: some reagents must be stored separately or under gas etc and this must in place prior to their arrival.
- PPE required for the project. This will be part of your risk assessment but you also need to consider where and how it must be stored and if cleaning is
necessary.

- Disposal of wastes: you must NOT dispose of wastes to the drain or to landfill without checking that this is allowed. Disposal can be expensive and must be factored into your budget.

General Safety Rules

- Children are not permitted in laboratories under any circumstances.
- Be aware of emergency procedures, location of emergency showers/eyewashes and emergency evacuation assembly locations.
- Appropriate personal protective clothing must be worn at all times in laboratories and comply with instructions to students.
- Closed-in footwear at all times. Bare feet, thongs and sandals are prohibited.
- Fasten loose clothing and tie back and restrain long hair (Hair that can hang below your shoulders when ‘tied back’ needs to be properly restrained to prevent it getting in your eyes or your work.) When using machinery, remove jewellery and rings. The possibility exists for such items to be caught in moving parts.
- It is prohibited to eat, drink and apply cosmetics in laboratories.
- Mobile phones and similar devices which could cause distraction or become contaminated during laboratory operations should be left outside the laboratory if possible. If this is not practicable then these items should be sealed in zip lock bags before they are taken into the laboratory. Items should only be taken into the laboratory area when communication is necessary – safety takes priority over entertainment!
- Do not store food and/or drink in laboratory refrigerators or laboratory storage units. The exception is if the food and drink are specifically for research or teaching, then these items must be clearly labelled as research or teaching items.
- Do not run or engage in reckless behaviour in or near laboratories.
- Cover all open wounds when handling chemicals, animals and other biological material. Band Aids are available in the First Aid boxes.
- Wash hands and remove laboratory coats after completion of experimental work and before leaving the laboratory.
- Use disinfectants after handling suspected infectious materials.
- Do not pipette by mouth. Use mechanical pipetting devices instead.
- Avoid lifting heavy objects. Use lifting devices and trolleys where appropriate. Where lifting is unavoidable, seek assistance if required (share the load).
- Do not use any machines, equipment or laboratory apparatus without prior instruction/training by the supervisor or technical staff on safe work procedures and practices. Whilst using any equipment you must adhere to the standard operating procedure.
- Observe safety signs at all times
Additional Rules Re PPE

- Approved safety spectacles, goggles and/or safety shields must be worn in all areas where tools or substances such as chemicals, liquids, UV light, lasers or radiation may cause eye injury.
- Appropriate protective clothing (for example gowns, overalls, closed laboratory coats, flame resistant clothing, etc.) shall be worn where required. Specific protective clothing/gloves will be at the discretion of the area but can be required by legislative/standards and or risk assessment.
- Laboratory coats should not be worn outside the laboratory (legal/contamination control requirements).
- Gloves must be removed before leaving the laboratory area. You must NOT touch laboratory door handles with a gloved (potentially contaminated) hand.
- Hearing protection must be worn if noise can damage or impair hearing (e.g. when using ultrasonic cleaning apparatus).
- A risk assessment is to be conducted to assess work practises regarding the frequency and likelihood of injury to the feet, i.e. moving furniture, gas cylinders, and heavy equipment. If there is a medium to high risk then safety footwear (e.g. hard-capped boots) is recommended.
- Ensure the correct gloves are used for chemicals. For assistance refer to Ansell: https://www.ansellpro.com/download/Ansell-Chemical-Glove-Resistance-Guide.pdf

Housekeeping Rules

- Keep floors tidy and dry.
- Keep benches clean and free from chemicals and apparatus that are not being used.
- Clean working area and equipment thoroughly after use.
- Keep aisles and exits free from obstructions.
- Ensure clear access to emergency equipment (fire extinguishers, first aid kits, chemical spill kits, emergency shower and eye washes).
- When leaving the laboratory, turn off all equipment in use (if appropriate), extinguish flames etc.
- Keep the interior of fume cupboards and nearby areas clean and clear.
- For information on gas cylinders refer to the relevant Safety Data Sheets (SDS) and the Chemical Safety Procedures.
- All contractors working in your area must be inducted into any hazards and controls which may exist in your area, i.e. flammable liquids and biological materials. It may be necessary to supervise contractors for some procedures.
- Cleaners will normally only sweep or mop floors and empty general waste bins of laboratories. They should not be exposed to hazards.

Chemicals

For more information please refer to the University’s Chemical Management Guidelines http://www.safety.uwa.edu.au/topics/chemical and your Faculty’s Chemical Safety Procedures.
● Obtain the relevant Safety Data Sheets (SDS) and conduct a risk assessment before commencing a new process involving chemicals. Refer to Section 6.5.

● Regard all substances as hazardous unless there is definite information to the contrary.

● Clearly label all containers in use within the laboratory according to the National Code of Practice for the labelling of Workplace Substances [NOHSC:2012]. Containers must carry proper labels with at least the:
  - Name of chemicals including solvents
  - Concentrations of chemicals
  - Name of owner
  - Dangerous goods class and/or GHS icons
  - Date opened or made

● Always use safety carriers for transporting glass or plastic containers with a capacity of 2 litres or greater.

● Carry out work in fume cupboards according to the SDS.

● Keep fume cupboard sashes closed whenever practicable.

● Do not place objects near fume cupboard baffles so that airflow is impeded.

● The use of recirculating fume cabinets is not encouraged; please contact the OHS Office for advice on these units.

● Segregate and store all Dangerous Goods according to class AND instructions on the SDS.

● Do not store flammables (Dangerous Goods class 3) in a domestic refrigerator (cooling and storage of flammables must only be done in a spark proof refrigerator or freezer).

● For work with carcinogens, toxins and embryotoxins, cryogenics, herbicides, pesticides, peroxides, organic and shock sensitive, cyanides, acid fluoride chemicals and gas cylinders refer to SDS and the Chemical Safety Procedures.

● Keep only the minimal required quantities of chemicals in the laboratory work area.

● Hazardous substances must be disposed of in accordance with University Policy, Statutory and SDS requirements. Use the correct containers provided to dispose of glass, sharps, metal, paper, infectious, OGTR, AQIS waste etc. (Regularly check dispositions against licence requirements.) UWA Safety, Health and Wellbeing coordinates two University-wide collections of unwanted and/or waste chemicals per year (http://www.safety.uwa.edu.au/topics/chemical/waste-service). Contact the Chemical Safety Officer on 6488 3412 email laurton.mcguirk@uwa.edu.au for manifesting forms and guidelines.

● Chemical waste should not be disposed of via sinks, drains or stormwater channels unless using neutralisation processes approved by the WA Water Corporation. Areas must provide suitable waste disposal containers and are responsible for their removal by an approved waste disposal contractor (refer to the Chemical Safety Procedures). Contact the Chemical Safety Officer on 6488 3412 for advice before disposing to sewers.
Safety and Emergency Principles

**Electrical Equipment**
- It is prohibited to use electric open bar radiators, electric fan heaters and kerosene heaters in laboratories or other hazardous environments.
- Switch off all electrical appliances when equipment is not in use if practicable.
- Display a "LEAVE ON" sign on any equipment required to be left on for an extended period. All apparatus left running overnight should be shielded and labelled with name and telephone number of the after-hours person to be contacted, and Security notified.
- Unless otherwise fitted, use Residual Current Devices (RCDs) for all hand held electrical appliances and ensure that all hand held electrical equipment is tested and tagged annually.
- Do not use double adaptors or piggyback plugs. Use power boards with overload protection as required. Power boards must have individual on/off switches for each powerpoint.

**Fire Prevention**
- Smoking is prohibited on UWA grounds.
- Open flames should not be left unattended and no open flames should be used near flammable solvents (the only permissible exception is in microbiology where very small quantities of ethanol are used to flame-sterilise.)
- Keep fire escape routes clear at all times.
- Before starting work, all staff and students are to become familiar with the fire procedures and location and use of fire-fighting equipment within the laboratory.

**Emergency/First Aid**
It is the responsibility of all supervisors, lecturers and demonstrators to ensure that persons working in a laboratory know the location of:
- the nearest fire extinguishers/ fire blankets
- fire / emergency escape routes
- first aid box
- emergency shower/eye wash facilities
- isolation devices for gas, water and power (where fitted)
- emergency spill containment equipment and procedures
- emergency personal protective equipment
- Any special substances that require antidotes
- Wash skin immediately with plenty of water if contaminated with acids and alkalis (if required seek medical attention).
- Eyes splashed with any chemical must be washed with water for 15 mins and medical advice obtained immediately.
- All breakages and spills must be reported to the supervisor and dealt with immediately. Materials should be cleaned up and a bin provided for broken glass and materials etc.
- Ensure all incidents and injuries are reported. Injuries should be recorded in the
First Aid log or reported on a UWA Confidential Incident/Injury report form depending upon the severity of the injury.

After-Hours Working
When you work outside of normal working hours you must allow for the lack (or delay) in support services. Make sure that you know where the first aid supplies are and how to raise the alarm in an emergency. Check the location of the emergency exit, shut down button, and the eye wash and emergency shower. Add emergency phone numbers including security to your phone.
To work outside of normal working hours, you must have the permission of your Manager or Supervisor. They must have assessed the risks associated with the planned activities, considered the availability of support services and concluded that such working arrangements are acceptable.
Persons wishing to work outside normal hours should provide a work plan that clearly defines the proposed task and limitations on that task outside normal working hours. They may need to fill in a log of arrival and departure times and advise Security on (+61 8) 6488 3020 or the appropriate number for laboratories not on the main University campus. IF ACCESSING THE WORKPLACE AFTER HOURS:

- Ensure that the doors of buildings are securely closed and locked after entering and exiting.
- Ensure that the doors to internal areas are secured on leaving.
- Ensure familiarity with health and safety rules and emergency contact numbers – these should already be displayed in the workplace.
- Do not give anyone else security codes, keys or access cards.
- Do not provide access to buildings to unauthorised persons as Security is instructed to remove them if they cannot demonstrate current authorisation.
- Report to University Security any breaches of security or suspicious behaviour.

Only competent persons may operate inherently hazardous equipment. A documented risk assessment must be made and/or adequate control measures must be implemented. Undergraduate students must be directly supervised by a staff member or approved nominee.
A minimum of two persons must be present to ensure that appropriate action and support is provided in the event of an incident or injury. The second person must be competent to obtain any assistance required and to make the area safe. If having a minimum of two people present is not possible, there are specific limitations on what types of work may be conducted. Refer to “Working alone” in this manual and also www.safety.uwa.edu.au/health-wellbeing/physical/alone.

A breach of any of these conditions may result in after-hours access being cancelled. This information is also available at:

In instances where risks are unacceptably high work shall be restricted to 8:00 am - 5:00 pm on weekdays (excluding public holidays and weekends).
Some work is too hazardous to be undertaken alone or after hours. This includes any activities involving:
Safety and Emergency Principles

- Hydrofluoric acid.
- Explosive and potentially explosive substances.
- Disposal of hazardous substances.
- Naked flames associated with flammable solvents (the only permissible exception is in microbiology where very small quantities of ethanol are used to flame-sterilise.)
- Low-temperature environments (e.g. cool rooms, freezers).
- High-powered, fast-moving machinery or equipment.
- Heights or confined spaces.
- Significant quantities of molten metals.

Other sources of OHS information are given in Table 2 below. The University can set a higher standard than is legally mandated and when we do so we must abide by this.

Table 1. Sources of further OHS information.

<table>
<thead>
<tr>
<th>Category</th>
<th>Link</th>
</tr>
</thead>
<tbody>
<tr>
<td>AS/NZS 2243</td>
<td>Australian New Zealand Standards 2243 Safety in Laboratories Parts 1 - 10</td>
</tr>
</tbody>
</table>
The responsibilities of various roles are summarised in Table 3 below. Safety is everyone’s duty and responsibility but different roles have different spheres of action within the University. The same responsibility may have require different actions of different roles.

**Table 2. OHS Responsibilities by Role.**

<table>
<thead>
<tr>
<th>Role</th>
<th>Responsibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Executive Deans</td>
<td>To ensure that the University meets all of its obligations in the area of OHS management.</td>
</tr>
<tr>
<td>Head of School/Section</td>
<td>Provide adequate resources and support for effective OHS management in their area of responsibility and monitor its effectiveness in preventing injury and ill health.</td>
</tr>
<tr>
<td>Safety, Health &amp; Wellbeing</td>
<td>It is the responsibility of each Faculty / School to implement and coordinate training in laboratory conduct across all campuses and provide advice to any area when requested. The OHS Office is responsible for formulating policy and guidelines to assist areas to achieve compliance.</td>
</tr>
<tr>
<td>Supervising Lecturer, Demonstrator or delegate</td>
<td>Supervisors of staff or students working in a laboratory are responsible for ensuring compliance with these guidelines. They must ensure that all personnel are fully instructed and trained in hazard management principles, risk assessments, SDS, control measures and any other measure to reduce exposure. They are responsible for ensuring correct reporting of any hazards, incidents and injuries which they are unable to attend to themselves.</td>
</tr>
<tr>
<td>Staff, students, visitors and contractors</td>
<td>All staff, students, visitors and contractors must comply with these Guidelines and are to follow all instructions and directions relating to laboratory conduct.</td>
</tr>
</tbody>
</table>

**Disciplinary Action**

Repeated or serious breaches of these guidelines may result in disciplinary action which could include exclusion from the laboratory. Retraining may be mandated and the person will have to demonstrate that their laboratory privileges will be respected before they are reinstated.

**End of joint Universities Laboratory Conduct Code**
MANUAL HANDLING
Injuries from manual handling affect many staffers each year. The time and productivity lost as a result of such injuries impacts on the individual and the University as a whole. As a guide, the risk of back injury increases when loads over 16 kg are handled from a standing position. Manual handling of loads at or more than 16 kg should be assessed to minimise risk of injury. Use equipment (e.g. trolleys or hoists) or have colleagues assist you in safely moving heavy items.

A number of factors can be identified with regard to determining the risk associated with lifting heavy objects. The weight of the object is one consideration but a number of other factors can increase the risk of injury, including:

- Size, shape and weight of objects (if carried or held) and forces required (if pushed, pulled or restrained);
- Sudden unexpected or jarring movements;
- Awkward movements, such as twisting, bending, over-reaching, especially if combined with load handling;
- Static postures, like holding the body or part of the body in a fixed position for a long time; and
- Personal factors, such as age, physical dimensions and any disabilities the person may have.

These risk factors are influenced by:

- How long and how often the tasks are performed (e.g. repetitive movement);
- The way work is organised, such as just one person performing all manual handling tasks;
- Design and layout of the work environment; and
- The degree of familiarity with the task and associated training.

Do not discount manual handling in your risk assessment. Many more workers are injured by manual handling than by chemicals or fire each year. Improving manual handling greatly reduces your chances of workplace injury. To book

Planning New Work
Additional safety precautions are needed when planning new work. Before undertaking new procedures or beginning work with a new chemical agent, the following points should be considered:

- Do not rush into any new work without considering and reviewing safety implications of the procedure and potential hazards of the chemicals to be used. If in doubt about a new procedure, do not use it.
- Consult safety data sheets. If not available, request them from the manufacturer or supplier.
- It may be necessary to consult other reference sources to find additional information on, for example, toxicology, chemical reactivity and chemical compatibility.
- Review the techniques to be used. Are written standard operating procedures for the method available? If the technique is unfamiliar, consult with your supervisor and experienced colleagues. It may be appropriate to consider performing a practice or “dry run”.

Safety and Emergency Principles
• Check that there is sufficient room to arrange all the equipment required, particularly if the operation is to be carried out in a fume cupboard. Ensure that everything around the work area(s), especially other chemicals are compatible with the chemicals to be used.
• Inform colleagues of the work to be carried out and the chemicals to be used and any risks they may pose to others in the vicinity. Be particularly aware of reproductive risks which may impact on co-workers who are planning or are pregnant or breastfeeding.
• If possible, do not work alone in the laboratory.
• Ensure that all equipment is in good operating condition. For example, check glassware for cracks or breaks, check that valves and connections do not leak and check that the fume cupboard is working efficiently. Check that electrical equipment is compliant and has a current electrical testing tag.
• Know what to do in an emergency - who to contact and where emergency equipment is located (such as fire extinguishers, breathing apparatus, safety showers and eye wash stations).
• Check first aid procedures and ensure that any specialised items that may be required are on hand. For example, if hydrofluoric acid is being used, calcium gluconate gel and tablets must be immediately accessible.
• Check that all personal protective equipment is the correct type for the work to be performed and that it is in good working order. For example, ensure that the protective gloves to be used are impervious to the chemical(s) involved.
• Assess manual handling risks of tasks including repetitive tasks e.g. pipetting or sampling.

Working Alone
Individuals may occasionally be required to work alone on University premises. Under these circumstances there are special risks due to the lack of immediate assistance in the event of an accident or sudden illness. This guidance applies to working alone at any time but when planning after-hours working there are specific limitations on accessing workplaces and also on the types of work that may be undertaken. Refer to “After-hours working” in this manual and also see:
http://www.safety.uwa.edu.au/health-wellbeing/physical/after-hours-working
Health and safety legislation requires that if an employee is isolated from other persons because of the time, location or nature of the work then the employer must ensure that there is a means of communication available which will enable the employee to call for help in the event of an emergency and arrangements made to ensure regular contact. The maximum penalty for breaching this regulation is $25,000.
If you are required or intend to work alone you must have permission to do so from a Manager or Supervisor who has assessed risks associated with the planned activities, considered the availability of any potentially required support services and concluded that such working arrangements are acceptable. This may include addressing unattended reactions or experiments. In addition, disclosure and consideration of any medical conditions that may give rise to a dangerous or life threatening situation when working alone must be taken into account.
In all of the following cases, working alone is not permitted where:
• There is no readily accessible means of communication.
• Work which is remote or isolated from the assistance of others due to the location, nature or time.
• Operation or maintenance of hazardous equipment.
• Handling of hazardous substances or use of large volumes of flammable solvents.
• Work which is too hazardous for a person to perform alone.
• Working with large or aggressive animals.
• Maintenance or adjustments on energised electrical or electronic systems.

Under the following circumstances, working alone is permissible:
• An authorised person is notified of the planned work, when it will commence and the expected completion time.
• Staff and students may work alone in office and other low risk environments.
• An easily accessible means of communication to gain assistance in an emergency is available.
• Undertake all required personal security measures e.g. lock doors, walk in well-lit areas.

The campus emergency number is 6488 2222. UWA Security (phone 6488 3020) offer a 24 hour escort service to vehicle or residences near the campus and also offer lectures on personal security. To request their assistance telephone 6488 3020 allow up to 30 minute’s notice for the escorting service.

WorkSafe WA provides guidance regarding working alone and how it influences the risk of harm or injury at:

This information is also available at
http://www.safety.uwa.edu.au/health-wellbeing/physical/alone

FIRE PROTECTION

A fire is like a triangle; it cannot exist if one of the sides is missing. The three sides that a fire depends upon are –

Fuel – fabrics, wood, paper, oil, anything that can burn.
Air – the oxygen needed to keep a fire burning.
Ignition source – any source of ignition that can set fire to flammable material. This could be a match, cigarette, spark, gas burner etc.
To prevent or fight a fire we ‘remove’ one of the three essential components. Firefighting facilities are for fighting fires; they are not to be interfered with and must be free of any obstructions. Empty or faulty fire extinguishing equipment is to be reported to your supervisor.

Make yourself familiar with the location of all fire-fighting appliances in your work area. Know the type of fire-fighting appliances to use on the various types of fires. Never use water or foam on electrical fire.
Figure 5. Portable Fire Extinguishers with old and new colour coding and effectiveness for different types of fire.
Report any fire that you observe, and seek assistance immediately. You should only attempt to extinguish a fire if you are trained to do so and are confident of success. To help prevent fires:

- Keep all areas clear. Don’t accumulate rubbish. Good housekeeping is the first principle of fire protection.
- Store and handle flammable liquids carefully.
- Don’t give a fire a chance. The first five minutes is worth more than the next five hours.

**General Emergency Procedures**

An emergency in a building can develop from a number of causes including fire, bomb threat, and release of chemical, biological or radioactive material, gas leakage, civil disorder, or structural fault. A prompt and organised response by occupants in such an emergency is essential for the welfare of occupants and for the preservation of University assets.


**Fire Alarm System**

The fire alarm is designed to provide notification of the presence of fire (by detecting heat or smoke) in the building. It is normally made up of fire detectors positioned throughout the building and wired to the fire indicator panel and fire alarm. When a detector is activated, its location is shown on the fire indicator panel, the fire alarm commences to sound continuously and a signal is sent automatically to the fire brigade.

The fire alarm system can be manually activated using the break-glass alarm.

**Emergency Warning and Intercommunication System (EWIS)**

The EWIS provides an audible signal throughout some buildings to warn occupants of a fire or other emergency situation. The ALERT is a steady tone sounding automatically on actuation of the fire alarm and warns people to get ready to evacuate. The EVACUATION signal is a rising tone and sounds automatically after a set time delay; evacuation of the area must proceed calmly but quickly.

**Priorities During an Emergency in a Building**


**FIRST PRIORITY:** Protection of Life

The first priority is to ensure peoples safety and save lives before any steps are taken to prevent the spread of the hazard, to secure assets, or to eliminate the hazard.

**SECOND PRIORITY:** Prevent Spread of Hazard

The second priority aims at controlling the extent of the hazard within the building and minimising its release into the environment.

**THIRD PRIORITY:** Save Assets in the Affected Area.

**FOURTH PRIORITY:** Eliminate the Hazard.

**Implementation of Emergency Procedures**

Emergency procedures for a building shall be implemented by the building’s emergency control organisation under direction of the Building Warden (also referred to as the Chief
Safety and Emergency Principles

Emergency Control Organisation for a building (ECO)
The emergency control organisation (ECO) facilitates the safe and orderly implementation of emergency procedures in a building including evacuation of occupants from the building when appropriate. The ECO is a hierarchy of people within the building who take command on declaration of an emergency until relieved by emergency services or the emergency is resolved. An ECO may comprise any or all of:

- Building Warden
- Deputy Building Warden
- Area Warden
- First Aid Personnel
- Other Specialists

Management should encourage implementation of an emergency control organisation and emergency evacuation procedures within all workplaces at the University.

Evacuation of lecture theatres, libraries, class rooms and teaching laboratories
These areas require explicit organisation because of the potential for large numbers of people to be congregated in a small area. The person in charge of the class shall act as the Warden and is responsible for evacuating his/her area.

Upon hearing the alert signal or when notified of an emergency
The person in charge of the class should direct students to:

- **Stand** and push chairs, large bags, etc. under desks or benches.
- **Turn off** electrical devices and laboratory operations that are not safe to be left unattended.
- In controlled sequence, move along gangways to main aisles and exit in an orderly manner through the nearest appropriate exit.
- Move to the Building Assembly Area.

Emergency evacuation for fire

1. **You discover a fire:**
   - Help people in immediate danger
   - Warn others by shouting "Fire, Fire, Fire", raise the alarm if not already sounding and telephone 6488 2222 or 2222 from internal telephone
   - Decide if you can put the fire out, **be over cautious**
   - Don’t attempt to use a fire extinguisher if you have never been instructed on how to use one.
   - If you can put out the fire then do so, then proceed to evacuate the building.

2. **The fire alarm is sounding; you must prepare to evacuate the building:**
   - Switch off all computers, printers and electrical appliances within immediate reach.
   - Gather your personal belongings in preparation to immediately evacuate the building.
   - Organise/help other people in the room.
   - Close all windows and doors along path of exit if safe to do so.

3. **Evacuate the building and proceed to your Building Assembly Area.**
   - Move at a quick walk, do not run.
   - If you have to move through a closed door that you cannot see through:
i. Feel the door to see if it is hot.
ii. Look for smoke coming under the door.
iii. Open the door slowly and look around it to see if there is a fire behind it.
iv. If there is no fire on the other side, proceed through and close the door behind you.

- Move to the Building Assembly Area as quickly as possible.
- Report to your Warden that you/your group is there and if you know of anyone trapped in the building.
- Remain in the assembly area until you are informed that you may leave or move by either the Building Warden or by a member of the emergency services.

4. You notice someone on the verge of panic:
- Give them a task or responsibility.
- The person will still require constant monitoring.
- Do not hit them.
- Take hold of one of their hands and guide them out of the building to the Assembly Area.
- If they will not co-operate or start to grab hold of things: Leave them where they are.
- Evacuate yourself and inform your fire warden, the occupational safety and health officer, one of the security personnel, or the police or fire brigade immediately.

5. Mobility impaired people:
If you encounter a person with some form of disability that restricts their mobility you may be required to assist them from the building. If you are unable to remove them from the building, many stairwells have respite areas for mobility impaired persons. They can be left there where they are shielded from the fire, and retrieved by emergency personnel on arrival. It is important to inform the emergency personnel or Building Warden of the person’s location so they can be retrieved as soon as possible. Leave the person’s mobility aids behind; they can always be claimed on insurance.

6. If you are trapped in a room:
- Exit through a window if you are on the ground floor.
- If you are not on the ground floor:
  - Close the door.
  - Go to the window.
  - If there is smoke in the room open the window a little so you can breathe fresh air. If not, do not open the window. This can assist spread of fire into your area from lower floors.
  - Attract people’s attention to your plight. Place a sign on the window or call out the window. If you open the window remember to close it again as this can be an entry point for fire. Do not open the window fully.
  - If the room is filling with smoke, stay close to the floor. The air is cooler and oxygen more plentiful in this region.
  - Wait for the Fire and Rescue Service to rescue you.

7. Do not procrastinate: Remember
- Fires spread rapidly.
- Fires produce a thick black smoke that is difficult to see through and causes suffocation.
- The freshest air will always be near the floor.
- Move quickly. Do not run.
• Be decisive.
• Think for 10 to 30 seconds.
• Make a decision and follow that decision.

Bomb threat procedure

Above all – keep calm and do not alarm others.

• If the threat is by telephone:
  • Prolong the call – keep the person talking and ask:
  • Location of bomb;
  • Time set to explode;
  • Record exact information - refer to bomb threat checklist at:
    http://www.safety.uwa.edu.au/policies/emergency
  • Do not replace handset (this enables calls to be traced).

Record information for Police.

• If an object is found:
  • Do not touch;
  • Report to Security (call 6488 2222);
  • Keep areas clear.

Basic Rules:

• Treat as genuine;
• Record exact information.

Do not use mobile phones, two way radios or other electronic equipment that may trigger a device – turn off mobile phones and two way radios.

• Raise the alarm.
  Phone Security (call 6488 2222 at any hour of the day).
  • Notify the Building Warden.
  • Do not use Break Glass alarms, public address system, mobile phones or two way radios.

Be prepared to evacuate – await further instructions from Security.

• Evacuate the building as instructed by the Building Warden.

Persons should be requested to remove all personal belongings (such as brief cases, bags and other personal articles) when evacuating lecture theatres/laboratories.

It is the responsibility of the lecturer / tutor to maintain control over their class during an emergency until released by the Emergency Control Organisation for their building.

Medical

A list of First Aid Officers is located in the School. If an injury requires further attention then the Medical Centre is located on campus, in the Guild Village and can be contacted on 6488 2118. Medical doctors and nurses are available at the Medical Centre during normal workdays between the hours of 9 am to 5 pm.

If an ambulance is required or the accident occurs outside the Medical Centre’s hours then phone Security on 2222 and they will arrange for an ambulance and assist in directing it to your location.

Refer to the web site:
http://www.safety.uwa.edu.au/policies/emergency for more information on suspicious mail packages, radioisotope or biohazard spills, chemical hazard spills and gas leaks.
LABORATORY EMERGENCY PROCEDURES

Laboratory work involves a number of hazardous substances and procedures. Laboratory personnel need to be fully aware of and able to respond in an appropriate manner should an incident or emergency situation arise. Examples of situations for which planning and rehearsals are needed include fire; personal injuries (including substances or objects in the eyes, minor cuts and puncture wounds); chemical spills; biological spills and radioactive spills. Guidelines for appropriate responses to minor and major incidents of these are provided in tables at the end of this section.

PERSONAL PROTECTIVE EQUIPMENT

In addition to exercising due care at all times, the laboratory worker must make full use of protective equipment appropriate to the task being undertaken.

Clothing

Protective clothing must be worn in all laboratories but must not be worn outside the designated laboratory in which it is used. Protective clothing should be colour coded to identify the laboratory area in which it should be used. Suitable protective clothing should be provided for visitors entering laboratory areas.

Eye Protection

Eye protection must be worn at all times whenever hazardous procedures are undertaken. This includes handling substances or materials which are infectious via the eye or which have likely physiological or physically damaging potential. The employer should provide suitable protective glasses for persons handling these substances. Err on the side of caution – eyes are extremely vulnerable to damage.

An appropriate eye wash station must be provided at an easily accessible location for each laboratory room. Sealed, sterile eye irrigation solutions may be suitable. Once the seal has been broken the solution and container must be discarded and replaced with a new unit. Kits must never be re-used or refilled for re-use. Units must be replaced before the expiry date displayed on the container which is usually no longer than 6 months.

Gloves

Gloves of suitable material and weight are essential items in laboratories. They should be worn when handling strong acids, strong alkalis, organic liquids and biological samples. Gloves also act as a barrier against dusts and fibres, and may be effective as a temporary barrier to dermatitis sensitisers.

As well as physical resistance to damage, the permeation resistance of the glove for the liquids to be used needs to be considered carefully. Persons with cuts and abrasions on their hands must wear gloves for handling hazardous materials. They must not become complacent about the need for care and protection when handling dangerous substances.

Typical examples of glove usage are provided in the following table. In all cases consult the recommended procedures before deciding upon what type of glove to use.
Table 3. Suitability of different materials for selected reagents.

<table>
<thead>
<tr>
<th>Type of glove</th>
<th>Examples of Usage</th>
<th>Not Suitable for</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural rubber</td>
<td>acetonitrile, ethylene glycol, butyl alcohol, sodium hydroxide (caustic soda)</td>
<td>benzene, sulphuric acid, mineral spirits</td>
</tr>
<tr>
<td>Neoprene</td>
<td>ethylene glycol, ammonium fluoride, nitric acid, sodium hydroxide, hydrochloric acid</td>
<td>methylene chloride, carbon disulphide, toluene</td>
</tr>
<tr>
<td>Nitrile</td>
<td>butyl alcohol, sodium hydroxide, hydrofluoric acid, hydrochloric acid</td>
<td>Freon TMC, trichloroethylene, nitric acid</td>
</tr>
<tr>
<td>PVA</td>
<td>styrene, xylene, benzene, methylene</td>
<td>water, sodium hydroxide,</td>
</tr>
<tr>
<td>PVC</td>
<td>cyclohexanol, sulphuric acid, nitric acid</td>
<td>acetone, acrylic acid, xylene</td>
</tr>
</tbody>
</table>


The Standards AS/NZS 2161 Parts 1 to 10 give information on a wide range of protective gloves and Parts 2161.10.1, 2161.10.2 and 2161.10.3 apply specifically to chemicals and micro-organisms.

**Gloves for Biological Specimen handling**

Types of gloves available for biological specimen handling include:

- Sterile latex
- Sterile vinyl
- Non-sterile latex
- Non-sterile vinyl

The choice of glove will be determined by a number of factors. The most important will be the material shape and size available so that comfortable, well-fitting gloves can be worn over a period of time without loss of manual dexterity or tactile responsiveness. It has been suggested that latex gloves are more effective in preventing the entry of virus particles than are polyethylene or polyvinylchloride. Whilst affording a high degree of protection, latex has a higher tensile strength than vinyl and greater resistance to abrasion, puncture and tearing. Generally, non-sterile latex surgeons' gloves are preferred for the above reasons; however staff will require guidance in the correct use of gloves, particularly with regard to handling of biological specimens.

**When and how to change gloves**

The number of glove changes necessary will depend on:

- The condition of the glove - visibly contaminated, split or holed.
- The permeability of the glove to the chemical or material being handled.
- The comfort of the glove.
- The period of use.
- Breaks from the laboratory area.
- When used in a sterile environment.

The correct method of removing soiled gloves needs to be taught to all users so that cross contamination is minimised. They must be correctly inverted and stripped individually. Gloves must be removed before handling telephones or performing office work. Avoid cross
contamination by excluding soiled gloves from "clean" environments.

**Problems associated with wearing gloves**
- Permeability of latex and vinyl gloves to water, blood, infective agents and chemicals.
- Lack of tactile responsiveness.
- Improper shape or size also reduces tactile responsiveness.
- Contact urticaria that may be relieved by wearing cotton gloves under the rubber gloves.

**Footwear**
Enclosed footwear must be worn in stores, workshops and laboratories. The footwear must be fully enclosed, low heeled and made from leather/vinyl uppers with rubber/synthetic soles. Overshoes may be required in some laboratories, for example high-level radioisotope areas. It is advisable to wear hard capped shoes or boots where heavy equipment is lifted or moved and these may be required under OSH regulations.

**Breathing Protection**
Appropriate masks with replaceable elements must be used when working in a dusty environment. Masks appropriate to the chemical in use, particularly gases, should always be available in the laboratory. Masks with canisters or cartridges are not acceptable for use in oxygen deficient areas.
To ensure the mask is correctly fitted, test mask by blocking the open end of the cartridge with the hand; obvious resistance should be found on inhaling. The mask must fit correctly to work effectively, before using a mask have it assessed for fit.

**Safety Helmets**
Safety helmets should be worn wherever work is carried out on more than one level in an open area.

**Other Personal Protection**
Such items as rubber boots, overshoes, leggings, plastic or rubber aprons and elbow length gloves may be required for some procedures and must be made available. Where a risk of explosion or implosion exists, a transparent face shield must be used. Barrier creams can provide adequate skin protection in certain circumstances but care must be exercised in their selection.

**FIRST AID**
First Aid is the emergency care of the injured or the sick and continues until the casualty is attended by a paramedic, is removed to a hospital or to home, or has fully recovered. First aid arrangements appropriate to the needs of the work environment should be set in place.
It is essential that the location of first aid cabinets and other relevant first aid equipment is known, and that employees are conversant with the phone number or extension that will quickly alert emergency assistance. Employees must be fully aware of their location and surrounds so that emergency assistance can be directed via the shortest possible route. Medical help should be sought where an injury or illness looks serious or there are any
doubts about cause or treatment. Treatment should be obtained for all injuries to minimise or prevent the development of complications. Always assess the situation before attending to first aid and emergency situations. **Do not rush in and also become a casualty.** Assess the immediate danger to yourself before responding.
The Australian Resuscitation Council Guideline on Cardiopulmonary Resuscitation advises that a universal compression-ventilation ratio of 30:2 (30 compressions followed by 2 ventilations) is recommended for all ages regardless of the number of
rescuers present.

First Aid Cabinets
First aid kits should be clearly labelled with the words FIRST AID and a safety information sign complying with AS1319. Anyone removing items from the first aid cabinet must inform the First Aid Officer. It is the responsibility of the First Aid Officer to maintain the contents of the first aid kit.

CASE STUDIES

Case Study One
A worker was using dimethyl mercury as a standard for an analytical procedure. The worker was aware that dimethyl mercury was extremely toxic and could be absorbed through the skin. To protect herself she wore latex gloves, a lab coat and safety glasses. On one occasion the worker spilt one drop on her gloved hand. Six months later she was diagnosed with terminal mercury poisoning. Tests showed that dimethyl mercury diffuses through latex gloves almost immediately.

Case Study Two
An accident occurred involving a cleaner who used a foaming liquid product containing 10% caustic potash and 3% sodium hypochlorite undiluted to clean a shower recess. Not wearing protective gloves, the cleaner immediately felt a burning sensation in her hands when the product started foaming. She washed her hands and a lanolin-based cream was applied. Within an hour, black spots and blisters had appeared on her right hand. Despite professional medical treatment, the pain and blistering continued for six weeks. Over the ensuing year, the severely damaged skin was removed and she received skin grafts. Eighteen months later, the woman's right hand was amputated due to the continual spread of necrosis.

Case Study Three
A laboratory worker had three fingers exposed to hydrofluoric acid vapour for two minutes. Incorrect treatment resulted in almost unbearable pain for 24 hours, unrelieved by a very large dose of morphine. The area and depth of wound increased for five days. Penetration stopped only after five weeks. The tips of two fingers disappeared.

Case Study Four
A laboratory worker was squirted on the arm with concentrations of hydrofluoric acid, but correct treatment was delayed for 50 minutes. He was absent from work for 70 days and ongoing medical treatment was required for three months.

Case Study Five
A man touched screws contaminated with low concentrations of hydrofluoric acid with his bare hands. Treatment was delayed for 17 hours until pain, stiffness and redness occurred. The result was absence from work for one week and ongoing medical treatment was required for three weeks.

Case Study Six
An experienced researcher was working alone in a home-based laboratory. He was transferring a 70% hydrofluoric acid solution from one plastic container to another, inside a fume cupboard. He was wearing kitchen gloves plus latex gloves and torn sleeve protectors. A protective apron was available but he was not wearing it at the time. Some of the acid spilt on his legs. He attempted to wash it off with a small laboratory hose before jumping into a swimming pool. The pool contained 280 ppm calcium which acted to wash away and dilute the acid. However the man became comatose within half an hour and died in hospital two weeks later.

Case Study Seven
A man was using a product containing 99-100% caustic soda in granular form to clear a partly blocked drain. Having filled the drain with hot water, he then added the caustic soda. The ensuing chemical reaction forcibly discharged a stream of hot water (probably containing dissolved and undissolved caustic soda) which hit the man in the face and eyes. He suffered skin burns and eye injuries which left him with partial loss of sight.

Case Study Eight
A student was setting up an acid digestion procedure when the liquid splashed into her eyes. There was no formal requirement to wear safety glasses and this matter had never been discussed by the supervisor. Rapid medical intervention minimised the damage, but she now has permanent scarring and diminished vision.

Case Study Nine
A scientist was working with a Class 4 NdYAG laser which produced invisible infra-red radiation of 1,064 nm wavelength. He was not wearing laser protective goggles and was hit in the eye by a weak reflection from a prism. As the beam struck his eye he heard a distinct popping sound, caused from the laser induced explosion at the back of his eyeball. His vision was immediately obscured by streams of blood and particulate matter suspended in the vitreous humour. Pain followed but was not excruciating. Shock took over as the realisation of eye damage dawned. Because he was not looking directly at the prism from which the reflection originated, the damage was confined to an area of the retina between the fovea and the optic nerve resulting in a permanent crescent shaped blind spot.

Case Study Ten
A lecturer had a brief unshielded eye exposure to a laser diode pointer and suffered an after-image which lasted for 10 days. Other University personnel and students (including in Western Australia) have received permanent eye damage from laser pointers and WA has now introduced stricter controls on their availability.

LEARNING OBJECTIVES
On completion of Chapter 2 you should have understood and be able:

1. To identify and organise general laboratory rules including:
   - Safe work practices;
   - Laboratory housekeeping;
• Manual Handling techniques;
• Planning new work; and
• Putting in place a safe system for access after normal working hours.

2. To locate fire extinguishers in the laboratory and carry out the local procedures for fire precautions, emergency warnings and emergency evacuations for the particular area.

3. To identify the need for personal protective clothing and to classify the particular type of protective equipment which may be needed such as the type of glove and respirator required for a particular procedure.
## Laboratory Emergency Response Procedures

<table>
<thead>
<tr>
<th>Emergency and precautions</th>
<th>Minor</th>
<th>Major</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Medical</strong></td>
<td>Initiate first aid. Report incident.</td>
<td>Call for emergency response. Initiate lifesaving measures if required. Do not move person unless there is danger of further harm. Keep person warm.</td>
</tr>
<tr>
<td><strong>Fire</strong></td>
<td>Alert people in laboratory and activate alarm. Smother fire or use correct fire extinguisher. Aim extinguisher at base of fire. Always maintain accessible exit. Avoid smoke or fumes.</td>
<td>Alert people in area to evacuate. Activate nearest fire alarm or call Security number. Close doors to confine fire. Evacuate to safe area or exit building through stairwell; <strong>do not use lift</strong>. Have person knowledgeable of incident and laboratory assist emergency personnel.</td>
</tr>
<tr>
<td><strong>Chemical spill</strong></td>
<td>Alert people in immediate area of spill. Wear protective equipment, including safety goggles, gloves, and long-sleeve lab coat. Avoid breathing vapours from spill. Confine spill to small area. Use appropriate kit to neutralize and absorb inorganic acids and bases. Collect residue, place in container, and dispose as chemical waste. For other chemicals, use appropriate kit or absorb spill with vermiculite, dry sand, or diatomaceous earth. Collect residue, place in container and dispose as chemical waste.</td>
<td>Attend to injured or contaminated persons and remove them from exposure. Alert people in the laboratory to evacuate. If spilled material is flammable, turn off ignition and heat sources. Call for assistance. Close doors to affected area. Have person knowledgeable of incident and laboratory assist emergency personnel.</td>
</tr>
</tbody>
</table>

The range and quantity of hazardous substances used in laboratories require preplanning to respond safely to chemical spills. The cleanup of a chemical spill should only be done by knowledgeable and experienced personnel. Spill kits with instructions, absorbents, reactants, and protective equipment should be available to clean up minor spills. A minor chemical spill is one that the laboratory staff is capable of handling safely without the assistance of safety and emergency personnel. All other chemical spills are considered major.
<table>
<thead>
<tr>
<th><strong>Emergency and precautions</strong></th>
<th><strong>Minor</strong></th>
<th><strong>Major</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Biological spill</strong>&lt;br&gt;Biological spills outside biological safety cabinets will generate aerosols that can be dispersed in the air throughout the laboratory. These spills are very serious if they involve microorganisms that require Group 3 containment, since most of these agents have the potential for transmitting disease by infectious aerosols. To reduce the risk of inhalation exposure in such an incident, occupants should hold their breath and leave the laboratory immediately. The laboratory should not be re-entered to decontaminate and cleanup the spill for at least 30 minutes. During this time the aerosol will be removed from the laboratory by the exhaust air ventilation system. Appropriate protective equipment is particularly important in decontaminating spills involving microorganisms. This equipment includes lab coat with long sleeves, back-fastening gown, disposable gloves, disposable shoe covers, and safety goggles and mask or full face shield. Use of this equipment will prevent contact with contaminated surfaces and protect eyes and mucous membranes from exposure to splattered materials.</td>
<td>Wear disposable gloves. Soak paper towels in disinfectant and place over spill area. Place towels in plastic bag for disposal. Clean spill area with fresh towels soaked in disinfectant.</td>
<td>Attend to injured or contaminated persons and remove them from exposure. Alert people in immediate area of spill. Close doors to affected area. Put on protective equipment. Cover spill with paper towels or other absorbent materials. Carefully pour a freshly prepared 1 in 10 dilution of household bleach around the edges of the spill and then into the spill. Avoid splashing. Allow a 20-minute contact period. Use paper towels to wipe up the spill, working from the edges into the centre. Clean spill area with fresh towels soaked in disinfectant. Place towels in a plastic bag and decontaminate in an autoclave. Have person knowledgeable of the incident and laboratory assist emergency personnel.</td>
</tr>
<tr>
<td><strong>Radioactive spill</strong>&lt;br&gt;Spreading of radiation beyond the spill area can easily occur by the movement of personnel involved in the spill or cleanup effort. Prevent spread by confining movement of personnel until they have been monitored and found free of contamination. A minor radiation spill is one that the laboratory staff is capable of handling safely without the assistance of safety and emergency personnel. All other radiation spills are considered to be major.</td>
<td>Alert people in immediate area of spill. Notify DRSO. Wear protective equipment, including safety goggles, disposable gloves, shoe covers, and long-sleeve lab coat. Place absorbent paper towels over liquid spill. Place towels dampened with water over spills of solid materials. Using forceps, place towels in plastic bag. Dispose in radioactive waste box. Monitor area, hands, and shoes for contamination with an appropriate survey meter or method. Repeat cleanup until contamination is no longer detected.</td>
<td>Attend to injured or contaminated persons and remove them from exposure. Alert people in the laboratory to evacuate. Have potentially contaminated personnel stay in one area until they have been monitored and shown to be free of contamination. Call DRSO. Close doors and prevent entrance into affected area. Have person knowledgeable of incident and laboratory assist emergency personnel.</td>
</tr>
</tbody>
</table>
## Contact with person

<table>
<thead>
<tr>
<th>Emergency</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CLOTHING ON FIRE</strong></td>
<td>Roll person around on floor to smother flame, or drench with water if safety shower is immediately available. Obtain medical attention, if necessary. Report incident to supervisor.</td>
</tr>
<tr>
<td><strong>RADIOACTIVE SPILL ON BODY</strong></td>
<td>Remove contaminated clothing. Rinse exposed area thoroughly with water. Obtain medical attention, if necessary. Report incident to supervisor and School Radiation Safety Officer.</td>
</tr>
<tr>
<td><strong>CHEMICAL SPILL ON BODY</strong></td>
<td>Flood exposed area with running water from faucet or safety shower for at least 5 minutes. Remove contaminated clothing at once. Make sure chemical has not accumulated in shoes. Obtain medical attention, if necessary. Report incident to supervisor and Chemical Safety Officer.</td>
</tr>
<tr>
<td><strong>BIOLOGICAL SPILL ON BODY</strong></td>
<td>Remove contaminated clothing. Vigorously wash exposed area with soap and water for 1 minute. Obtain medical attention, if necessary. Report incident to supervisor.</td>
</tr>
<tr>
<td><strong>HAZARDOUS MATERIAL SPLASHED IN EYE</strong></td>
<td>Immediately rinse eyeball and inner surface of eyelid with water continuously for 15 minutes. Forcibly hold eye open to ensure effective wash behind eyelids. Obtain medical attention. Report incident to supervisor.</td>
</tr>
<tr>
<td><strong>MINOR CUTS AND PUNCTURE WOUNDS</strong></td>
<td>Vigorously wash injury with soap and water for several minutes. Obtain medical attention. Report incident to supervisor.</td>
</tr>
</tbody>
</table>
Chapter 3 Laboratory and Engineering Safety

Electrical Safety
UWA has produced an electrical safety pamphlet to provide a User’s Guide to the safe use of electrical equipment. This is accessible at: http://www.safety.uwa.edu.au/electrical_safety/electrical_safety_pamphlet under the “Further Information” panel on the right of the screen.

UWA Safety, Health and Wellbeing also have electrical safety information available at: http://www.safety.uwa.edu.au/electrical_safety. These include:

- Electrical Equipment Safety Policy
- Creating a non-hostile electrical work environment
- Electrical Equipment work environment
- Portable Appliance Testing and Tagging Guideline
- Electrical Test Equipment Testing and Tagging Guideline
- Electrical safety Inspection Checklist
- Electrical Safety Frequently Asked Questions (FAQ)

Electrical Equipment
All electrical equipment to be used in laboratories should be tested and tagged annually.

Imported Equipment
Imported equipment sometimes has wiring and earth connections that do not meet the Australian Standards. It is most important that this equipment be thoroughly checked prior to use.

Equipment Leads
Flexible cords on equipment should be changed to suit the application of the equipment, or a power point fitted closer to the equipment so that extension cords are not used as a permanent solution. Leads must not be run through doorways or windows as damage to the cord could result.

Extension Cords
If extension cords are used in a temporary capacity they must be clear of passageways and stairs and must be supported in such a way that they will not be subject to mechanical damage.

The cord must be of adequate capacity to carry the electrical loading of the appliance it is supplying.

Extension cords must be made to suit the individual purpose so that excessive coiling does not occur. An exception to the above applies on certain movable equipment such as polishers, vacuum cleaners. With this equipment extreme care must be taken during operation so that cords are not damaged.
Double Adaptors
Double adaptors must not be used in the laboratory.

Power Boards
Power boards may be used in laboratories provided power requirements are checked first so overloading does not occur. Power boards are to be of an approved type. (Switched outlets and overload protection built in.)

Fluids and Electricity
Fluids and electricity do not mix. Keep the minimum of fluids that are needed in the laboratory. Make sure these fluids are not put on top of the equipment. They should be placed on the bench to one side.

Fluid Spill
If fluid is spilt on or into a machine, turn off immediately and report to the appropriate Equipment Maintenance Section so that inspection of the equipment can be carried out.

Mains Socket
Removal of the equipment from the mains socket must be done by pulling on the plug itself and not the power lead.

Relocating Equipment
Before operating equipment that has been relocated always check the flexible cord and plug to make sure they have not been damaged in transit.

Cleaning Electrical Equipment
Cleaning electrical equipment must be carried out with the equipment and the power supply switched off and the power cord removed.

Fire in Electrical or Electronic Equipment
In case of fire in electrical or electronic equipment, disconnect the equipment from the mains and turn off any exhaust or cooling fans. If possible extinguish the fire using either a dry powder or CO₂ fire extinguisher. Do not use a water based fire extinguisher or hose reel on fires involving electricity.

Electric Shock
Electric shock can occur when a person comes in contact with live connections and an earthed point. This can also occur through liquids if they come in contact with the live connections.
To rescue a person who has had an electric shock, speed is essential; however, extreme caution should be exercised. The rescuer may become another victim if adequate insulation is not provided between the victim and the rescuer.
Disconnect the supply to the equipment. If this is not possible use some method to remove the victim from the device, for example rubbers gloves or sheeting, dry timber, dry clothing or blankets.
Once the person is isolated from the power supply, commence resuscitation immediately.
SAFE USE OF FUME CUPBOARDS

General
The laboratory environment must be kept free of pollutants. Operations which may produce flammable or toxic vapours must be carried out in a fume cupboard. The exhaust system must be operating when the fume cupboard –

- Is in use for procedures.
- Contains volatile compounds.

Fume cupboard exhaust function must be checked regularly according to AS 2243.8. It must always be possible to shut the sash quickly without risk of disturbing the apparatus in the fume cupboard.

Types of Use
A distinction must be made between the following uses –

- Removal of toxic fumes during procedures.
- Storage of volatile toxic and corrosive substances.
- Storage of highly flammable substances.
- Confinement of potentially violent or flammable reactions.
- Experimental use should not be combined with storage use.

Use of Fume Cupboards for Procedures
The fume cupboard must be cleared of all unnecessary apparatus or reagents before setting up the experiment. Make sure that the experiment is compatible with any contents that must remain.

When using a shared facility a notice should be displayed indicating:

- Personnel in charge of procedure - work and home telephone number.
- Nature of experiment and any dangers.
- Duration of procedure.

When setting up a procedure within a fume cupboard the following points of potential danger must be considered:

- Ignition of flammable substances by naked flames, electrical sparking or hot surfaces.
- Corrosion of sensitive instruments and electrical leads.
- Bursting of bottles or cylinders by heat.
- Violent reactions between oxidising agents and organic matter.
- Escalation of a minor accident because of the presence of stored chemicals.

When a procedure is complete, clean the equipment and leave the fume cupboard clear of any unnecessary items.

A dangerous procedure to be performed in a fume cupboard should be planned in a way to minimise the operator’s exposure to the danger. Full remote control may have to be arranged. Where manipulation by hand does occur, appropriate gloves must be worn. Full length plastic aprons, full face visors and judicious use of the sash window will further
protect the operator.

**Use of Fume Cupboards for Storage**
Storage functions are not compatible with the use of fume cupboards for dangerous procedures. These often require heat and therefore may cause a rise in temperature within the work area. **Solvents** should preferably be stored in fire rated solvent storage cabinets complying with AS 1940 which may be vented through Davey-type fire eliminators to an exhaust system discharging outside the building. **Acids** should preferably be stored in storage cabinets which are mechanically vented to the atmosphere outside the building.

**OUT OF SERVICE TAGS**

**25 General**
Out-of-service tags are red and black on a white background. They are used to identify faulty or unsafe equipment placed out of service. This prevents the faulty equipment from damaging other equipment or causing injury to people operating the equipment. When equipment is being installed, altered or maintained, the person doing the work must attach an out-of-service tag in a suitable position on the equipment. The tag must have the name of the person (printed and signed), the date of placement and why the equipment has been placed out of service. Removal procedures include checking that all equipment can safely be energised and then notifying everyone involved with the work including the lab supervisor that the equipment is to be energised. The out-of-service tag should not be removed until the lab supervisor or authorised person has been advised that the job is completed and the equipment has been cleared for safe operation.

**CASE STUDIES**

**Case Study One**
Workers were using a mixture of hydrochloric acid and oxalic acid to clean mineral samples. After cleaning, the samples were dried by heating resulting in the workers being exposed to potentially lethal levels of oxalic acid vapour. There had obviously been inadequate assessment of the function and the need for adequate ventilation.

**Case Study Two**
It was normal practice at a university to store diethyl ether and etherised rat carcasses in a domestic refrigerator. The refrigerator was not modified for flammable liquid storage; nor was there any signs banning the storage of such. Electrical contacts ignited the vapours, blowing the door four metres onto the opposite wall. The explosion and fire resulted in nearly $100,000 worth of damage to the laboratory as well as the loss of valuable data which could not be retrieved. Fortunately no one was injured.

**Case Study Three**
Two technicians were transferring ethanol from a three litre storage vessel to 25 mL wash bottles on the laboratory bench when a colleague from another area took his cigarette lighter from his pocket and lit it close to a small pool of ethanol that had spilled on the bench. This ignited and the flame flashed over to the storage vessel, resulting in the ejection of two litres of burning liquid. The person responsible suffered serious burns and was taken to hospital.

The company transferred all such filling operations to a closed area fitted with vapour extraction apparatus.

**Case Study Four**

An explosion occurred within a specially designed distillation cabinet used for solvent distillation. The cabinet contained the explosion in compliance with its design. Fire alarms were activated by the incident and the fire brigade attended. The fire was extinguished by trained School personnel prior to the arrival of the Fire Brigade. Fortunately no one was injured.

Since the glass distillation flask, collection flasks and condenser remained intact, it was concluded that the most probable cause of the explosion was a pressure build-up in the inert gas flowing through the distillation apparatus to a bubbler. A kinked plastic line might have prevented nitrogen from escaping. The pressure build-up may have displaced one of the flask connections and vented highly flammable tetrahydrofuran vapour into the still enclosure, however, these vapours and smoke from the fire was exhausted to outside atmosphere by the properly designed exhaust systems.

**Case Study Five**

An experiment was performed on a bench with a local exhaust arrangement connected to a fume cupboard but some diphenyl phosphine vapour escaped into the laboratory. Later the same day the fume cupboard was shut down for maintenance without notification to the supervisor of the research project. Vapour again discharged into the laboratory and two students were taken to hospital suffering nausea and headache. They were discharged following observation. The failures included: Failure to perform the experiment in a fume cupboard; Inadequate communication to keep everyone informed of the activities including maintenance staff. Rectification included alterations to the fume cupboards, a tag and lock-out system for maintenance and by giving appropriate instructions to all relevant personnel. The employer was held to have been negligent.

**LEARNING OBJECTIVES**

On completion of this Chapter you should be able:

1. To describe the essential features of electrical safety required in laboratories and their operations.
2. To describe the essential aspects of safe fume cupboard use and ensure that these principles are used in practice.
3. To explain the need for and ensure the correct use of “Out of Service Tags”.

---

Laboratory & Engineering Safety
CHAPTER 4  HAZARDS AND RISKS

INTRODUCTION
A hazard means anything that may result in injury or harm to the health of a person. Risk, in relation to any injury and harm, means the probability of that injury or harm occurring. Under Section 19(1) (a) of the Occupational Safety and Health Act 1984, employers have a duty to ensure, as far as practicable, that employees are not exposed to hazards at the workplace. The Occupational Safety and Health Regulations 1996 require employers to identify hazards and assess and control risks.

Regulation 3.1 states;

A person who, at a workplace, is an employer, the main contractor, a self-employed person, a person having control of the workplace or a person having control of access to the workplace must, as far as practicable -

(a) identify each hazard to which a person at the workplace is likely to be exposed;
(b) assess the risk of injury or harm to a person resulting from each hazard, if any, identified under paragraph (a); and
(c) consider the means by which the risk may be reduced.

The regulation outlines three basic steps:

IDENTIFICATION OF HAZARDS
This involves recognising things which may cause injury or harm to the health of a person, such as flammable materials, ignition sources or unguarded machinery.

ASSESSING RISK
This involves looking at the possibility of injury or harm occurring to a person if exposed to a hazard.

Controlling the risk of injury or harm
This involves introducing measures to eliminate or reduce the risk of a person being injured or harmed.

It is important to regularly review these steps, especially if there are changes in the work environment, when new technology is introduced or standards are changed.

IDENTIFYING HAZARDS
There are a number of ways of identifying potential sources of injury or disease. Selection of the appropriate procedure will depend on the type of work processes and hazards involved. Procedures may range from a simple checklist for a specific piece of equipment or substance to a more open-ended appraisal of a group of related work processes. A combination of methods may provide the most effective results.
The following table lists some types of hazards and some specific examples.

<table>
<thead>
<tr>
<th>HAZARD</th>
<th>EXAMPLES</th>
<th>OUTCOMES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Falls</td>
<td>Falling objects, falls, slips and trips of people</td>
<td>Fractures, bruises, lacerations, dislocations, concussion, permanent or fatal injuries</td>
</tr>
<tr>
<td>Manual handling</td>
<td>Over-exertion/repetitive movement</td>
<td>Sprains, strains, fractures</td>
</tr>
<tr>
<td>Electricity</td>
<td>Electrical current, lightning</td>
<td>Shock, burns, electrocution</td>
</tr>
<tr>
<td>Machinery and equipment</td>
<td>Being hit, hitting objects, being caught in or between, over-turning vehicles</td>
<td>Cuts, bruises, dislocations, fractures, amputation, permanent or fatal injuries</td>
</tr>
<tr>
<td>Hazardous substances</td>
<td>Chemicals such as acids, hydrocarbons, heavy metals</td>
<td>Toxic effects, dermatitis, respiratory illnesses, cancers</td>
</tr>
<tr>
<td>Extremes of temperature</td>
<td>Effects of heat or cold</td>
<td>Burns, frost bite, heat stress, heat stroke</td>
</tr>
<tr>
<td>Noise</td>
<td>Excessive noise</td>
<td>Permanent hearing damage</td>
</tr>
<tr>
<td>Radiation</td>
<td>Ultra violet, welding arc flashes, microwaves, lasers</td>
<td>Burns, cancer, damaged eye sight, blindness</td>
</tr>
<tr>
<td>Biological</td>
<td>Viruses, bacteria, fungi, toxins</td>
<td>Hepatitis, Legionnaire's disease, Q Fever, tetanus, HIV/AIDS, allergies</td>
</tr>
<tr>
<td>Vibration</td>
<td>Hands and whole of body</td>
<td>Organ, nerve and muscle damage</td>
</tr>
<tr>
<td>Psychological stress</td>
<td>Intimidation, organisational change, violence, conflict, time pressure</td>
<td>High blood pressure, headaches and migraine, anxiety, depression, absenteeism</td>
</tr>
</tbody>
</table>

To assist in identifying workplace hazards consideration should be given to:
- incidents or accidents that have occurred at the workplace or other similar workplaces (refer to significant incident summary sheets published by WorkSafe WA and other agencies);
- relevant codes of practice and guidance notes;
- consultation with employees to find out what problems they may have in performing their jobs;
- consultation with safety and health representatives and safety and health committees;
- consultation with self-employed persons or contractors to find out if they are having or likely to have problems in performing their jobs;
- walk through inspections of the workplace (consider checklists); and
- records or statistics which indicate potentially unsafe work practices.
As part of the hazard identification, risk assessment and control process, procedures and work practices should be closely addressed. Safe work practices and documented procedures should be established before work commences. These should be drawn up in a consultative approach by all interested parties.

**ANALYSING AND ASSESSING RISKS**

A risk assessment of the hazards identified in the first step should result in a list of potential injuries or harm and the likelihood of these occurring. In assessing risks, consideration should be given to the state of knowledge about the frequency of injury or disease, the duration of exposure to injury or disease sources and the likely severity of the outcomes. Knowledge gained from similar workplaces or similar processes may be relevant to this risk assessment.

Matters to be considered include:
- frequency of injury - how often is the hazard likely to result in an injury or disease?
- duration of exposure - how long is the employee likely to be exposed to the hazard?
- outcome - what are the consequences or potential severity of injury?

Assessing these three factors will indicate the probability or likelihood of injury or harm occurring to workers involved in a particular work process. It will also indicate the likely severity of this harm.

Risk assessment requires good judgement and awareness of the potential risks of a work process. A person undertaking a risk assessment must have knowledge and experience of the work process. The task may be complicated by incomplete data or incomplete information regarding hazards of a work process.

In some cases, it may be necessary to break down the activity or process into a series of parts and assess each part separately.

Risk assessment should include:
- assessing the adequacy of training or knowledge required to work safely;
- looking at the way the jobs are performed;
- looking at the way work is organised;
- determining the size and layout of the workplace;
- assessing the number and movement of all people at the workplace;
- determining the type of operation to be performed;
- determining the type of machinery and plant to be used;
- examining procedures for an emergency (e.g. accident, fire and rescue); and
- looking at the storage and handling of all materials and substances.

A risk assessment form for chemical procedures is included at the end of this chapter. This step should provide information on where and which employees are likely to be at risk of incurring injury or disease, how often this is likely to occur, and the potential severity of that injury or disease risk. The following tables from the Standard AS/NZS 4360:1999 provide guidance on methods for categorizing and qualifying levels of risk.
Qualitative measures of consequence or impact

<table>
<thead>
<tr>
<th>Level</th>
<th>Descriptor</th>
<th>Example detail description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Insignificant</td>
<td>No injuries, low financial loss.</td>
</tr>
<tr>
<td>2</td>
<td>Minor</td>
<td>First aid treatment, on-site release immediately contained, medium financial loss.</td>
</tr>
<tr>
<td>3</td>
<td>Moderate</td>
<td>Medical treatment required, on-site release contained with outside assistance, high financial loss.</td>
</tr>
<tr>
<td>4</td>
<td>Major</td>
<td>Extensive injuries, loss of production capability, off-site release with no detrimental effects, major financial loss.</td>
</tr>
<tr>
<td>5</td>
<td>Extreme</td>
<td>Death, toxic release off-site with detrimental effect, huge financial loss.</td>
</tr>
</tbody>
</table>

**Note:** Measures used should reflect the needs and nature of the organization and activity under study.

Qualitative measures of likelihood

<table>
<thead>
<tr>
<th>Level</th>
<th>Descriptor</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Almost certain</td>
<td>Is expected to occur in most circumstances.</td>
</tr>
<tr>
<td>B</td>
<td>Likely</td>
<td>Will probably occur in most circumstances.</td>
</tr>
<tr>
<td>C</td>
<td>Possible</td>
<td>Might occur at some time.</td>
</tr>
<tr>
<td>D</td>
<td>Unlikely</td>
<td>Could occur at some time.</td>
</tr>
<tr>
<td>E</td>
<td>Rare</td>
<td>May occur only in exceptional circumstances.</td>
</tr>
</tbody>
</table>

**Note:** These tables need to be tailored to meet the needs of an individual organization.

Qualitative risk analysis matrix – level of risk

<table>
<thead>
<tr>
<th></th>
<th>Insignificant</th>
<th>Minor</th>
<th>Moderate</th>
<th>Major</th>
<th>Extreme</th>
</tr>
</thead>
<tbody>
<tr>
<td>Almost Certain</td>
<td>Medium</td>
<td>High</td>
<td>High</td>
<td>Very High</td>
<td>Very High</td>
</tr>
<tr>
<td>Likely</td>
<td>Medium</td>
<td>Medium</td>
<td>High</td>
<td>Very High</td>
<td>Very High</td>
</tr>
<tr>
<td>Possible</td>
<td>Low</td>
<td>Medium</td>
<td>Medium</td>
<td>High</td>
<td>Very High</td>
</tr>
<tr>
<td>Unlikely</td>
<td>Low</td>
<td>Low</td>
<td>Medium</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Rare</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Medium</td>
<td>High</td>
</tr>
</tbody>
</table>

- **Very High** - Extreme risk; immediate action required, no work to occur without written executive authorisation
- **High** – Senior management attention required before work commences
- **Medium** – Management responsibility must be specified
- **Low** – Manage with routine procedures

**IDENTIFYING CONTROL MEASURES**

The final step is to determine the control measures that need to be taken and the ongoing review of those measures. There is a hierarchy or preferred order of control measures ranging from the most effective to the least effective. The preferred order is outlined in the following table.
The control of occupational injury and disease risks should preferably be dealt with by design, substitution, redesign, separation or administration. These controls generally eliminate, reduce or minimise risk in a more reliable manner than personal protective equipment.

Controls involve implementing measures to reduce the hazard and risk in the workplace. Compliance with regulations requiring specific methods to control the risk is necessary. In some instances, a combination of control measures may be appropriate. Control measures should be designed:

- to eliminate or reduce the risks of a hazardous work process and to minimise the effects of injury or disease; and
- to reduce the risk of exposure to a hazardous substance.

<table>
<thead>
<tr>
<th>Hierarchy or preferred order of control</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Elimination</strong> - removing the hazard or hazardous work practice from the workplace. This is the most effective control measure;</td>
</tr>
<tr>
<td><strong>Substitution</strong> - substituting or replacing a hazard or hazardous work practice with a less hazardous one;</td>
</tr>
<tr>
<td><strong>Isolation</strong> - isolating or separating the hazard or hazardous work practice from people involved in the work or people in the general work areas from the hazard. This can be done by installing screens or barriers or marking off hazardous areas;</td>
</tr>
<tr>
<td><strong>Engineering control</strong> - if the hazard cannot be eliminated, substituted or isolated, an engineering control is the next preferred measure. This may include modifications to tools or equipment, providing guarding to machinery or equipment;</td>
</tr>
<tr>
<td><strong>Administrative control</strong> - includes introducing work practices that reduce the risk. This could include limiting the amount of time a person is exposed to a particular hazard; and</td>
</tr>
<tr>
<td><strong>Personal protective equipment</strong> - should be considered only when other control measures are not practicable or to increase protection.</td>
</tr>
</tbody>
</table>

**Control measures are not mutually exclusive. That is, there may be circumstances where more than one control measure should be used to reduce exposure to hazards.**

**CONTROL THROUGH PPE**

Personal protective equipment should be used in circumstances where other methods of control are not practicable or where there is a need to increase the level of protection. Factors determining the appropriateness of using personal protective equipment include:

- the nature of the work or the work process concerned;
- the severity of any potential injury or disease;
- the state of knowledge about the injury or disease related to the work or process;
- information available to employers about methods of preventing injury or disease associated with a particular hazard or risk;
- the availability and suitability of methods to prevent, remove or mitigate causes of injuries or diseases associated with a hazard or risk; and
- whether the costs of preventing, removing or mitigating that injury or disease are prohibitive in the circumstances.

There are some situations where temporary use of personal protective equipment may be necessary. These include:
• where it is not technically feasible to achieve adequate control of the hazard by other measures. In these cases, the hazard should be reduced as far as practicable by other measures and then, in addition, suitable personal protective equipment should be used to secure adequate control;
• where a new or revised risk assessment indicates that personal protective equipment is necessary to safeguard safety and health until such time as adequate control is achieved by other methods, for example, the use of fall arrest systems and devices until guard railing is erected; and
• during routine maintenance operations. Although exposure to hazards occurs regularly during such work, the infrequency and small number of people involved may make other control measures impracticable.

REVIEW OF CONTROL MEASURES
Constantly reviewing control measures is important to ensure that they continue to prevent or control exposure to hazards or hazardous work practices. Engineering controls should be regularly tested to ensure their effectiveness. Performance testing and evaluation standards should be established.

Repair and maintenance programs should specify:
• where servicing is required;
• the extent of servicing required;
• the nature of the servicing required;
• the frequency of servicing;
• who is responsible for maintaining repair and maintenance programs; and
• how defects will be corrected.

In order to keep accurate records, a recording or reporting system should be developed, implemented and maintained.

LEARNING OBJECTIVES
On completion of this Chapter you should be able to:

1. Describe what is meant by hazards and risks and provide examples.

2. Recall the main types of workplace hazards and be able to apply these to establish the hazards within your workplace.

3. Describe the main elements of a risk assessment and be able to conduct and record a risk assessment within your physical workplace or for a working procedure.

4. Describe the hierarchy of control measures.

5. Apply the hierarchy of controls to eliminate, reduce or minimise the risks for a hazard within your workplace.
### Chemical Process Safety Risk Assessment

**PART 1 – ACTIVITY / TASK DESCRIPTION**

- **Location**: [Field]
- **Assessment Date**: [Field]
- **Expiry Date (max. 5 years)**: [Field]
- **Assessor**: [Field]
- **Peer checked by**: [Field]

**Task / Activity / Project Title**

- **How many persons will be involved?** [Field]

**Description**

Describe the process to be undertaken, ensuring that you include names, quantities and concentrations of hazardous substances used. Alternatively, a separate Method Statement or equivalent detailed description may be referenced here if a copy is attached.

**Outcomes**

Note any hazardous reaction products formed, either key factors which may present a hazard and proposed waste disposal method.

**Related Documentation / Guidance** (this may include referenced articles, legislation, standards or codes which must be specifically highlighted)

**Method Statement:** [Field]

**Standard Operating Procedures (for equipment):**

**Other:**

**RISK CALCULATOR**

- **CONSEQUENCE** (the most probable outcome of exposure to the hazard)
  - **Likelihood**
    - Catastrophe: Multi-fatality
    - Disaster: Fatality
    - Very serious: Permanent disability or life
    - Serious: Non-permanent injury or life
    - Important: Medical attention needed
    - Noticeable: Minor cuts, burns, sickness

- **Exposure**
  - **Antecedence**
    - Continuous: Many times daily
    - Frequent: Approximately once daily
    - Occasional: Once a week to once a month
    - Rare: Once a month to once a year
    - Unnoticed: Not known to have occurred

**RISK SCORE**

- **RISK RATING**
  - Very High: Immediate action required.
  - High: Notification of Supervisor, Safety & Health Representative and Head of School, Review of control measures
  - Medium: Implement immediate action to minimise potential for injuries
  - Low: Required action to be agreed with Supervisor, Removal of risk to be taken as soon as practicable and within a month

**CONTROL STRATEGIES**

- Immediate action required
- Review of control measures
- Action plan to reduce risk
- Removal of risk

**Published**: July 2012
**Reviewed**: July 2018
**Page 1 of 2**

---

This document is controlled when printed. The current version is available on the Safety and Health website.
### PART 2 - IDENTIFY HAZARDS, ASSOCIATED RISK RATINGS AND CONTROL STRATEGIES

1. Pick out the hazards which are relevant for the task of activity.
2. Click entry fields for drop-down selection of inherent risk values for C, L and E.
3. In the comments box, describe when and where the hazard is present and other notes.
4. Specify the control measures type from the Hierarchy of Control (top right).
5. Under Control Measures give a description of the control to be implemented.
6. Click entry fields for drop-down selection of residual risk values for C, L and E.

<table>
<thead>
<tr>
<th>IDENTIFIABLE HAZARDS</th>
<th>INHERENT RISK</th>
<th>COMMENTS</th>
<th>CTRL</th>
<th>CONTROL MEASURES</th>
<th>RESIDUAL RISK</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slip and trip</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manual handling</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sustaining cold</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Burns</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electrical shock</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inhalation</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ingestion</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radiation exposure</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Skin contact</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eye contact</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cyanogenic</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPECIFIC - associated with chemicals to be used and particular chemical types including reaction products</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exposure</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Organic/pesticide</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flammable / Fire risk</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spontaneous reaction</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heads strong with liquid</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corrosive / Solvents</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asphyxiant</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pressurized tank / vacuum</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biological injectors</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Toxic / Poisonous</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carcinogenic (known or potential)</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mutagenic / Teratogenic</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radioactivity</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Geologic Technology</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OTHER</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**COMMON CONTROL MEASURES - if ELIMINATION or SUBSTITUTION are not possible**

<table>
<thead>
<tr>
<th>CONTROLLER</th>
<th>ADMINISTRATOR</th>
<th>PPE</th>
<th>WORST CASE RESIDUAL RISK SCORE FROM ABOVE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Mandatory protective factors for emergencies that must be readily available are antidotes, chemical spill kit, eye wash station, radioactive spill kit, emergency deluge shower, first aid kit, emergency shutdowns, evacuation / fire induction and health surveillance.**

### PART 3 - IMPLEMENTATION / ESCALATION PLAN

I have reviewed this risk assessment and agree that the control measures will be implemented as described above.

If other than a one-off activity, monitoring and review of their effectiveness will be carried out and recorded every _______ (enter period) weekly, monthly, quarterly, annually.

**SUPERVISOR:**

**HEAD OF SCHOOL, DIRECTOR, EQUIVALENT OR FORMALLY DELEGATED SIGNATORY:**

ANY SIGNATORY AUTHORITY MUST BE RECORDED AND ONLY DELEGATED TO COMPETENT PERSONS OR AN AUTHORISING COMMITTEE.

---

**CHEMICAL PROCESS SAFETY RISK ASSESSMENT**

Published: July 2012

Reviewed: July 2017

Version 1.3

This document is uncontrolled when printed. The current version is available on the Health and Safety website.

62
CHAPTER 5 TOXICOLOGY

ROUTES OF ENTRY OF CHEMICALS INTO THE BODY

In a laboratory setting, inhalation is the most important route of entry into the body. Next is contact with the skin. In either case there may be irritation of affected tissues and/or absorption into the blood with possible systemic intoxication. Although the gastrointestinal tract is a potential site for absorption into the blood, the ingestion of significant amounts of chemicals is rare.

The water solubility of a gas or vapour is an important factor in determining the amount of inhaled material that reaches the lungs. Highly soluble gases such as ammonia, hydrogen chloride and hydrogen fluoride dissolve readily in the moisture associated with the mucous membrane of the nose and upper respiratory tract. At low airborne concentrations, relatively little of these substances will reach the lungs owing to this 'scrubbing' effect. At high atmospheric concentrations however, sufficient quantities of the gas or vapour may reach the alveoli to cause severe irritation and pulmonary oedema. Comparatively insoluble gases, such as nitrogen dioxide and phosgene, are not removed by the moisture in the nose and upper respiratory tract and can easily reach the terminal recesses of the lungs. Gases such as carbon monoxide do not cause irritation but are rapidly absorbed into the blood. The particle size of aerosols (dispersion of microscopic particles) determines their ability to reach the small airways. Particles larger than 10 μm will become stuck in the mucous coat of the pharynx or nasal cavity, preventing them from reaching the alveoli; for these reason particles smaller than 10 μm are termed respirable. Particles between 1 and 5 μm in size often sediment within the bronchioles, whereas particles less than 1 μm can diffuse within the alveoli. Particles which lodge in the upper respiratory tract are moved by cilia and the mucous blanket upwards towards the glottis, where they are swallowed or expectorated.

Particles which travel past the ciliary epithelium may be absorbed through the alveolar lining into the blood, or as free phagocytized particles, may enter the lymphatic system. Some substances resist solubilisation by the blood or removal by phagocytes, and remain in the alveoli indefinitely. Irritation, inflammation, fibrosis, allergic sensitisation or malignant change may occur. However, substances such as iron oxide can be present for long periods of time with no apparent ill effects.

When a substance contacts the skin, four actions are possible:

- The skin and its associated film of lipid and sweat may act as an effective barrier and the substance cannot penetrate.
- The substance may react with the skin surface and cause primary irritation (acids, alkalis, many organic solvents).
- The substance may penetrate the skin and cause sensitisation (formaldehyde).
- The agent may penetrate the skin, enter the blood and act systemically (parathion, tetraethyl lead). Only a small number of substances are absorbed through the skin in hazardous amounts.
- Ingestion occurs as a route of entry through eating or smoking with contaminated hands or in contaminated work areas. Ingestion of inhaled materials also occurs.

DOSE AND RESPONSE

Toxicology is the study of adverse effects of chemicals on living organisms. The study of toxicity of chemicals is based on determining the relationship between the amount of a
chemical administered to an organism and the nature and extent of the response to that chemical. The dose response may be found from either an individual or population. In both cases the results may be displayed by a graph of response, which may be the degree of response in an individual or system or the fraction of a population responding, versus the range in administered dose. The two types of response are conceptually identical. Assumptions made in the application of a dose-response relationship are that:

- the response is due to the chemical administered (a causal relationship);
- the magnitude of the response is related the size of the dose. The assumption being that there is a molecular receptor site(s) with which the chemical interacts, the production of a response and degree of response are related to the concentration of the chemical at the reactive site and that the concentration at the site is related to the dose administered;
- there exists both a quantifiable method for measuring and a precise means of expressing the toxicity.

The normal starting point for evaluating new substances is to use lethality as an index. Toxicity data is usually obtained by using mice or rats and by either oral or intraperitoneal administration. A range of doses is found that results in some deaths and some survivals. The LD₅₀ is the statistically derived single dose of a substance that can be expected to cause death in 50 percent of the animals in a group of the same species when administered by the same route. The agent may also be administered by inhalation at different atmospheric levels for a specific time period. The term then calculated is the LC₅₀. During the determination of LD₅₀ and LC₅₀, observation of the animals provides information about the effects that may occur in humans. Autopsy of the animals shows which organs were affected. Table 6.1 is one scheme for the classification of toxic substances.

**Toxicity Classes**

<table>
<thead>
<tr>
<th>Toxicity Rating</th>
<th>Descriptive Term</th>
<th>LD₅₀ - wt/kg Single Oral Dose Rats</th>
<th>LC₅₀ - ppm 4-hr Inhalation Rats</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Extremely toxic</td>
<td>1 mg or less</td>
<td>&lt;10</td>
</tr>
<tr>
<td>2</td>
<td>Highly toxic</td>
<td>1 - 50 mg</td>
<td>10 - 100</td>
</tr>
<tr>
<td>3</td>
<td>Moderately toxic</td>
<td>50 - 500 mg</td>
<td>100 - 1000</td>
</tr>
<tr>
<td>4</td>
<td>Slightly toxic</td>
<td>0.5 - 5 g</td>
<td>1000 - 10,000</td>
</tr>
<tr>
<td>5</td>
<td>Practically non-toxic</td>
<td>5 - 15 g</td>
<td>10,000 - 100,000</td>
</tr>
<tr>
<td>6</td>
<td>Relatively harmless</td>
<td>15 g or more</td>
<td>&gt;100,000</td>
</tr>
</tbody>
</table>

Different chemicals cause a wide range of health effects. The various chemical groups are:

- acute poisons where a short exposure causes an immediate effect;
- chronic toxins which cause harm due to prolonged exposure;
- corrosive chemicals or irritants which usually affect mucous membranes (mouth, nose, throat, lungs);
- allergens or sensitisers which cause a change in the body’s reaction to that substance, so that subsequent exposure causes a reaction, such as dermatitis or asthma;
- carcinogens which are chemicals capable of producing cancer;
- mutagens which alter the genetic code of cells and can cause mutations; and
- teratogens which affect the growth of the fertilised egg and embryo, also causing mutations.

**TOXICITY AND HAZARD**

**Toxicity** is the ability of a substance to cause injury to a biological tissue. The **hazard** associated with the substance is the likelihood that it will cause injury in a given environment or situation. The hazard of a substance depends first on its toxicity, how it is
absorbed, metabolised and excreted, how rapidly it acts and its warning properties. In a second group are other factors that determine the hazard of a material, its physical characteristics and the manner in which the substance will be encountered in the workplace.

- Factors which determine the potential for fire and explosion.
- Any work practices that will cause high levels or frequent or prolonged exposure will contribute to the hazard associated with a substance.

EXPOSURE

Frequency and duration of exposure to chemicals in toxicological tests of animals are divided into four types:

- Acute exposure - exposure for less than 24 hours.
- Sub-acute exposure - repeated exposures to a chemical for 1 month or less.
- Subchronic exposure - exposure for 1 to 3 months.
- Chronic exposure - exposure for more than 3 months.

In the occupational setting though, acute human exposure generally means exposure that causes an immediate effect, whereas chronic exposure is applied to any repeated exposures over time.

EXPOSURE STANDARDS

Since reliable details of chronic chemical exposures in humans are rarely available, extrapolation from animal studies must be used and a safety factor of 100 is normally applied. The regulatory exposure limits for atmospheric contaminants are normally expressed as a threshold limit value (TLV). There are two categories of TLV:  

- Threshold Limit Value - Time Weighted Average (TLV-TWA). This is the time weighted average concentration for a normal 8 hour workday and 5 day week to which nearly all workers may be repeatedly exposed, without adverse effect.
- Threshold Limit Value - Short-Term Exposure Limit (TLV-STE). This is the highest concentration to which workers can be exposed for short periods of time (approx 15 min,) without suffering from irritation, chronic or irreversible tissue change or narcosis that might increase accident proneness or result in reduced work efficiency.  
  Note: STELs are only given for chemicals which have shown toxic effect from high short-term exposures in either humans or animals.

Exposure limits for many chemicals can be found in the Hazardous Substances Information System on the Australian Safety and Compensation Commission web site http://hsis.safeworkaustralia.gov.au

The ability to smell a substance may mean that it is present in a hazardous concentration or may mean that it has a low odour threshold. The following table provides odour thresholds and TLV - TWAs for some vapours.

<table>
<thead>
<tr>
<th>CHEMICAL</th>
<th>ODOUR THRESHOLD ppm</th>
<th>TLV - TWA ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetone</td>
<td>3.6 to 699</td>
<td>500</td>
</tr>
<tr>
<td>Ammonia</td>
<td>0.32 to 6</td>
<td>25</td>
</tr>
<tr>
<td>Benzene</td>
<td>0.84 to 53</td>
<td>1</td>
</tr>
<tr>
<td>Carbon disulphide</td>
<td>0.1 to 0.2</td>
<td>10</td>
</tr>
<tr>
<td>Substance</td>
<td>Concentration</td>
<td>TLV</td>
</tr>
<tr>
<td>----------------------</td>
<td>---------------</td>
<td>------</td>
</tr>
<tr>
<td>Chloroform</td>
<td>200 to 300</td>
<td>2</td>
</tr>
<tr>
<td>Formic acid</td>
<td>21</td>
<td>5</td>
</tr>
<tr>
<td>Ozone</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>Trichloroethylene</td>
<td>21.4</td>
<td>10</td>
</tr>
<tr>
<td>Xylene</td>
<td>0.25 to 140</td>
<td>80</td>
</tr>
</tbody>
</table>

**MEASUREMENT AND MONITORING**

If there is a possibility of significant exposure to a hazardous substance then monitoring is required. Since the most likely route of entry into the body is by inhalation, measurement of airborne contaminants is an important procedure. The most widely adopted unit of measurement is the threshold limit value time weighted average, TLV - TWA, which is an indication of the concentration to which a person can be continually exposed during a normal working 8 hour day. The unit is expressed in parts per million in air (ppm) or milligrams per cubic metre of air (mg/m³).

Air monitoring is done in several ways.

### Fixed Point Monitoring

- A sensor or collecting device is placed in a fixed position in the workplace;
- Samples are taken continuously or at regular intervals.

### Personal Sampling

- Individuals wear either a badge (passive monitoring) or a charcoal tube and a small pump (active monitoring).
- Analysis is carried out in the laboratory.
- The contaminant collected by the badge or tube is an indication of the amount being inhaled.
- Wearing of the tube and pump can be a nuisance so this method is only used as a means of checking the relevance of fixed point monitoring.
- Badges have been shown to be widely inaccurate.

### Grab Sampling

A known volume of workplace air is drawn by a small hand pump through a glass tube containing a test chemical. The extent of discolouration of the test chemical indicates the amount of pollution present. The discolouration extends down the tube which is calibrated in parts per million of contaminant. Tubes are available for a large range of chemicals (>200).

**LEARNING OBJECTIVES**

On completion of this Chapter you should be able to:

1. Describe the main routes of entry of intake into the human body.
2. Describe the basis of toxicity classifications and types of health effects which can be observed.
3. Describe exposure standards TLV-TWA and TLV-STEL and be able to establish and measure these as required.
4. Describe the main methods used to measure airborne contaminants.
CHAPTER 6 MANAGEMENT OF HAZARDOUS SUBSTANCES

HAZARDOUS SUBSTANCES REGULATIONS

The Occupational Safety and Health Act 1984 and Occupational Safety and Health Regulations 1996 provide for the protection of employees in WA workplaces. Part 5 of the Regulations contains specific provisions for working safely with or near hazardous substances. The employer, main contractor or person(s) having control of the workplace must ensure that:

- hazardous substances are identified (Regulation 5.15); and
- processes to identify, assess and control sources of hazardous substances are conducted in accordance with the following standards
  - Guidance Note for the Assessment of Health Risks Arising from the Use of Hazardous Substances in the Workplace [NOHSC:3017(1994)]
  - National Code of Practice for the Labelling of Workplace Substances [NOHSC:2012(1994)]
  - Guidance Note for the Completion of a Material Safety Data Sheet [NOHSC:2011(2003)]

**NOTE:** The NOHSC documents are stated in the WA legislation but NOHSC has become the Australian Safety and Compensation Commission (ASCC) and the information now comes through the Safe Work Australia website: [https://www.safeworkaustralia.gov.au](https://www.safeworkaustralia.gov.au). The responsibilities of employers and employees have already been discussed in section 1. As we move to GHS and the new federal WHS legislation these regulations and standards will be replaced by the models codes of practice which can be found here [https://www.safeworkaustralia.gov.au/resources_publications/model-codes-of-practice](https://www.safeworkaustralia.gov.au/resources_publications/model-codes-of-practice).

Under Regulation 5.3 manufacturers/importers are required to determine whether any substances are entered as hazardous substances in the List of Designated Hazardous Substances [NOHSC:10005(1994)] and if not, then determine in accordance with the Approved Criteria for Classifying Hazardous Substances [NOHSC:1008(2004)], whether the substance is a hazardous substance. Radioactive materials, infectious substances and substances based on other safety criteria (flammability, explosiveness) are excluded, mainly since the purchase, transport, storage, use and disposal of these substances are already covered by existing legislation. Foods, drugs, tobacco, cosmetics and toiletries for personal use are also excluded.

Under Regulation 5.8 manufacturers/importers are required to prepare safety data sheets (SDS) before the hazardous substances is supplied to the workplace. The material safety data sheets should be reviewed and revised by the manufacturer/importer as often as necessary and at least every 5 years. Regulation 5.8 requires the supplier of hazardous substances to provide a copy of the material safety
data sheet on first supply of the substance to the workplace.

**ELEMENTS OF A HAZARDOUS SUBSTANCES MANAGEMENT SYSTEM**

Elements of a successful hazardous substances management system include:

- Inspections and stocktakes of substances.
- Register of all hazardous substances;
- Assessments made of potential exposure scenarios at the workplace.
- Assessment made of control measures.
- Assessment of the need for health surveillance:
- Induction and training of employees to adequately mitigate risks from hazardous substances

The important elements for a workplace hazardous substances system are shown in figure 6.1. Note: the workplace register is fundamental to the management system.

![Figure 6.1 Elements of a hazardous systems management system.](image)
WORKPLACE CONSULTATIVE ARRANGEMENTS

Consultations between supervisors, employees, safety and health representatives and affected students should take place before new hazardous substances are introduced into the workplace. These consultations should consider:

- selection and supply of the new hazardous substance;
- information on and assessment of the hazardous substance;
- information, instruction, training and supervision requirements;
- safe handling procedures and measures to control potential exposures;
- transport, storage and waste disposal procedures;
- first aid and emergency procedures to be followed;
- requirements for any monitoring or health surveillance; and
- selection, use and maintenance of personal protective equipment.

LABELS

The label on a hazardous substance should draw attention to anyone handling or using the substance of the significant hazards involved. All containers of hazardous substances, including any produced within Schools, must be labelled. The National Code of Practice for the Labelling of Workplace Substances [NOHSC:2012(1994)] outlines requirements for labelling by manufacturers/suppliers. Schools must develop labels for designated hazardous substances produced in the workplace in accordance with this code of practice. Refer to the website https://www.safeworkaustralia.gov.au but be aware that as the new legislation for GHS and WHS take effect the NOHSC regulations and standards are being replaced with model codes of practice. The model code of practice: Labelling of workplace hazardous chemicals can be accessed via https://www.safeworkaustralia.gov.au/resources_publications/model-codes-of-practice

A label should:
- provide information and instructions;
- be firmly fixed to the container;
- be in legible English; and
- provide contact details for more information.

Information that labels must include:
- product identification (product name, chemical name);
- signal words and symbols (such as warning, hazardous, poison);
- risk phrases (general description of hazard such as flammable, irritating to skin);
- safety phrases (information on safe storage, handling and personal protection);
- safe use directions;
- first aid and emergency procedures;
- reference to the materials safety data sheet; and
- details of manufacturer or importer.

The label for a container that is too small for the above information should include:
- product name;
signal words(s) and/or dangerous goods class and subsidiary risk label(s); and
details of manufacturer or importer.

Labelling of decanted substances
There is no requirement for labelling if the decanted substance is being used immediately, provided that you clean the container so that it no longer contains the substance. Labels are required for all decanted hazardous substances not used immediately with the product name and the risk and safety phrases identical to those on the original container. The label should also include the name of the person decanting the substance and the date prepared.

SAFETY DATA SHEETS
The Occupational Safety and Health Regulations 1996 require suppliers to provide a safety data sheet (SDS) for each hazardous substance which formatted in accordance to Guidance Note for the Completion of a Safety Data Sheet [NOHSC:2011(2003)]. The SDS provides detailed information on the hazardous substance and includes:

- introductory details – number of pages, date of issue, statement of hazard;
- company details – name, address, phone numbers;
- identification of the product – product name, description, chemical composition, dangerous goods details/UN number, recommended use(s), recommended application method(s);
- health hazard information – health effects, first aid details, advice to doctors;
- precautions for use – exposure standards, engineering controls, personal protection, flammability;
- safe handling information – storage and transport, spills and disposal, fire and explosion hazard;
- other information – environmental parameters; and
- contact point – name and phone number.

An SDS is required on or before the first supply of the product, must be kept in a hazardous substances register and must be accessible to all employees. Employees are required to read and understand the SDS, seek additional information if concerned about the requirements and to not use the substance if the work area does not meet the safety directions on the SDS.

HAZARDOUS SUBSTANCES REGISTER (REGULATION 5.13)
The Occupational Safety and Health Regulations 1996 require all workplaces to establish a hazardous substances register (also referred to as a chemical register) that lists all the hazardous substances in the workplace. The register should include a copy of the SDS for each substance, locations where used, restrictions on use, maximum quantity held and the date the substance ceased to be used.
The register should contain separate entries for all hazardous substances used, including different formulations of the same ingredients (e.g. 5% chemical or 20% chemical in solution).
The register should be updated each time a new hazardous substance is ordered or
when an existing hazardous substance ceases to be used. The register must be readily accessible to all employees.

HEALTH SURVEILLANCE REQUIREMENTS
Under Schedule 5.3 of the Occupational Safety and Health Regulations 1996 (regulation 5.23(1)) there are sixteen hazardous substances for which health surveillance is required if a person at the workplace is at risk of exposure to the hazardous substance. Records need to be kept by the employer for no less than thirty years for:

- All assessments of exposure to hazardous substances;
- All workplace monitoring results; and
- Any employee health surveillance results.

The sixteen specified hazardous substances are:

- acrylonitrile
- inorganic arsenic
- asbestos*
- benzene
- cadmium
- inorganic chromium
- creosote
- isocyanates
- inorganic mercury
- 4,4'-methylene bis 2-chloroaniline (MOCA)
- organophosphate pesticides
- pentachlorophenol (PCP)
- polycyclic aromatic hydrocarbons (PAH)
- crystalline silica
- thallium
- vinyl chloride

Regulation 5.14 and Schedule 5.2 under the OHS Act prohibits certain asbestos uses. Other prohibitions or requirements regarding asbestos occur in Regulations 5.28 to 5.52 and Schedules 5.2 to 5.6. The Health (Asbestos) Regulations 1992 under the Health Act also apply to asbestos.

CARCINOGENIC SUBSTANCES REQUIREMENTS
Under Schedule 5.4 of the Occupational Safety and Health Regulations 1996 (regulation 5.28), there are nine carcinogenic substances that are not to be used at workplaces unless for bona fide research and with the Commissioner's approval.

The nine specified carcinogenic substances are:

- 2-Acetylaminofluorene
- Aflatoxins
- 4-Aminodiphenyl
- Benzidine and its salts (including benzidine dihydrochloride)
- bis(Chloromethyl) ether
- Chloromethyl methyl ether (technical grade which contains bis(chloromethyl) ether)
- 4-Dimethylaminoazobenzene (Dimethyl Yellow)
- 2-Naphthylamine and its salts
- 4-Nitrophenyl

Schedule 5.5 (regulation 5.32) also refers to eleven carcinogenic substances to be used only for purposes approved by the Commissioner.
The eleven specified carcinogenic substances are:

- Acrylonitrile
- Benzene
- Cyclophosphamide
- 3,3'-Dichlorobenzidine and its salts (including 3,3'-Dichlorobenzidine dihydrochloride)
- Diethyl sulphate
- Dimethyl sulphate
- Ethylene dibromide
- 4,4'-Methylene bis(2-chloroaniline)
- 3-Propiolactone (Beta-propiolactone)
- o-Toluidine and o-Toluidine hydrochloride
- Vinyl chloride monomer

All uses of any of the above carcinogenic substances requires the researcher to have completed a Carcinogens/Mutagens/Teratogens Approval Form. These are available from UWA Safety, Health and Wellbeing (see http://www.safety.uwa.edu.au/management/committees/carcinogenic) and must be approved prior to commencement of the work.

**CONTROL OF SECURITY RISK SUBSTANCES**

Dangerous Goods Safety (Security Risk Substances) Regulations 2007

Western Australia has developed dedicated security regulations for so-called security risk substances (SRS) rather than including them in the Explosives Regulations. This avoids confusion or inconsistencies between safety and security requirements for ammonium nitrate.

The requirements of the SRS Regulations are in addition to the requirements of the other dangerous goods safety regulations.

The following substances, other than Class 1 dangerous goods, are security risk substances (SRS) in Western Australia:

- solid mixtures containing more than 45% ammonium nitrate (AN); and
- ammonium nitrate emulsions, suspensions or gels.

*Note: This does not include single-phase, homogenous (as opposed to multiphase, heterogeneous mixtures) aqueous solutions of ammonium nitrate as commonly used in fertiliser applications or as hot, concentrated solutions (UN 2426) for making AN emulsion explosives. However, it does include calcium ammonium nitrate (CAN), which is not a dangerous good under the UN classification system.*

Commercial, industry and educational laboratories are exempted from licensing for the storage and use of less than 3 kg of SRS per laboratory building.

**DANGEROUS GOODS SAFETY (STORAGE AND HANDLING OF NON-EXPLOSIVES) REGULATIONS 2007**

Dangerous goods are generally chemicals that pose an immediate threat to health, safety,
Hazardous Substances

property or to the environment. Dangerous goods are classified by the United Nations, which has established an international system for naming, packaging, and the transport of dangerous goods. This system has been adopted in Australia through the Australian Code for the Transport of Dangerous Goods by Road and Rail (otherwise known as the Australian Dangerous Goods Code or the ADG code) and associated legislation.

The dangerous goods system is based on a numbering system for identification of specific chemicals or groups of chemicals with the same hazards (the UN number), a classification system according to the predominant hazard of the material (dangerous goods class), and a system for recognising the degree of danger or risk (packaging group).

The UN number is a system of four digits used internationally to identify dangerous goods. They may apply to one substance (e.g. 1671-Phenol) or may apply to groups of substances with similar characteristics (e.g. 2927-Fungicides, corrosive).

Each dangerous goods class (or subclass) can be denoted using a dangerous goods hazard “diamond”. This is called the class label. The label is divided into three areas:

Diagram of hazard or symbol (top half). Dangerous goods class name (bottom half). Dangerous goods class number (bottom corner).

In some cases, dangerous goods may also possess other hazard characteristics. This additional hazard (subsidiary risk) may also be displayed using a second, smaller diamond. The subsidiary diamond has no dangerous goods class number. It is permissible to cut the bottom of a class label to make it a subsidiary risk label.

Dangerous goods are classified according to the predominant hazard of the material. There are nine classes of dangerous goods. These classes are defined in Australian Standard AS 1216 Class labels for dangerous goods.

The following is a guide to the recognition of dangerous substances and their properties.

Class 1 Explosives

- Substances or articles that are manufactured or used to produce explosions or pyrotechnic effects, or are explosive by reason of their chemical nature.

- Explosives may be further subdivided into classes 1.1 through 1.6, depending on the rate and severity of the explosion.
Class 2 Gases

<table>
<thead>
<tr>
<th>Class 2.1 Flammable Gases</th>
<th>Class 2.2 Non-Flammable, Non-toxic gases</th>
<th>Class 2.3 Toxic (poisonous) Gases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gases which ignite on contact with an ignition source. Most are heavier than air, and thus flow and settle in low areas. May have a subsidiary risk classification e.g. poison (2.3)</td>
<td>Gases that are not flammable when exposed to an ignition source. Some of these gases are liquefied. Generally non-flammable compressed gases are heavier than air. May have a subsidiary risk category e.g. oxidising (5.1)</td>
<td>Gases that are liable to cause death or serious injury if inhaled. Most have a distinctive irritating odour. Some have subsidiary risks. Generally, most poison gases are much heavier than air.</td>
</tr>
</tbody>
</table>

Class 3 Flammable Liquids

- Liquids which ignite on contact with a source of ignition.
- Liquids, or mixtures of liquids and containing solids in suspension (e.g. paints), which have flashpoint less than 61°C.
- The vapours from Class 3 substances may have a narcotic effect and prolonged inhalation may result in unconsciousness or even death.
- This class is further subdivided into three packaging groups.
Class 4 Flammable Solids

<table>
<thead>
<tr>
<th>Class 4.1</th>
<th>Class 4.2</th>
<th>Class 4.3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Flammable Solids</strong></td>
<td><strong>Spontaneously Combustible</strong></td>
<td><strong>Dangerous When Wet</strong></td>
</tr>
<tr>
<td>Solids that may be easily ignited by external sources such as sparks and flames. They are readily combustible and may cause or contribute to fire through friction. These substances include self-reactive and related substances and desensitised explosives.</td>
<td>Solids or liquids which either immediately catch fire or self-heat on contact with air. Some of these substances are more liable to spontaneous ignition when wetted. Some may also give off toxic gases when they burn.</td>
<td>Solids or liquids that produce dangerous quantities of flammable gases when in contact with water or water vapour. In some cases the gases are liable to ignite due to the heat liberated by the reaction. Some evolve toxic gases when in contact with moisture.</td>
</tr>
</tbody>
</table>

Class 5 Oxidising Substances and Organic Peroxides

<table>
<thead>
<tr>
<th>Class 5.1 - Oxidising Substances</th>
<th>Class 5.2 - Organic Peroxides</th>
</tr>
</thead>
<tbody>
<tr>
<td>Substances which although in themselves not necessarily combustible, may increase the risk and intensity of fire in other materials with which they come into contact. Oxidisers may cause a fire when brought into contact with finely divided combustible materials and may burn with almost explosive violence.</td>
<td>May be either liquids or solids. They freely support the burning of combustible materials. Under long exposure to fire or heat, containers of these materials may explode. Most are sensitive to impact or friction. Many organic peroxides may react dangerously with other substances. Violent decomposition may be caused by traces of impurities such as acids. Decomposition may produce toxic and flammable gases.</td>
</tr>
</tbody>
</table>
### Hazardous Substances

#### Class 6 Toxic or Infectious Substances

<table>
<thead>
<tr>
<th>Class 6.1(a) Toxic Substances</th>
<th>Class 6.2 Infectious Substances</th>
</tr>
</thead>
<tbody>
<tr>
<td>Substances which are liable to cause death or serious injury if swallowed, inhaled or by skin contact. May be in solid or liquid form. Nearly all evolve toxic gases when burned or burned.</td>
<td>Substances which are known, or reasonably believed, to cause disease in plants or animals.</td>
</tr>
</tbody>
</table>

#### Class 7 Radioactive Substances

- Includes materials or combinations of materials with activity exceeding 70 kBq/kg which spontaneously emit radiation.
- Three packaging categories exist and are determined by the radiation exposure level at the package surface.

#### Class 8 Corrosives

- Substances which are solids or liquids possessing in their original state, the common property of being able to severely damage living tissue. They can also damage or even destroy other materials, especially metals.
- Many substances are sufficiently volatile to produce vapour irritating to nose and eyes.
- Some can be toxic, and poisoning may result if they are swallowed.
DO NOT STORE ACIDS AND BASES TOGETHER.

Recommended Storage:
- cabinet for organic acids
- cabinet for mineral acids
- cabinet for organic bases
- Do not store nitric or perchloric acids with acetic acid
- Do not store nitric or perchloric acids with mineral bases.

Class 9 Miscellaneous Dangerous Goods

- Substances or articles which present a danger not covered by the other classes. They are generally dangerous goods with a relatively low hazard, or an environmental hazard.

STATE REGULATIONS
States and Territories have separate legislation that outlines storage and licensing provisions for dangerous goods. In Western Australia this is the Dangerous Goods Safety (Storage and Handling of Non-Explosives) Regulations 2007, which is administered by the Explosives and Dangerous Goods Branch of the Department of Industry and Resources. Matters covered by the regulations include:
- Classification of dangerous goods;
- Subsidiary risks;
- Packing groups;
- Packing and container labelling;
- Dangerous Goods Sites;
- Licensing;
- Risk assessment and control;
- Safety management system;
- Design, build, maintenance and location of storage or handling systems;
- Placarding;
- Firefighting and other emergency response equipment;
- Training including Emergency response training; and
- Records.

The need for a licence is based upon the quantities and nature of materials stored.

Assistance with the storage and transport requirements for dangerous goods can be obtained from UWA Safety, Health and Wellbeing. Refer:
POISONS ACT REQUIREMENTS

The supply, labelling, sale and use of poisons in Western Australia are controlled by the Medicines and Poisons Act 2014, administered by the Health Department of Western Australia. Medicines and Poisons are classified into Schedules based on their level of toxicity and their use. The National Drugs and Poisons Scheduling Committee (NDPSC) make recommendations to determine in which Schedule a substance should be included. The Standard for the Uniform Scheduling of Medicines and Poisons (SUSMP) is the publication containing all scheduled poisons and is adopted by reference in the Poisons Act. The SUSMP can be downloaded from the Federal Register of Legislation https://www.legislation.gov.au/ or via the link on the Therapeutic Goods Administration (TGA) webpage https://www.tga.gov.au/publication/poisons-standard-susmp.

There are ten classifications of poisons which at October 2018 are:

- **Schedule 1** - No longer in use
- **Schedule 2** - (PHARMACY MEDICINE) Substances, the safe use of which may require advice from a pharmacist and which should be available from a pharmacy or, where a pharmacy service is not available, from a licensed person.
- **Schedule 3** - (PHARMACY ONLY MEDICINE) – Substances, the safe use of which requires professional advice but which should be available to the public from a pharmacist without a prescription.
- **Schedule 4** - (PRESCRIPTION ONLY MEDICINE or PRESCRIPTION ANIMAL REMEDY) Substances, the use or supply of which should be by or on the order of persons permitted by State or Territory legislation to prescribe and should be available from a pharmacist on prescription.
- **Schedule 5** - (CAUTION) Substances with a low potential for causing harm, the extent of which can be reduced through the use of appropriate packaging with simple warnings and safety directions on the label.
- **Schedule 6** - (POISON) Substances with a moderate potential for causing harm, the extent of which can be reduced through the use of distinctive packaging with strong warnings and safety directions on the label.
- **Schedule 7** - (DANGEROUS POISON) – Substances with a high potential for causing harm at low exposure and which require special precautions during manufacture, handling or use. These poisons should be available only to specialised or authorised users who have the skills necessary to handle them safely. Special regulations restricting their availability, possession, storage or use may apply.
- **Schedule 8** - (CONTROLLED DRUG) Substances which should be available for use but require restriction of manufacture, supply, distribution, possession and use to reduce abuse, misuse and physical or psychological dependence.
- **Schedule 9** - (PROHIBITED SUBSTANCE) Substances which may be abused or
misused, the manufacture, possession, sale or use of which should be
prohibited by law except when required for medical or scientific research, or
for analytical, teaching or training purposes with approval of Commonwealth
and/or State or Territory Health Authorities.

- **Schedule 10 (previously Appendix C)** – SUBSTANCES OF SUCH DANGER TO
  HEALTH AS TO WARRANT PROHIBITION OF SALE, SALE, SUPPLY AND USE –
  Substances which are prohibited for the purpose or purposes listed for each
  poison.

University personnel may be required to obtain permits to purchase poisons for
specific purposes such as educational or research use, but not for resale. The use
of schedule 8 and 9 poisons for research is strictly controlled. The use of such
poisons requires the user to obtain a poisons licence and the chemicals must be kept
in a very secure location, such as a safe. The use of all schedule 8 and 9 poisons must
be recorded. The records will be periodically audited by the relevant authority. For
further information regarding poison permits at The University see

For information on Chemical Safety refer:
http://www.safety.uwa.edu.au/about_chemical_safety

**ANNUAL CLEAN UP**

Management and supervisors should arrange that all laboratories have an annual
clean-up programme to ensure that old and no longer used chemicals are removed
and disposed of safely.

**LEARNING OBJECTIVES**

On completion of this Chapter you should be able to:
1. Describe the elements of a hazardous substances management system and
   apply these to your own workplace.
2. Describe the types of information provided on an SDS and be able to
   interpret these for hazardous substances used in your workplace.
3. Describe the legislative requirements for health surveillance and ensure
   that these are followed within your workplace.
4. Describe the system used for labelling, transporting and storing dangerous
   goods.
5. Apply the segregation of dangerous goods table, SDS and other
   information for the safe storage of chemicals within your workplace.
6. Explain the differences between hazardous substances and dangerous goods.
7. Describe requirements for the supply, labelling, sale, use and storage of
   classified poisons and ensure compliance with these within your workplace.
8. Management of Hazardous Substances
3 Segregation Table of Dangerous Goods
This table is to assist laboratory personnel to safely arrange their chemicals.

<table>
<thead>
<tr>
<th>Class</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>COMPRESSED GASES</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.1 Flammable</td>
<td>C</td>
<td>KA</td>
<td>S</td>
<td>S</td>
<td>S</td>
<td>S</td>
</tr>
<tr>
<td>2.2 Non-flammable/Non-toxic</td>
<td>KA</td>
<td>C</td>
<td>KA</td>
<td>SM</td>
<td>S</td>
<td>SM</td>
</tr>
<tr>
<td>FLAMMABLE LIQUIDS and Combustible Liquids</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.1 Flammable Solids</td>
<td>S</td>
<td>KA</td>
<td>C</td>
<td>KA</td>
<td>S</td>
<td>S</td>
</tr>
<tr>
<td>4.2 Spontaneously Combustible</td>
<td>S</td>
<td>SM</td>
<td>KA</td>
<td>C</td>
<td>KA</td>
<td>S</td>
</tr>
<tr>
<td>4.3 Dangerous When Wet</td>
<td>S</td>
<td>SM</td>
<td>S</td>
<td>KA</td>
<td>C</td>
<td>KA</td>
</tr>
<tr>
<td><strong>OXIDISING SUBSTANCES</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.1 Oxidising Agents</td>
<td>S</td>
<td>SM</td>
<td>S</td>
<td>S</td>
<td>S</td>
<td>S</td>
</tr>
<tr>
<td>5.2 Organic Peroxides</td>
<td>I</td>
<td>S</td>
<td>I</td>
<td>S</td>
<td>I</td>
<td>S</td>
</tr>
<tr>
<td><strong>TOXIC SUBSTANCES</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>KA</td>
<td>KA</td>
<td>KA</td>
<td>KA</td>
<td>KA</td>
<td>KA</td>
</tr>
<tr>
<td><strong>CORROSIVE SUBSTANCES</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>KA</td>
<td>KA</td>
<td>KA</td>
<td>KA</td>
<td>KA</td>
<td>KA</td>
</tr>
<tr>
<td><strong>DEDICATED COMPRESSED GAS STORE UNDER AS 4332:2004</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Class / Sub-risk</td>
<td>2.1</td>
<td>2.2</td>
<td>2.2/5.1</td>
<td>23 or 23/6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.1</td>
<td>C</td>
<td>C</td>
<td>KA</td>
<td>KA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.2</td>
<td>C</td>
<td>C</td>
<td>C</td>
<td>C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.2/5.1</td>
<td>KA</td>
<td>C</td>
<td>C</td>
<td>C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>23 or 23/6</td>
<td>KA</td>
<td>C</td>
<td>KA</td>
<td>C</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>MAXIMUM MINOR STORAGE QUANTITIES</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Description</td>
<td>PG I</td>
<td>PG II</td>
<td>PG III</td>
<td>Combustible Liquids</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total quantity of all dangerous goods</td>
<td>25</td>
<td>250</td>
<td>1000</td>
<td>1500</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**LEGEND**
- C: SHOULD BE COMPATIBLE. Consult the SDS or supplier about requirements for individual substances.
- S: SHOULD BE SEGREGATED by at least 3m and kept in separate compounds or building compartments.
- !: COULD BE INCOMPATIBLE or react dangerously. Consult the SDS or supplier about requirements for individual substances.
- SM: SEgregation may be necessary. Consult the SDS or supplier.
- KA: SHOULD BE KEPT APART by at least 3m. Consult the SDS or supplier.
CHAPTER 7  CHEMICALS

Hazards of chemical substances may arise from one or more of the following:

- Instability;
- High reactivity;
- Flammability;
- Toxicity;
- Compressed state;
- Volatility;
- Radioactivity; and
- Storage conditions.

UNSTABLE CHEMICALS

Many chemicals are prone to react violently, either spontaneously or due to environmental contact. This often results in an explosion or fire. Dangerous instability is usually indicated by a note or warning placed on the container by the supplier. Warnings of this type are often based on bitter experiences and must not go unheeded.

It is important to note that new data on compound ability is constantly appearing in the literature. Special precautions must be taken when it is necessary to work with:

- Substances which are unstable or potentially unstable.
- Reactions which may produce unstable substances. In such cases, the following rules must be observed:
  - Authorisation must be obtained from laboratory supervisor.
  - Quantities of chemicals employed must be kept to the minimum necessary.
  - Safety screening and appropriate protective clothing must be used.
  - Handling should be by remote control devices if at all possible.
  - Reserve stocks of unstable substances must be removed from the work area and stored in a properly designed enclosure.

HIGHLY REACTIVE CHEMICALS

Many chemicals have a dangerously high level of reactivity. This is true even of some common reagents and the extent and nature of this reactivity is not always known or appreciated. Heat evolved from mixing chemicals can cause splashing, resulting in burns and poisoning. If the heat of reaction is not controlled, fire and explosions can occur. Safety visors or spectacles must be worn when any highly reactive materials are in use. Safety carriers must be used to transport containers of corrosive or reactive liquids.

TOXIC CHEMICALS

Poisons can gain entry into the body by three different routes:-

- Absorption through the skin, eyes or wounds.
- Ingestion through the mouth.
- Inhalation via the respiratory tract.

Sometimes chemical laboratory activities involve the use of substances which are:
• Quick-acting poisons;
• Cumulative poisons;
• Dangerous drugs;
• Toxic gases;
• Dermatitis causing agents;
• Allergenic;
• Radioactive; and or
• Carcinogenic.

A nominated officer shall be responsible for ensuring that the hazards are understood and the chemicals properly stored and safely used. It is particularly essential to institute controlled safety procedures when toxic chemicals are introduced in laboratories for chemical experimentation. When highly toxic chemicals are being used, testing facilities must be provided for monitoring the concentration in the environment.

**General Precautions**

a) High odour levels in laboratories require immediate remedial action as they indicate unhygienic or toxic conditions. Work should be planned and executed to eliminate smells in the working area. Fume cupboards must be used in such cases.

b) Discharge of material into ducts or drains must be in compliance with environmental regulations. If permissible contamination limits may be infringed, preventative measures must be taken. Concentrations of toxic material in the vicinity of fume cupboard release vents should not significantly exceed the occupational exposure limit (O.E.L.). A fume cupboard is mandatory when working with highly toxic volatile substances. Air flow should exceed 0.5 m/s at full face opening. A sealed trap must be provided in the drain from the cupboard. Apparatus or equipment must not impede quick closure of the sash.

c) Suitable respirators may be provided for dealing with contaminated atmospheres. Canister type respirators provide little protection against concentrations of gas exceeding 1% and they are useless in oxygen-deficient atmospheres.

d) Cylinders containing volatile toxic gases under pressure must not be used in the open laboratory. These substances are normally obtainable in small cylinders, which can be placed inside a fume cupboard. They must be kept at room temperature and be effectively shielded from any source of heat. Appropriate markings must identify contents of cylinders of all gases.

e) It is necessary to consult the appropriate sources of safety information contained in material data sheets before starting work involving toxic chemicals. Volatile toxic compounds must be stored in a ventilated cupboard. It may be necessary to reserve a fume cupboard for this purpose. The storage place must never contain any source of heat or ignition and must not be a work area.

**Toxic Dust**
The danger of poisoning by inhalation or absorption through the skin is obvious when the substance is a liquid or gas. With solids, the danger can also arise from breathing dust or from powder lodged under fingernails. Gloves and masks must be worn. Complete protection from dust may be obtained by handling a solid in a ventilated glove box.
Carcinogens
The toxic effects of chronic exposure to certain chemicals can lead to carcinogenesis. Many carcinogens require several years between time of exposure and development of the disease. Susceptibility appears to vary greatly from individual to individual. Whenever possible the use of human carcinogens should be avoided.

Some common laboratory chemicals are suspected of being human carcinogens. The following list is not complete:

<table>
<thead>
<tr>
<th>Chemical Name</th>
<th>Carcinogen Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-Acetylaminofluorene</td>
<td>Ethyl diazoacetate</td>
</tr>
<tr>
<td>3-Amino-1,2,4-triazole</td>
<td>Ethyleneimine</td>
</tr>
<tr>
<td>4-Aminobiphenyl</td>
<td>Ethylenethiourea</td>
</tr>
<tr>
<td>Acrylonitrile</td>
<td>Ethyl N-nitrosocarbamate</td>
</tr>
<tr>
<td>Asbestos</td>
<td>Hexachlorobutadiene</td>
</tr>
<tr>
<td>Benzene</td>
<td>Hexamethylphosphoramide</td>
</tr>
<tr>
<td>Benz - a – pyrene</td>
<td>Hydrazine</td>
</tr>
<tr>
<td>Benzidine</td>
<td>Iodomethane</td>
</tr>
<tr>
<td>Beryllium</td>
<td>4,4‘-Methylenebis (2-chloroaniline)</td>
</tr>
<tr>
<td>Chloroform</td>
<td>Methylhydrazine</td>
</tr>
<tr>
<td>Carbon tetrachloride</td>
<td>3-Methylcholanthrene</td>
</tr>
<tr>
<td>Chromates of lead and zinc</td>
<td>Methyl ethanesulphonate</td>
</tr>
<tr>
<td>Dianisidine</td>
<td>1-Naphthylamine</td>
</tr>
<tr>
<td>3,3-Dichlorobenzidine</td>
<td>2-Naphthylamine</td>
</tr>
<tr>
<td>1,2-Dibromoethane</td>
<td>4-Nitrobenzylchloride</td>
</tr>
<tr>
<td>Dimethylcarbamoyl chloride</td>
<td>2-Nitropropane</td>
</tr>
<tr>
<td>1,1-Dimethylhydrazine</td>
<td>N-Nitroso(methyl)urea</td>
</tr>
<tr>
<td>Dimethyl sulphate</td>
<td>N-Phenyl-2-naphthylamine</td>
</tr>
<tr>
<td>Diazomethane</td>
<td>1,3-Propanesultone</td>
</tr>
<tr>
<td>1,4-Dichlorobutene</td>
<td>1,3-Propiolactone</td>
</tr>
<tr>
<td>4-Dimethylaminoazobenzene</td>
<td>Propyleneimine</td>
</tr>
<tr>
<td>7,12-Dimethylbenzanthracene</td>
<td>0-Tolidine</td>
</tr>
<tr>
<td>Epichlorhydrin</td>
<td>Vinyl chloride</td>
</tr>
<tr>
<td>Ethyl carbamate</td>
<td>Vinylecyclohexene dioxide</td>
</tr>
</tbody>
</table>

Risk
This is dependent upon the length and frequency of exposure and the concentration of the chemical. Exposure can result from:
- Inhalation of dust or vapour.
- Absorption through the skin.
- Ingestion from contaminated hands.
- Absorption from contaminated clothes.
- Contact with contaminated benches or apparatus.

Precautions
- All the listed substances should be labelled as “Carcinogenic” and “Dangerous” and marked “Not to be handled without the proper precautions.”
• All persons likely to use these substances must be aware of the risks and know how to avoid them.
• These substances must always be kept in a closed container and must never come in contact with the skin.
• If there is any accidental contact, the affected parts including eyes should be immediately washed in cold running water for 5 minutes.
• Any operations involving the risk of vapour or dust formation must be carried out in a properly exhausted fume-cupboard.
• Laboratory coats and gloves must always be worn when handling these chemicals.
• If any spillage occurs on the body, all contaminated clothes must be removed and the skin thoroughly washed with water.
• Empty apparatus and storage jars must be rinsed in cold water after use.
• Impervious working bench surfaces must be used because absorption into wood surfaces may occur.
• Arrangements must be made for the correct method of laundering contaminated clothing and for the safe disposal of waste materials containing these chemicals.
• Carcinogenic and highly toxic chemicals must be securely kept away from other reagents and be available only on request to a senior member of the laboratory staff.

**FLAMMABLE CHEMICALS**

**General**
Adequate precautions must always be taken when working with flammable chemicals and in their handling and storage. The reduced sense of danger which comes from familiarity with them should be guarded against.
A few important chemicals, e.g. yellow phosphorous, ignite spontaneously and expert advice must be sought before working with them.
Flammable materials must be stored and maintained below flashpoint wherever possible and must not be used in proximity to flames or hot surfaces.
The vapour from flammable substances, even at ambient temperature, can be carried by draught, or suction through a fume cupboard flue, into contact with a source of ignition. The vapour may thus ignite and burn back, setting fire to the surroundings or igniting the parent substance.
An area free of ignition sources must be provided when working with flammable substances.

**Safety Measures**
The following precautions are necessary for work with highly flammable chemicals. They must be applied to the whole working bench, not just to one person’s work space. For work with 4 litres or more of any substance that has a flashpoint below 30°C, the following precautions must apply to the whole laboratory:
• No smoking.
• No flames.
• Heat, only by steam, by water bath or by infrared radiation.
• Electrically heated hot plates or mantles fitted with regulators may be used, provided that suitable precautions are taken.
• Electrical equipment shall be suitable for use in the hazardous location.
• Continuous and undivided attention must be given to preparations and distillations.
• Where highly reactive reagents are to be used, the working site must be in a fume cupboard behind a safety screen.
• Suitable and well maintained fire equipment must be provided.
• Bulk liquid chemical storage areas must be air conditioned, external to laboratory work area, adequately sign-posted, electrically safe, reticulated and provided with suitable fire extinguishers. A safety shower should also be immediately accessible to the area.
• Flammable solvents must not be stored near oxidising compounds such as nitric acid or potassium permanganate. Chemical storage compatibility charts must be adhered to as the authoritative reference.
• A fume cupboard for handling solvents must have an air face velocity of 0.5m/sec and either a sealed motor external to ducting or be of a flashproof design.
• The transport of Winchesters or receptacles containing large quantities must be undertaken using the appropriate carriers.
• Solvents should not normally be stored in plastic containers.
• Where possible use a substitute for toxic or highly flammable solvents, e.g. toluene to replace benzene.
• If possible, do not work alone. However, where this is impossible, arrangements must be made for regular contact with isolated workers at least once per hour.
• Quantities of flammable solvent in the laboratory area must not exceed immediate requirements; unwanted solvent must be returned to solvent store or disposed of without delay in accordance with local regulations. Do not pour down sinks.

Continuous Operations
Continuous large-scale work with organic solvents requires a specially designed laboratory. Forced ventilation giving at least eight air changes an hour is required. Switched electrical outlets should be of the flameproof type. Chemical laboratories require portable fire-fighting equipment in greater numbers than for office buildings. Where large quantities of solvents are to be used, or stored, fixed inert gas systems may be required. Personnel should be aware of the dangerous possibility of asphyxiation if caught in a small enclosed area when a reticulated system is activated.
Water is the most effective medium for extinguishing timber and paper fires, but is dangerous in fires involving solvents or electrical equipment. For general laboratory purposes requiring instant action against small solvent or electrical fires, a CO₂ portable fire extinguisher must be used. Chemical laboratories must be provided with at least one fire extinguisher per 45m². Research laboratories usually require twice as many. The fire extinguisher requirements are determined by the type and quantity of flammable materials in stored in the room.

Special Sources of Danger
Volatile flammable liquids in enclosed areas may create an explosive mixture. As little as 1 per cent of vapour in air, e.g. 1 ml of ether dispersed in a volume of 30 litres of air may create an explosive mixture.
Ovens
Unventilated electric convection ovens must not be used for evaporating organic solvents or for removing residual solvent from deposits or crystals. Ignition can occur from electrical sparking, or hot spots on the heated surface. Apparatus that is to be oven-dried should be rinsed out with distilled water, not with an organic solvent. Do not use an unventilated oven for regeneration of absorbents (silica gel molecular sieves) which have been in contact with organic vapours.

Refrigerators
Scientific work often requires that solutions prepared in flammable liquids be kept at a low temperature. Where a properly designed cold store is not available, the refrigerator in use must be certified free of internal electrical contacts. There should be no interior light. Such units should bear a prominent label with the words: 'Suitable for flammable solvents'.
Strict supervision of laboratory refrigerators is required. All containers must be closed and labelled. A complete check of contents should be made at least once a month.

Oil Baths and Molten Salt Baths
Oil baths must be securely supported and temperature monitored. Care must be taken to guard against the possibility of accidental addition of water or other volatile substance to the oil, which can splatter over a very wide area.

Static Electricity
The removal of one surface from contact with another causes charge separation and may give rise to static electrification. High speeds, large quantities, dry atmosphere and insulating floor coverings may magnify the effect. The following are common systems in which static electrification occurs:
- Pumping of hydrocarbons.
- Belts passing over pulleys.
- Unearthed compressed gas lines.
- Agitation of insulated solids.
- Mixing of immiscible liquids so that one settles through the other.
- Leaks of steam vapour and condensable gases.
- Plastic sheets or surfaces parted from metallic or non-metallic objects.

Attention must be given to the personal charge which may be acquired by movement and stored in the body and clothing. The major danger arises from the grounding of these charges in a flammable atmosphere when the energy released acts as a source of ignition. A secondary feature is that persons who have become charged are likely to drop objects and materials that they are holding when their charge is grounded.
The system must be rendered safe by provision of sufficient low resistance paths to earth for every component (including personnel).

INCOMPATIBLE CHEMICALS
When transporting, storing, using or disposing of any substance, utmost care must be exercised to ensure that the substance cannot accidentally come in contact with another with which it is incompatible. Such contact could result in a serious explosion or the formation of substances that are highly toxic and/or flammable.

Read the SDS for each chemical to obtain information on compatibility. Consult the following two references for the most comprehensive information:


**LIQUID CHEMICAL SPILLS**

**Acid Spills (Excluding hydrofluoric acid)**
Evacuate non-essential personnel from the spill area. Put on goggles and gloves before you begin to clean up. Circle the spill with an absorbent. Products are available for this purpose or you could use solid bicarbonate for a liquid spill. Carefully fill in the circle to cover the entire spill. Evenly cover the wet absorbent with excess neutraliser (Na₂CO₃).
Mix the neutraliser thoroughly with the wet absorbent and wait for 5 minutes. Scoop up the neutralised mixture and transfer to waste bags. If the spill is a solid, scoop up as much as possible then wash down with dilute solution of say 1 molar bicarbonate. If the spill acid is perchloric, the neutralized material should not be permitted to contact organic materials. For small spills dissolve and flush down the drain with copious quantities of water. For larger spills contact a waste disposal company.

**Basic Spills**
Evacuate non-essential personnel from the spill area. Put on goggles and gloves before you begin to clean up. If the spill is a solid, scoop up as much as possible then wash down with say 1 molar citric acid. If the spill is a liquid, circle the spill with absorbent such as solid citric acid. Evenly cover the wet absorbent with excess neutraliser (citric acid). Mix the neutraliser thoroughly with the wet absorbent and wait for 5 minutes. Scoop up the neutralised mixture and transfer to waste bags.

**Organic Spills**
Evacuate non-essential personnel from the spill area. Put on goggles, gloves and mask or respirator before you begin to clean up. Circle the spill with an absorbent such as activated charcoal or vermiculite. Carefully fill in the circle with absorbent to cover the entire spill. Mix thoroughly and wait for 5 minutes. Scoop up the absorbed mixture and transfer to waste bags. Remember that this mixture could still be highly flammable, giving off flammable vapours.
The waste bags must be labelled and not be kept for any length of time, but disposed of as soon as possible.
All stores and service rooms must have all appropriate safety equipment available for use when cleaning up after accidents or when dispensing or handling dangerous chemicals.
CSIRO Chemical Spill Kit

The contents of the Western Australian CSIRO’s spill kit for use in laboratories is provided in the below.

CSIRO CHEMICAL SPILL KIT CONTENTS

- Acid (neutralizing) powder: 500 g
- Acid (neutralizing) solution: 2 litres
- Activated charcoal: 250 g
- Barrier cream: 1 tube
- Basic (neutralizing) powder: 500 g
- Basic (neutralizing) solution: 2 litres
- Bucket: 1
- Chemical resistant gloves (neoprene long sleeves): 1 pair
- Detergent: 1
- Disposable aprons: 2
- Disposable forceps: 2
- Disposable suit: 1
- Dust mask: 2
- Dust mask (with filter): 2
- Dust pan and brush: 1
- Eyewash bottle: 1
- Felt tip marker pen: 1
- Garbage bags: 5
- Hazard report sheet: 1 pad
- Indicator paper (pH 1 to 14): 1 packet
- Latex gloves (medium): 1 box
- Masking tape: 1 roll
- Mop sheets: 5
- Nail scrubbing brush: 1
- Nitrile gloves (medium): 1 box
- Overshoes: 2 pairs
- Paper towel: 1 roll
- Rubber gloves (medium): 1 pair
- Safety glasses: 2 pairs
- Scissors: 1 pair
- Sharps container: 1
- Sponges: 3

Note in kit: Please let your laboratory supervisor know when you have used any of the goods from this spill kit so that they can be replaced.

DISPOSAL OF WASTES

Collection
Collection of chemical waste that cannot be neutralized and disposed by normal means is essential. Any collection system must be convenient and without danger to the environment.
Collection of flammable wastes will be facilitated by a system for bringing labelled containers of waste to areas convenient for truck pick-up and modified as necessary to provide fire-protected storage.

Handling
Waste solvents should be stored and handled in safety cans that are prominently labelled with the type of waste. Halogenated and non-halogenated wastes should be kept separate. Solvents which have contained sodium or similar material should be placed in separate waste containers from solvents which contain water, for obvious and important reasons. Earthing and other precautions to prevent static sparks or other sources of ignition are recommended.

Final Disposal
Methods for final disposal of waste substances include:

a) Evaporation - Solvents which are not combustible or which have flash-points above ambient temperatures may be disposed of by evaporation if there is assurance that the vapours will not create problems. Empty containers should be washed thoroughly before disposal.

b) Neutralisation and Dilution - Acid and alkaline materials can be carefully neutralised, and many soluble materials can be carefully diluted into a sewer or watercourse after consultation with the appropriate local authority. Inventories of all chemicals and their volumes need to be kept as per Water Corporation’s requirements for disposal of industrial waste to sewer.

c) Burial - Burial is a common method of disposal which may accomplish gradual dispersion of waste. Burial methods should be planned according to land fill and environmental regulations.

d) Storage - Storage may be applicable to certain classes of hazardous wastes pending satisfactory arrangements being made for disposal.

e) Incineration - Most chemicals can be destroyed by high temperature incineration.

Responsibility
Within each individual laboratory a nominated person must be responsible for seeing that the laboratory's waste chemicals are safely collected, identified and stored for disposal. They shall advise on the need for any special methods or facilities required for disposal.

AGRICULTURAL CHEMICALS
Special chemical hazards in the form of pesticides are occasionally encountered by the grounds staff and some personnel in the School of Plant Biology and School of Animal Biology.
Recognised pesticides include a wide variety of chemical types, some of which are stable while others break down under certain environmental conditions, e.g. water, temperature. The term 'pesticide' includes any substance, or mixture of substances,
intended for prevention or control of any unwanted species of plant or animal, or for use as a plant-growth regulator, defoliant or desiccant. It includes the following categories:

- fungicide
- herbicide
- insecticide
- rodenticide
- veterinary chemicals

Inhalation and skin absorption are the most common routes of entry. Inhaled pesticides are almost completely absorbed by the lungs and risk is increased when a pesticide is used in a confined space, e.g. glass house. The appropriate respiratory protection device must be used - cartridge or canister respirators and supplied air devices. Respiratory protection is not effective for persons with beards. Respirators should be checked frequently for deterioration and following use should be washed thoroughly with soap and water. Organic solvents must not be used to clean respirators.

Most of the commonly used pesticides may be absorbed through the skin. Protective clothing is necessary (overalls, disposable gloves, waterproof boots and a face shield) and is compulsory when using organochlorine pesticides (e.g. dieldrin, lindane and heptachlor) and organophosphorous pesticides (e.g. Malathion and parathion). Any cuts or abrasions should be covered with waterproof dressing (e.g. Tegaderm).

Containers must be clearly labelled showing their contents, instructions for use and safety procedures. Supervisors should hold copies of the supplier’s or manufacturer’s safety data sheets.

Pesticides should be kept in separate locked storage facilities with access restricted to responsible and informed persons.

Following treatment with a pesticide, warning notices should be displayed showing the name of the pesticide, date of application, safe re-entry date and the name of the responsible officer. All equipment, including tractors, must be appropriately decontaminated at a suitable site.

Detailed requirements for the handling and storage of agricultural chemicals and pesticides are contained in Australian Standard AS2507:1998 “The Storage and Handling of Agricultural and Veterinary Chemicals” and this is accessible on line through the UWA Library at http://www.saiglobal.com/online/autologin.asp and also in the Agricultural and Veterinary Chemicals (Western Australia) Regulations 1995 which includes the Pesticides Regulations 1956 (WA).

PHOTOGRAPHIC CHEMICALS

Persons who work in photographic laboratories and dark rooms come into contact with a large number of chemicals, many of which are hazardous. Old photographic chemicals and film may include dangerously unstable items; contact UWA Safety, Health and Wellbeing for assistance with safe decommissioning of photographic labs and disposal of any chemicals. Principles of safety in laboratories extend to photographic work.

STORAGE OF CHEMICALS

Chemicals need to be stored in compatible groups. Within compatible groups they may be stored alphabetically. (Storing ALL chemicals in alphabetical order leads to
potential for unwanted reactions between incompatible chemicals.)

Note that Class 1 Explosives may not be stored with anything else.

Incompatible substances need to be separated by a least 3 metres but when both are solids this reduces to 1 metre.

Where stored substances may react dangerously they must be at least 5 metres apart and be held in separately bunded areas which do not share a common drainage system. Bunding is the provision for containment of any unintended spill or escape of materials. In chemical storage this could be an internal retaining wall within a large facility or a secondary tub for a single reagent bottle.

It is good practice to store all liquids containers in trays so if a bottle breaks or cracks, the spill is confined. Liquid reagents should be stored on lower shelves below dry reagents to minimise the potential for damage in the event of leaks.

It is very important that all flammable liquids be stored in approved safety cabinets. Only the minimum quantity necessary for day to day operations should be stored in the laboratory.

The SDS for each substance should provide information on its incompatibility or reactivity with other substances. Figure 7.1 from Australian/New Zealand Standard AS/NZS 3833:2007 provides guidance on segregation of substances in storage.

LEARNING OBJECTIVES

On completion of this Chapter you should be able to:

1. Describe the main hazards involved with chemicals and safety precautions required when using them.
2. Describe the safety measures required for the use of flammable chemicals and be able to apply these to your own workplace when using these.
3. Describe the special considerations needed when using flammable chemicals in regard to ovens, refrigerators, oil baths and molten salt baths and conduct a check within your workplace for full compliance with these requirements.
4. Apply information on incompatible chemicals from their SDS and other sources when transporting, using, disposing or storing of chemicals.
5. Describe the general response steps to a liquid chemical spill.
6. Describe the main methods of chemical disposal and apply these to your workplace in accordance with legislative and best practice requirements.
7. Describe the main hazards and safety control measures when handling agricultural chemicals.
8. Describe the main hazards and safety control measures when handling darkroom chemicals.
9. Describe the main safety control measures when storing chemicals.
CYROGENICS

A cryogenic fluid is a fluid having a boiling point below -150°C at atmospheric pressure. Those most commonly used are helium, hydrogen, nitrogen, argon, oxygen, methane and liquefied natural gas.

Any person handling cryogenic fluids should be fully trained in the safety techniques to be used and should be aware of the potential hazards that may occur and how to avoid them. Check Safety Data Sheets for specific precautions.

Containers

Liquefied gases at atmospheric pressure are contained in vacuum-jacketed vessels or, if they boil at very low temperatures, with a guard jacket of liquid nitrogen surrounding them. Blocked Dewar flask outlets can cause explosion and should be cleared immediately.

Transfer

If the boiling point of the gas is below that of liquid air, care must be taken in transferring the liquid from stock to the apparatus, i.e. Dewar-type vessels or cryostat. A vacuum-jacketed siphon must be used. If the gas is poured from the container a solid plug may form in the outlet. These operations may only be undertaken after consultation with the suppliers of the liquefied gas.

It is sometimes convenient to transfer liquid oxygen or nitrogen from its container by pressurisation. This may be done safely if the appropriate dry gas is used, and if the liquid gas container is of the type that will withstand pressure.

Empties

Containers of liquid oxygen and liquid nitrogen should not be completely emptied. Occasionally they should be allowed to warm up to ambient temperature, and they should be purged with dry nitrogen. This will avoid danger from accumulation of hydrocarbon gases extracted from the atmosphere, and the nuisance from water freezing in the container.

Spills

Particular care must be taken not to spill liquefied gases. Spills on seamless vinyl flooring will cause it to split and lose its integrity. Apart from the potential physical harm to soft tissue that contact with the cryogenic material can cause, there are other dangers involved.

Nitrogen will displace life-supporting gases, oxygen increases fire risk, and hydrogen and methane are potentially flammable.

Where fire results from spillage of liquefied gases it should be treated as a flammable solvent fire.

Use of Liquid Nitrogen

Traps open to air at atmospheric pressure must not be placed where they can be cooled by liquid nitrogen.

Liquid nitrogen is sufficiently cold to condense oxygen from the atmosphere and quite
large quantities of liquid oxygen may accumulate in an open vessel cooled by liquid nitrogen. The liquid oxygen will evaporate violently if the coolant is removed.

**Use of Liquid Oxygen**
Liquid oxygen must not be allowed to mix with flammable material, as a potential hazard may result.

**Use of Dry Ice**
Large quantities of dry ice should not be used in a confined space unless adequate forced ventilation is provided. Dry ice must never be handled with bare hands, as a severe burn may result.

**Other Gases**
Generally, instructions for handling liquid nitrogen, helium, argon and methane should be sought from the suppliers. The experimental work should be based on their advice. It is common practice to put liquefied gases into Dewar flasks but make sure that such flasks are taped or boxed to guard against implosion.

**HANDLING**
Always handle cryogenic fluids carefully. Cryogenic substances can produce an effect on the skin similar to a burn. This will vary in severity with temperature, heat capacity of the fluid and exposure time. Delicate tissues such as those of the eyes can be damaged by an exposure too brief to affect the face or hands.
Naked or insufficiently protected parts of the body coming into contact with uninsulated pipes or vessels may stick fast because of the freezing of available moisture. The flesh may be torn on removal.
Stand clear of boiling and splashing liquid when filling a warm container or when inserting a transfer tube or other objects into the liquid. Always perform these operations slowly to minimise boiling, splashing and thermal shock. Where practicable, allow the tube or object to cool in the evolved vapour before immersion in the liquid.
Use tongs and gloves to withdraw objects immersed in liquid, and handle the tongs and the objects carefully. Pre-cool the tongs in the vapour. In addition to the hazards of burns, or skin sticking to cold surfaces, objects that are soft and pliable at room temperatures usually become hard and brittle at cryogenic temperatures and are very easily broken.
Vessels with a carrying handle and splash guard should be used for transporting small quantities of fluid. Care will still be necessary if the inner vessel is glass because it may fracture unexpectedly, allowing the contents to boil rapidly and discharge through the neck of the outer vessel.
Larger vessels fitted with integral wheels should be transported on a stable trolley designed to hold them securely in position during transit and to permit easy and safe loading and unloading.

**Personal Protection**
When transferring liquid from a bulk supply or from one vessel to another, or when immersing objects or at any other time when spraying or splashing is a real possibility, a full face shield must be worn. A full face shield must be worn when working with any cryogenic system which is or has the capacity to come under positive or negative pressure.
Use a protective screen when working with glass systems. In bulk transfer operations under the control of a valve in the transfer line, a protective barrier between the vessel being filled and the operator will give equally good protection. During transfer operations the hands must be protected by clean and dry leather or other suitably insulated gloves. Gloves should be loose fitting so that they may be thrown off should any liquid splash on or into them. Gloves should also be worn when carrying fluid in small containers, including those with handles or when handling anything that is, or may have been in contact with cryogenic fluids. Even with gloves, cold equipment can be held only for a short time.

To protect the body and limbs, the basic aim is to shield the areas that are particularly sensitive to cold, to avoid creating traps capable of holding liquid in close proximity to the flesh and to avoid exposing the parts of the body and limbs that form natural traps. For example, footwear with solid toecaps should always be worn to prevent spilt liquid being trapped between the toes. The degree of protection necessary will depend on the operation being carried out and the quantity of liquid involved. For example, when transferring liquid from a bulk supply, without the benefit of a protective barrier, overalls without pockets or turn-ups, and with leg length sufficient to shield the top of the shoes, must be worn in addition to eye and hand protection. Trousers must be worn outside the boots or shoes, particularly gum boots. When filling a small cold trap in the laboratory this degree of protection may be unnecessary. Eye and perhaps hand protection should be sufficient provided reasonable care is exercised.

Storage and Transport
Use only containers specifically designed for holding cryogenic liquids. They are made to withstand the rapid changes and extreme divergences in temperature encountered when working with cryogenics; and are thermally insulated to minimise loss by evaporation. The most common container is the double-walled evacuated vessel known as a Dewar flask. It can be either metal or glass. The small glass versions are similar in appearance to the domestic vacuum flask. The lower portion generally has a metal base which serves as a stand, or the whole flask may be encased in metal up to its neck. Exposed glass portions should be taped to prevent fragmentation of the glass should it break. The larger glass versions are usually spherical and protected by a cylindrical metal outer casing with a conical top. All glass vessels must be handled with care as they may get scratched and break unexpectedly, since they are always under stress due to the vacuum. With encased containers, sudden failure of the inner container will result in the liquid boiling rapidly and being ejected from the neck of the vessel. Metal containers are generally used for storing quantities over 10 litres. They have double walls and frequently contain some absorbent materials in the evacuated space. Depending on the nature of the cryogenic fluid, containers should either be open to the atmosphere or protected by a vent or other safety device which permits vapour to escape. Where a special vented stopper or venting tube is used, as on some small portable containers, check the vent at regular intervals to be sure it is not plugged with ice formed from water vapour condensed from the air. Should an ice plug form it can be cleared by inserting a brass or copper rod down the neck.
This source of heat should melt the plug. Care must be taken in these techniques to avoid
burns from the escaping vapour or sudden ejection of the plug, rod or tube. Gloves and
safety glasses are appropriate.
Inadequate venting can result in excessive gas pressure, which may damage or burst a
container. Use only the stopper supplied with the container. Containers not supplied with
vented stoppers should be kept covered with a loose fitting cap to prevent air or moisture
from entering, and to provide pressure relief.
Small containers should not generally be stored in the open where they may come into
contact with rain or moisture, unless suitable protection from the weather is provided.

Even then, excessive moisture on moving parts such as valves, relief devices and couplings
might cause malfunction due to formation of external ice.
Cryogenic liquids with boiling points below that of liquid nitrogen require specially
constructed and insulated containers to prevent rapid loss from evaporation. The risk of
ice plugs forming in vents and discharge orifices is increased.

Transfer Techniques
Pressurisation is the conventional method used to transfer cryogenic fluid from a storage
container to another vessel. Gas pressure is used to force the fluid from storage container
to receiver through a transfer tube with one end immersed in the storage container. The
necessary pressure can be obtained by heat leak from the storage container, a heat source
within the container, or pressurisation with a gas corresponding to the liquid product.
Alternatively, liquid nitrogen may be transferred by use of a small submersible pump
which can pass down the neck of the container. If the pump is electrically driven it may be
stopped and started by level controls in the apparatus being filled.
Transfer tubes range in complexity from the metal evacuated, multilayer insulated lines
used for very low temperature liquids such as helium, to rubber hose, if appropriate. Flow
through the tube is often controlled by means of an inline valve.
The heat added by the insertion of a transfer tube at ambient temperature can be utilised
to generate sufficient pressure to transfer liquid from a small flask. The warm tube
vapourises liquid as it is placed into the flask. If a gas seal is made at the outlet of the neck
tube, the vapour generated provides a source of pressurisation which can be sufficient to
transfer up to 20 litres of liquid without the use of additional pressurising gas. The quantity
which can be transferred by this means is obviously dependent on the thermal
characteristics of the tube and liquid. Quite small containers can be safely and
conveniently filled using this method and it is preferable to pouring liquid from one vessel
to another.
If pouring is the only means available, a filling funnel should be used. The top of the funnel
should be partly covered to reduce splashing.
Care must be taken in the choice of hose material used for transfer tubes. Some types can
split explosively after a short time in use.

Bulk Storage Units
Access to pressurised bulk storage units should be restricted to a limited number of
trained personnel. This is for both safety and economic reasons.
If there is unlimited access, untrained personnel may attempt to fill small containers
without following the correct transfer procedures or taking adequate safety precautions.
Under these conditions the risk of personal injury is high. The practice is economically unsound because each time liquid is withdrawn some is lost to evaporation in cooling the transfer pipe work.

Small containers should be filled by the users, via a transfer tube from a small bulk container of approximately 50 litres that is recharged as required from the bulk storage unit and is located in the same locked compound. Personal safety equipment must be held with the access key and issued to those wanting to fill small containers.

Operation of bulk pressurised storage units must be in accordance with the supplier's instructions. Trained operators must be familiar with the emergency shutdown procedure.

Concise emergency, safety and transfer instructions must be clearly displayed near the units.

As a general rule, before withdrawing fluid from a pressurised bulk supply, the indicated pressure should be kept as low as practicable. In this way it is possible to safely achieve optimum fill time and percentage fill.

If practicable, a protective barrier should be provided between the receiving vessel and the operator.

Proprietary Equipment
Proprietary equipment, such as cryostats and liquefiers, must always be operated and maintained in accordance with manufacturer's instructions. Regular maintenance and inspections are necessary.

Air Condensation and Oxygen Enrichment
Air coming into contact with a surface cooled below 82°K will condense. The composition of this condensate is approximately 50% oxygen and 50% nitrogen. This oxygen enriched mixture will significantly enhance combustion of flammable materials and of materials which are normally regarded as being relatively non-flammable.

If condensation occurs at the surface of a cryogenic liquid, the liquid can become contaminated. This can occur, for example, with liquid nitrogen, its boiling point being 77.3°K. If condensation is allowed to continue for any length of time, the oxygen content of the liquid nitrogen may become appreciable and the liquid will require the same precautions as liquid oxygen when handled. The small neck area of most liquid nitrogen containers and the barrier formed by the nitrogen gas issuing from the surface together usually prevent this occurring in storage. Liquid neon, which has a boiling point of 27.2°K, is another example of a cryogenic material that can become contaminated in this way.

Care must be taken when using liquid nitrogen as coolant for a cold trap. Where possible the system should be pumped down before charging the trap, otherwise liquid air can condense in the trap, inviting explosion when the system warms up.

Working at Reduced Pressure
If the pressure of a cryogenic liquid is reduced below atmospheric pressure the following additional precautions should be taken:

a) Ensure the system is vacuum tight to prevent moist air being drawn in and forming ice plugs.

b) Provide a protective screen when working with glass Dewar flasks.

c) Carefully control initial pumping speed to avoid pressure oscillation and liquid entrainment.
d) Prevent violent boiling of superheated liquid by the use of boiling centres, such as silicone preparation deposited inside the Dewar flask. This precaution is especially necessary when working with nitrogen in a glass system.

e) Where the backing pump is used to pump evolved gas into a valved recovery system, provide a pressure relief valve on the exhaust side of the pump to protect against the situation where the pump may be turned on with the recovery valves shut.

VENTILATION
While a number of gases in the cryogenic range are not toxic, they are capable of causing asphyxiation by displacing oxygen in the air. Even oxygen may have harmful effects if it is inhaled at high concentrations for lengthy periods. Prolonged inhalation of cold vapour or gas, whether respirable or not, can produce deleterious effects in the lungs. The large ratio of expansion in volume from liquid to gas can rapidly change the composition of the atmosphere if the fluids are used or stored in poorly ventilated areas. A build-up can occur when a room is closed off overnight.

Always handle the fluids in well-ventilated areas to prevent excessive concentration of gas. If there is any doubt about the composition of the air in a room that has been closed off, ventilate it well before entering.

EMERGENCY MEASURES AND FIRST AID
Cold Contact Burns
Tissue damage does not normally occur immediately, cryogenic liquid touches warm flesh. Initially, the blood-supply to the tissue acts as a heat source and creates a heat-insulating gas film at the liquid/flesh interface. This time delay is usually sufficient for severe injury to be avoided even when a large volume of fluid is involved, provided that appropriate action is subsequently taken.

If cryogenic fluid is splashed on the body, immediately flush the affected area with water and remove any clothing which may be saturated with the fluid. It is especially important to remove gloves or footwear quickly if liquid is splashed into them as large volumes can be trapped thereby enhancing the risk of tissue damage by prolonged contact.

The high heat capacity, harmlessness and ready availability all combine to make water an important safety contribution to cryogenic operations. If practicable, water should be made readily available wherever cryogenic liquids are handled. All bulk storage installations should have a safety shower.

Irrespective of severity, general first aid rules are -

i) DO NOT rub or massage the affected area.

ii) DO NOT expose to radiant heat source.

iii) DO NOT allow the casualty to smoke, or to drink alcoholic beverages.

First aid and general treatment for cryogenic burns are virtually the same as those specified for frostbite in first aid and medical manuals.

Asphyxia
If a person begins to exhibit signs of asphyxia while working with cryogenic liquids, get them to a well ventilated area immediately. If breathing has stopped, apply expired air resuscitation. If the oxygen level is depressed to below about 15% V/V in air or the gas is

97
toxic, the rescuer will need to wear a self-contained or supplied-air respirator. In sudden and acute asphyxia, such as that from inhalation of pure nitrogen, unconsciousness is immediate. The victim falls as if struck down by a blow on the head and may die within a few minutes. Where asphyxia develops slowly by gradual reduction of oxygen content in the air, early outward signs are the inability to think clearly, disturbance of muscular co-ordination, rapid fatigue and easy arousal of emotions, particularly ill-temper. If oxygen reduction becomes severe, complete physical collapse may occur. The victim may be unaware that anything is wrong until beyond self-rescue or summoning aid.

**Safety Precautions for Specific Cryogenic Materials**
The following are some specific precautions that should be taken in addition to the general precautions when handling some of the cryogenic fluids. Expert advice about precautions to be taken should be obtained before using flammable, toxic or highly corrosive liquids and before working at ultra-low temperatures with liquefied helium, neon or hydrogen.

**Oxygen**
Do not permit organic material or flammable substances of any kind to come in contact with liquid oxygen. Some materials can react violently with oxygen under certain conditions of temperature and pressure, grease, asphalt, kerosene, cloth, wood, organic formed insulation and dirt which may contain oil or grease. Oxidation reactions, once initiated, proceed at enormously enhanced rates in liquid oxygen. Materials not normally combustible react at rapid rates and combustible materials react at explosive rates. Under certain conditions mixtures of organic materials with liquid oxygen can detonate.

- Remove clothing that comes in contact with liquid oxygen.

Ventilate the clothing away from sources of ignition for at least 1 hour. Organic materials will burn violently if ignited even several minutes after they have been splashed with the liquid.

- Smoking must be forbidden and other sources of ignition excluded in any area where liquid oxygen is stored, handled or used.

Signs to this effect must be posted in these areas.

- Do not use oil or grease on any oxygen equipment.

- Purge equipment thoroughly with oil-free dry air before repairs are made.

**Nitrogen**
Liquid nitrogen exposed to the atmosphere can become contaminated with oxygen condensed from the air. If the oxygen content becomes appreciable the liquid will require the same precautions in handling as liquid oxygen. The appearance of a blue tint in liquid
nitrogen indicates its contamination by oxygen.

**Carbon dioxide**

Because of its role in the respiratory process, even small quantities of carbon dioxide in the atmosphere tend to increase the breathing rate and an excessive amount can affect the ability of the body to rid itself of carbon dioxide in the blood. The recommended threshold limit value for an 8 hour day is 0.5% V/V in air. Atmospheres that contain 9% carbon dioxide can be tolerated for only a few minutes.

**Hydrogen**

Hydrogen is a flammable, non-toxic, colourless, odourless gas that can act as an asphyxiant if it displaces the air needed to support life. It forms readily ignitable mixtures with air or oxygen over a wide range of concentrations and conditions.

Oxygen contamination can occur and detonatable mixtures may be formed if the liquid is exposed to air. Some of the precautions that should be taken when handling liquid hydrogen are:

- Eliminate all ignition sources unless used for a particular application;
- Earth all metal or prevent build-up of static electricity;
- Conduct all fluid handling and transfer operations in well ventilated areas;
- Eliminate pockets that may tend to trap gas as it rises;
- Provide explosion relief vents or a lightweight lift-off roof for enclosures; and
- Purge vessels and equipment with an inert gas before transferring liquid into them.

**Helium**

Helium has the lowest boiling point of all the cryogenic liquids and a very low latent heat of vaporisation.

The low temperature of liquid helium or cold gaseous helium can solidify any other gas. Therefore the liquid must always be stored and handled under positive pressure and in closed systems to prevent the infiltration and solidification of air or other gases in neck tubes, vents and lines.

Take care to prevent air from entering containers when inserting and removing transfer lines. Minimise the time the container is open during these operations. Also, air will condense on the cold outer tube of a transfer line and as it is being withdrawn the condensate, unless restricted, will run down the tube and into the container. Use a wiping rag, such as an absorbent cloth to prevent this occurring. A more positive method of preventing air entry is the use of a ball valve device in the neck of the container.

The low latent heat of vaporisation of the liquid, about 450 times less than that of water on a volume basis, creates problems in handling and storage. All containers and equipment used with liquid helium require elaborate thermal protection to prevent heat leak.

Transfer techniques must be designed to reduce cool-down losses. Transfer elements and receiving apparatus should be pre-cooled. Pre-cooling with liquid nitrogen followed by helium gas purge is one technique that can be employed. Helium gas, pre-cooled by liquid nitrogen in a heat exchanger can be used for purging, thereby eliminating one step in the operation.

Slowly insert transfer element, probes, etc., to permit cooling with helium vapour rather than liquid helium. If the heat input from a transfer tube is being used to build up the
pressure required for transfer, fast insertion will result in high vapour discharge accompanied by liquid entrainment. Rapid insertion can result in almost explosive boiling.

OPERATION UNDER VACUUM

Assembly of Glass Apparatus
Standard glass joints should be used to assemble systems of a temporary type. Ball-and-socket joints are valuable where some flexibility or ease of adjustment is required. Dry cone-and-socket joints tend to stick and they give a poor seal. If grease is incompatible with the contents of the apparatus, use PTFE sleeves in the joints.

Permanent high-vacuum systems usually contain sections that are fabricated by glass-blowing. Before assembly the parts should be cleaned with distilled water and dried in a stream of air. Organic solvents must not be used for this purpose; pockets of vapour can cause explosions during glass-blowing.

Particular care is necessary when repairing systems that have been in use. All vapours should be pumped or flushed out with nitrogen. Sections in which radioactive materials have been used should be replaced, not repaired.

Protection
Glass globes, vacuum desiccators and Dewar flasks should be taped or boxed to guard against implosion. A vacuum such as that achieved by a water pump is just as dangerous as the high vacuum produced by a rotary oil pump.

Filtration Under Vacuum
Filtration of flammable liquids must not be performed near a naked flame. Fatal accidents have resulted from the collapse of filter flasks in such circumstances.

Distillation Under Vacuum
The distillation of organic liquids is often carried out at a controlled reduced pressure. Vacuum is produced by water pump or rotary oil pump. In either case a trap is necessary between the pump and apparatus to avoid the danger of sucking back water or oil into the apparatus.
Where the distillation temperature is high, a danger may be associated either with the presence of air or with a sudden ingress of air. This danger is best minimised by allowing a slow leak of nitrogen into the system during distillation and admitting nitrogen instead of air at the end of the distillation.
Use a safety screen. Undivided attention is necessary.

Use of Flammable Substances
Oil or mercury diffusion pumps can act as ignition points for air/vapour mixtures both inside and outside the vacuum system. Thus very special care is required when organic cooling baths are used. With liquids of low flashpoint, it is advisable to turn off the diffusion pump.

Protective Trap
A protective trap is a device used to protect the vacuum system from chemical vapours.
arising from work with or storage of condensable gases such as ethylene or propane in liquid or solid form. The trap is usually cooled by liquid nitrogen, although for some substances solid CO₂ suffices. Immediate danger arises if the supply of refrigerant fails. The volume of gas produced by the volatilisation of the substance is often far greater than the available volume within the trap. The gas will escape, through any manometer, by blowing out the key of a trap, or by bursting the vessel. Therefore, the level of refrigerant in the Dewar flask must be checked at regular intervals. No general-purpose Dewar flask is likely to hold its charge of refrigerant for longer than 24 hours. Whenever possible, condensable gases in a vacuum system should be stored as gas at sub-atmospheric pressure. Globes having volumes of several litres may be required.

**Pump Effluent**
Effluent from the pumps must be piped to a fume cupboard or to open air, especially when a mercury diffusion pump is used.

**Hammering by Mercury**
Rising or quickly-flowing mercury in a vacuum apparatus strikes bends or top surfaces with hammer-like force. The rate of movement of mercury must be controlled by careful use of the traps or by inclusion of restricting capillaries. McLeod gauges are particularly prone to destruction by ‘mercury hammer’.

**Mercury Poisoning**
All mercury surfaces must be enclosed except where access to atmospheric air pressure is required as in a mercury barometer. Avoid sudden changes in pressure which may eject mercury from manometers.

**Closing Down the Experiment**
At the conclusion of the experiment, the apparatus and pumping system must be returned to atmospheric pressure. The order in which this is done must be established.

**Apparatus Under Internal Pressure**
When it is known beforehand that apparatus is expected to work under internal pressure, it must be designed accordingly, and appropriate materials selected. The assembly should be tested beforehand by applying hydrostatic pressure with a water pump to a suitable proof pressure. In all these matters, adequate advice should be sought before putting the apparatus under pressure.
Note: It is vitally important to recognise that, compared with liquids, gases under pressure store a great quantity of energy. Failure of apparatus under gas pressure is therefore much more mechanically dangerous than when under liquid pressure. Hence also the need to test with water, not with compressed air. For pressures that are deemed to be high, the apparatus including its safety devices must be designed by a professional engineer, and be tested under supervision. The Laboratory Manager shall ascertain whether the apparatus, some or all of it, including pressure vessels and reactors, comes within the scope of statutory regulations for inspection, testing, approval and/or certification. The design engineer in the first instance, and (if it applies) the statutory authority, shall
instruct on the provision of protective barriers against failure of the apparatus in use. Carius tubes and other glass vessels that are heated to produce high pressure reactions should be enclosed in steel tubes, carefully cooled before removal of contents.

COMPRESSED AND LIQUIFIED GASES

Storage
Gases used in laboratories are usually stored in one of three different ways, depending on the nature of the gas, each presenting its own specific hazards as follows:

- **High pressure cylinders** at approx. 13.8 x 10^3 kPa (2000 psi) or at approx. 24.1 x 10^6 kPa (3500 psi). Examples of such gases are oxygen, nitrogen, hydrogen, methane.
- **Liquefied or dissolved gases** in cylinders under pressure. Examples are liquid propane gas (LPG), propane, ethylene, acetylene, chlorine, ammonia, sulphur dioxide.
- **Liquefied gases in jacketed containers** at 1 atmosphere (approx. 101 kPa). Examples are air, oxygen, nitrogen, hydrogen, neon.
- Both cylinders and cylinder storage areas must be adequately signposted.
- Cylinders in use or in storage must be secured in an upright position.
- Old regulators may not withstand current higher pressures in gas cylinders.

**General Principles**
All compressed and liquefied gases are hazardous. The hazards arise from one or more of the following factors:

- **Compressed state** - this means that rapid expansion may occur suddenly with considerable force on release of the gases from their container.
- **Low temperature** - many of these gases are still at exceptionally low temperatures when released from the container. This applies especially to those classified as cryogenic fluids. Serious burns may result from bodily contact.
- **Strong reactivity** - gases which are normally highly reactive with certain substances, e.g. chlorine, oxygen, ammonia, tend to be very much more so when released from the compressed state, by virtue of their high concentration. Explosions can occur.
- **Flammability** - many compressed gases are flammable and must be treated as such. Their high concentration and pressure increases the danger.
- **Toxicity** - many compressed gases are also toxic and, as mentioned under flammability, their high concentration and pressure increase the danger. In addition, a secondary effect may occur whereby asphyxia is caused due to the replacement of air by the toxic gas despite the fact that it may be of mild toxicity.

**Handling Compressed or Liquefied Gases in Cylinders**
Flammable gases have cylinder connectors with left-hand threads, non-flammable with right-hand threads, with each type having an appropriate valve. The cylinders must be inspected to ensure the mating surfaces of the connection are clean; any dirt should be removed.

The connection may then be made to the cylinder, but excessive leverage and hammering must not be used; only the tools provided by the suppliers of the gas should be employed. Keep grease and oil away from the connector, the valves and the cylinder. When gas is required, the regulator should be kept shut, the cylinder valve opened and careful note
taken of whether the cylinder gland is tight. The valve and regulator connections can be tested for leaks with detergent solutions.

All operations must be carried out with the cylinder secured. The cylinder must be secured tightly to a wall stanchion or bench by a chain with a clip-lock. If the cylinder is resting in a trolley the trolley must also be secured.

Cylinders must not be thrown or allowed to drop to the ground, as valves or connections may be damaged. Damaged cylinders must not be used.

‘Empty’ cylinders should be left with a slight positive pressure and the cylinder valve closed, the valve cap replaced, where provided, and marked “empty” and removed from the work area.

Faulty valves, regulators and pressure gauges must not be used. If the gas cylinder contains corrosive or toxic gases, adequate precautions must be taken before it is used, and emergency equipment must be readily available, e.g. respirator, breathing apparatus, antidote.

Acetylene must not be allowed to contact copper or an alloy containing more than 70 per cent copper. Cylinder valves must be opened slowly to avoid shock-loading the diaphragm of the regulator.

Generally they must not be unscrewed more than two or three turns. If the valve spindles are not captive, serious injuries have resulted from them being unscrewed too far and then blown out.

In the mid-1990s suppliers of compressed gases increased cylinder pressures significantly. The higher cylinder pressures then exceeded the design pressure for which many cylinder gas regulators had been designed. The gas suppliers sent out safety warnings but there may still be some old gas regulators in use which have not been replaced. If in doubt, contact the gas supplier and quote the model numbers and other identifying information on the regulator to ensure that it is not one of the old ones needing to be replaced.

**LEARNING OBJECTIVES**

On completion of this Chapter you should be able to:

1. Describe the main types and hazards involved in the use of cryogenic fluids.
2. Describe the general preparation, use, handling, storage, transport and emergency requirements for cryogenic fluids.
3. Describe the main hazards and safety control measures involved in the use of equipment and apparatus under vacuum.
4. Describe the main hazards and safety control measures involved in the use of compressed and liquefied gases.
CHAPTER 9  BIOLOGICAL SAFETY

You should have undertaken the online component of the biosafety training listed below before attending this portion of the class.

INTRODUCTION

Working with living organisms, or samples from them, can be hazardous to people and the natural environment. Working with living organisms is therefore a highly legislated and regulated work environment.

You will need to undertake special training to learn how to work with living organisms or biological products safely. You will also need to apply for, and gain, approval before you begin to work with them. Approvals may be required from your Head of School/Centre/Institute, the UWA Institutional Biosafety Committee (IBC), the UWA Animal Ethics Committee (AEC), the UWA Human Research Ethics Committee (HREC), the Deputy Vice Chancellor of Research, or various State and Federal Government Departments including (but not limited to) the Australian Quarantine and Inspection Service (AQIS), Quarantine WA, the Office of the Gene Technology Regulator (OGTR), the WA Department of Food and Agriculture, or the WA Department of Environment and Conservation.

This Chapter provides information about the workplace hazards encountered when studying living organisms and their products, and the UWA and legislative requirements you will need to fulfil before you can work in this area.

BIOSAFETY TRAINING

All staff and postgraduate students using or working around biohazards must undertake the Biosafety training module 1 on Blackboard.

UWA biosafety induction

This induction must be completed by all staff and postgraduate students in the Faculty of Science and the Faculty of Health and Medical Sciences;

This induction must be repeated every time your status at UWA changes (for example if you graduate from a PhD student to a Research Assistant, or you are promoted from an Assist/Prof to a Professor, etc) or at a minimum, every five years.

Online Enrolments for Biohazard, Gene technology, and Biosafety Induction signoff

- Log on to www.lms.uwa.edu.au
- Go to the "Community" tab
- Search under "Organizations" for "Biosafety"
- Hover your cursor over the right of 'UWA-Biosafety-Induction'. A grey down arrow will appear and you should click on the 'enrol' option.
- You can now take the modules "Biosafety 1 (Biohazards)", "Biosafety 2 (Gene technology)" with the associated quizzes, and complete the Biosafety Induction signoff.
- Your certificates should be saved and submitted to the Biosafety Office when applying for approvals. Your lab manager should also keep a copy.

Problems with your online enrolment? Please contact the IT Help Desk on ithelp-is@uwa.edu.au
AUSTRALIAN STANDARD FOR BIOSAFETY
When working with microorganisms or biological products at UWA you must follow the practices detailed in the Australian/New Zealand Standard 2243.3:2010 Safety in laboratories Part 3: Microbiological safety and containment. This Standard contains valuable information about how this kind of research should be carried out. https://law.resource.org/pub/nz/ibr/asnzs.2243.3.2010.pdf

GENETICALLY MODIFIED ORGANISMS (GMOS)
GMOs are a threat to the genetic stability of the non-modified members of their species, as well as potentially a threat to human health, or damaging to ecosystems. GMOs must be contained at all times and never released from containment. GMOs are regulated through the Gene Technology Act 2000, Gene Technology Amendment Act 2007 and Regulations 2011.
If you want to make a new GMO, work with an existing GMO, or have a GMO sent to you by a colleague or commercial company, you will need to apply for approval from the UWA Institutional Biosafety Committee (IBC) prior to commencing, via the instructions on this webpage:

http://www.research.uwa.edu.au/staff/biological/gmo

If you will be receiving a GMO from overseas, you will require the approval from the IBC, plus approval from the Australian Quarantine and Inspection Service (AQIS), Quarantine WA, and the Office of the Gene Technology Regulator (OGTR), prior to the GMO arriving in WA. In this case we recommend you first contact the Biosafety Office so that we are able to assist you with this process.

http://www.research.uwa.edu.au/staff/biological

If you want to work with a GMO you will also need to complete the on-line training unit Gene Technology Awareness Session (GTAS), and you can enrol through the instructions above.
Some GMOs need to be worked with inside facilities (labs, animal and plant facilities) certified by the OGTR. If you want to work in (or administrate) an OGTR-certified facility you will need to complete the GTAS. All upper management of Schools/Centres that have certified facilities must also complete the GTAS.

9.3 MICROORGANISMS
Microorganisms include groups such as protozoa, fungi, free-living bacteria, cell-dependent bacteria, and viruses. It also encompasses hazardous proteins including prions and toxins. Microorganisms also include cultures of cells or tissues from multicellular macroorganisms including humans, other animals and plants.
Some microorganisms are usually relatively harmless to humans, plants, animals, and the environment. Some microorganisms can live on or in humans, animals or plants, and some can cause disease when they colonise. Microorganisms vary widely in their ability to infect humans, animals, plants and invertebrates or to spread in the environment. And even microorganisms that don't normally cause disease can be dangerous when our immune systems are compromised, for example by pregnancy or complications such as diabetes. The most devastating microbial infections can cause human death, kill our pets or livestock.
animals, destroy our crop plants, kill our crop-fertilising insects, or ravage our native ecosystems. These outcomes must be prevented, by containing any dangerous microorganisms we work with and ensuring that they cannot escape to infect their hosts. Microorganisms can’t be seen with the naked eye, they can’t be felt when they touch your skin, they can’t be heard or smelt when they are present. In order to keep them contained, we need to use behaviours and equipment that we know will keep the microorganisms contained. We mustn’t do these behaviours wrong, or fail to use the containment equipment correctly, because we will release the microorganisms and have no way to detect their escape until they infect and cause disease. The principle of microbial containment is shown diagrammatically below as a system of layered containment measures, including both physical containment such as tubes, biosafety cabinets and closed rooms, as well as behavioural elements including training, the use of protective clothing, and decontamination processes.

![Figure 1 Relationship between Containment Measures](AS/NZS 2243.3:2010)

A Figure copied from AS/NZS 2243.3:2010 showing the principle of layered containment for handling microorganisms.

Microorganisms can be spread by touch, splashes of contaminated liquid, bites or punctures to the skin, or by breathing in the microorganisms in the microscopic aerosols produced when handling microbes. Some microorganisms that infect animals or plants can be spread by insects. Cultures of microorganisms in the lab are at much greater concentrations then are usually found in the wild and so can be more infective in the lab.
than they are by the normal environmental routes of infection. Microorganisms that are being studied in the lab do infect researchers, and these are called Laboratory Acquired Infections (LAIs). About 20% of these infections are from accidents such as needle-stick injuries, cuts from broken glass, spills and animal bites. The remaining 80% are from unknowing inhalation of the aerosols produced when pipetting, vortexing, homogenising, centrifuging, opening containers, harvesting tissue from infected animals, and performing intranasal inoculation of animals. Avoid LAIs by containing your microorganisms properly, and report any suspected LAIs to your Facility Manager so that the route of infection can be investigated.

HANDLING DIFFERENT RISK GROUPS OF MICROORGANISMS

All work with microorganisms requires the use of the standard lab techniques described in AS/NZS 2243.3:2010. These techniques protect people and the environment from the lab microorganisms, plus also protect the lab microorganisms from being contaminated by unwanted microorganisms derived from people and the environment. The safest way to work with microorganisms is to regard them all as potential pathogens, and to handle them accordingly. However, you don’t have to be as careful when handling lab strains of E.coli as you do when handling blood from diseased human patients. You can handle microorganisms that pose different hazards in different ways. The AS/NZS 2243.3:2010 splits microorganisms into different Risk Groups and then describes the level of Physical Containment required to handle them safely.

Microorganisms are classified into their Risk Groups based on the level of risk they pose. There are 12 microbiological Risk Group Classifications: 4 for human and animal infectious microorganisms, 4 for plant infectious microorganisms, and 4 for insects that carry infectious microorganisms.

The following four Risk Groups of microorganisms infectious to humans and animals are classified based on the pathogenicity of the agent, the mode of transmission and host range of the agent, the availability of effective preventive measures, and the availability of effective treatment:

- **Risk Group 1** (low individual and community risk) - a microorganism that is unlikely to cause human or animal disease.
  Examples: brewer’s and baker’s yeast.

- **Risk Group 2** (moderate individual risk, limited community risk) - a microorganism that is unlikely to be a significant risk to laboratory workers, the community, livestock, or the environment; laboratory exposures may cause infection, but effective treatment and preventive measures are available, and the risk of spread is limited.
  Examples: Staphylococcus aureus, Leishmania (infective stage only), Hepatitis B.

- **Risk Group 3** (high individual risk, limited to moderate community risk) – a microorganism that usually causes serious human or animal disease and may present a significant risk to laboratory workers. It could present a limited to moderate risk if spread in the community or the environment, but there are usually effective preventive measures or treatment available.
  Examples: Bacillus anthracis, Japanese Encephalitis.
- **Risk Group 4** (high individual and community risk) - a microorganism that usually produces life-threatening human or animal disease, represents a significant risk to laboratory workers and may be readily transmissible from one individual to another. Effective treatment and preventive measures are not usually available. Example: Ebola, Hendra.

AS/NZS 2243.3:2010 also contains lists of commonly used microbes in Risk Groups 2, 3 and 4 for easy reference (see example below). Always check your microorganisms against the Standard to find out the Risk Group your microorganisms are in and therefore what level of Physical Containment you need to contain them.

![Table of Bacteria of Risk Group 2](image)
A Table copied from AS/NZS 2243.3:2010 containing examples of Risk Group 2 bacteria.

Diagnostic specimens from humans or animals are considered to be Risk Group 2 (unless you suspect that they contain RG3 or 4 microorganisms) and need to be handled in Physical Containment Level 2 facilities. If a microbial pathogen of a higher risk group is isolated from a specimen, it needs to be handled according to the corresponding risk group and in the appropriate physical containment level facility.

You will need to do a Risk Assessment for each type of microorganism you use in the lab, to identify its Risk Group and therefore the level of Physical Containment required to handle it, as well as the kind of chemical disinfectant required to kill it. The AS/NZS 2243.3:2010 contains useful tables of disinfectants in Appendix F (see example below).

A Table copied from AS/NZS 2243.3:2010 containing examples of chemical disinfectants.

The Public Health Agency of Canada Office of Laboratory Security has produced Safety Data Sheets for Infectious Substances which are available at: http://www.phac-aspc.gc.ca/lab-bio/res/psds-ftss/index-eng.php
These SDSs are produced for personnel working in the life sciences as quick safety reference material relating to infectious micro-organisms. The SDS are organized to contain health hazard information such as infectious dose, viability (including decontamination), medical information, laboratory hazard, recommended precautions, handling information and spill procedures. The intent of these documents is to provide a safety resource for laboratory personnel working with these infectious substances. Because these workers are usually working in a scientific setting and are potentially exposed to much higher concentrations of these human pathogens than the general public, the terminology in these SDS is technical and detailed, containing information that is relevant specifically to the laboratory setting.

**CLASSIFICATION OF LABORATORIES**
The AS/NZS 2243.3:2010 describes four levels of Physical Containment facilities that correspond to the four microorganism Risk Groups. Therefore, for example, RG2 microorganisms need to be contained in a PC2 facility. The Standard describes labs, animal facilities, plant facilities and insectaries. The door to your facility should be labelled with the physical containment level of the facility.

Each PC level describes the physical room construction of the facility, any necessary equipment required in the facility, the personal protective clothing required to be worn in the facility, and behaviours that the users must follow. Find out the PC level of the facilities that you use and read the Standard to learn how to use those facilities.

A Physical Containment Level 1 (PC1) lab is suitable for working with RG1 microorganisms and specimens that have been inactivated or fixed. Users can be adequately protected by standard laboratory practice, with no containment equipment required, and work can be carried out on the bench. Undergraduate teaching labs are usually of this level.

A Physical Containment Level 2 (PC2) lab is suitable for working with RG2 microorganisms, as well as samples from humans and animals carrying potentially zoonotic diseases. PC2 incorporates all the requirements of a Laboratory PC1 facility with additional requirements relating to conditions of access, safety equipment and staff training requirements. With good microbiological techniques, work with these microorganisms may be carried out on the open bench. If working with specimens containing microorganisms transmissible by the respiratory route, or if the work produces a significant risk from the production of infectious aerosols, a biological safety cabinet needs to be used.

A Physical Containment Level 3 (PC3) lab is suitable for working with RG3 microorganisms. UWA doesn’t have many PC3 facilities and you will receive specialised training if you ever have to work inside one.

A Physical Containment Level 4 (PC4) lab is suitable for working with RG4 microorganisms. UWA doesn’t have any PC4 lab facilities.

AS/NZS 2243.3:2010 has been updated over time. Previous versions have not required PC2 labs to have directional airflow, but this has been required in the latest versions. Some UWA PC2 labs, which were built before these changes to the Standard, do not have directional airflow. The purpose of directional airflow is to protect users of the building containing the lab from infection in the event of a spill of infectious microorganisms in the lab. Therefore, labs that run at a PC2 level but lack the directional airflow, will double-
contain their microbes within the lab to help protect against spills, and may use fume cupboards or other airflow to create an artificial pressure system. As well as reading and following the requirements set out for the different facility types in AS/NZS 2243.3:2010, it is vital that you be inducted into each facility by a responsible person such as a lab manager or senior researcher.

**BIOLOGICAL SAFETY CONTAINMENT EQUIPMENT**

All biological safety equipment requires regular testing and servicing. There will be a sticker clearly visible on it showing the date when it was last serviced, the pass or fail status, and when the next service is due. Always check this sticker before using the equipment and never use it if it is overdue for a service. If any equipment is overdue for servicing then tell your Lab Manager. You must be trained how to use all equipment properly. If you need further advice then contact the Biosafety Office [http://www.research.uwa.edu.au/staff/biological](http://www.research.uwa.edu.au/staff/biological).

High Efficiency Particle Air (HEPA) filters are found in many pieces of biological safety equipment. They filter microorganisms out of air. HEPA filters are decontaminated and changed regularly, by trained service professions.

Laminar flow cabinets draw in room air and HEPA filter it, before passing the air over the microbial cultures the operator is handling, and towards the operator. This protects the cultures, but provides no protection for the operator and can’t be used to handle infectious microorganisms.

A Class I Biological Safety Cabinet draws in room air past the operator, and across the microbiological cultures the operator is handling, and then HEPA filters the air before releasing it back into the room. This protects the operator, and can be used for handling cultures of infectious microorganisms, but doesn’t protect the cultures from contamination.

A Class II Biological Safety Cabinet draws in air from the lab where the operator sits, HEPA filters it, passes it over the cultures of microorganisms being handled, and HEPA filters it again before releasing it back into the lab. It protects both the operator and the cultures. Both Class I and Class II Biological Safety Cabinets rely on stable airflow for protection. Avoid blocking this airflow with objects, or disrupting it with other air currents such as by moving quickly past it.

A CLASS III Biological Safety Cabinet is a totally enclosed workspace that is accessed via sealed glove ports. The air flowing into and out of it is HEPA-filtered. It provides very high levels of protection for both the operator and the cultures.

An Autoclave is used to sterilise things using high temperature and pressure. It is used to create clean equipment to contain microorganisms and to decontaminate wastes contaminated with microorganisms. There are two types of autoclave. They must be used differently and are suitable for different uses. You must be specifically trained to use each kind of autoclave.

**NON-GM BIOHAZARDOUS ORGANISMS (NGMBOS)**

By definition, nGMBOs pose a health risk to people, animals, plants or ecosystems. They must therefore be properly contained while working with them at UWA. If you want to work with any naturally occurring, non-GM:

- microorganism that is classified as Risk Group 2, 3, or 4 by the Australian/New Zealand Standard 2243.3:2010 Safety in Laboratories Part 3: Microbiological
safety and containment,
- multicellular organism (except vertebrate animals, cephalopods and crustaceans) that could harm its handlers,
- poisonous plant, or weedy plant on the Department of Agriculture and Food’s Declared Plants List,
then you must apply to the UWA IBC for permission, following the instructions on the Biosafety website.


ANIMAL TISSUE USE
Animal tissues can harbour microorganisms that can cause disease in humans. Animal Tissues must therefore be handled in a way that reduces people’s exposure to the tissues, and equipment must be decontaminated after use.

If you want to use animal tissues, fluids or carcases (meat from the butcher, tissues from pre-euthanized lab animals, etc) in your research then you must apply to the UWA Animal Welfare Officer and Biosafety Manager for permission, following the instructions on the Biosafety website.

http://www.research.uwa.edu.au/staff/biological/tissue-use

USING LIVE ANIMALS FOR RESEARCH AND TEACHING
The use of live animals for research and teaching is legislated by various State Animal Welfare Acts and Bills. If you want to work with live animals (vertebrates, cephalopods and decapod crustaceans) at UWA then you will need to apply to the UWA Animal Ethics Committee through this website:

http://www.research.uwa.edu.au/staff/animals

You will receive specialised training before you can work with animals at UWA, including the PAWES course, induction into the animal facilities, and lengthy supervision. You may also be asked to get vaccinated against various zoonotic diseases that can be caught from working with animals. For more information about animal handling policies and recommended vaccines, see these webpages:

http://www.research.uwa.edu.au/staff/animals/policies
http://www.safety.uwa.edu.au/policies/immunisation
http://www.safety.uwa.edu.au/policies/animal_handling

RESEARCH INVOLVING HUMAN SUBJECTS
Research involving people is guided by the National Statement on Ethical Conduct in Human Research 2007. If you want to do research involving human subjects then you will need to apply to the UWA Human Research Ethics Committee through this website:

HUMAN BLOOD AND FLUID USE
Human blood and fluids can contain microorganisms that can cause disease in humans. You must always take care to protect yourself from human fluids, and decontaminate equipment used to handle human fluids. Treat all blood and products of human or animal origin as being of at least RG2.

Follow the precautions provided:
- in the AS/NZS 2243.3:2010
- on these websites http://www.safety.uwa.edu.au/policies/immunisation
- in these two online publications:
  a) Department of Health and Ageing publication: Infection control guidelines for the prevention of transmission of infectious diseases in the health care setting.

SECURITY SENSITIVE BIOLOGICAL AGENTS (SSBAS)
The possession and use of SSBAs is regulated by the National Health Security Act 2007 and Regulations 2008. These build on Australia’s obligations under the Biological and Toxin Weapons Convention and UN Security Council Resolution 1540. Anyone possessing or using SSBAs must register with the Department of Health and Aging. UWA is not registered to work with SSBAs and therefore it is illegal for any UWA personnel to work with, or store, SSBAs.
You must check the Biosafety website to make sure that you are not working with an SSBA. If you want to work with an SSBA you must gain approval from the UWA IBC before you start any project, and to begin this process contact the Biosafety Office.

http://www.research.uwa.edu.au/staff/biological/ssba

IMPORTING ORGANISMS OR BIOLOGICAL PRODUCTS
Importing organisms or biological products into WA, from the Eastern States or overseas, is regulated by several State and Federal Quarantine Acts. If you want to import any organism or biological product into WA from overseas, you might need approvals from both the Australian Quarantine and Inspection Service (AQIS) and Quarantine Western Australia (QWA). If you want to import any organism or biological product into WA from interstate, you might need approval from QWA.
All the information you need to apply for AQIS and QWA Permits is on the Biosafety website.

You might be required to keep the imported organism or product in a Quarantine Approved Premises (QAP) and the Biosafety Office can help you to find one, or to get your lab approved.
COLLECTING BIOLOGICAL SAMPLES FROM THE WILD
You will need various permissions to go out into the environment, collect samples from the wild, and bring them back to your lab. Advice can be found on this webpage:

http://www.research.uwa.edu.au/staff/biological/collecting

TRANSPORTING MICROORGANISMS OR BIOLOGICAL PRODUCTS
If you are transporting microorganisms or biological products by post or airplane then you must package them according to the International Air Transportation Association (IATA) Dangerous Goods Regulations (DGR). You can view a copy of the IATA DGR through UWA Safety, Health and Wellbeing or the Biosafety Office. Alternatively, if you use the transport company World Courier then they will pack your dangerous goods properly for you.

http://www.safety.uwa.edu.au/contact
http://www.research.uwa.edu.au/staff/biological

If you are transporting microorganisms or biological products by road then you must package them according to the Australian Code for the Transport of Dangerous Goods by Road and Rail. The IATA and the DGR are very similar to the Code, and so you can also follow the IATA DGR for transporting by road.


RISK ASSESSMENTS
You must do a Risk Assessment for every research task you want to do. Follow the instructions and resources on the UWA Safety, Health and Wellbeing website.

http://www.safety.uwa.edu.au/safety_management

9.4 ONLINE RESOURCES
There are various free online biosafety training resources that are listed on the bottom of the biological safety training webpage


LEARNING OBJECTIVES
On completion of chapter 9 you should:
1. Understand the general principles of hazard management for microbiology, which are also the general occupational safety and health approaches to dealing with hazards.
2. Understand the hazard classification for microorganisms.
3. Understand the scope of work restrictions and classifications of PC1, PC2, PC3 and PC4 laboratories.
4. Understand the role of the OGTR and the Institutional Biosafety Committee, which at the University is called the Biosafety Committee.
5. Be able to recognise an OGTR certified facility.
6. Be aware of the PC2 Facility Practices and adhere to them when you are working in an OGTR certified facility.
7. Be familiar with the requirements for PC2 laboratories.
8. Be familiar with the requirements for PC3 laboratories.
CHAPTER 10 - CASE STUDIES –

LABORATORY ACCIDENTS AND INCIDENTS

- A worker was heating a large amount of alcohol in a beaker, using a faulty electrical hotplate. The solution overheated and resulted in a fire that caused more than $500,000 worth of damage to the laboratory, fume cupboard and surrounding area. Fortunately, no one was injured.
- A student was setting up an acid digestion procedure when the liquid splashed into her eyes. There was no formal requirement to wear safety glasses and this matter had never been discussed by the supervisor. Rapid medical intervention minimised the damage, but she now has permanent scarring and diminished vision.
- A technician was using a wool scouring machine and removed the guard in order to adjust a settings whilst the machine was in motion. His hand became caught in the machine, the skin was de-gloved and he required extensive surgery and rehabilitation.
- Two technicians were transferring ethanol from a three litre storage vessel to 25 mL wash bottles on the laboratory bench when a colleague from another area took his cigarette lighter from his pocket and lit it close to a small pool of ethanol that had spilled on the bench. This ignited the flame flashed over to the storage vessel, resulting in the ejection of two litres of burning liquid. The person responsible suffered serious burns and was taken to hospital. The company transferred all such filling operations to a closed area fitted with vapour extraction apparatus.
- An unlabelled mercury barometer was placed into storage. During renovations the barometer was dropped and damaged, resulting in the spillage of between 2 and 3 kilograms of mercury. The clean up of the area required removal of a large amount of contaminated material.
- A worker was using dimethylmercury as a standard for an analytical procedure. The worker was aware that dimethylmercury was extremely toxic and could be absorbed through the skin. To protect themselves they wore latex gloves, a lab coat and safety glasses. On one occasion the worker spilt one drop on their gloved hand. Six months later the worker was diagnosed with terminal mercury poisoning, tests showed that the dimethylmercury diffuses through the latex gloves almost immediately.
- Workers were using a mixture of hydrochloric acid and oxalic acid to clean mineral samples. After cleaning, the samples were dried by heating resulting in the workers being exposed to potentially lethal levels of oxalic acid vapour.
- A trainee technical officer was burned from acid splashes to the face, neck and chest. It arose from trying to make a solution of sulphuric, nitric and hydrochloric acids and water. Despite having been shown how to make the solution safely, it seems that the trainee used an inappropriate method, believing it to be faster. As a result the lid of the mixing cylinder blew off, splashing the acid. The Court considered that the trainee had received inadequate instruction and had no real understanding of why the mixture had to be prepared as shown. The employer was held to have been negligent.
- An experiment was performed on a bench with a local exhaust arrangement
connected to a fume cupboard but some diphenyl phosphine vapour escaped into the laboratory. Later the same day the fume cupboard was shut down for maintenance without notification to the supervisor of the research project. Vapour again discharged into the laboratory and two students were taken to hospital suffering nausea and headache. They were discharged following observation. The failures included:

- Failure to perform the experiment in a fume cupboard;
- Inadequate communication to keep everyone informed of the activities including maintenance staff.

Rectification included alterations to the fume cupboards, a tag and lock-out system for maintenance and by giving appropriate instructions to all relevant personnel. The employer was held to have been negligent.

- At 3.37 am the local Police Department received both a fire alarm signal from a Physics research building and an emergency call from a principal investigator arriving early to work and discovering the fire. The Fire Department was called and successfully extinguished the fire in a relatively short time. A Hazardous Materials Response Team evaluated the site for hazardous materials and determined that a routine clean up only would be required. The clean up team required 8-10 people over 10 hours to identify the waste materials and pack them appropriately for transfer to a hazardous waste facility. The origin of the fire appeared to be a Thermolyne Model FB 1415M metallurgical furnace situated on a wooden table/bench on the east wall of the room. The evidence suggests that heat from the furnace (which was in operation overnight at a probable temperature of 750-800°C) ignited the underlying combustible table surface, due to the absence of a steel bottom cover plate originally installed on the furnace. It appears that the fire spread and grew as other fuels contributed to the fire. The furnace was listed as a piece of heating equipment, which was based on testing performed with all safety features in place, including the steel bottom plate. The operation manual for the furnace stated that ‘the furnace should be installed at least six inches away from any combustible material’. With the bottom cover plate removed, the bottom of the furnace was only 4 ½ inches from the surface of the table. The furnace was obviously not being used in accordance with the manufacturer’s recommendations. The absence of an automatic fire sprinkler protection system directly extended the duration of the fire and contributed to the magnitude of the loss. The estimated damage bill as a result of the fire was US$500,000.

**Lessons to be learnt from this incident are:**

- Equipment should only be used exactly as intended by the manufacturer. Equipment should never be modified or used in any manner that would defeat the in-built safety features.

- Heating equipment should only be used on non-combustible surfaces.

- Flammable storage cabinets are very effective in a major fire in protecting flammables.

- The chemical inventory was valuable, even though it was out of date. The fire fighters referred to it prior to entry and it also assisted recovery staff in identifying the various waste steams prior to disposal.

- All run off water needed to be checked for chemical and radioactive contamination prior to release to the sewer. Fortunately in house resources were available and able to perform the necessary assessments promptly.
• The University recognised the need to incorporate fire sprinkler systems into new and/or renovated research laboratory buildings. In the interim, automatic heat detectors connected to the building fire alarm system would provide for earlier reporting of fires.

CASE STUDIES - EXPLOSIONS
• It was normal practice at a university to store diethyl ether and etherised rat carcasses in a domestic refrigerator. The refrigerator was not modified for flammable liquid storage, nor were there any signs banning the storage of such. Electrical contacts ignited the vapours, blowing the door four metres onto the opposite wall. The explosion and fire resulted in nearly $100,000 worth of damage to the laboratory as well as the loss of valuable data which could not be retrieved. Fortunately no one was injured.
• The laboratory supervisor decided that it was about time to rationalise and clean out the chemical store since the laboratory was running out of room. Even long-time employees could not remember the last time this was done. At the back of the store, in a corner, they came across an old Winchester of ether with a strange looking crystal in it. Expert assistance was summoned and the building was evacuated while the oxidised ether was detonated in the car park, since it was too dangerous to move any further.
• In May 1995 a chemical explosion flooded a university laboratory with fumes. The incident occurred when a 2.5 litre glass container of waste chemicals left on a trolley overnight exploded. Fortunately, the students involved were unhurt. However, the security officer who proceeded to evacuate the building suffered a burning throat and tight chest that lead to his treatment in hospital. Under the State Occupational Health and Safety Act the university was found to have breached its duty of care to employees and others not in its employment and fined $25,000. The Industrial Court heard evidence that the university had failed to heed not only its own code of safe laboratory practices but advice from a WorkCover safety assessment survey and a Dangerous Goods assessment. The court was also told that no formal training in the disposal of waste chemicals had been given to either laboratory technicians or to research students who were nevertheless given responsibility for disposal.
• An explosion occurred within a specially designed distillation cabinet used for solvent distillation. The cabinet contained the explosion but was slightly damaged. The fire alarms were activated by the incident and the fire brigade attended. The fire was extinguished by trained school personnel prior to the arrival of the fire brigade. Fortunately no one was injured. Since the glass distillation flask, collection flasks and condenser remained intact, it was concluded that the most probable cause of the explosion was a pressure build-up in the inert gas flowing through the distillation apparatus to a bubbler. A kinked plastic line might have prevented nitrogen from escaping. The pressure build-up may have displaced one of the flask connections and vented highly flammable tetrahydrofuran vapour into the still enclosure, however, these vapours and smoke from the fire was exhausted to outside atmosphere by the properly designed exhaust systems.
• A worker was performing an extraction procedure with liquid carbon dioxide. The
liquid was evaporated in a glass vessel with the rate of evaporation (and hence the pressure) controlled by a needle valve on the outlet of the vessel. The pressure rating of the vessel was insufficient, leading to an explosion. No safety shield was in use and the worker suffered severe lacerations to the chest and arms.

- A worker was preparing a molten salt bath. The recipe called for one part potassium nitrate and 0.85 parts sodium nitrite. The worker actually used three parts sodium nitrite and one part potassium thiocyanate. When heated, the mixture exploded destroying a Fumehood and embedding the sash in a wall 7 metres away. It is unclear why the worker made the substitution but the SDS of these compounds note that this mixture can be explosive.

- An experienced chemist was working with a mixture of 95% ethanol and sodium peroxide when it underwent an unexpected and uncontrolled explosion in an Erlenmeyer flask. The chemist sustained cuts to his face, second degree burns to his hands and chemical burns to his chest. The accident investigation found that the cause of the explosion could not be fully determined. However, the information on the material safety data sheet, together with data from other reference sources, indicated that potential for an unstable reaction. Despite this, the flask had been placed on a benchtop with no explosion or blast shield in place. It was recommended that SDS be used as the primary source of information when working with chemicals. There were also recommendations for additional safety training and supervision. It was found that the use of a safety shield and an explosion shield between the worker and the flask would have been considered the minimum reasonable safety precaution that should have been taken in this case.

- The reaction of hydrogen peroxide and acetone under acidic conditions produces beautiful white crystalline material. This material is acetone peroxide and is a highly unstable primary explosive. Having performed a reaction which involved several steps and involving a combination of reagents as well as these two chemicals, a worker attempted to collect the white precipitate from their reaction mixture by filtration. A violent explosion occurred.

**CASE STUDIES - MECHANICAL**

- An experimental apparatus had a thick-walled plastic cylinder which would be subjected to high pressure during the experiment. A blast shield was placed between the researcher and the cylinder. Pressure was applied using compressed gas. As the researcher crouched down below the bench top to make adjustments, the cylinder split and fragmented. The blast shield and cylinder fragments were blown metres away and had the researcher been standing, they would have been severely injured. This demonstrated the power release and hazards of working with compressed gases. The pressure could equally well have been applied using a non-compressible liquid which would not have the same hazardous features. With liquid pressurisation, the pressure would drop as soon as the cylinder split and the blast shield would have remained in place.
CASE STUDY - HYDROGEN EXPLOSION IN MICROBIOLOGICAL ANAEROBIC CHAMBER
An explosion occurred involving a COY Microbiological Anaerobic Chamber of approximately 2 m³ capacity, containing an explosive mixture of hydrogen and air. A fire followed the explosion, but was rapidly extinguished by staff using fire extinguishers, prior to the arrival of fire service personnel. The pressure wave from the explosion blew windows out of the laboratory, with glass hitting a passerby on a path outside, and glass shards landing up to 30 m away. Ceiling panels were dislodged in the laboratory and adjacent rooms, and a worker using the apparatus at the time was taken to hospital by ambulance to have burns treated. They have subsequently fully recovered from their injuries. Another worker in the lab at the time required medical observation but was otherwise unharmed.
Mixtures of inert gases and hydrogen are intended to be routinely used in the type of anaerobic chamber involved in the incident. The mixtures used in the chamber involved were produced locally in the laboratory using nitrogen, carbon dioxide, and hydrogen. The hydrogen in the mixture reacts with any oxygen present in the chamber, on a heated catalyst, to eliminate oxygen and keep the chamber anaerobic. The local operating procedures used in the lab allowed high concentrations of hydrogen to be introduced into the chamber. A worker inadvertently admitted air to the chamber whilst undertaking maintenance, allowing the hydrogen enriched atmosphere in the chamber to mix with air, and subsequently ignite, most probably on contact with the oxidation catalyst in the chamber, resulting in the explosion and subsequent fire.

Factors to Consider
Hydrogen gas has a very wide range of flammability when mixed with air (approx 4 – 74 %). Oxidation catalysts can ignite explosive gas mixes without heating, spark or flame. Local operating procedures and practices varied from manufacturer’s advice. An unknown concentration of hydrogen was present in the chamber, presenting a significant fire and explosion risk.

Recommendations
The practice of making gas mixtures in the laboratory should be eliminated, and gas mixtures with a known low hydrogen concentration should be purchased for use. The concentration of hydrogen used should be such that it is not possible to form an explosive mixture on dilution with air. (i.e. hydrogen concentration less than 4% after mixing with air from a leak, damage to the chamber, or inadvertent admission of air to the chamber). A gas monitor with inbuilt alarm should be purchased and installed to continuously monitor both hydrogen and oxygen concentrations in the chamber, and provide visible and audible indication of any problems. The manufacturer’s instructions and manuals should be closely followed. All users should be fully trained in the use of the equipment, and should be fully conversant with the potential hazards and how to manage the associated risks.

CASE STUDY - SOLVENT FIRE AND EXPLOSION WHAT HAPPENED
A distillation of hexane under inert gas atmosphere was being conducted in a fume cupboard in a research laboratory when a fire and explosion occurred resulting in a student receiving significant thermal burns to his arms, hands, legs, torso and head. He was conveyed by ambulance to hospital and spent 18 days in the burns unit undergoing
Case Studies

skin grafting and other treatments. The explosion was clearly heard at a Police Station, over a kilometre away.

**Contributing Factors**
There were numerous factors, which contributed to the occurrence and severity of the incident, as follows:

**Procedural Issues**
A tap through which vapour would usually vent from the distillation apparatus was left closed. This meant that the heated vessel of solvent was effectively sealed, and pressure would have built up in the apparatus until part of it gave way, at which time the superheated solvent vapourised.
The heating mantle used to heat the distillation flask was plugged directly into the mains power outlet, with no power regulation device used. As a consequence, the full heating power of the mantle was applied to the flask of hexane continuously, contributing to the incident.

**Protective Clothing**
The injured student was wearing shorts, a t-shirt, shoes, socks, and safety glasses at the time of the explosion. Had they been wearing long trousers, a long sleeved shirt and flame retardant laboratory coat, then it is likely that the extent and severity of burns sustained would have been significantly diminished. Their eyes were protected since they were wearing safety glasses at the time.

**Engineering Controls**
There were purpose built ventilated distillation cabinets available within the department but these were generally used for the distillation of more common solvents.
The fume cupboard used for this procedure was not free of potential ignition sources. Had this been the case then the hexane vapour would not have ignited and the fire and explosion would not have occurred. It was noted that the fume cupboard light fittings were not spark proof, and that some of the apparatus in the fume cupboard also posed potential ignition sources.
The fume cupboard did not incorporate a front lip or sump to contain spills, as is required for fume cupboards under Australian Standards 2243.8-1992 and later versions.
A deluge shower was not available in the building concerned. Had a deluge shower been located in the corridor outside the laboratory involved, its prompt use may have reduced the overall severity of the injuries sustained. This also applies to the lack of shower facilities external to the building, where injured persons could be evacuated to during an emergency.

**Recommendations**

**Use of Flammable Liquids**
A new flammable liquids protocol was developed for the use of flammable liquids within the department. This protocol uses a tiered hierarchy of controls and safety measures, which become more stringent with increasing volumes of flammable solvent used.
Power control devices are to be hard wired to heating mantles, to eliminate the possibility of erroneous omission of them from an experimental apparatus.
Distillation units are to have signage providing vital information about the procedure and emergency instructions.
Hazards of ether, petrol and other volatile solvents with low flashpoints and auto ignition temperatures are to be stressed to all personnel.
A formal written procedure be used for all hazardous chemical processes such as the
distillation undertaken, with completion of a brief written checklist, prior to work, to ensure compliance with the procedure.

CASE STUDY LABORATORY EXPLOSION INVOLVING CHEMICALS (FORMIC ACID)

An explosion involving chemicals occurred within the storage compartment underneath a fume cupboard in a University undergraduate laboratory. The force of the explosion blew out the plastic panelling of the storage compartment and extensively damaged the sink and plumbing in the fume cupboard. All but three of the nine glass Winchesters of chemicals in the storage compartment were broken and glass, chemicals and plastic debris forcefully blown throughout the laboratory.

The explosion occurred at 7.30 pm on a Thursday night. Fortunately no one was injured. Normally there would have been two postgraduate students using the laboratory but on this particular night they fortunately needed to attend to other matters. Upon hearing the explosion, other persons in the building approached the laboratory. They first noticed a red liquid coming out from underneath the laboratory door. Upon opening the door they observed a red coloured vapour with pungent chlorine-like odour. They promptly closed the door and contacted Security for assistance. One person complained of a throat irritation and was advised to seek medical attention.

The Fire and Emergency Service attended and identified four chemicals: formic acid, sulphuric acid, lactic acid and acetic acid using labels on the broken bottles. They were unable to identify the contents of a number of broken bottles and also two unbroken bottles since they no longer had labels on. One unbroken bottle was identified as containing nitric acid.

Due to the state of the containers involved in the explosion the Fire and Emergency Service requested further information on the contents of the Winchesters prior to undertaking a clean up. A registry of chemicals stored within the laboratory or school was not centrally available and it was nearly one hour later before the laboratory technician could be contacted. A recent stocktake had been performed and a list of chemicals stored in the laboratory was obtained.

Since the Fire and Emergency Service still remained uncertain as to the cause of the explosion they used full protective equipment with self-contained breathing apparatus to clean up the laboratory using sawdust (peatsorb) and lime. In addition all windows within the laboratory were opened to increase ventilation within the laboratory. The clean up was completed by 11.30 pm before the building was declared safe to re-enter. The laboratory was isolated and a further clean up conducted of residual lime and sawdust the following day which took 8 hours to complete.

All evidence pointed to a build-up of pressure in the formic acid Winchester. Formic acid (HCO2H) slowly decomposes with the liberation of carbon monoxide. A 2.5 litre 98-100% formic acid solution in the absence of a gas leak would be expected to develop a pressure of 7 atmospheres during 1 year at 25oC. Whilst manufacturers have been using pressure relieving caps for many years it may be possible to seal these bottles with non-venting caps.

A follow up audit of the school located nine more bottles of formic acid, two of which vented a considerable amount of gas when professionally and safely vented. Both bottles of formic acid and another were stored in the same plastic bunding dish as Winchesters of concentrated nitric acid, concentrated sulphuric acid and glycerol. Had the pressure build up exploded the container, damaging the other Winchesters and allowing the contents to
mix, the result could have been very spectacular and life threatening to occupants in the building. No one knew what the formic acid was used for or could recall when anyone last used it.

DISCUSS THE ABOVE CASE STUDY WITH REGARDS TO MATERIALS COVERED IN THIS COURSE.
Consider the following:
- What were the main contributing factors to the explosion?
- What factors contributed to the extended time required to clean-up after the explosion?
- What recommendations would you make to prevent a recurrence of this or a similar explosion involving chemicals?

You may wish to consider aspects from the following:
- Chemical management procedures
- Chemical registers, training, labelling, SDS, storage, use, disposal
- Material safety data sheets
- Working in isolation
- Emergency response procedures
- Roles and responsibilities.

CASE STUDY CAUSTIC BURNS
- A man was using a product containing 99-100% caustic soda in granular form to clear a partly blocked drain. Having filled the drain with hot water, he then added the caustic soda. The ensuing chemical reaction forcibly discharged a stream of hot water (probably containing dissolved and undissolved caustic soda) which hit the man in the face and eyes. He suffered skin burns and eye injuries which left him with partial loss of sight.
- An accident occurred involving a cleaner who used a foaming liquid product containing 10% caustic potash and 3% sodium hypochlorite undiluted to clean a shower recess. Not wearing protective gloves, the cleaner immediately felt a burning sensation in her hands when the product started foaming. She washed her hands and a lanolin-based cream was applied. Within an hour, black spots and blisters had appeared on her right hand.

Despite professional medical treatment, the pain and blistering continued for six weeks. Over the ensuing year, the severely damaged skin was removed and she received skin grafts. Eighteen months later, the woman's right hand was amputated due the continual spread of necrosis.

CASE STUDIES HYDROFLUORIC ACID
- An experienced researcher was working alone in a home-based laboratory. He was transferring a 70% hydrofluoric acid solution from one plastic container to another, inside a fume cupboard. He was wearing kitchen gloves plus latex gloves and torn sleeve protectors. A protective apron was available but he was not wearing it at the time.

Some of the acid spilt on his legs. He attempted to wash it off with a small laboratory hose before jumping into a swimming pool. The pool contained 280
ppm calcium which acted to wash away and dilute the acid. However the man became comatose within half an hour and died in hospital two weeks later.

- A laboratory worker had three fingers exposed to hydrofluoric vapour for two minutes. Incorrect treatment resulted in almost unbearable pain for 24 hours, unrelieved by a very large dose of morphine. The area and depth of wound increased for five days. Penetration stopped only after five weeks. The tips of two fingers disappeared.

- A laboratory worker was squirted on the arm with concentrations of hydrofluoric acid, but correct treatment was delayed for 50 minutes. He was absent from work for 70 days and ongoing medical treatment was required for three months.

- A man touched screws contaminated with low concentrations of hydrofluoric acid with his bare hands. Treatment was delayed for 17 hours until pain, stiffness and redness occurred. The result was absence from work for one week and ongoing medical treatment was required for three weeks.

**BIOSAFETY CASE STUDIES**

- Viruses and organisms have been rated according to their hazard levels since the 1980's, after a US-based international survey found hundreds of incidents of laboratory infection. Viruses that cause serious infections or death, such as Japanese encephalitis (JEV) yellow fever and large cultures of the AIDS virus are rated PC3, and must only be handled in laboratories with a PC3 or higher rating.

- A university researcher was discovered injecting mice with JEV in a PC2 rated laboratory, placing everyone using the laboratory at risk of being infected with JEV. The researcher was suspended for a year.

- A worker received a needle stick injury after attempting to re-sheath a needle prior to disposal. The needle was contaminated with blood from a Hepatitis B patient and the worker subsequently contracted the disease. The institution had no Hepatitis B immunisation programme and no instructions or training was provided on the disposal of sharps.

- A Laboratory worker needed to transfer medical samples infected with tuberculosis to another laboratory on the other side of the city. The worker packed the samples into a common insulated polystyrene foam drink container and carried it by hand on the train. The worker got off at the correct stop but left the samples on the train. Fortunately, the container was discovered at a later stop before anyone had inadvertently opened it.

**CASE STUDIES X-RAY ANALYSIS**

An x-ray analysis worker removed the x-ray tube housing from an operating x-ray fluorescence analyser machine and held it in his arms. The safety microswitch which should have terminated x-ray production, as the housing was withdrawn, did not operate. As the x-ray tube itself within the housing was still connected to the high tension cable and the cooling water hoses, it continued to emit x-rays through the exit port. The worker was extremely fortunate to have cradled the housing in his arms with the x-ray port directed away from his body. Had he held it with the x-ray port directed towards his body he would have suffered extremely serious x-ray burns within seconds. Four main factors contributed to this accident:

- the worker did not deliberately turn off the x-rays as he should have;
• it was possible to open the back panel of the machine without it automatically turning the x-rays off;
• the safety microswitch on the x-ray tube housing failed to operate as the housing was withdrawn; and
• the safety systems were not designed to fail-to-safety.

Late on a Friday afternoon a technician shut down x-ray diffraction units in preparation for the weekend. One finger was exposed to a direct x-ray beam for less than one second. On the following evening he felt a tingling sensation and an x-ray blister developed over the next few days. The blister was small and eventually healed over after a few months.

CASE STUDY - LASERS
• A scientist was working with a Class 4 NdYAG laser which produced invisible infra-red radiation of 1,064 nm wavelength. He was not wearing laser protective goggles and was hit in the eye by a weak reflection from a prism. As the beam struck his eye he heard a distinct popping sound, caused from the laser induced explosion at the back of his eyeball. His vision was immediately obscured by streams of blood and particulate matter suspended in the vitreous humour. Pain followed but was not excruciating. Shock took over as the realisation of eye damage dawned. Because he was not looking directly at the prism from which the reflection originated, the damage was confined to an area of the retina between the fovea and the optic nerve resulting in a permanent crescent shaped blind spot.
LABORATORY CHECKLIST

Building: __________________________ Inspected by: __________________________

School/Discipline: __________________________ Signature: __________________________

Location: __________________________ Date: __________________________

<table>
<thead>
<tr>
<th>1. LAYOUT</th>
<th>6.5 Access to EHS information on noticeboards, Email and Web provided</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1 Area is tidy and well kept</td>
<td>Y / N / NA</td>
</tr>
<tr>
<td>1.2 Adequate storage area provided</td>
<td>Y / N / NA</td>
</tr>
<tr>
<td>1.3 Floor is free of obstructions</td>
<td>Y / N / NA 7. MANUAL HANDLING</td>
</tr>
<tr>
<td>1.4 Floor coverings in good condition</td>
<td>Y / N / NA 7.1 Operations are assessed using the Manual Handling Checklist</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2. ENVIRONMENT</th>
<th>7.2 Often used items are within easy access, between knee and shoulder</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1 Temperature is comfortable</td>
<td>Y / N / NA 7.3 Heavy items stored at waist height</td>
</tr>
<tr>
<td>2.2 Lighting is adequate</td>
<td>Y / N / NA 7.4 Step –ladders or –stools are used</td>
</tr>
<tr>
<td>2.3 Area is free from odours</td>
<td>Y / N / NA 7.5 Repetitive operations minimised</td>
</tr>
<tr>
<td>2.4 Noise level is acceptable</td>
<td>Y / N / NA 7.6 Regular rest breaks are taken</td>
</tr>
<tr>
<td>2.5 Ventilation is adequate</td>
<td>Y / N / NA</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>3. EMERGENCY PROCEDURES</th>
<th>7.7 Trolleys are available and used to transport items</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1 Written procedures posted</td>
<td>Y / N / NA</td>
</tr>
<tr>
<td>3.2 Staff are aware of procedures and know emergency personnel</td>
<td>Y / N / NA 8. ENVIRONMENTAL ISSUES</td>
</tr>
<tr>
<td>3.3 Staff are inducted and records kept</td>
<td>Y / N / NA 8.1 Use of energy sources minimised - electricity, Gas and Water</td>
</tr>
<tr>
<td>3.4 Extinguisher of appropriate type is close by; ie, within 20 M</td>
<td>Y / N / NA 8.2 Paper, Toner and Commingle</td>
</tr>
<tr>
<td>3.5 Tag on extinguisher has been checked in the last 6 months</td>
<td>Y / N / NA 8.3 Electronic mail used when possible</td>
</tr>
<tr>
<td>3.6 Visitor Emergency Guides are available (where required)</td>
<td>Y / N / NA 8.4 Double sided photocopying and printing used when possible</td>
</tr>
<tr>
<td>3.7 Alarm can be heard in the area</td>
<td>Y / N / NA</td>
</tr>
<tr>
<td>3.8 Escape routes are in good order</td>
<td>Y / N / NA 9. ELECTRICAL SAFETY</td>
</tr>
<tr>
<td>3.9 Emergency and hazard signage is clearly visible</td>
<td>Y / N / NA 9.1 Equipment has current test tags</td>
</tr>
<tr>
<td>4. FIRST AID FACILITIES</td>
<td>9.2 Extension leads are used only for temporary power supply</td>
</tr>
<tr>
<td>4.1 Location of kits is known to staff</td>
<td>Y / N / NA 9.3 Powerboards used, not adaptors</td>
</tr>
<tr>
<td>4.2 Kits accessible within 5 minutes</td>
<td>Y / N / NA 9.4 Power leads kept clear of floor</td>
</tr>
<tr>
<td>4.3 Kits have been checked 3 monthly</td>
<td>Y / N / NA 9.5 Tags used on faulty equipment</td>
</tr>
<tr>
<td>4.4 Qualified first aiders available</td>
<td>Y / N / NA 9.6 Assessment required for new staff</td>
</tr>
<tr>
<td>4.5 Staff know first aid personnel</td>
<td>Y / N / NA</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>5. WORKSTATION ERGONOMICS</th>
<th>10.1 Risk assessments completed on laboratory procedures</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.1 Workstation assessed using the keyboard Workstation Assessment</td>
<td>Y / N / NA 10.2 Staff trained in general laboratory procedures and Safe Work Practices</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>6. GENERAL FACILITIES</th>
<th>10.3 Warning and Safety signage is in place for High Risk tasks</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.1 Washing facilities are adequate</td>
<td>Y / N / NA 10.4 Procedure, plant and equipment</td>
</tr>
<tr>
<td>6.2 Lockers available for staff</td>
<td>Y / N / NA</td>
</tr>
<tr>
<td>6.3 Cleaning of area is adequate</td>
<td>Y / N / NA</td>
</tr>
<tr>
<td>6.4 Cleaning Chemicals labelled</td>
<td>Y / N / NA 10.5 Food and Drink not permitted</td>
</tr>
<tr>
<td>11. CHEMICAL ASPECTS</td>
<td>14. Staff are aware of procedures</td>
</tr>
<tr>
<td>-----------------------</td>
<td>----------------------------------</td>
</tr>
<tr>
<td>11.1 Written procedures for chemical handling, storage and spillage in place</td>
<td>Y / N / NA 14.4 Radioactive sources are labelled</td>
</tr>
<tr>
<td>11.2 Staff are aware of procedures and have been trained</td>
<td>Y / N / NA 14.5 Records of isotope use are kept</td>
</tr>
<tr>
<td>11.3 Staff trained in chemical handling and monitored for leakage</td>
<td>Y / N / NA</td>
</tr>
<tr>
<td>11.4 current chemical inventory and awareness</td>
<td>Y / N / NA 14.6 Staff are monitored by badges</td>
</tr>
<tr>
<td>SDSs available</td>
<td>Y / N / NA</td>
</tr>
<tr>
<td>15. WASTE DISPOSAL</td>
<td>15.1 Written procedures for handling</td>
</tr>
<tr>
<td>regularly maintained</td>
<td>Y / N / NA</td>
</tr>
<tr>
<td>11.5 Spill kits are available and disposing of waste in place</td>
<td>Y / N / NA</td>
</tr>
<tr>
<td>11.6 Containers are labelled with staff</td>
<td>Y / N / NA</td>
</tr>
<tr>
<td>11.7 Chemicals are stored correctly, and labelled with Class Diamonds</td>
<td>Y / N / NA</td>
</tr>
<tr>
<td>bunded and segregated from all drains</td>
<td>Y / N / NA</td>
</tr>
<tr>
<td>11.8 Gas cylinders secured adequately</td>
<td>Y / N / NA</td>
</tr>
<tr>
<td>11.9 Procedures in place for transport</td>
<td>Y / N / NA</td>
</tr>
<tr>
<td>of chemicals across University grounds</td>
<td>Y / N / NA</td>
</tr>
<tr>
<td>11.10 Documented risk assessments</td>
<td>Y / N / NA</td>
</tr>
<tr>
<td>Completed for Hazardous Substances</td>
<td>Y / N / NA</td>
</tr>
<tr>
<td>minime waste on site</td>
<td>Y / N / NA</td>
</tr>
<tr>
<td>15.8 Records of waste are kept</td>
<td>Y / N / NA</td>
</tr>
<tr>
<td>15.9 Procedures in place for transport</td>
<td>Y / N / NA</td>
</tr>
<tr>
<td>16. PPE</td>
<td>Y / N / NA</td>
</tr>
<tr>
<td>16.1 Provided where necessary</td>
<td>Y / N / NA</td>
</tr>
<tr>
<td>and is appropriate for the task</td>
<td>Y / N / NA</td>
</tr>
<tr>
<td>13.1 Adequate handling, sterilisation and disposal procedures for Biological materials</td>
<td>Y / N / NA</td>
</tr>
<tr>
<td>16.2 Correctly stored and maintained</td>
<td>Y / N / NA</td>
</tr>
<tr>
<td>13.2 Staff are aware of procedures</td>
<td>Y / N / NA</td>
</tr>
<tr>
<td>16.3 Staff trained to use PPE</td>
<td>Y / N / NA</td>
</tr>
<tr>
<td>16.4 Worn by all staff</td>
<td>Y / N / NA</td>
</tr>
<tr>
<td>13.3 Benches are disinfected regularly</td>
<td>Y / N / NA</td>
</tr>
<tr>
<td>16.5 Comply with Australian Standards</td>
<td>Y / N / NA</td>
</tr>
<tr>
<td>13.4 Cabinets are regularly cleaned</td>
<td>Y / N / NA</td>
</tr>
<tr>
<td>17.6 Records of supply kept</td>
<td>Y / N / NA</td>
</tr>
<tr>
<td>17. PLANT / EQUIPMENT</td>
<td>Y / N / NA</td>
</tr>
<tr>
<td>17.1 Hazard assessments have been conducted on plant using the checklist</td>
<td>Y / N / NA</td>
</tr>
<tr>
<td>17.2 Equipment left on after hours has contact and emergency details</td>
<td>Y / N / NA</td>
</tr>
<tr>
<td>material handling, storage and spillage are in place</td>
<td>Y / N / NA</td>
</tr>
<tr>
<td>17.4 Staff Trained in safe plant use</td>
<td>Y / N / NA</td>
</tr>
<tr>
<td>18. OTHER COMMENTS:</td>
<td></td>
</tr>
<tr>
<td>____________________________</td>
<td>____________________________</td>
</tr>
<tr>
<td>19. RECOMMENDATIONS:</td>
<td></td>
</tr>
<tr>
<td>____________________________</td>
<td>____________________________</td>
</tr>
</tbody>
</table>

Signature of Person responsible: ____________________________ Date of next Review: ____________________________

131
### School/Discipline Chemical Safety Checklist

<table>
<thead>
<tr>
<th>Building: ___________________________</th>
<th>Inspected by: ___________________________</th>
</tr>
</thead>
<tbody>
<tr>
<td>School/Discipline: ___________________</td>
<td>Signature: _____________________________</td>
</tr>
<tr>
<td>Location: ___________________________</td>
<td>Date: ________________________________</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Item</th>
<th>V</th>
<th>X</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td>Chemical management system</td>
</tr>
<tr>
<td>-does one exist?</td>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>-are hazards, safer alternatives, and disposal procedures investigated prior to acquisition of chemicals?</td>
<td></td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>-how are acquisitions entered in the system?</td>
<td></td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>-how are disposals / use recorded?</td>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>-how do purchases occur / who orders &amp; receives?</td>
<td></td>
<td></td>
<td>6</td>
</tr>
<tr>
<td>-stock reviewed / stocktakes annually?</td>
<td></td>
<td></td>
<td>7</td>
</tr>
<tr>
<td>8</td>
<td></td>
<td></td>
<td>Register of hazardous materials &amp; dangerous goods</td>
</tr>
<tr>
<td>-central location</td>
<td></td>
<td></td>
<td>9</td>
</tr>
<tr>
<td>-up to date (who is responsible)</td>
<td></td>
<td></td>
<td>10</td>
</tr>
<tr>
<td>-accessible/conspicuous</td>
<td></td>
<td></td>
<td>11</td>
</tr>
<tr>
<td>-widely known of</td>
<td></td>
<td></td>
<td>12</td>
</tr>
<tr>
<td>-includes risk assessments and SDS</td>
<td></td>
<td></td>
<td>13</td>
</tr>
<tr>
<td>14</td>
<td></td>
<td></td>
<td>SDS for all hazardous materials and dangerous goods</td>
</tr>
<tr>
<td>-&lt; 5 years old</td>
<td></td>
<td></td>
<td>15</td>
</tr>
<tr>
<td>-WorkSafe Australia format</td>
<td></td>
<td></td>
<td>16</td>
</tr>
<tr>
<td>17</td>
<td></td>
<td></td>
<td>Chemical Weapons convention</td>
</tr>
<tr>
<td>-are substances from the schedules to the convention used?</td>
<td></td>
<td></td>
<td>18</td>
</tr>
<tr>
<td>-who is responsible?</td>
<td></td>
<td></td>
<td>19</td>
</tr>
<tr>
<td>-is the appropriate accounting occurring?</td>
<td></td>
<td></td>
<td>20</td>
</tr>
<tr>
<td>21</td>
<td></td>
<td></td>
<td>After hours contacts register?</td>
</tr>
<tr>
<td>22</td>
<td></td>
<td></td>
<td>Information package for emergency services personnel</td>
</tr>
<tr>
<td>-location of major hazards (chemical stores, toxic gases, etc)</td>
<td></td>
<td></td>
<td>23</td>
</tr>
<tr>
<td>-map</td>
<td></td>
<td></td>
<td>24</td>
</tr>
<tr>
<td>-contacts</td>
<td></td>
<td></td>
<td>25</td>
</tr>
<tr>
<td>-location of fire services, stormwater drains, gas isolation valves</td>
<td></td>
<td></td>
<td>26</td>
</tr>
<tr>
<td>-updated frequently (who is responsible)</td>
<td></td>
<td></td>
<td>27</td>
</tr>
<tr>
<td>28</td>
<td></td>
<td></td>
<td>Doors labelled re major hazards/precautions &amp; area contacts</td>
</tr>
<tr>
<td>29</td>
<td></td>
<td></td>
<td>Enclosed footwear</td>
</tr>
<tr>
<td>30</td>
<td></td>
<td></td>
<td>Eye protection</td>
</tr>
<tr>
<td>31</td>
<td></td>
<td></td>
<td>Lab coats</td>
</tr>
<tr>
<td>32</td>
<td></td>
<td></td>
<td>Routine disposal of chemicals (monthly/quarterly)</td>
</tr>
<tr>
<td>33</td>
<td></td>
<td></td>
<td>Annual clean-up of work areas</td>
</tr>
<tr>
<td>Cleanout procedure at end of work for all students / personnel</td>
<td>34</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Written guidelines/policies/procedures</td>
<td>35</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-do they exist, particularly for more hazardous processes, techniques, substances?</td>
<td>36</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-up to date/regularly reviewed?</td>
<td>37</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-accessible/widely disseminated/conspicuous in workplace?</td>
<td>38</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-followed?</td>
<td>39</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-how are problems identified and addressed, and policies / procedures reviewed?</td>
<td>40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PPE</td>
<td>41</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-policy</td>
<td>42</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-available/provided</td>
<td>43</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-suitable</td>
<td>44</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-in good repair</td>
<td>45</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-clean</td>
<td>46</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-conspicuously located/placarded</td>
<td>47</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-training provided</td>
<td>48</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visitors</td>
<td>49</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-does a policy exist?</td>
<td>50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-is the policy known?</td>
<td>51</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-is the policy followed?</td>
<td>52</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-PPE provided/who is responsible for supply/acquisition?</td>
<td>53</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inspections</td>
<td>54</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-who conducts them?</td>
<td>55</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-conducted regularly?</td>
<td>56</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-results documented and passed to person responsible for area</td>
<td>57</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-follow up undertaken to ensure action on outcomes</td>
<td>58</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poisons licence</td>
<td>59</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-is there one?</td>
<td>60</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-who is responsible?</td>
<td>61</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-does it cover all substances used? (esp. CN and HF)</td>
<td>62</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carcinogens</td>
<td>63</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-any used from schedule S.4/5.5 of WA OHS Regs 1996?</td>
<td>64</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-permission obtained from commissioner of WorkSafe WA</td>
<td>65</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-policy and procedures in place/disseminated</td>
<td>66</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Health Monitoring</td>
<td>67</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-are substances used which make monitoring necessary?</td>
<td>68</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-who is responsible for monitoring?</td>
<td>69</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-records kept for required period of time</td>
<td>70</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Waste disposal</td>
<td>71</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-water authority permit (is there one, who is responsible)</td>
<td>72</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-what can’t go down the drain?</td>
<td>73</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-solid waste (what goes in the bin)</td>
<td>74</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-biohazardous waste / electrophoresis gels</td>
<td>75</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Checklists</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---------------------------------------------------------------------------</td>
<td>---</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- chemical waste</td>
<td>76</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- empty containers / contaminated glassware</td>
<td>77</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- solvent waste</td>
<td>78</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- procedures and protocols for labelling, collection, packaging,</td>
<td>79</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- sharps</td>
<td>80</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- specific wastes (ethidium bromide, etc)</td>
<td>81</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chemical spills</td>
<td>82</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- procedure</td>
<td>83</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- spill kits (special for HF- including Calcium Gluconate)</td>
<td>84</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fire and safety equipment</td>
<td>85</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- checked regularly (wardens)</td>
<td>86</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- appropriate location and type</td>
<td>87</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- conspicuous/signposted</td>
<td>88</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- accessible / unobstructed</td>
<td>89</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- tested as appropriate</td>
<td>90</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- training provided to all personnel</td>
<td>91</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fume cupboards tested annually &amp; passed</td>
<td>92</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Training</td>
<td>93</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- requirements identified</td>
<td>94</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- who conducts it?</td>
<td>95</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- what records are kept</td>
<td>96</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- is refresher training required and provided?</td>
<td>97</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- inductions performed</td>
<td>98</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- who is responsible?</td>
<td>99</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Incidents / accidents</td>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- what has occurred in the past in this area?</td>
<td>101</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- how was it investigated / addressed?</td>
<td>102</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- what was the outcome?</td>
<td>103</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- were improvements / modifications made?</td>
<td>104</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- were personnel informed of the outcome?</td>
<td>105</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- are improvements / modifications still complied with?</td>
<td>106</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- report forms available for accident / near miss / injury / hazard</td>
<td>107</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Central storage areas</td>
<td>108</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- are gas cylinders individually secured?</td>
<td>109</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- deliveries (arrangements, responsibilities)</td>
<td>110</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- are sufficient quantities of DG held to require a licence from DOME?</td>
<td>111</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- is a there a DG licence from DOME?</td>
<td>112</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- do current holdings and facilities comply with the DOME licence?</td>
<td>113</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- who is responsible for large holdings?</td>
<td>114</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- secure /restricted access</td>
<td>115</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- placarded</td>
<td>116</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- cryogens (LN$_2$, LHe, dry ice)</td>
<td>117</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- policies and procedures for use</td>
<td>118</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- training and documentation of training</td>
<td>119</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Checklists</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>------------------------------------------------</td>
<td>---</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>PPE for decanting and use/adequate ventilation</strong></td>
<td>120</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Emergencies</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- are procedures in place to deal with emergencies?</td>
<td>121</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- are responses tested, documented and reviewed?</td>
<td>122</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- do all personnel know response procedures and responsibilities?</td>
<td>124</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- are all personnel appropriately trained?</td>
<td>125</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- who has overall responsibility in an emergency?</td>
<td>126</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Transport</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- are chemicals/samples transported?</td>
<td>127</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- are policies and procedures in place, disseminated and followed?</td>
<td>128</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- who is the contact for relevant info, have they been trained?</td>
<td>129</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- who is responsible for ensuring regulatory compliance?</td>
<td>130</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- no private vehicles used</td>
<td>131</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- appropriate documentation provided</td>
<td>132</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- vehicle meets requirements and contractors are licensed</td>
<td>133</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>First Aid</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- is appropriate equipment/kits available, accessible, conspicuous, functional and placarded?</td>
<td>134</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- are first aid personnel available, and their identity and contact numbers known?</td>
<td>135</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- specific antidotes/equipment/protocols and training available for particular hazards (CN, HF)</td>
<td>136</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- ample calcium gluconate available, readily accessible and clearly placarded (if reqd - HF)</td>
<td>137</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- is equipment regularly checked and checks documented?</td>
<td>138</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>COMMENTS</th>
<th></th>
</tr>
</thead>
</table>
## INDIVIDUAL LABORATORY CHEMICAL SAFETY AUDIT

**Building:** -----------------------
**Inspected by:** -----------------------
**DATE:** -----------------------

**School:** -----------------------
**Room:** -----------
**Signature:** -----------------------

<table>
<thead>
<tr>
<th>Item #</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>General</strong></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Are safety procedures and policies readily available in the workplace?</td>
</tr>
<tr>
<td>2</td>
<td>Are people aware of them?</td>
</tr>
<tr>
<td>3</td>
<td>Are they followed?</td>
</tr>
<tr>
<td>4</td>
<td>-general</td>
</tr>
<tr>
<td>5</td>
<td>-specific hazards -substances</td>
</tr>
<tr>
<td>6</td>
<td>-processes/techniques</td>
</tr>
<tr>
<td>7</td>
<td>-apparatus</td>
</tr>
<tr>
<td>8</td>
<td>Have all personnel had inductions? (Site + work area/s, equipment)</td>
</tr>
<tr>
<td>9</td>
<td>Are there records of this?</td>
</tr>
<tr>
<td>10</td>
<td>How would you report a hazard / near miss / accident /injury?</td>
</tr>
<tr>
<td>11</td>
<td>Is there anything in this work area you feel uneasy about the safety of?</td>
</tr>
<tr>
<td>12</td>
<td>Has it been reported / queried?</td>
</tr>
<tr>
<td>13</td>
<td>What was the outcome?</td>
</tr>
<tr>
<td>14</td>
<td>Is there a register of hazardous substances?</td>
</tr>
<tr>
<td>15</td>
<td>Where is it?</td>
</tr>
<tr>
<td>16</td>
<td>Where do you find SDSs?</td>
</tr>
<tr>
<td>17</td>
<td>Have risk assessments been performed?</td>
</tr>
<tr>
<td>18</td>
<td>Are risk assessments and SDS up to date?</td>
</tr>
<tr>
<td>19</td>
<td>Is safety equipment appropriate, accessible, conspicuous, regularly tested (records kept where appropriate), and have personnel been trained in its use?</td>
</tr>
<tr>
<td>20</td>
<td>-Fire extinguishers/blankets</td>
</tr>
<tr>
<td>21</td>
<td>-Chemical spill kit</td>
</tr>
<tr>
<td>22</td>
<td>-First Aid kit</td>
</tr>
<tr>
<td>23</td>
<td>-PPE (face shield, respirator, SCBA, gloves, labcoat, apron, etc)</td>
</tr>
<tr>
<td>24</td>
<td>-Deluge shower</td>
</tr>
<tr>
<td>25</td>
<td>-Eyewash</td>
</tr>
<tr>
<td>26</td>
<td>-Other... (antidotes, etc)</td>
</tr>
<tr>
<td>27</td>
<td>Are exits clear, unobstructed, and signposted?</td>
</tr>
<tr>
<td>28</td>
<td>Are contact details (including A/H) on the doors of the work area?</td>
</tr>
<tr>
<td>29</td>
<td>Are hazards and precautions displayed on the door to the area?</td>
</tr>
<tr>
<td>30</td>
<td>Are they up to date?</td>
</tr>
<tr>
<td>31</td>
<td>When was the last formal inspection of the area?</td>
</tr>
<tr>
<td>32</td>
<td>Are there records of it?</td>
</tr>
<tr>
<td>33</td>
<td>What improvements were suggested, if any?</td>
</tr>
<tr>
<td>34</td>
<td>Have they been actioned?</td>
</tr>
<tr>
<td>Question</td>
<td>Page</td>
</tr>
<tr>
<td>-------------------------------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>Is there signage to prohibit foodstuffs / chewing gum etc?</td>
<td>35</td>
</tr>
<tr>
<td>When was the last cleanout of the area?</td>
<td>36</td>
</tr>
<tr>
<td>Is footwear / eye protection / protective clothing required?</td>
<td>37</td>
</tr>
<tr>
<td>Is the requirement signposted near the point of entry?</td>
<td>38</td>
</tr>
<tr>
<td>Is PPE etc. provided for visitors?</td>
<td>39</td>
</tr>
<tr>
<td>Is it used properly?</td>
<td>40</td>
</tr>
<tr>
<td>Are Winchester or other safety carriers available?</td>
<td>41</td>
</tr>
<tr>
<td>Are they used?</td>
<td>42</td>
</tr>
<tr>
<td>Where is the nearest</td>
<td>43</td>
</tr>
<tr>
<td>- first aid kit</td>
<td>44</td>
</tr>
<tr>
<td>- fire blanket</td>
<td>45</td>
</tr>
<tr>
<td>- fire extinguisher</td>
<td>46</td>
</tr>
<tr>
<td>- emergency exit</td>
<td>47</td>
</tr>
<tr>
<td>- telephone</td>
<td>48</td>
</tr>
<tr>
<td>- first aid officer</td>
<td>49</td>
</tr>
<tr>
<td>- fire warden</td>
<td>50</td>
</tr>
<tr>
<td>- fire hose</td>
<td>51</td>
</tr>
<tr>
<td>- chemical spill kit</td>
<td>52</td>
</tr>
<tr>
<td>Fume cupboards</td>
<td>53</td>
</tr>
<tr>
<td>- tested regularly and pass test</td>
<td>54</td>
</tr>
<tr>
<td>- not used for storage and other uses</td>
<td>55</td>
</tr>
<tr>
<td>- clear area 1.8 m in front of cabinet</td>
<td>56</td>
</tr>
<tr>
<td>- additional fire extinguisher of 5B capacity within 3-5 m of cabinet</td>
<td>57</td>
</tr>
<tr>
<td>- label states no more than 2.5 L of flammable liquid inside</td>
<td>58</td>
</tr>
<tr>
<td>- perchloric / nitric acid digestions in dedicated fume cupboards</td>
<td>59</td>
</tr>
<tr>
<td>Refrigerators</td>
<td>60</td>
</tr>
<tr>
<td>- no unmodified domestic ‘fridges in labs (fire/explosion hazard)</td>
<td>61</td>
</tr>
<tr>
<td>- lab fridges labelled not for food / medicines / drinks (+picto)</td>
<td>62</td>
</tr>
<tr>
<td>- food fridges labelled not for chemicals / samples etc (+picto)</td>
<td>63</td>
</tr>
<tr>
<td>- fridges used to store chemicals / DG externally labelled to clearly identify hazard</td>
<td>64</td>
</tr>
<tr>
<td>Ignition sources</td>
<td>65</td>
</tr>
<tr>
<td>- Flames</td>
<td>66</td>
</tr>
<tr>
<td>- mantles, hotplates, ovens, furnaces etc</td>
<td>67</td>
</tr>
<tr>
<td>- electrical equipment</td>
<td>68</td>
</tr>
<tr>
<td>- catalysts (including those on gas soldering iron, car exhausts etc)</td>
<td>69</td>
</tr>
<tr>
<td>Chemical storage</td>
<td>70</td>
</tr>
<tr>
<td>- appropriate segregation</td>
<td>71</td>
</tr>
<tr>
<td>- minimum quantities in work areas</td>
<td>72</td>
</tr>
<tr>
<td>- old / unused materials disposed of</td>
<td>73</td>
</tr>
<tr>
<td>- unstable materials identified and checked / disposed of</td>
<td>74</td>
</tr>
<tr>
<td>- no explosives</td>
<td>75</td>
</tr>
<tr>
<td>- bunding adequate and suitable</td>
<td>76</td>
</tr>
<tr>
<td>- DG licence required? (using storage factors)</td>
<td>77</td>
</tr>
<tr>
<td>- stocktakes conducted?</td>
<td>78</td>
</tr>
</tbody>
</table>
### Checklists

#### Labelling
- all chemicals, decanted solutions, wash bottles etc labelled IAW WA OHS Regs
- Wastes appropriately labelled prior to disposal
- labels removed from empty cleaned containers before disposal

#### Solvent and chemical cabinets
- needed but not provided?
- ventilated to outside?
- used?
- contain incompatible materials?
- More needed? (or more shelves in existing ones)
- no ignition sources nearby
- locked if appropriate
- in good repair / self closing
- cleaned out / stocktakes done
- appropriately located

#### Class 1 Explosive
- identified
- disposed of

#### Class 2.X
- 2.1 Flammable Gas
- 2.2 Non-flammable gas
- 2.3 Toxic Gas
- cylinders held outside whenever possible (in minimum quantities indoors). The smallest suitable cylinder should be used (rather than G)
- correct orientation for liquefied gases
- cylinders individually secured (chained)
- segregated properly
- ignition / heat sources
- old / unwanted / unlabelled / leaking cylinders disposed of
- toxic gases used and stored in appropriate ventilated enclosures
- valve caps and plugs used on toxic gas cylinders
- regulators appropriate for type, flow and pressure of gas used
- no grease on fittings
- suitable trolley used for transport of cylinders
- respirators / SCBA required?

#### Class 3 Flammable liquids
- minimum quantities
- in ventilated flammables cabinet where possible
- Winchester / safety carriers used
- extinguishers appropriate for fuel load / hazards
- fire blanket available
- segregated

#### Class 4.X
- 4.1 Flammable Solid
- 4.2 Spontaneously Combustible
- 4.3 Dangerous When Wet
- Minimum quantities
- significant quantities stored in purpose built ventilated cabinets
- segregated / appropriate storage (away from water for class 4.3, some 4.2)
- used and stored over metal / fire resistant bunding tray
Checklists

- clean dry sand or suitable alternative available for fires and spills
- personnel know how to deal with spill / fire

**Class 5.1 Oxidising Agents**
- significant quantities in purpose built cabinets
- cabinets mechanically ventilated to outdoors
- suitably bunded
- away from flammable or combustible materials
- not stored directly on wooden or combustible shelves or materials

**Class 5.2 Organic Peroxides**
- minimum quantity purchased / held
- stored in plastic bunding tray
- not allowed to dry out if supplied wet (don’t touch if dried out)
- disposed of if no longer used

**Class 6 Toxic Substances**
- poisons licence appropriate?
- cyanides protocol and O₂ resuscitation gear
- locked up securely / restricted access to keys
- CCl₄ locked up (class 6.1 not in flammables cabinet)
- bunded in ventilated cabinets
- procedures for high toxicity materials

**Class 7 Radioactive**
- U, Th compounds and other radioisotopes identified
- appropriate hygiene, procedures, waste disposal

**Class 8 Corrosive**
- corrosives cabinets (ventilated)
- segregated (from other classes, acids / bases + incompatibilities within classes)
- bunded
- eyewash suitable, available, signposted, conspicuous, tested, working
- shower suitable, available, signposted, conspicuous, tested, working
- plastic containers checked for embrittlement

**Unstable substances**
- identified
  - formic acid
  - H₂O₂
  - organic peroxides
  - peroxidisable substances
  - azides
  - chlorates, perchlorates, perchloric acid
  - organic nitro compounds
  - other
- held in minimum quantities
- old stocks disposed of
- procedures in place to check stocks regularly for decomposition and dispose of material after a specified period of time or on signs of deterioration
- containers appropriate (vented if necessary)
- safe working procedures identified and used
<table>
<thead>
<tr>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Appropriate bunding</td>
<td>171</td>
</tr>
<tr>
<td>Appropriate engineering controls / PPE</td>
<td>172</td>
</tr>
</tbody>
</table>

**COMMENTS**
# WORKSHOP CHECKLIST

**Building:**  
**Inspected by:**  
**DATE:**  
**School:**  
**Room:**  
**Signature:**

<table>
<thead>
<tr>
<th>1. LAYOUT</th>
<th>6.5 Access to SHO information on noticeboards, Email and Web provided</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1 Area is tidy and well kept</td>
<td>Y / N / NA</td>
</tr>
<tr>
<td>1.2 Adequate storage area provided</td>
<td>Y / N / NA</td>
</tr>
<tr>
<td>1.3 Floor is free of obstructions</td>
<td>Y / N / NA</td>
</tr>
<tr>
<td>1.4 Floor coverings in good condition</td>
<td>Y / N / NA</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2. ENVIRONMENT</th>
<th>7. MANUAL HANDLING</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1 Temperature is comfortable</td>
<td>Y / N / NA</td>
</tr>
<tr>
<td>2.2 Lighting is adequate</td>
<td>Y / N / NA</td>
</tr>
<tr>
<td>2.3 Area is free from odours</td>
<td>Y / N / NA</td>
</tr>
<tr>
<td>2.4 Noise level is acceptable</td>
<td>Y / N / NA</td>
</tr>
<tr>
<td>2.5 Ventilation is adequate</td>
<td>Y / N / NA</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>3. EMERGENCY PROCEDURES</th>
<th>7.7 Trolleys are available and used to transport items</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1 Written procedures posted</td>
<td>Y / N / NA</td>
</tr>
<tr>
<td>3.2 Staff are aware of procedures and know emergency personnel</td>
<td>Y / N / NA</td>
</tr>
<tr>
<td>3.3 Staff are inducted and records kept</td>
<td>Y / N / NA</td>
</tr>
<tr>
<td>3.4 Extinguisher of appropriate type is close by; ie, within 20 M</td>
<td>Y / N / NA</td>
</tr>
<tr>
<td>3.5 Tag on extinguisher has been checked in the last 6 months</td>
<td>Y / N / NA</td>
</tr>
<tr>
<td>3.6 Visitor Emergency Guides are available (where required)</td>
<td>Y / N / NA</td>
</tr>
<tr>
<td>3.7 Alarm can be heard in the area</td>
<td>Y / N / NA</td>
</tr>
<tr>
<td>3.8 Escape routes are in good order</td>
<td>Y / N / NA</td>
</tr>
<tr>
<td>3.9 Emergency and hazard signage is clearly visible</td>
<td>Y / N / NA</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>4. FIRST AID FACILITIES</th>
<th>9. ELECTRICAL SAFETY</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1 Location of kits is known to staff</td>
<td>Y / N / NA</td>
</tr>
<tr>
<td>4.2 Kits accessible within 5 minutes</td>
<td>Y / N / NA</td>
</tr>
<tr>
<td>4.3 Kits have been checked 3 monthly</td>
<td>Y / N / NA</td>
</tr>
<tr>
<td>4.4 Qualified first aiders available</td>
<td>Y / N / NA</td>
</tr>
<tr>
<td>4.5 Staff know first aid personnel</td>
<td>Y / N / NA</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>5. WORKSTATION ERGONOMICS</th>
<th>10. GENERAL WORKSHOP</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.1 Workstation assessed using the keyboard workstation assessment</td>
<td>Y / N / NA</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>6. GENERAL FACILITIES</th>
<th>10.1 Risk assessments completed on workshop procedures</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.1 Washing facilities are adequate</td>
<td>Y / N / NA</td>
</tr>
<tr>
<td>6.2 Lockers available for staff</td>
<td>Y / N / NA</td>
</tr>
<tr>
<td>6.3 Cleaning of area is adequate</td>
<td>Y / N / NA</td>
</tr>
<tr>
<td>6.4 Cleaning Chemicals labelled</td>
<td>Y / N / NA</td>
</tr>
</tbody>
</table>
### 11. CHEMICAL ASPECTS

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>11.1 Written procedures for chemical handling, storage and spillage in place</td>
<td>Y / N / NA</td>
<td>and disposing of waste are in place</td>
</tr>
<tr>
<td>11.2 Staff are aware of procedures and are trained in chemical handling and are aware of chemical hazards</td>
<td>Y / N / NA</td>
<td>Y / N / NA</td>
</tr>
<tr>
<td>11.3 Staff are aware of procedures and are trained in chemical handling and are aware of chemical hazards</td>
<td>Y / N / NA</td>
<td>Y / N / NA</td>
</tr>
<tr>
<td>11.4 current chemical Inventory and SDSs available</td>
<td>Y / N / NA</td>
<td>13.4 Waste is segregated and stored appropriately away from drains</td>
</tr>
<tr>
<td>11.5 Spill kits are available and regularly maintained</td>
<td>Y / N / NA</td>
<td>13.5 Spill kits are available and regularly maintained</td>
</tr>
<tr>
<td>11.6 Containers are labelled with chemical name and Class diamonds</td>
<td>Y / N / NA</td>
<td>13.6 Waste is recycled where possible</td>
</tr>
<tr>
<td>11.7 Chemicals are stored correctly, bundled and segregated from all drains</td>
<td>Y / N / NA</td>
<td>13.7 Regular waste disposal is done to minimise waste on site</td>
</tr>
<tr>
<td>11.8 Gas cylinders secured adequately</td>
<td>Y / N / NA</td>
<td>13.8 Records of waste are kept</td>
</tr>
<tr>
<td>11.9 Procedures in place for transport of chemicals across University grounds</td>
<td>Y / N / NA</td>
<td>13.9 Procedures in place for transport</td>
</tr>
<tr>
<td>11.10 Documented risk assessments completed for Hazardous Substances</td>
<td>Y / N / NA</td>
<td>and is appropriate for the task</td>
</tr>
<tr>
<td>12.1 Hazard assessments have been conducted on plant using the checklist</td>
<td>Y / N / NA</td>
<td>14.1 Provided where necessary and is appropriate for the task</td>
</tr>
<tr>
<td>12.2 Equipment left on after hours has contact and emergency details</td>
<td>Y / N / NA</td>
<td>14.2 Correctly stored and maintained</td>
</tr>
<tr>
<td>12.3 Procedures in place for plant use</td>
<td>Y / N / NA</td>
<td>14.3 Staff trained to use PPE</td>
</tr>
<tr>
<td>12.4 Staff Trained in safe plant use</td>
<td>Y / N / NA</td>
<td>14.4 Worn by all staff</td>
</tr>
<tr>
<td>15.1 Spray painting operations comply with Victorian Regulations</td>
<td>Y / N / NA</td>
<td>14.5 Comply with Australian Standards</td>
</tr>
<tr>
<td>15.2 Written procedures for spray painting are in place</td>
<td>Y / N / NA</td>
<td>14.6 Records of supply kept</td>
</tr>
<tr>
<td>15.3 Ventilation is adequate for spray painting operations</td>
<td>Y / N / NA</td>
<td></td>
</tr>
<tr>
<td>15.4 Respiratory equipment is properly maintained and used as required</td>
<td>Y / N / NA</td>
<td></td>
</tr>
<tr>
<td>15.5 Paint and thinner at minimum levels and stored appropriately</td>
<td>Y / N / NA</td>
<td></td>
</tr>
</tbody>
</table>

### 16. OTHER COMMENTS:

---

---

### 17. RECOMMENDATIONS:

---

---