

Health and safety in the laboratory

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Whilst studying S288, you may have the opportunity to conduct investigations in the laboratory. However, even if you are not attending a laboratory course, as a practising scientist it is important to be familiar with the science underlying the procedures and the safe use of reagents and laboratory equipment.

In this guide you will learn about sources of chemical and **radiation** hazards in the laboratory and how evidence-based judgements are made about their safe use. You will consider how to minimise risks by selecting appropriate hazard control and risk management strategies and become aware of some of the relevant health and safety legislation. We will not be discussing hazards from biological sources in any great detail in this guide, such as those from infectious agents, as you will not encounter these (other than in an online environment) in S288.

If you are attending a laboratory-based residential school associated with a topic you are studying for S288 there will be specific health and safety notes that are applicable to the topic. You should ensure that you have consulted this information. In some cases you may also be required to demonstrate an understanding of, and competence in, safety issues before you attend the laboratory sessions.

1 Controlling laboratory environments: risk and hazards

Risk is something that impinges on all of our lives every day. All human activities have risks associated with them. With experience, we learn to weigh up the degree of risk associated with familiar situations, such as crossing the road, without thinking too hard about them, but in new or unfamiliar situations we usually have to take more time to consider available options and the likely consequences of our decisions.

The terms risk and **hazard** are often confused.

- Risk consists partly of the probability of an event coming to pass, but also involves the nature of the consequences arising from the event.
- Hazards are components of risk: they are defined as the potential to cause harm and can be an object or a situation that poses a level of threat to life, health, property or environment.

For example, when we go up and down stairs there is a chance we might fall. Here, the stairs are a hazard and the likelihood of falling and getting injured represents the risk. Another hazard might arise from this situation if, for instance, your balance or mobility were impaired.

Some hazards are significant only if we are exposed to them for a long time or in large amounts or concentrations. Let's consider the example of flour. This is not normally a hazard; we handle it at home without a second thought. However, if a baker is exposed to flour dust for a prolonged period of time then he or she could develop dermatitis (inflammation of the skin), conjunctivitis (inflammation of the eyes) or asthma. In addition, when dealing with large quantities of fine powder or dust, such as flour, then there is the possibility of an explosion as the dust is explosive if a source of ignition is present. One famous example of such an explosion, resulting from ignition of flour dispersed in air from a spark, destroyed a flour mill in Minnesota in 1878, killing 18 workers. Many similar incidents have occurred since.

You could also ask how hazardous water can be? Whilst drowning in 1 cm of water is rather unlikely, a swimming pool is a different situation. So hazards are often context dependent and what might not be a hazard in one scenario could be in another. It is

important to also bear in mind that whilst we are specifically discussing laboratory work in this guide, general issues of health and safety must not be overlooked. For example, a trip hazard in a non-laboratory study area has the potential to become even more of a hazard in a laboratory, where the consequences of falling whilst carrying chemicals or radioactive substances could be serious. We will discuss specific hazards that you may encounter in the laboratory later in this guide, but for now we will start with how we assess the impact of a hazard, a process called **risk assessment**.

1.1 Risk assessment

Once hazards have been identified, they can be evaluated to determine how serious the problems are and what actions can be taken to control them. This process is called risk assessment and involves the identification of hazards, assigning levels of risk to them and making judgements on whether the level of risk is acceptable or if something needs to be done to reduce it.

The simplest form of risk assessment is to rate the risk as high, medium or low, depending on the *consequences* and the *likelihood* of harm. The ‘consequences’ describe the impact or outcome component of the risk and the ‘likelihood’ is the probability or frequency of a consequence occurring. The degree of risk associated with a hazard is thus determined by the consequences that an undesired event would have and the likelihood of it happening.

Let’s think about the overall level of risk you would assign to the following events: a large asteroid colliding with the Earth, and travelling to work by car.

The severity of a large asteroid striking our planet would be ‘catastrophic’, but the likelihood of the event is ‘rare’ as it is likely to be a one off event. On the other hand, the harm that may occur when travelling by car varies from ‘slight’ to ‘serious’, and the likelihood of such an event is ‘possible’ as many of us travel daily by car. It is impossible to remove all subjectivity from this process, and different people could assign different levels of severity and likelihood to a particular hazard, but we have assigned a low risk to an asteroid colliding with our planet and a moderate risk to travelling by car.

1.1.1 Reducing risk through the use of control measures

The process of risk assessment seeks to answer the questions:

- ‘what can go wrong?’,
- ‘how bad are the consequences?’,
- ‘how often might it happen?’,
- ‘who might be harmed?’
- ‘is there a need for action?’.

Taking the example of staff in the baking industry, exposure to flour dust is considerably reduced by the installation of local exhaust ventilation (this will also reduce the risk of a dust explosion) and the use of protective respiratory equipment and overalls. These are examples of **control measures** (precautions), which help to minimise risk.

Table 1 shows a hierarchy of control measures that are commonly used in laboratories; remember that some corrective measures are better than others. The most

effective control measures are to eliminate a hazard or replace it with something less hazardous.

Control measure	Description
1 Hazard elimination	Using an alternative or different process
2 Substitution	If it cannot be eliminated, replacing a hazardous chemical with a less hazardous substance.
3 Use of local exhaust ventilation, fume cupboards or biological safety cabinets	Isolating or segregating the hazard, extraction and removal of hazardous materials from the user
4 Use of safety procedures	Using safe systems of work, safe equipment, training, supervision
5 Use of warnings	Using signs, labels, audible alarms etc
6 Use of personal protective equipment	Using laboratory coats, gloves and glasses. To be used only after all the above control measures have been considered.

Table 1 The hierarchy of control measures

In the S288 laboratory, the procedures, equipment and reagents will already have undergone the first two control measures listed in Table 1, aimed at eliminating hazards and replacing anything identified with less hazardous reagents or equipment.

Control measures 3-5 will be measures that you will encounter in the laboratory and it is part of working as a practitioner scientist to be able to apply these as required and appropriate and as directed by the staff and in laboratory manuals. Using fume cupboards or hoods, following safety procedures and noting safety warning signs are all your responsibility in the S288 laboratory.

The sixth item on the list, using **personal protective equipment (PPE)**, is a requirement in all S288 laboratories.

1.1.2. Steps involved in risk assessment

Though you may not be required to perform an assessment of risk for your S288 laboratory work, it is useful to be familiar with the process that has been used.

There are several stages that have been used to perform an assessment of risk whilst your laboratory was being set-up and which have also generated the specific safety advice given to you for your laboratory work.

- The first stage is to identify the hazards, identify who might be harmed and then how they might be harmed.
- The next stage is to evaluate the risk itself (i.e. what the consequence of the hazard being realised is) and then to determine the risk level. The risk level is a product of the risk (consequence) and the likelihood of that risk occurring. In all cases, the objective is to minimise the risk of people in the laboratory being exposed to hazards.

In the laboratory, the main hazards arise from the nature of the radiation, chemicals or biological reagents being used and/or the physical processes or instrumentation being used.

Now that you have considered the general principles of hazard identification and risk assessment, we will move on to some specific areas of safety management, starting with important legislative requirements that govern laboratory work in the UK.

2 Control of Substances Hazardous to Health (COSHH) Regulations

Using chemicals or other hazardous substances can put your health and the health of others at risk, both immediately and in the long term. The law requires control of exposure to these harmful substances. In the UK, the **Control of Substances Hazardous to Health (COSHH) Regulations** are a very useful tool that set basic measures to adequately control substances that are hazardous to health.

This includes any substance that is labelled as or believed to be:

- toxic
- harmful
- an irritant
- a **carcinogen** (a substance directly involved in the promotion of cancer or in the facilitation of its propagation)
- a **mutagen** (a substance that induces hereditary genetic defects)
- a **teratogen** (a substance that induces non-hereditary congenital malformations)
- a **sensitiser** (a substance that causes dermatitis or asthma only after alteration of the skin or respiratory system by previous exposure to that substance)
- an **asphyxiant** (a substance capable of reducing the level of oxygen in the body to dangerous levels)
- a substance listed in the **Health and Safety Executive (HSE)** publication EH40/2005: *Workplace Exposure Limits* [HSE, 2011]
- a biological agent that may cause disease in humans
- dust (in high concentrations)
- explosive
- corrosive
- flammable
- oxidising.

The hazard exists regardless of the form taken: the substance may be a solid, liquid, vapour, gas, mist, dust or **spore**, bacteria or other organism.










2.1 Classification, labelling and packaging of chemicals

There are a number of **regulations** related to the classification and labelling of chemicals. In the UK the **chemicals hazard information and packaging for supply (CHIP)** regulations were first introduced in 1994, when they were known as CHIP1. They were revised in 1996, 2002 and 2009 and are now called CHIP4 to keep up with developments in the field of health and safety.

The aim of these regulations, which apply to both single substances and mixtures of substances (often called preparations), is to help to protect people and the environment from the ill effects of chemicals. They require suppliers to provide labelling information about the chemicals they manufacture (hazard symbols are shown in Table 2) and to package them safely; suppliers are also required to provide **material safety data sheets** (MSDS) which list hazards and control measures. The intention is that if users know about the chemicals and how to control them they are less likely to do things with them that will harm themselves, other people or the environment. Information required by the regulations includes:

- the category of danger: this is a description of the hazard type, for example *highly flammable* (see Table 2).
- the classification: this is the precise identification of a chemical by assigning categories of danger, **risk phrases** and **safety phrases** using set criteria.
- the risk phrase (R), which is a standard phrase that gives simple information about the hazards of a chemical in normal conditions of use (see Appendix 1 on Risk and safety phrases). They also indicate what can happen if you are exposed to the substance; for example, risk phrase R36 means ‘irritating to the eyes’;
- the safety phrase (S), which is a standard phrase that gives advice on safety precautions when using the chemical (see Appendix 1 on Risk and safety phrases). These indicate simple control measures that should reduce the risk of exposure to a potentially harmful substance (for instance, phrase S37 means ‘wear suitable gloves’).
- The chemical benzylamine has the following risk and safety phrases: R20/21, R34 and S26, S36/37/38, S45. What particular risks are identified for this chemical and what safety precautions should be taken when handling it?
- The risk phrases identify the following hazards: harmful by inhalation and in contact with skin (R20/21) and causes burns (R34). In terms of safe handling the safety phrases provide the following advice: in case of contact with eyes, rinse immediately with plenty of water and seek medical advice (S26), wear suitable protective clothing (S36), wear suitable gloves (S37), in case of insufficient ventilation, wear suitable respiratory equipment (S38) and in case of accident or if you feel unwell, seek medical advice immediately (Show label where possible) (S45).

These regulations will be replaced in the next few years by EU wide chemical, labelling and packing (CLP) regulations, as part of the UN globally harmonized system of classification and labelling of chemicals (GHS). These apply to all EU member states, including the UK and came into force on 20 January 2010 and are being phased in through a transitional period which runs until 1 June 2015. The new CLP hazard symbols are shown together with the existing CHIP hazard labels in Table 2, as you might encounter both sets of symbols. Other changes will be made to the risk phrases and safety phrases, which will be replaced by hazard statements (H) and precautionary statements (P) respectively, each assigned a unique code (for example H2xy for physical hazards, H3xy for health hazards and H4xy for environmental hazards).

Symbol CHIP, hazard phrase (and abbreviation)	Symbol CLP	Description of hazard (and example of a hazard statement)
 Explosive (E)		Chemicals that explode (H203: Explosive; fire, blast or projection hazard)
 Oxidising (O)		Chemicals that cause or intensify fire or react exothermically with other chemicals (H270: May cause or intensify fire; oxidiser)
 Extremely/highly flammable (F+/F)		Flammable gases, aerosols, liquids or solids, pyrophoric liquids and solids or substances which emit flammable gases in contact with water (H224: extremely flammable liquid and vapour)
no equivalent CHIP symbol		Compressed gas cylinder, liquefied gas, refrigerated liquefied gas or dissolved gas (H280: Contains gas under pressure; may explode if heated)
 Very toxic (T+) Toxic (T)		Chemicals that at very low or low levels cause damage to health (H300: Fatal if swallowed)








		<p>Chemicals that may cause cancer, induce heritable genetic defects or increase their incidence, or chemicals that produce or increase the incidence of non-heritable effects in progeny and/or an impairment in reproductive functions or capacity (H350: May cause cancer)</p>
 <p>Corrosive (C)</p>		<p>Chemicals that may destroy living tissue on contact, causing skin burns or eye damage or are corrosive to metals (H314: Causes severe skin burns and eye damage)</p>
 <p>Irritant/Harmful (Xi/Xn)</p>		<p>Chemicals that may cause damage to health or cause inflammation to the skin or other mucous membranes. (H302: Harmful if swallowed)</p>
 <p>Dangerous for the environment (N)</p>		<p>Chemicals that may present an immediate or delayed danger to one or more components of the environment, particularly aquatic life (H400: Very toxic to aquatic life)</p>

Table 2 Pictograms (hazard symbols), abbreviation and description of hazards for the main categories of hazard.

Activity 1

(20 minutes)

Use Table 2 to identify different chemical hazards around your home. You will find symbols on items such as oven cleaners, household bleach, cigarette lighter fluid and kettle descaler.

2.2 Health problems associated with the use of chemicals

Table 2 identified a number of different health problems associated with the use of chemicals. These are considered in more detail in this section.

Sensitizing substances

Various chemicals, for example formaldehyde, are known to cause **allergic reactions** in some people. These allergic reactions can produce respiratory problems, similar to hay fever and occupational asthma. Other chemicals, such as nickel or turpentine, may give rise to skin allergies, which may lead to eczema. Under CLP these would be classed as respiratory or skin sensitisation (Category 1).

Carcinogenic chemicals

A number of chemicals are known or suspected to cause cancer in humans and animals. These are known as carcinogenic substances and under CHIP are divided into three categories:

- categories 1 and 2 (under CLP they are assigned 1A and 1B) are defined as *toxic* (chemicals that at low levels cause damage to health), e.g. benzene;
- category 3 (under CLP category 2) is defined as *harmful* (chemicals that may cause damage to health); this is often applied to chemicals that are suspected of being carcinogenic, such as dichloromethane.

Mutagenic chemicals

This is the term given to substances that are known to cause or are suspected of causing changes to the DNA of genes (subsections of the DNA of the body's cells). These mutations can be passed along as the cell reproduces, sometimes leading to defective cells or cancer. Once again there are three categories:

- categories 1 and 2 (under CLP categories 1A and 1B) are *toxic*, e.g. iodomethane;
- category 3 (under CLP category 2) is *harmful*, e.g. tetraethylenepentamine.

Teratogenic chemicals (under CLP toxic for reproduction)

These chemicals are toxic for reproduction. A teratogen is an agent that can cause malformations of an embryo or foetus. Once again there are three categories:

- categories 1 and 2 (under CLP categories 1A and 1B) are *toxic*, e.g. chromium trioxide;

- category 3 (under CLP category 2) is *harmful*, e.g. nandrolone (19-nortestosterone) an anabolic steroid.

CLP has introduced a new health warning not found under the old CHIP regulations called Specific Target Organ Toxicity (STOT), which can be related to a single exposure ((Category 1, 2) and (Category 3 for narcotic effects and respiratory tract irritation only)) or repeated exposure (Category 1 and 2).

2.3 Biological agents

A **biological agent** is a micro-organism, cell culture or parasite living within the body (that may or may not have been genetically modified), which may cause infection, allergy, toxicity or otherwise create a hazard to human health (Figure 1).

COSHH classifies biological agents into four hazard groups based on their ability to infect healthy humans. Distinctions are made according to the following criteria:

- whether the agent is pathogenic (causes disease) for humans
- whether the agent is a hazard to employees
- whether the agent is transmissible to the community
- whether there is effective treatment or prophylaxis (preventative measures) available.



Figure 1 Biological hazard warning sign.

The hazard groups are defined as follows (HSE, 2005d).

- Hazard group 1: a biological agent unlikely to cause human disease. Examples are *Lactobacillus* species and varicella virus.
- Hazard group 2: a biological agent that can cause human disease and may be a hazard to employees. It is unlikely to spread to the community and there is usually effective prophylaxis or effective treatment available. Examples are *Salmonella* species and *Cryptosporidium*.
- Hazard group 3: a biological agent that can cause severe human disease and presents a serious hazard to employees. It may present a risk of spreading to the community, but there is usually effective prevention or treatment available. Examples are *Mycobacterium tuberculosis* and *Bacillus anthracis* (the causative agent of anthrax).
- Hazard group 4: a biological agent that causes severe human disease and is a serious hazard to employees. It is likely to spread to the community and there

is no effective prevention or treatment available. Examples are Ebola virus and Machupo virus (the causative agent of Bolivian fever).

There are four containment levels for laboratory work; each containment level directly relates to the equivalent hazard group, where level 1 represents minimum risk and level 4 represents extreme risk. As you will not be handling biological samples within the lab we will not consider these in any more detail.

2.4 COSHH risk assessment

Carrying out COSHH risk assessments of all activities that could expose you or other people to hazardous substances is essential. Regulations require formal written records of these assessments to be made. You can see copies of them in your laboratory.

Figure 2 presents the structure of a COSHH risk assessment approach.

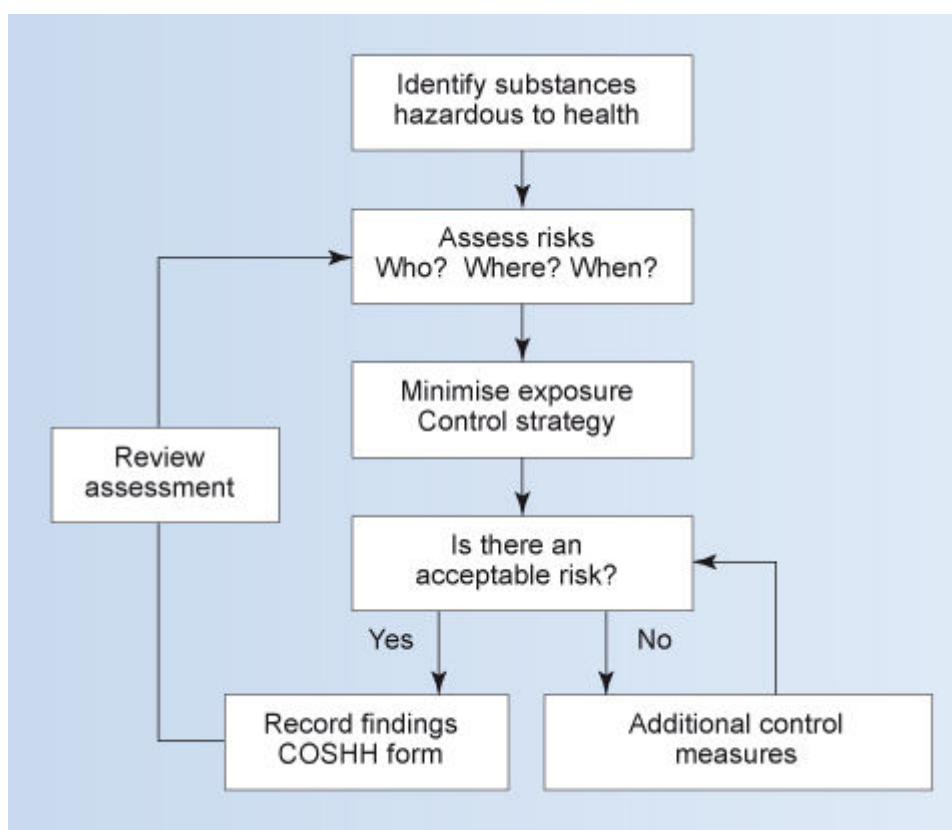


Figure 2 COSHH risk assessment flow chart

In common with a general risk assessment, there are a number of steps to carrying out a risk assessment (we have broken these down here in more detail):

1. *Identifying the hazards* –this stage involves identifying what could reasonably be expected to cause harm.
2. *Identifying who might be harmed and how* – including all people who might be exposed to a hazard, the route and duration of exposure and how it can be minimised. The routes into the human body for harmful substances include inhalation, ingestion and absorption. This should also include information on how to proceed if someone is exposed to a hazard, as well as considering what to do in case of spillage.

3. *Evaluating the risks and risk level (consequence × likelihood)* – this should take into account the present precautions and consider if and how the risk levels can be reduced (if they need to be) to avoid or minimise the risks.
4. *Recording the findings* – the evaluation should be recorded and become the basis of safe working practice.
5. *Reviewing and revising the assessment where necessary* –if things change the risk assessment will need reviewing; e.g. if a chemical reagent is changed to improve some aspect of a reaction, the risk assessment would require review to ensure that it is still suitable.

The material safety data sheets provided by suppliers (and typically available for download on their websites) are a good source of information when writing a COSHH risk assessment. As well as considering different reagents in a reaction, any products or mixtures of chemicals should also be considered. In addition, if two or more chemicals are to be mixed together as part of your procedure then you must consider the possibility of incompatibility, which may lead to toxic fumes or even an explosion. A common example can be found in the home, where mixing bleach with an acid-containing limescale remover can lead to the release of chlorine gas, an irritant. Information on incompatibility is often given in the material safety data sheets and indeed appears on labels of household bleach (Figure 3).



Figure 3 Photograph of the safety information on a label of household bleach

The COSHH risk assessment must list all the substances or organisms involved in a procedure and their potential to cause harm; it must collate information on their properties and effects, identify who will be using them (where/when), the time of exposure and the quantity of the substance in use.

The COSHH risk assessment must include any special control measures required (such as substituting the hazardous substance for one less harmful, using a safer form of the substance, working with protective equipment such as gloves or respirators and using fume cupboards).

Another important aspect of working with harmful substances is their storage (metal cabinet, fridge or freezer); some poisonous, carcinogenic and also radioactive substances must be kept locked up. Emergency procedures, training and advice given to the people who may be exposed to the hazardous substances are also recorded in the COSHH risk assessment. It will also consider what action should be taken in terms of spillage. In addition, safe disposal should also be considered.

3 Personal protective equipment

Health problems associated with harmful substances are likely to arise from:

- inhalation, by breathing in a substance or organism
- ingestion, by eating a substance or organism
- contact, by touching a substance or organism, or it passing through the skin
- injection, by having a substance or organism forced through the skin
- infection, developing a disease or condition as a result of contact.

From Table 1, you can see that one control measure is the use of personal protective equipment (PPE). Personal protective equipment means all equipment and accessories designed to be worn by a person to protect him/her against one or more hazards.

Some types of PPE you will be required to use in the S288 laboratory are shown in Table 3. Signs to this effect (shown in Figure 4) are displayed on the doors to laboratories; you should not enter a laboratory without lab coats, goggles or safety glasses and appropriate clothing and footwear.

Table 3 Body parts protected by commonly used laboratory PPE

Body part protected	PPE used
Body	lab coats
Hands	disposable gloves
Eyes	goggles, safety glasses
Feet	Closed shoes



Figure 4 Common signage used to indicate PPE usage you will be most likely to encounter in the S288 laboratory classes.

PPE is, of course, not a substitute for properly planned prevention of exposure to hazardous chemicals or biological agents through the use of items 1-3 in Table 1. In addition, other methods can be used to limit your exposure to chemical or biological agents, although these do not reduce the need for PPE:

- The most common way, particularly to avoid inhalation of volatile chemicals, is to use a fume cupboard.
- Some chemicals have adverse reactions when exposed to air or moist air; these have to be handled under an inert atmosphere, usually oxygen-free nitrogen or argon.
- Highly toxic or unstable chemicals may require a ‘dry box’ or negatively pressurized containment.

Further details for PPE in the S288 laboratory that you are likely to have responsibility for are given in the next few sections.

3.1 Hand protection

One of the most common pieces of PPE you will come across is gloves. The use of gloves in laboratories has increased since the 1990s, when studies showed that some chemicals can be toxic by skin absorption and other chemicals can give rise to dermatitis. Biological samples can also contain pathogenic organisms, which can cause infection.

When selecting gloves for use in the S288 laboratory, the topic teams will have anticipated risk levels by evaluating the type of task to be performed, the equipment to be used and the potential exposure to chemicals or biological agents.

It is important, however, to recognise that there is not a single type of glove that will protect an individual from all hazards that are encountered in a laboratory. The main types of gloves used in the laboratory are gloves made from latex, nitrile and vinyl. Two more specialist types of gloves you might encounter are cryogenic gloves (for handling solid carbon dioxide and liquefied gases) and thermal gloves (for protection against heat).

In most S288 laboratories latex, nitrile and vinyl gloves are used as disposable protective equipment. Note that latex can sometimes cause allergies (see box 1) and if you know you have an allergy to latex gloves you should inform your S288 laboratory tutor when you arrive for your laboratory class.

Box 1 Latex Glove problems

Natural rubber latex (NRL) is a milky fluid derived from the *Hevea brasiliensis* tree and can be found in many laboratory products (e.g. gloves, tubing). Latex provides the best protection against infection and certain chemicals, and gives the sensitivity and control needed to perform delicate and precise tasks. However, some people may experience a mild to severe allergic reaction when using products containing NRL.

Allergies are hypersensitivities, overreactions of the immune system; a network of tissues and organs that work together to defend the body against 'attacks' by 'foreign' invaders from outside the body. These overreactions are grouped into four types (I through IV), based on what part of the immune system is activated and how long it takes for a reaction to occur. Latex allergy can give rise to a broad range of symptoms including redness, soreness, dryness or cracking of the skin in areas exposed to natural rubber latex. More severe reactions can include localised or generalised rash, inflammation of the mucous membranes in the nose, red and swollen eyes with discharge and asthma-like symptoms. These reactions can appear almost immediately on contact with the gloves but some allergic responses occur 10 to 24 hours after exposure and can get worse over the subsequent 72 hours.

Using gloves properly

Here are some tips on what you should and shouldn't do when wearing gloves.

Do:

- Wash and dry your hands before putting gloves on and after using them.
- Wash your hands and change the gloves if spillage or splashes with hazardous substances have occurred.
- Report any skin reaction to your laboratory tutor.

Don't:

- Apply barrier creams prior to wearing gloves, because these will increase the absorption of proteins in the glove and can also cause glove deterioration. If you need to apply hand cream to stop your hands drying out, it is best to do this when you've finished your work.
- Scrub your skin and use abrasive cleansers or solvents to clean your hands.
- Use latex gloves if you have sensitivity to natural rubber latex.

Individuals with sensitive skin should use cool water and an antimicrobial hand wash, dry their hands thoroughly and change their gloves often to reduce irritation.

3.2 Eye protection

In most laboratories, safety glasses are compulsory. Many potential eye injuries in the laboratory can be avoided by wearing safety glasses. Safety glasses look very much like normal glasses but their lenses are impact resistant, their frames are far stronger and they also have side shields.

Unfortunately safety glasses do not provide adequate protection from significant chemical splashes as they don't seal to the face and chemicals may seep through gaps at the top, bottom and sides. When there is potential for splash from hazardous material, goggles should be worn to eliminate the risk of substances draining into the eye area. Sometimes when working with large volumes of hazardous materials, face shields are used in conjunction with safety glasses or goggles.

3.3 Laboratory coats

In most laboratories, lab coats are compulsory PPE appropriate for minor chemical/biological splashes and solids contamination. Make sure your lab coat is always done up! Cotton lab coats are preferable to nylon ones when working with organic solvents. Plastic and rubber aprons are best for protection from corrosive or irritating liquids. Howie style, wraparound coats with a Chinese collar and elasticated cuffs are recommended for microbiology labs.

4 Waste disposal

Waste of all kinds poses a threat to human health and the environment if it is not managed properly and recovered or disposed of safely. The waste from your own laboratory work must be handled safely and disposed of properly, hence the requirement for you to observe all guidance on appropriate disposal routes.

Disposal requirements are considered in any risk assessment; for example, any chemical harmful to the environment should not be disposed of down the sink. Likewise, volatile organic solvents should not be disposed of down the sink, because most are immiscible with water. There are a number of documented instances of fires and explosions associated with people disposing of volatile and flammable solvents down the sink.

In this part, we are going to summarise the main **waste streams** that are commonly found in a laboratory.

4.1 Chemical waste

Each laboratory will have local rules regarding the disposal of chemicals, and it is important that you follow these. Almost no chemical waste is allowed to be put down the drain, unless advised otherwise. Labelled waste containers or glass bottles (Winchesters) will be provided in the laboratory.

The following categories of chemical waste from laboratories are segregated:

- Non-halogenated solvents: acetone, methanol, ethanol, diethyl ether, petroleum ether, toluene, xylene, acetonitrile and benzene are compatible in the same disposal container. Separating acetone from other flammable solvents is good laboratory practice.
- Halogenated solvents: chloroform, methylene chloride, dichloromethane, trichloroethane and trichloroethylene, bromobenzene are compatible in the same disposal container.
- Organic acids: formic acid, acetic acid and propionic acid are compatible in the same disposal container, but should be segregated from inorganic acids.
- Heavy metal solutions, eg. Mercury (II) chloride
- Inorganic bases: do not mix sodium hydroxide, potassium hydroxide or ammonia. This waste should not be mixed with inorganic acids.
- Oxidisers: do not mix potassium nitrate, hydrogen peroxide, potassium permanganate or bleach. This waste should never be mixed with any other type of waste.
- Reactive wastes: do not mix phosphorus pentoxide, sodium hydride or sodium methoxide. Acid mixed with cyanides and sulfides has the potential to generate toxic gas.

4.2 Biological waste

Biological waste is separated into waste that is potentially infectious to humans or animals and waste that is not. Biological waste taking the wrong disposal route and ending up, for example, in the domestic waste stream would lead to serious risks to the health and safety of staff handling the waste.

The most common method of segregating biological waste is by applying a colour-coded system, with infectious or potentially infectious waste that requires disposal by incineration being packaged in yellow packaging.

Some waste that looks as if it might be non-biological (such as Petri dishes, agar plates or autoclave waste) is disposed of as biological waste. The reason for this is that if this waste were to be discovered at a facility that handles domestic waste, it would be difficult to prove that it was not biological waste. This would render the waste producer liable to prosecution.

4.3 Radioactive waste

Most laboratories make every effort to reduce the use of radioactive material. Radioactive waste must not be disposed of with any other laboratory refuse. If your work involves working with radioactive substances there will be clear guidance as to how waste should be collected and disposed of in your experimental work. For information purposes it is perhaps helpful for you to realise that there are many legal constraints on what can and cannot be done with radioactive substances in the laboratory, even those considered to be low risk.

The waste must be sealed in an appropriate receptacle labelled with the laboratory of origin, date of delivery, isotopes present and estimated activity on the date of disposal. Syringe needles and pipette tips must be shrouded before disposal. In the case of short-lived isotopes the waste may be kept in a radioactive waste store, allowing it to decay to background levels for disposal as either chemical or biological waste. When work involves the potential release of radioactive gases (e.g. the generation of ^{14}C labelled carbon dioxide) all such work must be performed in a designated fume cupboard.

4.4 Sharps waste

Sharps are items that could cause cuts or puncture wounds, including needles, syringes with needles attached, and small pieces of broken glass, scalpels and other blades. All sharps should be placed into suitable purpose-designed storage bins. Sharps contaminated with chemical waste should be separated from those that are contaminated with biological waste.

4.5 General laboratory waste

Only non-contaminated gloves, wipes or pipette tips can be disposed of in the laboratory waste bins. For broken glassware use special glass bins; if it is contaminated, decontamination will be necessary before disposal.

5 Radiation

Radiation is the emission of energy as either waves (electromagnetic radiation) or particles and can be encountered in the laboratory when working with lasers, X-ray analysers and nuclear magnetic resonance spectrometers, and with chemicals that contain radioactive tracers.



Figure 5 Radiation signage

There are two classes of radiation: ionising and non-ionising. The process of ionisation is the removal of electrons from atoms, leaving behind electrically charged particles (ions). Many forms of radiation, such as visible light, heat, microwaves and radio waves, do not have sufficient energy to produce ions, and they are grouped as examples of non-ionising radiation.

5.1 Non-ionising electromagnetic radiation

Non-ionising electromagnetic radiation covers two main regions of the electromagnetic spectrum: the optical radiation range (ultraviolet (UV), visible and infrared) and the electromagnetic fields range (microwaves and radio frequencies). Some common sources of optical radiation are the sun, sun beds and lasers, while some typical sources of electromagnetic fields are electrical supply equipment and telecommunications systems.

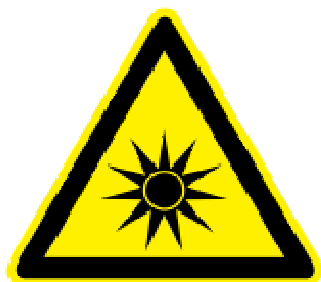


Figure 6 Signage for UV light warning.

The main method of protection for a user against non-ionising radiation is through the use of appropriate shielding. For example, it is common to visualise biological molecules such as plant pigments using UV light. To avoid exposure, this is usually performed in a cabinet that prevents exposure to the user. An image is captured of UV-exposed laboratory items using a digital camera with suitable wavelength filters. Items of equipment that generate UV will be labelled with a warning as in (Figure 6) and suitable PPE should be worn.

5.2 Ionising radiation

Ionising radiation occurs in the form of either electromagnetic rays (such as X-rays and gamma rays) or particles (such as alpha and beta particles, electrons, positrons and neutrons) that are capable of producing ions directly or indirectly in their passage through matter. It occurs naturally (e.g. from the radioactive decay of natural radioactive substances such as radon gas and its decay products) but can also be produced artificially. Ionising radiation is used in medicine (for diagnosis and treatment), industry (for measurement and other purposes as well as for producing electricity) and research.

Ionising radiation can cause damage to living tissue and especially rapidly dividing cells. As such, blood-forming cells, those of the intestinal lining and those of a foetus are more susceptible to radiation damage.

Isotopes are commonly used in all areas of practical science, for example, ^{14}C is commonly used to label biological molecules. In common with non-ionising radiation, shielding is usually used to protect from the effects of ionising radiation and work with radiation sources is limited to specific working areas of a laboratory or within a specialist facility. These areas will carry a warning label as shown in Figure 5.

In addition, care must be taken to note that exposure might also occur due to contact with skin or through inhalation or ingestion. In addition, the nature of the molecule carrying the particular isotope being used will influence both the route of possible exposure and also the possible consequences. For example, a gaseous compound might be more likely to enter the body through inhalation, or an isotopically labelled naturally occurring molecule could be enriched and transformed biochemically within the human body (or within the organism under study).

6 Putting it into practice: working safely in the laboratory

Whilst all laboratory work you will perform when studying S288 will be carefully controlled and monitored, you will be expected to contribute to the health and safety of your laboratory class. In particular you should:

- Ensure that you have read and understood laboratory manuals and notes before your lab class.
- Pay particular attention to written guidance in your notes and oral briefings given out during the class as to particular hazards you are likely to encounter.
- Ensure that you recognise and understand the various warning symbols you are likely to encounter in the laboratory.
- Ensure that you use appropriate personal protective equipment such as gloves, a laboratory coat and safety glasses.
- Ensure that you work using the safe laboratory practice that is suitable for the laboratory you are working in.
- Ensure that you use appropriate containment or control measures provided, such as fume cupboards or safety cabinets when required.
- Work in an organised manner; know what you are doing in advance and plan your work accordingly.
- Understand all the appropriate waste disposal routes for the work you are carrying out.

Finally, whilst this unit has provided an oversight into safe laboratory working on residential school sessions you will study in S288, you should familiarise yourself with local good laboratory practice guidelines if you are working elsewhere. Differences exist between the legal requirements in different countries in the way hazards are identified, assessed, managed and recorded. You should always perform laboratory work safely and use the local good laboratory practice guidance.

You should now read the Health and Safety briefing appropriate to the laboratory class you will be attending.

References and further information

Health and Safety Executive (HSE) (2011) List of Approved Workplace Exposure Limits [online], available from <http://www.hse.gov.uk/coshh/basics/exposurelimits.htm> (Accessed 18 January 2012).

For further information on COSHH please visit the Health and Safety Executive website: <http://www.hse.gov.uk/coshh/index.htm>

Acknowledgments

We are grateful to the S130 course team for supplying a large component of this guide.

Appendix 1: Risk and safety phrases for hazardous substances

Risk phrases

Indication of particular risks:

R1 Explosive when dry

R2 Risk of explosion by shock, friction, fire or other sources of ignition

R3 Extreme risk of explosion by shock, friction, fire or other sources of ignition

R4 Forms very sensitive explosive metallic compounds

R5 Heating may cause an explosion

R6 Explosive with or without contact with air

R7 May cause fire

R8 Contact with combustible material may cause fire

R9 Explosive when mixed with combustible material

R10 Flammable

R11 Highly flammable

R12 Extremely flammable

R14 Reacts violently with water

R15 Contact with water liberates extremely flammable gases

R16 Explosive when mixed with oxidising substances

R17 Spontaneously flammable in air

R18 In use, may form flammable/explosive vapour-air mixture

R19 May form explosive peroxides

R20 Harmful by inhalation

R21 Harmful in contact with skin

R22 Harmful if swallowed

R23 Toxic by inhalation

R24 Toxic in contact with skin

R25 Toxic if swallowed

R26 Very toxic by inhalation

R27 Very toxic in contact with skin

R28 Very toxic if swallowed

R29 Contact with water liberates toxic gas

R30 Can become highly flammable in use

R31 Contact with acids liberates toxic gas

R32 Contact with acids liberates very toxic gas
R33 Danger of cumulative effects
R34 Causes burns
R35 Causes severe burns
R36 Irritating to the eyes
R37 Irritating to the respiratory system
R38 Irritating to the skin
R39 Danger of very serious irreversible effects
R40 Limited evidence of a carcinogenic effect
R41 Risk of serious damage to eyes
R42 May cause sensitization by inhalation
R43 May cause sensitization by skin contact
R44 Risk of explosion if heated under confinement
R45 May cause cancer
R46 May cause heritable genetic damage
R48 Danger of serious damage to health by prolonged exposure
R49 May cause cancer by inhalation
R50 Very toxic to aquatic organisms
R51 Toxic to aquatic organisms
R52 Harmful to aquatic organisms
R53 May cause long-term adverse effects in the aquatic environment
R54 Toxic to flora
R55 Toxic to fauna
R56 Toxic to soil organisms
R57 Toxic to bees
R58 May cause long-term adverse effects in the environment
R59 Dangerous for the ozone layer
R60 May impair fertility
R61 May cause harm to the unborn child
R62 Possible risk of impaired fertility
R63 Possible risk of harm to unborn child
R64 May cause harm to breast-fed babies
R65 Harmful, may cause lung damage if swallowed
R66 Repeated exposure may cause skin dryness or cracking
R67 Vapours may cause drowsiness and dizziness

R68 Possible risk of irreversible effects

Safety phrases:

S1 Keep locked up

S2: Keep out of reach of children

S3: Keep in a cool place

S4: Keep away from living quarters

S5: Keep contents under ... (appropriate liquid to be specified by the manufacturer)

S6: Keep under ... (inert gas to be specified by the manufacturer)

S7: Keep container tightly closed

S8: Keep container dry

S9: Keep container in a well-ventilated place

S12: Do not keep the container sealed

S13: Keep away from food, drink and animal feeding stuffs

S14: Keep away from ... (incompatible materials to be indicated by the manufacturer)

S15: Keep away from heat

S16: Keep away from sources of ignition – no smoking

S17: Keep away from combustible material

S18: Handle and open container with care

S20: When using, do not eat or drink

S21: When using, so not smoke

S22: Do not breathe dust

S23: Do not breathe gas/fumes/vapour/spray (appropriate wording to be specified by the manufacturer)

S24: Avoid contact with the skin

S25: Avoid contact with the eyes

S26: In case of contact with eyes, rinse immediately with plenty of water and seek medical advice

S27: Take off immediately all contaminated clothing

S28: After contact with skin, wash immediately with plenty of ... (to be specified by the manufacturer)

S29: Do not empty into drains

S30: Never add water to this product

S33: Take precautionary measures against static discharges

S35: This material and its container must be disposed of in a safe way

S36: Wear suitable protective clothing

- S37: Wear suitable gloves
- S38: In case of insufficient ventilation, wear suitable respiratory equipment
- S39: Wear eye/face protection
- S40: To clean the floor and all objects contaminated by this material use ... (to be specified by the manufacturer)
- S41: In case of fire and/or explosion, do not breathe fumes
- S42: During fumigation/spraying wear suitable respiratory equipment (appropriate wording to be specified)
- S43: In case of fire, use ... (indicate in the space the precise type of fire-fighting equipment. If water increases the risk, add- Never use water)
- S45: In case of accident or if you feel unwell, seek medical advice immediately (Show label where possible)
- S46: If swallowed, seek medical advice immediately and show this container or label
- S47: Keep at temperature not exceeding °C (to be specified by the manufacturer)
- S48: Keep wet with ... (appropriate material to be specified by the manufacturer)
- S49: Keep only in the original container
- S50: Do not mix with ... (to be specified by the manufacturer)
- S51: Use only in well-ventilated areas
- S52: Not recommended for interior use on large surface areas
- S53: Avoid exposure – obtain special instruction before use
- S56: Dispose of the material and its container at hazardous or special waste collection point
- S57: Use appropriate containment to avoid environmental contamination
- S59: Refer to manufacturer/supplier for information on recovery/recycling
- S60: This material and/or its container must be disposed of as hazardous waste
- S61: Avoid release to the environment. Refer to special instructions/safety data sheet
- S62: If swallowed, do not induce vomiting: seek medical advice immediately and show this container or label
- S63: In case of accident by inhalation, remove casualty to fresh air and keep at rest
- S64 If swallowed, rinse mouth with water (only if person is conscious)